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5158 Blackhawk Road, Aberdeen Proving Ground, Maryland 21010-5403

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Toxicology Portfolio

The FishRand Spatially-Explicit Bioaccumulation Model – Final Report

Prepared by Dr Mark A. Williams, Health Effects Research Program

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Study Title

The FishRand Spatially-Explicit Bioaccumulation Model
Final Report

Authors

Katherine von Stackelberg, Sc.D.
Mark A. Williams, Ph.D.
Mark S. Johnson, Ph.D.

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Toxicology Portfolio
Health Effects Research Program
MCHB-IP-THE
5158 Blackhawk Road
Aberdeen Proving Ground, MD 21010-5403

Prepared by:

______________________________ __________________

Mark A. Williams Ph.D., FAAAAI Date
Biologist
Army Institute of Public Health
Health Effects Research Program

Approved by:

______________________________ __________________

Mark S. Johnson, Ph.D., DABT Date
Director Toxicology Portfolio
Army Institute of Public Health

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Acronyms and Abbreviations

ACOE	U.S. Army Corps of Engineers
AF	Attraction factor
AFB	U.S. Air Force Base
APG	Aberdeen Proving Ground
BSAF	Benthic:Sediment Accumulation Factor
C_{Bentho}	Concentration in benthos
C_d	Dietary concentration of the contaminant
C_s or C_{sed}	Concentration of contaminant in sediment
C_w or C_{wd}	Dissolved concentration of contaminant in water
CBR	Critical body Residue
CDF	Cumulative Distribution Function
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DOD	US Department of Defense
DS	Disposal site (proxy for contaminated area within the FR model)
EPA	U.S. Environmental Protection Agency
EPC	Concentration in the modeling grid cells that a fish encounters within its foraging area (FA) over a specified time period (t_i)
EqP	Equilibrium partitioning

ERED	Effects Residue Database
ERM	Effects Range Medium
ERL	Effects Range Low
ESTCP	Environmental Security Technology Certification Program
FA	Foraging area
f_L	fraction lipid (kg lipid/kg weight wet weight)
f_{oc}	fraction organic carbon (unitless); same as TOC or total organic carbon
FLDD	Flightline Drainage Ditch
FH^2	Intersection of FA and DS (used within the model; foraging area and disposal site or contaminated area)
FR	FishRand Spatially-Explicit Model
GIS	Geographical information system
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
ICF	Inner City Fund International
k_1	gill uptake rate; model rate constant (L/kg/d)
k_2	gill elimination rate; model rate constant (d^{-1})
k_d	dietary uptake rate; model rate constant (d^{-1})
k_e	fecal egestion rate; model rate constant (d^{-1})
k_g	growth rate; model rate constant (d^{-1})
k_m	metabolic rate; model rate constant (d^{-1})
MA	Management area
NPL	National Priorities List
NSSC	U.S. Army Natick Soldiers Systems Center

PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PDF	probability density function
POL	Petroleum, Oils and Lubricants
RCRA	Resource Compensation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RPD	Relative Percent Difference
SERDP	Strategic Environmental Research and Development Program
SWAC	Surface-Area Weighted Average Concentrations
t_i	time intervals over which model is run (e.g., one week, one month, etc.)
TOC	Total Organic Carbon (or Fraction Organic Carbon)
TSCA	Toxic Substances Control Act
TSERAWG	Tri-Service Environmental Risk Assessment Work Group
UCL	Upper Concentration Limit
U.S. EPA	United States Environmental Protection Agency

Appendices

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Regulatory decision making at contaminated sediment sites are typically informed by the results of human health and ecological risk assessments. Bioaccumulation of sediment-associated contaminants through aquatic food webs often represents the predominant pathway of concern in these risk assessments. Site data provides an indication of current conditions. However, predictive models are required to evaluate the impact of potential management alternatives.

Bioaccumulation models predict fish tissue concentrations under one or more future scenarios. Although the mechanistic process of bioaccumulation is well-understood, particularly for heavy organic compounds such as polychlorinated biphenyls (PCBs), dioxins, and many pesticides (e.g., dichlorodiphenyltrichloroethane or DDT), none of the models in current use account for the influence of spatial heterogeneity in contaminant distribution in combination with fish foraging behaviors and strategies. Similarly, temporal changes in contaminant concentrations are infrequently evaluated.

We demonstrate the application of a probabilistic, spatially-explicit, and dynamic bioaccumulation model, referred to as FishRand at two Army sites. We compare those results to the currently accepted practice of a deterministic application, and a probabilistic but not spatially-explicit application. In all cases, the mathematical framework of the bioaccumulation model is based on the well-recognized "Gobas Model," which has been used at many sites.

The data requirements for FishRand are similar to those required for any bioaccumulation model, although more information is required on fish foraging areas and strategies than would otherwise be developed. Exposure concentrations in surface sediments rely on the commonly used geographical information system (GIS)-based characterizations of site data. All modeling and results presented in this report are based on the original version of the FishRand model, which did not provide a direct, quantitative linkage to GIS files (e.g., .SHP files), as will be discussed. However, since this effort was completed, the model has been updated to provide a direct linkage to GIS files. The latest version of the model is available from http://el.erdc.usace.army.mil/trophictrace/.

We develop the application for total PCBs, two individual PCB congeners, and three homologue groups at one site, and DDT, dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyldichloroethane (DDD) at the other site. The spatially-explicit model consistently predicts tissue concentrations that closely match both the average and the variability of observed data across contaminants and environments. The probabilistic framework allows direct linkages to ecological assessments of impacts to fish populations. Since the model explicitly distinguishes between "uncertainty" (e.g., lack of knowledge) and "variability" (e.g., population heterogeneity), different output statistics are generated depending on whether the results are used to support risk assessments for fish consumers (either human or ecological) or direct risks to fish.

1.0 INTRODUCTION

The Department of Defense (DoD) faces legacy contamination at approximately 6,000 nationwide sites (GAO Report, 2005), many of which contain sediment-associated organic contaminants likely to bioaccumulate in aquatic food webs leading to the potential for human health and ecological impacts through fish consumption. Bioaccumulation models quantifying the relationship between sediment exposures and resulting tissue concentrations have been in use for many years to support remedial decision making. However, the predictive power of these models remains a concern. Participants at a recent combined Strategic Environmental Research and Development Program (SERDP)/Environmental Security Technology Certification Program (ESTCP) workshop identified the "evaluation of food web models in setting remedial goals and long-term monitoring requirements" as a critical research area. This was particularly evident when using these models as the basis for evaluating potential risk reductions associated with site-specific management actions (Thompson *et al.* 2012). It is recognized that bioaccumulation represents the exposure pathway of primary concern for many sediment-originating contaminants. Predicted aquatic-organism concentrations provide exposure estimates for human health and ecological risk assessments, which provide risk-based frameworks for back-calculating remedial levels in sediments. Since bioaccumulation models quantify the relationship between sediment-exposure concentrations and resulting tissue levels in aquatic organisms, these models strengthen the available tools used in the decision-making process at sediment sites.

Bioaccumulation modeling approaches range from deriving empirical trophic relationships based on site-specific data, to dynamic, mechanistic models. Of the available bioaccumulation models, the FishRand (FR) model presented here is the only one that simulates fish foraging behavior over GIS-defined spatially-variable sediment and water exposure concentrations using a dynamic (time-varying) mathematical framework. The model has been applied in both the non- and spatially-explicit modes for several different sites on behalf of the Army Corps of Engineers. It has also been applied under a Small Business Innovation Research Grant as part of a larger decision analytic framework (von Stackelberg, 2013). Technology development for the FR model has focused on improving how exposure is defined, both in terms of spatially-explicit exposure concentrations and simulating fish foraging behavior relative to those spatially-defined exposures. Decision makers cannot control the ways in which fish behavior and physiology interact with exposure concentrations. However, decision makers can control spatial patterns of contaminant concentrations (e.g., through remediation alternatives, maintenance dredging, and so on). The basic uptake equations are kept as conservative as possible, while adding greater realism to the ways in which exposure influences predicted uptake. We present the results of applying the FR model under several different exposure scenarios at two separate DoD sites to demonstrate its strengths and potential limitations.

1.1 BACKGROUND

Bioaccumulation models rely on sediment and water exposure concentrations to drive exposure and uptake in aquatic food webs incorporating site-specific data on trophic levels, species foraging strategies, and feeding preferences. Frequently, the bioaccumulation models are highly detailed and increasingly complex in their representation of the food web (Arnot and Gobas 2004; Windward Environmental 2010; Lopes *et al.* 2012; Gobas and Arnot 2010) and yet in almost all cases rely on simple averaging techniques such as surface-area weighted average concentrations (SWACs) to describe potential exposures (Gustavson *et al.* 2011). These averaging techniques poorly capture the spatial and temporal variability of the majority of contaminated-sediment sites. More generally, applications of bioaccumulation models do not take advantage of GIS-based site characterizations that have been available for many years. Moreover, if GIS-based exposures are used, they are static inputs in the sense that the foraging strategies of fish, which influence exposures, are not directly simulated.

Since bioaccumulation models quantify the relationship between sediment-exposure concentrations and subsequent tissue levels in aquatic organisms, these models represent a key link in the suite of tools used to support decision-making at sediment sites. Results of bioaccumulation modeling are used as inputs to human health and ecological risk assessments. They are also used to evaluate how temporal changes in the contaminant concentrations of aquatic organisms change over time following remedial actions or other management alternatives at sediment sites. The focus of this effort was to explore improvements in predictive capacity associated with use of a spatially-explicit bioaccumulation model.

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective was to demonstrate application of a spatially-explicit bioaccumulation model as we ran the model under three scenarios:

1. Deterministic Case: Deterministic sediment and water exposure concentrations defined as arithmetic averages, or SWACs, consistent with typical exposure characterization

2. Probabilistic Case: Non-spatially explicit but probabilistic sediment and water exposure concentrations (e.g., exposure concentrations were defined by distributions rather than point estimates, and not by a deterministic SWAC)

3. Spatially-Explicit Case: Sediment (and water, if appropriate) exposure concentrations were spatially defined, and aquatic organism foraging activities were simulated over GIS-based representations of exposure

The results of a set of runs were compared to each other and to site-specific data and goodness-of-fit statistics were developed to evaluate potential improvements in prediction accuracy attributable to the way in which exposures were captured when holding all other cross-scenario inputs consistent. Bioaccumulation modeling results were used as inputs to risk assessments (see Regulatory Drivers, Section 1.3), and were used to predict changes in tissue concentrations associated with implementation of remedial or management alternatives. Although predicted tissue concentrations serve as inputs to human health and ecological risk assessments, we noted that predicted risk was linear with respect to fish tissue concentrations. The key metric to evaluate model performance was thus predicted versus observed fish tissue levels.

1.3 REGULATORY DRIVERS

During the mid-1980's, risk assessment emerged as the primary tool that supported decision making for potential remediation at hazardous waste sites under programs such as the Comprehensive

Environmental Response, Compensation, and Liability Act (CERCLA, commonly referred to as Superfund), and the Resource Compensation and Recovery Act (RCRA) (U.S. EPA 1989, 1992a, 1992b, 1998). Numerous state cleanup programs also rely on risk assessment, and prospective programs for permitting. For example, the U.S. Army Corps of Engineers (ACOE) is responsible for maintaining the nation's navigable waterways. Maintenance dredging of variably degraded waterways typically generates large volumes of quality diminished sediments that require disposal. Since ACOE has the required expertise, it often collaborates with the U.S. Environmental Protection Agency (EPA) in large-scale remediation of contaminated sediments. The U.S. Army is also responsible for environmental management of its properties, including remedial studies of contaminated sites. To such an extent that bioaccumulation represents the key pathway of concern for sediments contaminated with heavy organics, including polychlorinated biphenyls (PCBs), pesticides, and certain metals, modeling tools and approaches that efficiently predict contaminant exposures in fish tissues, and appropriate inputs to human health and ecological risk assessments are both needed.

Understanding ecological risks requires a comprehensive approach. Federal guidance recognizes assessment to populations of species, of habitats, and the heterogeneity of contamination (U.S. EPA 1992a, 1992b, 1998). An understanding of contaminant fate in the environment is essential in the required predictive ecological risk assessment that is specific to published guidance (U.S. EPA 1998). This is consistent with DoD Technical Guidance (TSERAWG 2000, and 2002). For sediment-contaminated sites, tiered approaches that start with simple comparisons between sediment concentrations and sediment-based benchmarks are used. For example, use of Effects Range-Medium (ERMs), and Effects Range-Low (ERLs) (Long and Morgan 1990; O'Connor 2004). However, ERMs and ERLs do not address potential impacts associated with bioaccumulation of contaminants through the food web to aquatic organisms that are subsequently consumed by human and ecological receptors. Thus, bioaccumulation models are required to predict expected contaminant concentrations in aquatic organisms.

2.0 TECHNOLOGY

This section provides an overview of the spatially-explicit approach of FishRand, including a brief description of the mathematical framework and underlying conceptual assumptions.

2.1 TECHNOLOGY DESCRIPTION

In areas of localized contamination, exposure of aquatic organisms to varying concentrations of sediment and water contaminants, are a function of spatial factors and species biology, including foraging strategies, feeding preferences, and habitats. Due to local variability in species behavior and contaminant distributions, species with overlapping foraging areas from the same site may experience significantly different contaminant exposures as they overlap with preferred foraging and migratory areas. Predicted exposure estimates and subsequent human health and ecological risk projections typically assume static exposures of receptors to contaminant concentrations that are characterized by a descriptive statistic (e.g., a mean or maximum). The level of health protection is unknown, and in a dynamic system, results may not represent actual exposures of aquatic organisms. Further, uncertainty and variability in underlying input parameters are not accounted for in these static exposures.

The FishRand spatially-explicit model (FR) calculates season, chemical and species-specific body burdens based on time- and spatially-varying sediment and water exposure concentrations. These data are used to calculate deterministic toxicity quotients or in refined ecological risk assessment models are used to estimate population-level risks for fish, or as inputs to ecological and human health risk assessment models for higher-order fish-consuming receptors. Figure 2-1 depicts a conceptual schematic of the relationship across compartments in the FR model.

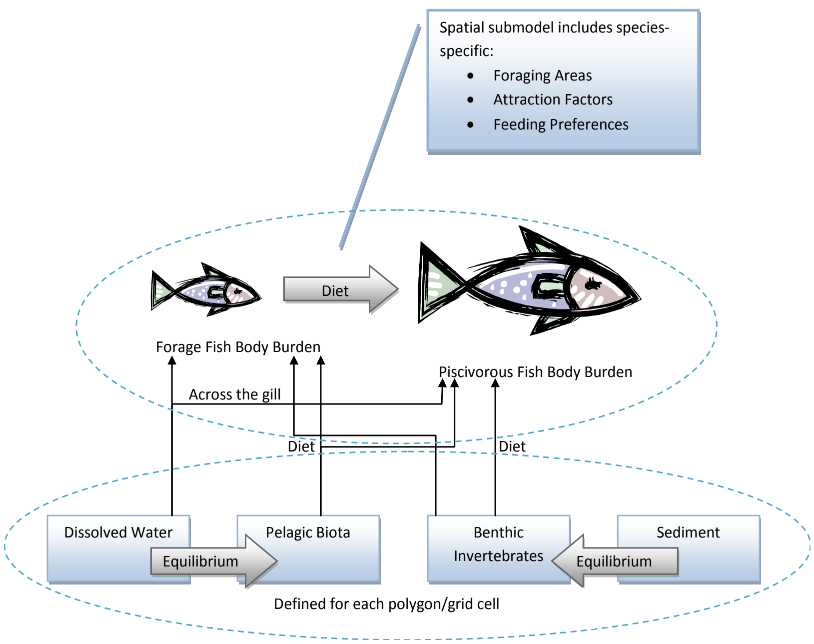


Figure 2-1. Schematic of Compartments in the FishRand Model

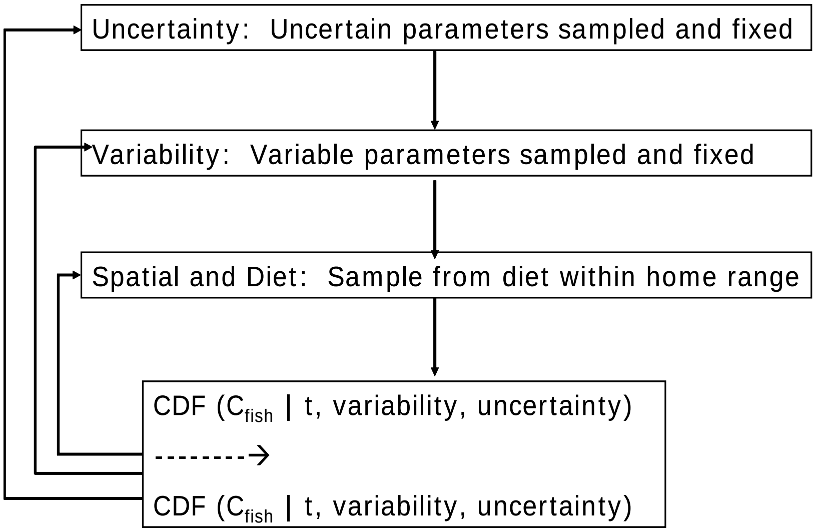


Figure 2-2. Nested Monte Carlo Modeling Scheme in FR

The FR model assumes that anglers or ecological receptors are sampling (catching) fish from a population, and every individual caught fish is obtained from a larger distributed population. In addition to population variability, uncertainty in the distribution of the true population exists. This is attributable to uncertainty in the input parameters, which are included in the FR approach. In some cases, the literature indicates that specific parameters may contribute to uncertainty or variability in the output distribution (von Stackelberg *et al.* 2002; Kelly *et al.* 2007). Hence the FR model separates "uncertain" from "variable" inputs as opposed to explicitly modeling the uncertainty in a variable input. These assumptions lead to the computed nested Monte-Carlo subroutines as depicted in Figure 2-2. Input variables are described by distributions rather than point estimates. The model first selects values for each uncertain variable input. It then selects values for each variable input. The final nested spatial feeding subroutine allows fish to forage for a specified time period (e.g., t_i) within a predefined area and calculates the expected body burden (C_{fish} or concentration in fish tissue). Since the model is probabilistic, results are stored as a cumulative distribution function or CDF. The procedure repeats for as many simulations as the user specifies for each subroutine (e.g., uncertainty, variability, and time). The

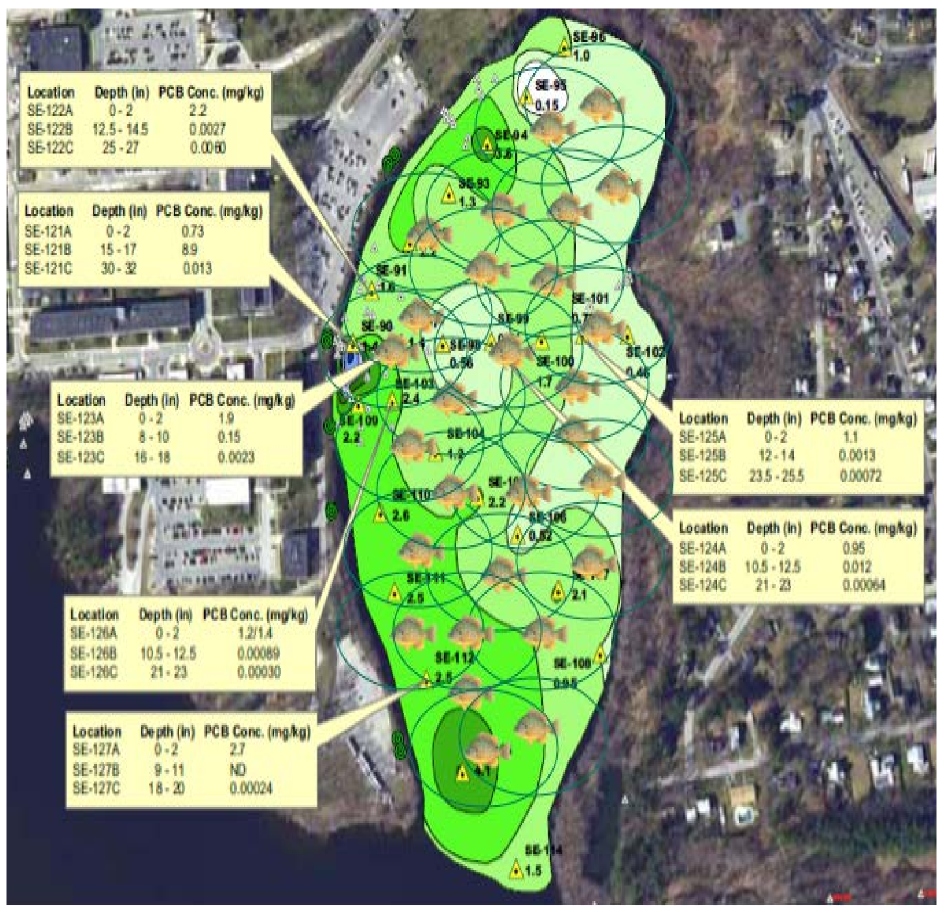


Figure 2-3. Example of Random Fish and Foraging Areas (e.g., no Attraction Factors).

FR model defines hypothetical populations of invertebrates and fish. Invertebrates are in equilibrium with localized sediment and water, depending on their feeding preferences, and do not move from their locations for the simulation period. However, initially, fish species are randomly placed on the modeling grid (or polygons). If particular species preferentially forage within subareas, this is accommodated by using species-specific "attraction factors" (discussed below, and described in Figures 2-3 and 2-4). The fish are allowed to forage over the grid (within their defined foraging areas) by a time period (e.g., one week or one month) specified by the analyst, following which, the fish are "gathered up" and again randomly dispersed over the modeling grid. Each individual fish contributes to the overall population distribution for each time interval (e.g., CDF or cumulative distribution function as shown in Figure 2-2). Essentially, the FR model does not track individual fish since these are mathematically represented by the number of simulations specified by the analyst (e.g., the number of draws in that Monte Carlo iteration). Further, each fish contributes to an overall population distribution of predicted tissue concentrations. The modeling grid in FR is defined by a map that is imported as a JPEG or GIF file. Contaminant concentrations in sediment and water, and physical locations, are defined using polygon tools to draw contaminate areas on the map.

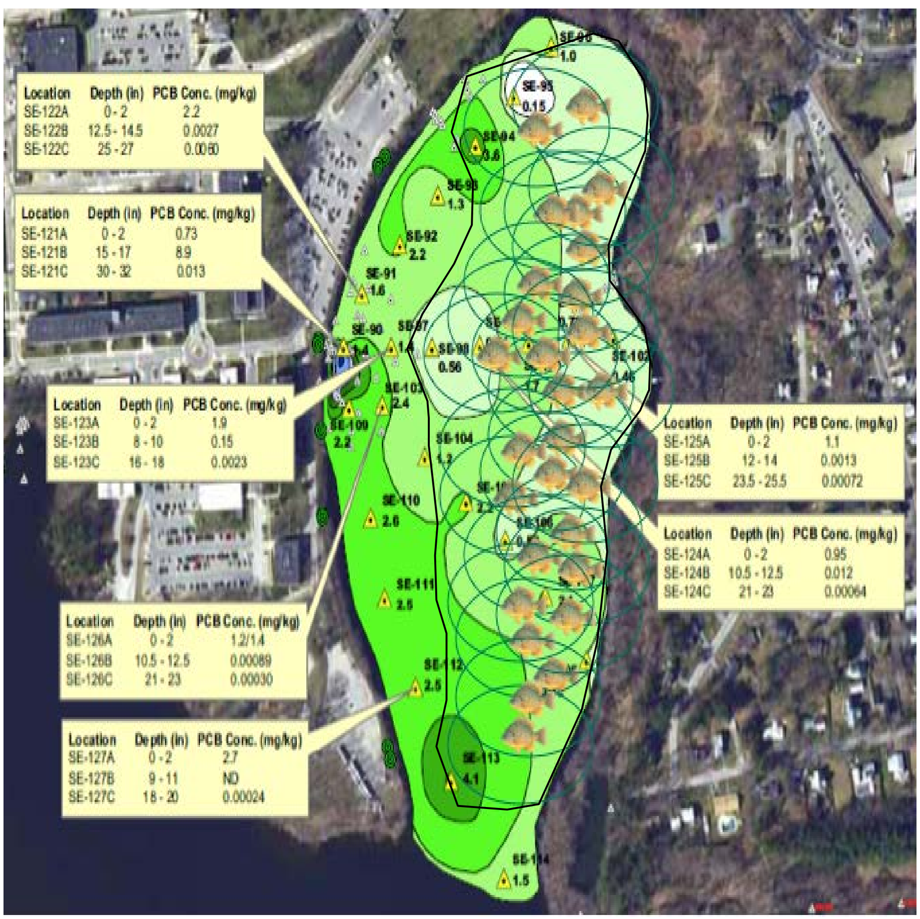


Figure 2-4. Example of Fish Foraging in a Cluster on a Map with an Attraction Factor of One for the Black-Outlined Sub-Area

The version of the model used here did not allow a direct link to GIS-generated exposure concentrations. These had to be drawn by hand based on underlying maps such as those shown in Figure 2-3 and Figure 2-4. However, the version of the model that is publicly available does not link directly to GIS-generated files (e.g., .SHP files). Next, the user specifies the aquatic food web, which typically includes benthic and pelagic invertebrates, phyto-plankton, forage fish, and piscivorous fish. Figure 2-3 provides a conceptual example of individual fish with small foraging areas placed on a map of sediment concentrations; individual fish are dispersed over the user-defined exposure field.

If the foraging area of the fish extends beyond the model domain, it is truncated (in Figure 2-3, water is shown as green areas). Fish can preferentially forage in particular areas based on features of the aquatic landscape (e.g., particular substrates, presence of specific aquatic vegetation, and physical disturbances, such as fallen trees, among others). The FR model allows fish to be "attracted" to these physically defined features again using the map-based polygon tool. In this case, the random dispersal of fish over the modeling grid is weighted toward these attractive areas (e.g., the probability that the fish will land near these areas is increased and not completely random). There are no formal methods or databases incorporated in FR (e.g., the analyst must make this determination outside the software).

However, the attraction factor increases the probability that fish are found in a particular area of the site. This information can be based on data obtained through a wildlife biologist, or tag-recapture studies. Figure 2-4 provides a schematic of the effect of an attraction factor of one to the subarea represented by the black outline.

FR predicts fish body burdens in aquatic food webs given site-specific exposure conditions. One key aspect to this is a complete understanding of the relationship between sediment and water concentrations (e.g., to understand how sediment interacts with water and how concentrations in either media change over time as a result of this interaction). Although fish are primarily exposed to bioaccumulative contaminants through sediment sources, significant dynamics might exist that allow sediments to release contaminants. For example, through various flux mechanisms that might result from disequilibrium between sediment and water – an important consideration to capture with respect to exposure. FR is not a sediment fate and transport model – these issues need to be addressed outside the realm of the bioaccumulation model. It is likely that deficiencies attributed to the bioaccumulation model actually result from an imperfect understanding of the sediment-water interaction and dynamics.

FR allows users to specify probability distributions for model inputs, and users can specify whether a parameter contributes predominantly to "uncertainty" or population "variability." Uncertainty and variability should be viewed separately in risk assessment because they have different implications to regulators and decision makers (Thompson and Graham, 1996). For example, there is "true" uncertainty (e.g., lack of knowledge) in the estimated concentrations of sediment and water to which aquatic organisms are exposed. Concurrently, parameters contributing to contaminant bioaccumulation display variability. Variability is a population measure, and provides a context for a deterministic point estimate (e.g., average or reasonable maximum exposure). Variability typically cannot be reduced, only better characterized and understood. In contrast, uncertainty represents unknown but often measurable quantities. Oftentimes, uncertainty is reduced by obtaining additional measurements of the uncertain quantity. Quantitatively separating uncertainty and variability allows an analyst to determine the fractile of the population, for which a specified risk occurs, and the uncertainty bounds or confidence interval around that predicted risk (von Stackelberg *et al.* 2002a).

If uncertainty is large relative to variability (i.e., it is the primary contributor to the range of risk estimates), and if the differences in cost among management alternatives are high, additional collection and evaluation of information is recommended before making management decisions for contaminated sediments. Alternatively, including variability in risk estimates allows decision makers to quantitatively evaluate the likelihood of risks above and below selected reference values or conditions (e.g., average risks as compared to 95th percentile risks).

2.1.1 MATHEMATICAL FRAMEWORK

The FR model is based on the mathematical algorithms described in detail by Gobas (1993). The basic form of the time-varying uptake equation is given by:

$$\frac{dC_f}{dt} = k_1 * C_{wd} + k_d * C_{diet} - (k_2 + k_e + k_m + k_g) * C_{fish} \qquad \text{(Eq. 1)}$$

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 (μg/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_{fish} = concentration in fish (μg/kg)

The individual rate constants are described in detail by Gobas (1993); Gobas *et al.* (1995); von Stackelberg *et al.* (2002b); and the U.S. EPA (2000). Figure 2-5 provides a schematic of the equations used in the FR model, and the relationships across submodels. Although the basic modeling framework of Gobas (1993) has been updated (e.g., Arnot and Gobas 2004), model improvements have focused on increased complexity with respect to fish physiology rather than exposure *per se*, which effectively increases the number of required input parameters outside the domain of the decision maker (e.g., fish physiology). Further development of the FR model focused on improving and refining approaches for modeling exposure as a target for decision making.

Ultimately, decision makers influence exposure by implementing site-specific management alternatives (e.g., remediation). However, decision makers have no control, for example, over physiological parameters related to absorption of contaminants at the gut, in addition to other, similar factors. This was the primary motivation for continued development of the FR model, and why the chosen mathematical framework does not incorporate Arnot and Gobas (2004) but rather relies on the original Gobas (1993) approach.

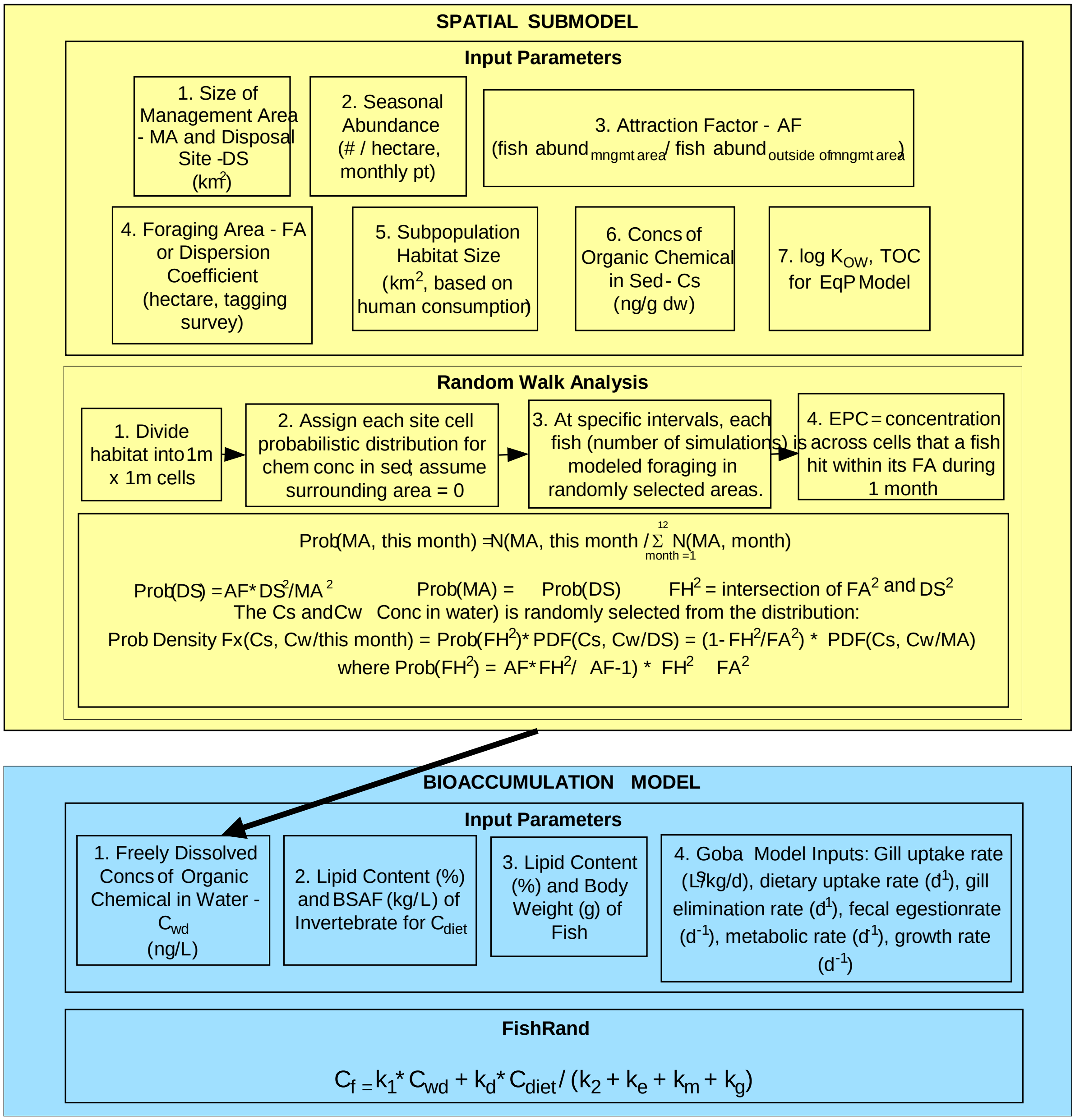


Figure 2-5. Equations Used in the FishRand Spatially-Explicit Model

2.1.2 SPECIFIC INPUTS TO THE FR MODEL

User-defined inputs to the FR model are categorized as site-specific, contaminant-specific, and species-specific. With few exceptions, each input is described by distributions rather than point estimates (although point estimates can be used). Each of these inputs is discussed below.

Site-Specific	Contaminant-Specific	Species-Specific
Sediment concentrations (mg/kg dry weight)	(Sediment and water exposure concentrations)	Fraction lipid (%)
Dissolved water concentrations (ng/L)	Log K_{ow} (L/L)	Weight (g)
Total organic carbon (%)	BSAF (optional)	Feeding preferences (frac)
Water temperature (^{O}C)		Foraging area (map-based) (optional)
		Attraction factor (frac) (optional)
		Uptake rate constants (optional)

Table 2-1. FishRand Model Inputs

Site-Specific Inputs

Site-specific sediment and water concentration exposure inputs are defined using the map-based polygon tool. Input can be automated to link to an Excel file with x-y locations and corresponding concentrations, or can be entered manually. The most sophisticated use of FR allows sediment and water exposure concentrations to change over time. Additionally, sediment and water exposure concentrations can be described by probability distributions or point estimates. Users specify contaminated areas within a larger uncontaminated area, or areas of contamination within an area of background contamination. The other key site-specific input is sedimentary total organic carbon, which differs across discrete areas of the site represented by the polygons, which are defined differently for total organic content (TOC) versus sediment, and water exposure concentrations, if desired.

Finally, water temperature at a commensurate temporal scale is a required input. Water temperatures are defined for different areas or for the entire modeling grid.

Contaminant-Specific Inputs

The contaminant-specific input (aside from sediment and water exposure concentrations for each polygon, grid cell and/or background) is the water-octanol partition coefficient (Log K_{ow}) for each contaminant. These are obtained from the literature.

Benthic Sediment Accumulation Factor (BSAF) (optional)
The other optional contaminant-specific input is the benthic:sediment accumulation factor (BSAF) defined as:

$$BSAF = (C_{Benthos} / f_L)/(C_{Sed} / f_{OC}) \qquad \text{Eq. (2)}$$

where:

C_{Bentho}	= concentration of contaminant in biota, mg/kg wet weight
f_L	= fraction lipid in benthos, kg lipid/kg wet weight
C_{Sed}	= concentration of contaminant in sediment, mg/kg dry weight
f_{OC}	= fraction organic carbon in sediment, kg organic carbon/kg dry weight

BSAFs are often defined using site-specific data and are contaminant-specific (e.g., the model does not allow users to specify more than one BSAF per contaminant). Mathematically, BSAF is a multiplier on the equilibrium partitioning equation used to predict benthic invertebrate concentrations. Since the FR model incorporates distributions rather than point estimates for all three inputs (i.e., sediment concentration, organic carbon, and fraction lipid), BSAF is not used. The effect of incorporating distributions results in a partitioning of predicted invertebrate concentrations, including the higher (or lower) deterministic value embedded in BSAF.

Species-Specific Inputs

Species-specific inputs are defined by the conceptual model of the aquatic food web, and may be based on site-specific data or obtained from the literature. For the base of the food web (e.g., invertebrates, zooplankton, phytoplankton etc. assumed as being in equilibrium with either sediment or water) the required input is percent lipid. For fish, the required inputs include species-specific fish weights, foraging areas, feeding preferences, and fraction lipid. An optional input is the attraction factor.

Fish-Specific Inputs (Required)
The percent lipid in all organisms from phytoplankton to invertebrates to fish is a required input to the model. Concentrations at the base of the food web are estimated using equilibrium partitioning with either sediment or water, and depends on the compartment (e.g., phytoplankton, zooplankton, and pelagic invertebrates are assumed to be in equilibrium with dissolved water concentrations, and benthic invertebrates are assumed to be in equilibrium with sediment). Fish lipid values are also required and are typically available from site-specific data often augmented with data from the literature. In some cases or for some interim species (particularly forage fish) for which data were not collected, literature values are used.

In addition to lipid content, all fish in the aquatic food web require weight (in grams), and feeding preferences, which are defined as the proportion of diet across prey items (e.g., invertebrates, phytoplankton, and forage fish).

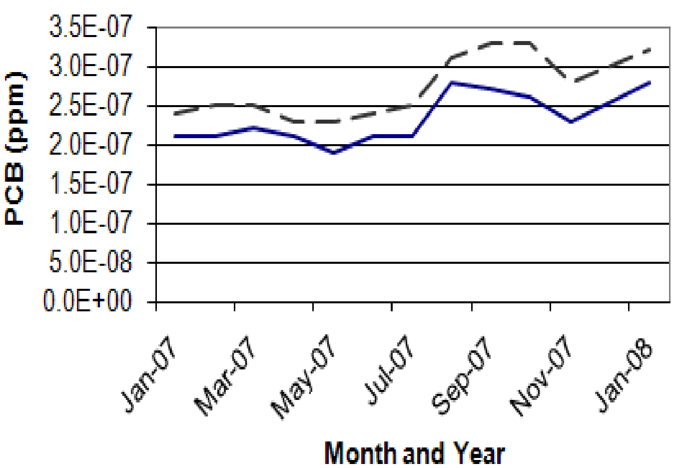
Fish-Specific Inputs (Optional)
There are two map-based species-specific inputs related to fish behavior. One is the foraging area, which defines the area within which fish can forage for the given time interval, and the second is the attraction factor, which allows the analyst to define areas of preferential foraging. If the foraging area is not specified, the model defaults to allow the fish to forage anywhere within the modeling grid as defined by the map, which is referred to in the model as "site."

FR allows users to edit the uptake rate constants. Growth rate is the most common uptake rate constant where site-specific information might be available. Metabolic rate, which is species-specific and set to zero, or no metabolism, as a default setting, is another rate constant for which more detailed information may be available (e.g., contaminants that are metabolized, including polycyclic aromatic hydrocarbons or PAHs). In general, bioaccumulative substances such as polychlorinated biphenyls (PCBs) metabolize poorly and hence the default for this term is zero.

Once the model inputs have been defined, and assuming they have been defined as distributions rather than point estimates, the user defines which parameters contribute most to population variability, and which represent uncertainty prior to running the model. More detailed information is found in the help screens throughout the model and in the User's Manual.

2.1.3 FR OUTPUT

FR predicts species-specific body burdens or critical body residues (CBRs) in units of mg compound/ kg body mass. These outputs can be directly compared to toxicity-based CBRs that are correlated to adverse toxic effect (Micheletti *et al.* 2008, Nendza *et al.* 1997).



Fish: Black Sea Bass , Chemical: PCB

		Central Tendency		Variability & Uncrtaint		Uncertainty of Mean
Beginning	Ending	Mean	Median	Stdev	Variance	UCL95%
1/15/2007	2/15/2007	2.00E-07	1.30E-07	5.20E-07	2.70E-13	2.30E-07
2/15/2007	3/15/2007	2.30E-07	1.40E-07	5.80E-07	3.40E-13	2.60E-07
3/15/2007	4/15/2007	2.40E-07	1.50E-07	6.20E-07	3.80E-13	2.70E-07
4/15/2007	5/15/2007	2.40E-07	1.60E-07	6.30E-07	4.00E-13	2.70E-07
5/15/2007	6/15/2007	2.50E-07	1.60E-07	6.40E-07	4.10E-13	2.80E-07
6/15/2007	7/15/2007	2.30E-07	1.50E-07	5.90E-07	3.50E-13	2.60E-07
7/15/2007	8/15/2007	2.30E-07	1.50E-07	6.00E-07	3.70E-13	2.70E-07
8/15/2007	9/15/2007	2.80E-07	1.80E-07	7.40E-07	5.50E-13	3.00E-07
9/15/2007	10/15/2007	2.70E-07	1.70E-07	7.10E-07	5.00E-13	3.00E-07
10/15/2007	11/15/2007	2.60E-07	1.70E-07	6.90E-07	4.70E-13	3.00E-07
11/15/2007	12/15/2007	2.10E-07	1.40E-07	5.70E-07	3.20E-13	2.40E-07
1/15/2008	12/15/2008	2.90E-07	1.90E-07	7.60E-07	5.80E-13	3.00E-07

Figure 2-6. Example of the Graphical and Tabular Output from the FR Model

Many of these are referenced and searchable in the Effects Residue Database (ERED; ERED website here). An example of the graphical and tabular output from FR is presented in Figure 2-6.

The model is flexible and allows users to calculate a variety of statistics over different averaging times (e.g., monthly or annualized predicted body burdens, averages and 95% confidence intervals), or to simply output all of the results and percentiles.

2.2 TECHNOLOGY DEVELOPMENT

The FishRand model is a spatially-explicit aquatic bioaccumulation model that was originally developed to support decision making at the Hudson River Superfund Site (assuming single, non-spatially explicit reach-wide exposure concentrations in sediment and water). It was used to compare remedial alternatives (and no action) on the basis of predicted fish tissue concentrations. The mathematical engine of the model is based on the work of Dr. Frank Gobas (Gobas, 1993), which is run in dynamic time-varying mode and augmented to allow all inputs to be defined by distributions or ranges and not by point estimates, including the spatially-explicit foraging module to better characterize exposures for migratory and wide-ranging fish species.

This section describes the development of the FishRand Spatially-Explicit Model. Many original publications and presentations provide details of the development and application of this model. For example:

von Stackelberg K. 2013. Platform presentation on spatially-explicit bioaccumulation modeling at the SedNet conference in Lisbon, Portugal. http://www.sednet.org/2013-presentations.htm.

von Stackelberg K. 2013. Decision analytic strategies for integrating ecosystem services and risk assessment. *Integrated Environmental Assessment and Management* 9(2):260-268.

von Stackelberg K. 2012. The FishRand spatially-explicit bioaccumulation model. Platform presentation at the North America SETAC Annual Meeting, November 2012, Long Beach, CA.

von Stackelberg K. 2012. Incorporating fish behavior in bioaccumulation modeling. Invited platform presentation at the North America SETAC Annual Meeting, November 2012, Long Beach, CA.

von Stackelberg K. 2012. Bioaccumulation and Potential Risk from Sediment-Associated Contaminants in Dredged Materials. Platform presentation at Dredging 2012, Dredging in the 21st Century, San Diego, CA.

von Stackelberg K, Johnson M and WT Wickwire. 2012. Spatially-Explicit Exposure and Ecological Risk Modeling Tools: SEEM and FISHRAND. Platform Presentation at the SETAC Europe Annual Meeting, May 2012, Berlin, Germany.

von Stackelberg K. 2010. Spatially-Explicit Bioaccumulation Modeling. Presented at the Society for Environmental Toxicology and Chemistry Annual Meeting, November 2010, Portland, OR.

Sunderland ES, Knightes CD, von Stackelberg K and NA Stiber. 2010. Environmental fate and bioaccumulation modeling at the U.S. Environmental Protection Agency: Applications to inform decision making. In Modelling of Pollutants in Complex Environmental Systems Volume II. United Kingdom: ILM Publications.

Johnson MS, Korcz M, K von Stackelberg and B. Hope. 2009. Spatial analytical techniques for risk based decision support systems. In Decision Support Systems for Risk Based Management of Contaminated Sites. Marcomini, A., Suter, G.W. and A. Critto, Eds. Springer-Verlag.

von Stackelberg K, Wickwire WT and D Burmistrov D. 2005. Spatially-explicit exposure modeling tools for use in human health and ecological risk assessment: SEEM and FISHRAND-Migration. pp. 279–288. In: Environmental Exposure and Health, 2005. Aral MM, Brebbia CA, Maslia ML and Sinks T (eds.), United Kingdom: WIT Press.

von Stackelberg K, Burmistrov D, Linkov I, Cura J and Bridges TS. 2002. The use of spatial modeling in an aquatic food web to estimate exposure and risk. *Sci Total Environ* 288(1-2):97-110.

Linkov I, Burmistrov D, Cura J and Bridges TS. 2002. Risk-based management of contaminated sediments: consideration of spatial and temporal patterns in exposure modeling. *Environ Sci Technol* 36(2):238-246.

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

United States Environmental Protection Agency. 2000. Phase 2 Revised Baseline Modeling Report for the Hudson River Remedial Investigation/Feasibility Study. Prepared by Limno-Tech, Inc., Menzie-Cura and Associates, Inc., and TAMS Consultants, Inc. for U.S. EPA. December, 2000. www.epa.gov/hudson.

The model has been applied in both the non- and spatially-explicit modes for several different sites on behalf of the Army Corps of Engineers. It has also been applied under a Small Business Innovation Research Grant as part of a larger decision analytic framework (von Stackelberg, 2013). Technology development for the FR model has focused on improving how exposure is defined, both in terms of spatially-explicit exposure concentrations and simulating fish foraging behavior relative to those spatially-defined exposures. Decision makers cannot control the ways in which fish behavior and physiology interact with exposure concentrations. However, decision makers can control spatial patterns of contaminant concentrations. The basic uptake equations are kept as conservative as possible, while adding greater realism to the ways in which exposure influences predicted uptake.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

This technology provides a number of analytical advantages. While limitations exist, appreciation and comprehension of these limitations within the context of each user's specific modeling goals should permit uncomplicated management of the technology.

The <u>advantages</u> of this technology include:

- Avoidance from selecting the site or contamination area as the only spatial context
- Direct simulation of fish foraging strategies over GIS-defined, spatially-explicit sediment and water exposure fields
- Easier description and translation of model mechanics to stakeholders
- Improving the analysis of population risk

- Accessible design and user-determined complexity encourages use of technology
- Provision of relative indicators of sensitivity, and assistance in the understanding of factors that contribute most to exposure, and hence risk
- Provision of quantitative estimates bounding uncertainty and variability in exposure/risk estimates
- Provision of more usefully formatted fish body burden estimates (probability distributions) that link to other analyses (e.g., risk assessments, economic forecasts, injury determinations, etc.)

The limitations of this technology include:

- Simplified bioaccumulation options/assumptions (true of any bioaccumulation model)
- Suitability of the habitat as defined by attraction factors might be subjective
- Lacks direct linking to the GIS output (e.g., .SHP files) since users must manually draw the exposure fields
- Dynamic habitats and resulting changes in wildlife usage are not accounted for
- Simplified foraging strategies (lacking important considerations such as competition for limited resources, bioenergetics, and fluctuating food availability)
- It is not possible to quantitatively specify the uncertainty in the variability, e.g., a second-order probabilistic analysis in which a variability distribution (mean and standard deviation) are also specified as distributions. For example, a distribution for lipid content specified by a mean and standard deviation, each themselves consisting of means and standard deviations.
- Increasing model complexity linked to increasing calibration challenges

3.0 PERFORMANCE OBJECTIVES

The objectives for this project are provided in Table 3-1 below.

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
Verify FR results for a number of fish species across two sites and two different contaminants	See Table 2-1	Comparison of FR predicted fish body burdens with analytical results from site; an improvement relative to non-spatially explicit results AND lowest relative percent difference (RPD)	RPDs for Spatially-Explicit Case consistently improved over Deterministic or Probabilistic
Improve and refine FR	Feedback from peer reviewers and workshop panelists	Favorable feedback regarding refinements	The only direct recommendation for FR was to consider inclusion of a direct linkage to GIS
Qualitative Performance Objectives			
Ease of use	Feedback on usability of the model and time required	Risk assessors and non-risk assessors will be able to learn to apply FR, practical examples of use	Held a hands-on workshop with all users successfully using the model with their own datasets
Develop a publication from the workshop highlighting current thinking on spatial models in risk assessment – applications, benefits vs. risks of using, improvements	Preparation of the final publication using notes/feedback from workshop participants	Acceptance for publication in a peer reviewed journal	A publication is currently in preparation

Development of a User Guide	Information on how to use and set up models to include relative comparisons of options	Feedback from users at training sessions	Held a hands-on workshop with all users successfully using the model with their own datasets
Cost and Performance Report	Results of field validation assays	If performance criteria are met	Completed
Final Technical Report	Results and final conclusions/ recommendations	N/A	This document

Table 3-1. Performance Objectives

3.1 VERIFY FISHRAND RESULTS

This objective involves comparing model predictions to observed data to evaluate whether there is an improvement in prediction accuracy when exposures are better characterized. As described previously, the approach was to apply the bioaccumulation model under three scenarios with the way in which exposure was characterized as the only difference in assumptions across scenarios. Background information for each of the sites is provided in Section 4.0, model inputs in Section 5.0, and detailed performance results in Section 6.0.

The specific metrics presented here are modified slightly as originally proposed. The original metric was written as: “Comparison of FR predicted fish body burdens with analytical results from site; development of risk metric using critical body residue (CBR)-relevant toxicity benchmark. Compare CBR hazard quotients (HQs) using space (FR) with no spatial resolution (95% UCL; single value – Deterministic Case). Both will be compared to actual fish HQs. A > 10x improvement considered successful.”

In a typical ecological risk assessment following U.S. EPA guidance (U.S. EPA 1992b; 1998), the HQ is defined as the comparison between predicted (or observed) site-specific fish body burdens and literature-derived threshold tissue concentrations (CBRs) associated with adverse effects of interest (e.g., typically endpoints related to growth, reproduction, or survival). The same CBR is used in the denominator irrespective of whether the body burdens are predicted from a bioaccumulation model or based on observed data. In essence, the HQ is merely a linear transformation of the key metric: how well the bioaccumulation model predicts a body burden as compared to data. The reader is reminded that “actual fish HQs” as proposed originally, simply refer to a numerator that is an actual, data-based fish tissue concentration as compared to the same literature-derived CBR. Thus, we directly compare predicted body burdens to observed data to simplify the evaluation of model performance, which is identical to a comparison on the basis of HQ. Consequently, the revised performance metric is "Comparison of FR predicted fish body burdens with analytical results from site; compare predicted means and standard deviations to observed means and standard deviations of tissue concentrations."

3.2 IMPROVE AND REFINE FISHRAND

Workshops were conducted to explore broader value of spatial models, and application of the models by the scientific community and regulators. Model improvements were discussed, and addressed four key questions: 1) What are spatially-explicit exposure models and why are they valuable? 2) How have the models been applied? 3) Are there regulatory impediments to their use? 4) Are there limitations to the models and can they be improved?

Workshop participants were asked to develop a list of considerations for model improvement and functionality. The only recommendation specific to FR was to provide a direct link to GIS output files (e.g., ".shp" files) rather than requiring users to redraw exposure concentrations. As the model was developed when GIS use was less common and expensive for routine use, the direct link was not initially included. Resource constraints combined with the software development platform of the original FR model precluded adding in the direct linkage to GIS output at the time these analyses were developed. However, the version of the model publicly available through the Army Corps of Engineers does include the direct GIS linkage as FR has now been reprogrammed in a Java-based programming environment.

Workshop participants focused their recommendations on how to increase use of spatially-explicit models to support regulatory decision making rather than on technical aspects of the model itself. These recommendations included identifying factors impeding regular use of spatially-explicit models generally, such as few precedents for their use, misguided perceptions as to their purpose, traditional regulatory practices, when such models are considered during the site assessment process, and specific technical concerns, including the quality of input data. A summary of the workshop is provided in Wickwire et al. (2011).

3.3 EASE OF USE

A two-day workshop held in April 2010 with attendees from DoD, industry and government allowed participants to use the model based on both the demonstration datasets contained within the model and their own data. Participants were invited to provide comments, which focused on strategies for increasing general use of spatially-explicit models (Wickwire et al. 2011).

3.4 PUBLICATION DEVELOPMENT

A publication for submission to the peer-reviewed literature is in preparation.

3.5 USER'S GUIDE

The User's Guide is contained within the program and is available directly from the desktop. Each input screen in the model also contains detailed instructions for that set of inputs.

The User's Guide is also included in Appendix E.

3.6 COST AND PERFORMANCE REPORT

The cost and performance report provides a summary of the final report.

3.7 FINAL REPORT

This document constitutes the final report.

4.0 DESCRIPTION OF THE MODELING SITES

4.1 U.S. ARMY NATICK SOLDIERS SYSTEMS CENTER (NSSC) SITE DESCRIPTION

The U.S. Army Natick Soldiers Systems Center (NSSC) site is located approximately 17 miles west-southwest of Boston in the town of Natick, Middlesex County, Massachusetts (Figure 4-1). The facility occupies a small peninsula extending from the eastern shoreline of the South Pond of Lake Cochituate and encompasses approximately 74 acres. NSSC has been a permanent U.S. Army installation since October 1954. The installation's mission includes research and development activities in food engineering, food science, clothing, equipment, materials engineering, and aeronautical engineering.

NSSC was listed as a Superfund site based on contamination in ground water and was added to the U.S. EPA National Priorities List (NPL) in May 1994. The ground water is undergoing treatment and removal, and other onsite investigations are ongoing, pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) ID number for the Site is MA1210020631. The U.S. Department of the Army is the lead agency responsible for environmental cleanup at this site. Primary documents that provide information for this site include ICF International (2008, and 2009). Data were not provided electronically and were extracted from hard copy files. All the original data as presented in source documents for both NSCC and Tyndall AFB are provided in Appendix D.

4.1.1 SITE LOCATION AND HISTORY

As noted above, NSSC is located near Boston, Massachusetts, and has been used for various U.S. Army activities since October 1954. For approximately 50 years, runoff from parking lots, equipment storage areas, bulk chemical storage areas, areas with high vehicle traffic, and unpaved areas has contributed to the presence of polycyclic aromatic hydrocarbons (PAHs), PCBs, pesticides, and metals in the sediments at each of the outfalls at NSSC.

One confirmed PCB release occurred at the NSSC facility during the mid-1980s following an explosion at a transformer on an outdoor pad. The release resulted in PCB contamination of the concrete pad, soils within the fenced transformer area, and soils at least 8 feet outside of the fenced area. Soil concentrations up to 14,000 parts per million (ppm) were detected. The transformer pad was scarified and sealed, and the surrounding soils were removed in accordance with the Toxic Substances Control Act (TSCA) during the summer of 1992. Analyses of the pad and surrounding soils following the cleanup indicated that further investigation was not required (ICF, 2009). This release of PCBs in the mid 1980s is believed to be the primary cause of the elevated PCB concentrations observed in sediments in South Pond of Lake Cochituate. Storm drains to the west of this area drain to Lake Cochituate. PCBs in the concrete and soils underneath the exploded transformer likely migrated into the stormwater drainage system and into Lake Cochituate. In 1990, the facility performed a preventative maintenance program on all of its transformers that included removal, replacement with PCB-free units, refilling with PCB-free oil, and washing/rinsing transformer pads. Therefore, there are no continuing PCB sources at the site.

4.1.2 SITE GEOLOGY/HYDROGEOLOGY

The South Pond of Lake Cochituate has a mean depth of 19.8 feet and covers an area of 0.39 square miles (ICF, 2009). Water depths along the immediate shoreline of the NSSC facility range from 0 to 10 feet. The main storm water outfall discharges to an area of South Pond (Pegan Cove) where the depths range from 0 to 10 feet. Another storm water outfall discharges to an area where the water depth progressively increases up to 30 feet. Water depth continues to increase to a maximum of more than 60 feet further out from this second outfall (referred to as the T-25 area).

The texture of the sediments encountered at NSSC varies from sand to finer-grained silts and clays. The texture of the sediments in the main storm water outfall area is silty clay. Most sediment samples collected around Lake Cochituate were classified as silty sand or sand with silt. Near shore sediments tend to consist of a larger proportion of sand, due to the winnowing of the finer-grained sediments from shallow water wave action. In deeper water (e.g., > 5 to 10 feet), sediments tend to consist of predominantly silts and clay. The organic matter content in many of the sediments associated with NSSC is high, and particularly those at outfall locations. The water content in most of these same sediments is also high. During field sampling of many sediments associated with NSSC, passive dewatering could not be accomplished during laboratory preparation. Centrifuging and freeze-drying of the sediment samples enabled moisture content requirements of the analytical methods to be met.

4.1.3 CONTAMINANT DISTRIBUTION

The results of an earlier human health risk assessment (HHRA) for fish ingestion indicated potentially unacceptable risks associated with consuming native fish species contaminated with PCBs caught from the NSSC shoreline near the main storm water outfall in Pegan Cove. Several sampling programs were tested at the NSSC site. The first provides sediment data collected before 2007. The 2007 sampling program contains fish and sediment data to further characterize and delineate the extent of sediment contamination with PCB associated with the main storm water outfall, in addition to fish samples to support the HHRA. Surface sediment samples were collected from the main storm water outfall area.

Figure 4-1. Total PCBs in Sediment at the NSSC Site for 2007

Sediment sampling locations and analytical results are shown in Figure 4-1. The GIS maps based on site data and used as the basis for model inputs are provided as part of Appendix B. Sediments were analyzed for PCB congeners and for TOC. Total PCB and homolog sums were calculated by addition of detected results for all congeners.

Total PCB concentrations within the main storm water outfall area ranged from 0.15 to 4.1 mg/kg (average of 1.7 mg/kg). The highest total PCB concentrations occur in the main storm water outfall/Pegan Cove area. Total PCB concentrations in sediment samples collected during the 2007 sampling event within this area were similar to those previously collected, which ranged from 0.058 to 7.4 mg/kg, with an average of 1.4 mg/kg. However, the 2007 data suggested that the extent of elevated PCB concentrations is broader than previous data had indicated. The 2007 data indicate that elevated concentrations of total PCB extend across much of the Pegan Cove area, and are greatest along the NSSC shoreline, particularly to south of the main outfall area. Total PCB concentrations appear to decrease east-northeast of the main storm water outfall and along the eastern shoreline of the cove. The original sediment data is found in Appendix B, which contains all data files and FR model input and output files.

Three fish species (largemouth bass, bluegill, and yellow perch) were collected and analyzed during the program, and concurrently with the sediment sample collection. Bluegill and yellow perch were analyzed whole body, and largemouth bass were filleted in the field with fillet (skin-on) and offal portions analyzed separately. Largemouth bass were retained for sampling only if they were exceeded 12 inches in length, which is the legal size limit for catching this species in Massachusetts. There are no size limits imposed by the State of Massachusetts for bluegill or yellow perch. Therefore, the sizes of bluegill and yellow perch targeted and analyzed in this study, which were approximately 4 to 8 inches in length, were consistent with size classes taken by anglers. The original tables from ICF International (2009), and the FR inputs and output files are provided in Appendix B.

4.2 TYNDALL AIR FORCE BASE

The primary document providing the information for modeling is the Draft Feasibility Study (Weston, 2009). Sediment and fish data were provided electronically and all original data is given in Appendix D. Model inputs and outputs from the FishRand model are provided in Appendix C.

4.2.1 SITE LOCATION AND HISTORY

Tyndall Air Force Base (AFB) is located in the eastern portion of Bay County in the Panhandle of western Florida, and occupies approximately 29,000 acres on a narrow 16-mile-long northwest-southeast trending peninsula. Bordering the peninsula and the Base is the Gulf of Mexico and St. Andrew Sound to the south, St. Andrew Bay to the west, and St. Andrew Bay and East Bay to the north. Site OT029 is located on the northern portion of the Base. Site OT029 encompasses Shoal Point Bayou (also known as Fred Bayou), the Southwest Branch of Shoal Point Bayou, the Construction Debris Landfill, the Palm Tree Landfill, an area west of the Landfills, an area south of the Southwest Branch (South of Southwest Branch), and the peninsula, which is located between the Southwest Branch and Shoal Point Bayou. The peninsula is also known as the Drum Disposal Area. Moreover, the primary contaminant DDT and its metabolites are the major focus of the modeling effort.

4.2.2 SITE GEOLOGY/HYDROGEOLOGY

Shoal Point Bayou is an estuarine bayou of the St. Andrew Bay estuary system that is located directly adjacent to Panama City, Florida. The estuary system encompasses West Bay, North Bay, St. Andrew Bay, and East Bay. Shoal Point Bayou is located on the southern side of East Bay. The St. Andrew Bay estuary system is connected with the Gulf of Mexico via two passes on the eastern and western ends of Shell Island. Tidal estuarine was from East Bay, and intermittent storm water runoff from two drainage ways at the northwestern end of Tyndall AFB influences Shoal Point Bayou.

Shoal Point Bayou has an average depth of approximately 5 to 10 feet, and a maximum depth of less than 20 feet along its centerline. According to the bathymetric map, the southern end of the bayou is approximately 10 feet deep. Shoal Point Bayou is predominantly underlain with silty sands, except in the vicinity of the fuel loading dock where sand is prevalent. The drainage ditches are predominantly underlain with quartz sand sediment.

4.3 CONTAMINANT DISTRIBUTION

For the purposes of modeling the effects of remedial activities, Shoal Point Bayou is subdivided into five areas as described below (and Figure 4-2):

- Area 1 (Upper Reach of Southwest Branch): This area represents approximately 720 linear feet of stream with a width of 15 to 30 feet. The upper reach of the Southwest Branch comprises small isolated communities of needlerush and cordgrass. The approximate total area is 19,000 square feet or 0.2 acres.
- Area 2 (Lower Reach of Southwest Branch): This area represents approximately 570 linear feet of stream with a width of 35 to 200 feet. The lower reach of the Southwest Branch in this area is bounded on the western side by a significant needlerush community. The approximate total area is 75,000 square feet or 1.7 acres.
- Area 3 (Southern Portion of Shoal Point Bayou): This area is open water representing the most southern portion of Shoal Point Bayou. It was used as a turning basin for Petroleum, Oils, and Lubricants (POL) barges. The flightline drainage ditch (FLDD) is the predominant contributor to flow in this area, which is approximately 800 feet long in a north-south direction, with a variable width of 80 to 350 feet. Area 3 is bounded by two small needlerush communities on the southeast and northeast. The approximate total area is 238,000 square feet or 5.5 acres.
- Area 4 (Central Portion of Shoal Point Bayou): This area represents the confluence of the Southwest Branch and the turning basin/FLDD, which extends northward to the POL dock. The area is approximately 1,100 feet long in a north-south direction, and the width varies from 180 to 1,000 feet. Area 4 is bounded by needlerush communities on the east, west, and northeast. The approximate total area is 463,000 square feet or 10.6 acres.
- Area 5 (Northern Portion of Shoal Point Bayou): This area represents the northern extent of Shoal Point Bayou to its discharge point into East Bay. The area is approximately 2,200 feet long in a north-south direction, and the width varies from 350 to 500 feet. Area 5 is bounded by relatively narrow needlerush communities on the east, west, and northeast. The approximate total area is 1,000,000 square feet or 23 acres.

Original sediment data are provided in Appendix C as part of documenting all modeling inputs and outputs, and a full description of all input data as provided is given in Appendix D. A summary of the sediment exposure concentrations used in the modeling is provided in Section 5.2.2.

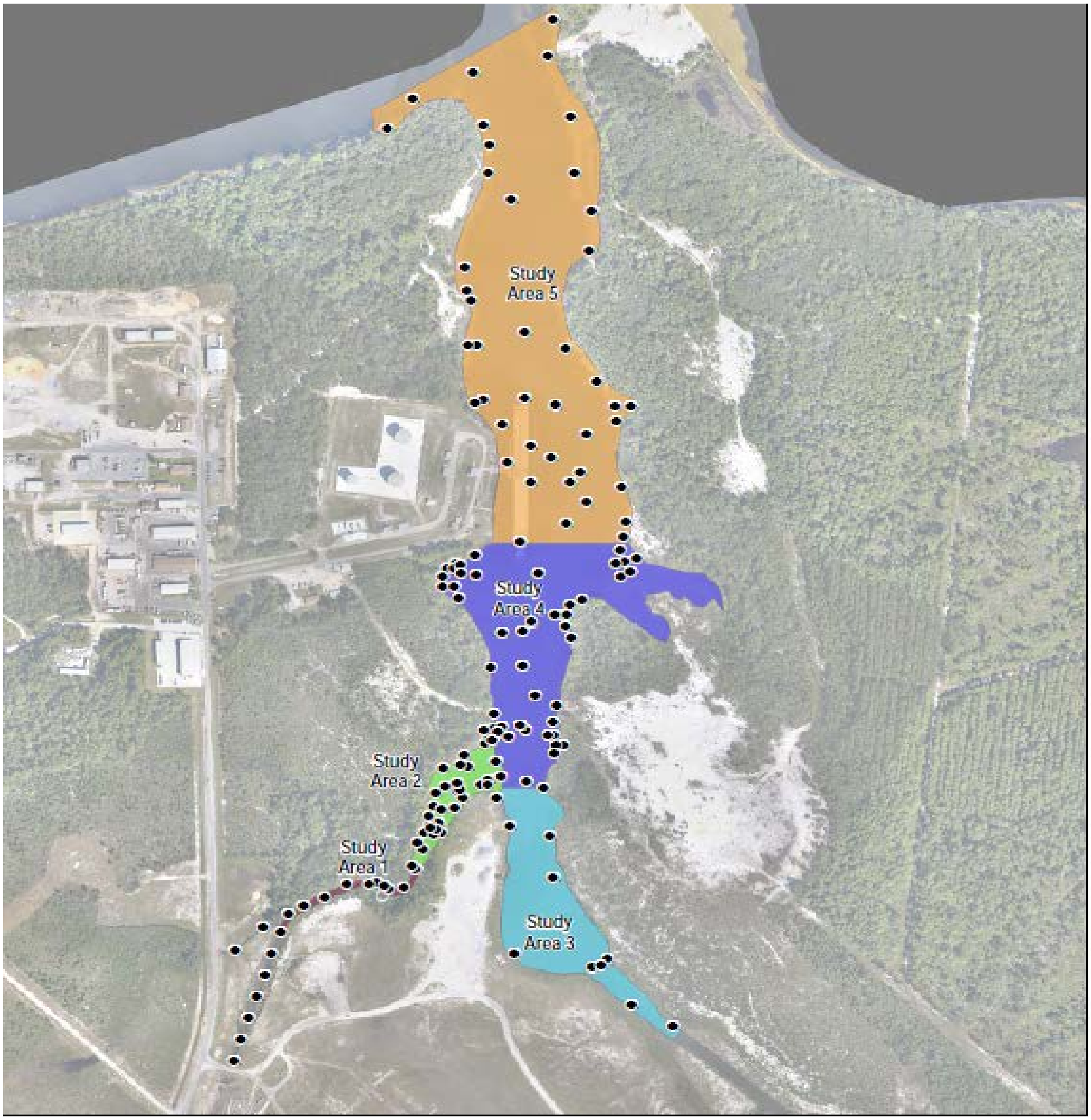


Figure 4-2. Sediment Sampling Locations and Study Areas in the Shoal Point Bayou, Tyndall Air Force Base

Fish Tissue Data

A summary of the available composited fish tissue data are presented in Table 4-1 below:

Sample ID	Adjacent Sediment Sample Locations	Species	Number of Fish Collected	Total Weight of Fish Collected (g)	Range of Fish Length (cm)			Area
Reference - Smack Bayou								
OT029-SMB-SE-1	NS	Pinfish	60	285	5.1	-	9.3	
OT029-SMB-SE-2	SE-2	Gulf killifish	28	263	--		--	
Fred Bayou								
OT029-SE-05	SE-3, SE-4, SE-5, and SE-6	Pinfish	29	150.1	5.1	-	8.6	1
OT029-SE-06	SE-3, SE-4, SE-5, SE-6, SE-7, and SE-8	Gulf killifish	25	138.5	5.1	-	8.9	1
OT029-SE-11 [A]	SE-10, SE-11, and SE-14	Gulf killifish	13	126.9	7.0	-	12.7	1,2
OT029-SE-11 [A]	SE-10, SE-11, and SE-14	Longnose killifish	10	25.3	3.8	-	6.4	1,2
OT029-SE-12	SE-8, SE-9, SE-10 and SE-12	Gulf killifish	21	201.3	5.7	-	11.4	1,2
OT029-SE-27 [B]	SE-33 and SE-34	Gulf killifish	12	67.7	6.4	-	9.9	5
OT029-SE-48 [B]	SE-34	Gulf killifish	12	77.1	6.7	-	10.5	5
OT029-SE-48	SE-34	Pinfish	30	166.9	5.4	-	8.6	5

-- Not available.
NS = Not sampled.
A - Gulf and longnose killifish from OT029-SE-11were combined for analysis.
B - Gulf killifish from OT029-SE-27 and OT029-SE-48 were combined for analysis.

Table 4-1. Fish Tissue Data for the Tyndall AFB site (all original data is provided in Appendix D; model inputs and outputs provided in Appendix C)

5.0 TEST DESIGN: MODEL APPLICATION

Parameterization of the FR model evaluation relied exclusively on existing data, typical of what would be provided during a Remedial Investigation/Feasibility Study (RI/FS) conducted at Superfund sites or other types of site characterization. Both demonstration sites had Feasibility Studies available as referenced below, and these provided the spatially-explicit sediment and water exposure concentrations, and the fish concentrations used for comparing predicted model outputs. In addition, fish lipid content and total organic carbon were based on site-specific data. Benthic and pelagic invertebrate lipid content and Log K_{ow} were obtained from the literature as neither of these sites conducted invertebrate sampling programs.

The modeling application presented here relied on publicly available data from the RI/FS process, and as such, there were existing conceptual models of the aquatic food web. This is a necessary step that is not unique to an application of the FishRand model and would be required irrespective of the chosen modeling approach. The conceptual model identifies the linkages across components in the food web in a general sense, e.g., the specific fish species and their foraging preferences expressed as compartments across trophic levels. In general, the food web should capture all relevant exposure pathways, but not be so detailed as to be redundant. For example, it is generally not necessary to identify individual benthic invertebrate species unless there are clear differences in parameters that would influence exposure (e.g., lipid content) in the context of fish feeding preferences. An oligochaete would differ from a clam, but would not differ from other soft-bodied, burrowing organisms.

The conceptual model of bioaccumulation in the aquatic food web must link to the larger conceptual model of site exposures and interactions, and these are developed together with the risk assessors and other analysts working at the site. The application of the bioaccumulation model relies on data obtained from the sampling program and the approach must be tailored to identify the species relevant to decision making at the site (e.g., fish consumption pathway). Typical contaminated sediment sites rely on a suite of models and analyses to support decision making. U.S. EPA (2009) provides a primer for those not experienced in the development and use of models at sediment sites. It explains the objectives of modeling, how models are developed and applied, how they are used to predict the effectiveness of management alternatives, and, finally, an approach for addressing uncertainties in model predictions.

5.1 CONCEPTUAL EXPERIMENTAL DESIGN

The FR model was applied at two sites for different sets of contaminants. The approach involved applying a parameterized FR model under three scenarios: 1) Deterministic, which is a deterministic, average exposure concentration (e.g., surface-area weighted average concentration or similar averaging technique) input typical of most bioaccumulation modeling applications; 2) probabilistic: using probabilistic sediment exposure concentrations but not spatially-explicit; and, 3) spatially-explicit sediment exposure concentrations (which, in this case, are defined by point estimates but could be defined by distributions if such monitoring data or fate and transport modeling results were available). Contaminants included DDD, DDE, and DDT (Tyndall AFB) and PCBs (NSSC Site). Water concentrations at both sites were always below the detection level. Thus, a nominal, deterministic value at the detection level was used for water concentrations across all scenarios.

The FR model was parameterized for each food web using data publicly available from the relevant site documents augmented with data from literature reviews. The models were parameterized and all inputs held constant across scenarios except for the way in which exposure concentrations were defined. Species-specific predicted body burdens were compared to data and the results compared across scenarios. In this case, explicit model calibration was not utilized (e.g., initial model parameterization led to a largely satisfactory comparison between predicted and observed with some exceptions for the Tyndall Site – see Section 6.0). Thus, a second step of model verification following calibration was not conducted in this case. Model calibration and verification (often referred to as validation) is discussed further in Section 7.0. Full model input/output files are found in Appendix B for the NSSC Site and Appendix C for the Tyndall Site.

5.2 MODEL INPUTS

5.2.1 NSSC SITE MODEL INPUTS

All model inputs were identical across the three scenarios except for the way in which sediment exposure concentrations were defined. Table 5-1 provides the feeding preferences for the modeled species, while Table 5-2 provides a summary of the model inputs in common across all scenarios. Feeding preferences were obtained from the modeling in the RI/FS augmented by an independent literature review as stomach content analyses were not available for this site. Site-specific data was used to define lipid content and weight for each fish species, as well as estimates of total organic carbon content and water temperature. Log K_{ow} and benthic and pelagic lipid content were obtained from the references cited in Table 5-2 given that site-specific data were not available for these inputs. A site-wide attraction factor of one was used in the absence of site-specific tagging studies or preferential fish habitat and foraging information. This particular application of the model, across all scenarios, assumes that fish have no particular foraging area preference within the site. Additionally, fish can forage anywhere within the site (e.g., the foraging area is essentially the size of the site). However, fish are not permitted to leave the modeling grid (site) across scenarios under this application.

Species	Water Column Invertebrates	Benthic Invertebrates	Pumpkinseed	Yellow Perch
Pumpkinseed	70%	30%		
Bluegill	70%	20%	10%	
Yellow Perch	20%	70%	10%	
Largemouth Bass		50%	40%	10%

Table 5-1. Fish Feeding Preferences at the NSSC Site

The only difference in inputs across the three runs is the way in which sediment exposure concentrations were specified as shown in Table 5-3. The key difference between the Deterministic Case and the Probabilistic Case was that the Deterministic Case incorporates a deterministic exposure concentration, while the Probabilistic Case had the same central tendency but included standard errors to characterize the uncertainty in the deterministic means. The Spatially-Explicit Case could utilize distributions if sufficient data were available. However, for this site, they were unavailable.

Input	Units	Distribution type	Parameters	Source
Water column invertebrates lipid content	%	triangular (min, mode, max)	0.5, 1.2, 3	Assumed
Sediment invertebrates lipid	%	triangular (min, mode, max)	1.8, 3.1, 4.7	KABAM v.1.0 documentation
Pumpkinseed				
Weight	g	triangular (min, mode, max)	34, 42, 47	FS Report, Table 3-2, 2007
Lipid	%	triangular (min, mode, max)	0.3, 0.5, 0.7	FS Report, Table 3-2, 2007
Bluegill				
Weight	g	triangular (min, mode, max)	70, 98, 135	ICF International 2008
Lipid	%	triangular (min, mode, max)	0.08, 0.61, 2.8	ICF International 2008
Yellow Perch				
Weight	g	triangular (min, mode, max)	50, 134, 175	ICF International 2008
Lipid	%	triangular (min, mode, max)	0.1, 0.43, 1.1	ICF International 2008
Largemouth Bass				
Weight	g	normal (μ, σ, min, max)	526 (186) 273 - 965	ICF International 2008
Lipid	%	normal (μ, σ, min, max)	0.83 (0.94) 0.05 - 4.43	ICF International 2008
Log K_{ow}				
PCBs	kg/kg	normal (μ, σ, min, max)	6.6 (0.7) 4.1 - 9.1	Mackay et al. 2006
PCB52	kg/kg	point estimate	5.93	Mackay et al. 2006
PCB153		point estimate	7.05	Mackay et al. 2006
Homolog 4		triangular (min, mode, max)	5.45, 5.96, 6.43	Mackay et al. 2006
Homolog 5	kg/kg	triangular (min, mode, max)	5.72, 6.39, 7.52	Mackay et al. 2006
Homolog 6	kg/kg	triangular (min, mode, max)	6.24, 6.8, 7.31	Mackay et al. 2006
Total Organic Carbon	%	normal (μ, σ, min, max)	1.7 (0.67) 0.11 - 3.8	ICF International 2008
Water Temperature	deg C	triangular (min, mode, max)	8, 13, 18	Assumed (Average based on FS Table 3-1)
Water Concentration (ng/L)				
PCBs	ng/L	point estimate	1.00	nominal value (FS Table 3-1 states "0")
PCB52	ng/L	point estimate	0.01	nominal value (FS Table 3-1 states "0")
PCB153	ng/L	point estimate	0.01	nominal value (FS Table 3-1 states "0")
Homolog 4	ng/L	point estimate	0.01	nominal value (FS Table 3-1 states "0")
Homolog 5	ng/L	point estimate	0.01	nominal value (FS Table 3-1 states "0")
Homolog 6	ng/L	point estimate	0.01	nominal value (FS Table 3-1 states "0")

Table 5-2. Model Inputs in Common across Scenarios for the NSSC Site

Therefore, the Spatially-Explicit Case relied on the areas and concentrations as defined by the GIS-based analysis. The GIS-maps are provided as part of Appendix B, which also provides the full FR model input and output files.

Deterministic Average Case	Point Estimate (mg/kg dw)		Probabilistic Case	Distribution Type	Parameters (mg/kg dw)
PCBs	1.4		PCBs	normal (μ, σ, min, max)	1.4, 1.56, 0.0002, 8.9
PCB52	0.054		PCB52	normal (μ, σ, min, max)	0.054, 0.26, 0.0001, 1.81
PCB153	0.1		PCB153	normal (μ, σ, min, max)	0.1, 0.09, 0.0001, 0.37
Homolog 4	0.171		Homolog 4	normal (μ, σ, min, max)	0.171, 0.53, 0.00001, 3.6
Homolog 5	0.263		Homolog 5	normal (μ, σ, min, max)	0.263, 0.39, 0.00001, 2.5
Homolog 6	0.51		Homolog 6	normal (μ, σ, min, max)	0.51, 0.47, 0.00001, 1.8

Spatially-Explicit Case	PCBs (mg/kg dw)	PCB52 (mg/kg dw)	PCB153 (mg/kg dw)	Homolog 4 (mg/kg dw)	Homolog 5 (mg/kg dw)	Homolog 6 (mg/kg dw)
Site	0.30	0.001	0.010	0.010	0.010	0.020
SE96	1.00	0.013	0.100	0.100	0.160	0.400
SE100	2.00	0.021	0.173	0.173	0.250	0.860
SE99	1.00	0.013	0.100	0.100	0.160	0.680
SE92	3.00	0.03	0.306	0.250	0.380	1.000
SE94	4.00	0.052	0.306	0.330	0.580	1.400
SE110	3.00	0.03	0.306	0.250	0.380	1.000
SE113	4.00	0.068	0.370	0.250	0.580	1.800
SE109	4.00	0.052	0.370	0.330	0.580	1.800
SE90	9.00	0.068	0.500	0.130	0.600	2.000

Table 5-3. Sediment Input Concentrations by Scenario for the NSSC Site

5.2.2 TYNDALL AFB MODEL INPUTS

Table 5-4 provides a summary of the input data in common to all scenarios and locations, except for feeding preferences. Sediment exposure concentrations, which differed across scenarios and locations, are found in Tables 5-5 through 5-7.

Input	Units	Distribution type	Parameters	Source
Water column invertebrates lipid content	%	triangular (min, mode, max)	0.5, 1, 2	Assumed
Sediment invertebrates lipid	%	triangular (min, mode, max)	1, 2, 4	KABAM v.1.0 documentation
Pinfish				
Weight	g	triangular (min, mode, max)	2, 5, 10	Weston 2009
Lipid	%	triangular (min, mode, max)	0.3, 0.5, 0.7	Weston 2009
Killifish				
Weight	g	triangular (min, mode, max)	25, 150, 200	Weston 2009
Lipid	%	triangular (min, mode, max)	0.3, 0.7, 1	Weston 2009
Log K_{ow}				
DDD	kg/kg	triangular (min, mode, max)	6.02, 6.1, 6.2	Karickhoff 1995; USGS 2001; ATSDR 2002
DDE	kg/kg	normal (μ, σ, min, max)	6.96 (0.011) 6.3 - 7.0	Karickhoff 1995; USGS 2001; UNEP 1995; ATSDR 2002
DDT	kg/kg	normal (μ, σ, min, max)	6.0 (0.045) 4.89 - 6.91	Karickhoff 1995; USGS 2001; UNEP 1995; ATSDR 2002
DDx	kg/kg	triangular (min, mode, max)	4.3, 6.02, 6.91	Karickhoff 1995; USGS 2001; ATSDR 2002
Total Organic Carbon				
Area 1	%	normal (μ, σ, min, max)	1.68 (2.39) 0.2 - 9.1	Weston 2009
Areas 1 & 2	%	normal (μ, σ, min, max)	1.7 (0.67) 0.11-3.8	Weston 2009
Area 5	%	normal (μ, σ, min, max)	1.02 (2.02) 1.0 - 10.5	Weston 2009
Temperature	deg C	triangular (min, mode, max)	10, 12, 18	Assumed (no data available)
Water Concentration (ng/L)				
DDD	ng/L	point estimate	0.00001	less than detection level
DDE	ng/L	point estimate	0.00001	less than detection level
DDT	ng/L	point estimate	0.00001	less than detection level
DDx	ng/L	point estimate	0.00001	less than detection level

Table 5-4. Model Inputs in Common across Scenarios for the Tyndall AFB Site

Feeding preference information was obtained from the literature (Kjelson and Johnson 1976; Luczkovich 1988; McMahon *et al.* 2005; Merten 2005; Rozas and LaSalle 1990; Prado and Heck 2011). Postlarval pinfish in this size range consumed a variety of zooplankton and copepods. Based on the available information, we assume that pinfish consume 30% sediment-associated invertebrates and 70% water-column associated invertebrates. Killifish are more closely tied to sediment-associated food sources. Therefore, the model assumes that killifish consume 90% benthic invertebrates and 10% pelagic invertebrates. These assumptions remain consistent across scenarios and modeling areas.

Sediment exposure concentrations differ significantly across the areas as shown in Tables 5-5 and 5-7 for the deterministic and probabilistic scenarios, respectively. Within areas, Area 1 and Areas 1 and 2 show significant spatial heterogeneity, while Area 5 is relatively homogenous with only one small localized "hotspot." In addition, overall, concentrations in Area 5 are quite low relative to the other areas, with a number of samples at the detection level or close to it.

Deterministic Case (Average)	Point Estimate (mg/kg dw) Area 1	Point Estimate (mg/kg dw) Areas 1&2	Point Estimate (mg/kg dw) Area 5
DDD	0.292	0.713	0.029
DDE	0.054	0.204	0.02
DDT	0.202	3.43	0.112
DDx	0.548	4.35	0.161

Table 5-5. Sediment Concentrations under the Deterministic Scenario for the Tyndall AFB Site

Spatially-Explicit Cases	DDD (mg/kg dw)	DDE (mg/kg dw)	DDT (mg/kg dw)	DDx (mg/kg dw)
AREA 1				
Site	0.10	0.018	0.106	0.228
NR1	0.31	0.11	1.700	2.200
SE6	1.04	0.224	0.336	1.600
SED111	1.60	0.15	0.290	2.040
SE70	0.83	0.013	0.027	0.870
SED162	0.01	0.005	0.135	0.150
SE72	0.02	0.004	0.006	0.032
SED161	0.10	0.034	0.560	0.691
AREA 1 & 2				
Site	0.13	0.101	0.031	0.262
SED160	0.18	0.042	0.226	0.444
SE3	0.06	0.019	0.073	0.148
SE73	0.005	0.0049	0.005	0.015
SE4	0.36	0.024	0.093	0.477
SE112	0.08	0.016	0.260	0.355
SED161	0.10	0.034	0.560	0.690
SE72	0.02	0.0043	0.007	0.032
SED162	0.01	0.003	0.001	0.014
SED6	1.04	0.223	0.336	1.600
SED105	0.04	0.0082	0.011	0.058
SED8	0.14	0.022	0.213	0.374
SED123	1.63	0.321	1.900	3.851
SE68	0.02	0.006	0.007	0.032
NR3	11.40	3.25	4.100	18.700
SE12	0.057	0.026	0.0087	0.092
SE67	0.057	0.009	0.0074	0.073
SED130	0.363	0.206	0.109	0.678
SE10	0.053	0.022	0.021	0.096
SED134	2.35	0.424	3.4	6.174
SE74	0.0022	0.0046	0.0068	0.013
SE11	0.264	0.25	0.184	0.698
SE64	0.004	0.004	0.004	0.012
SED136	0.012	0.027	0.028	0.067
SED139	42.3	4.3	94	140.6
SED149	0.062	0.067	0.017	0.146
AREA 5				
Site	0.029	0.195	0.112	0.161
SED175	0.267	0.482	0.152	0.468

Table 5-6. Sediment Concentrations under the Spatially-Explicit Scenario for the Tyndall AFB Site

The sediment data also reveal differences across areas with respect to the proportion of DDT, DDD, and DDE in the total DDx mixture. For example, the proportion of DDT in the total DDx mixture ranges from 3% to 81% across individual samples with an average of 36%. This introduces a complexity to the modeling in that a key determinant of uptake is, in many ways, the Log K_{ow}, and this value is the obviously the same across scenarios within a contaminant (e.g., DDT has one Log K_{ow} and so on). Consequently, if the proportion of individual isomers relative to the total differs, the model has no mechanistic basis for predicting that difference and might be expected *a priori* to perform better for total DDx than for individual isomers.

Probabilistic Case	Distribution Type	Parameters (mg/kg dw) Area 1	Parameters (mg/kg dw) Areas 1 & 2	Parameters (mg/kg dw) Area 5
DDD	normal (μ, σ, min, max)	0.292, 0.747, 0.0024, 3.9	0.713,2.0, 0.00049, 11.4	0.029, 0.069, 0.000092, 0.515
DDE	normal (μ, σ, min, max)	0.054, 0.157, 0.0011, 0.78	0.204, 0.469, 0.00023, 3.25	0.02, 0.033, 0.0000495, 0.16
DDT	normal (μ, σ, min, max)	0.202, 0.35, 0.0021, 1.79	3.43, 13.0, 0.00018, 87.8	0.112, 0.569, 0.00009, 4.6
DDx	normal (μ, σ, min, max)	0.548, 1.06, 0.011, 5.35	4.35, 14.2, 0.0014, 94.6	0.161, 0.615, 0.323, 4.92

Table 5-7. Sediment Concentrations under the Probabilistic Scenario for the Tyndall AFB Site

6.0 PERFORMANCE ASSESSMENT

This section provides a summary of the performance assessment for both sites. Since a number of the performance objectives relate equally to both sites (e.g., are fundamental to the FR model), these are not separately described for each model application, but are combined. Model performance at each of the sites is described separately.

6.1 NSSC SITE PERFORMANCE ASSESSMENT

The key performance criterion is predicted model results vs. observed tissue concentrations under each of the three scenarios.

6.1.1 PREDICTED VS. OBSERVED MODEL RESULTS

Table 6-1 provides a summary of predicted model outputs under the three scenarios as compared to fish data for the NSSC Site. Figure 6-1 provides these same data graphically.

Species	Observed Mean (mg/kg ww)	Deterministic Case (mg/kg ww)	Probabilistic (No Spatial) (mg/kg ww)	Spatially-Explicit Model Results (mg/kg ww)	RPD Deterministic	RPD Probabilistic	RPD Spatially-Explicit
Yellow Perch							
PCB-052	0.016	0.037	0.155	0.015	78%	162%	-7%
PCB-153	0.289	0.156	0.191	0.281	-60%	-41%	-3%
Cl-4 Tetrachlorobiphenyls	0.124	0.122	0.351	0.122	-1%	96%	-1%
Cl-5 Pentachlorobiphenyls	0.247	0.328	0.53	0.323	28%	73%	27%
Cl-6 Hexachlorobiphenyls	0.938	0.745	0.903	1.130	-23%	-4%	19%
Total PCBs	2.266	1.56	2.12	2.260	-37%	-7%	0%
Bluegill							
PCB-052	0.008	0.016	0.079	0.006	69%	164%	-21%
PCB-153	0.072	0.049	0.043	0.086	-39%	-51%	17%
Cl-4 Tetrachlorobiphenyls	0.045	0.05	0.171	0.049	10%	116%	8%
Cl-5 Pentachlorobiphenyls	0.087	0.111	0.192	0.108	24%	75%	22%
Cl-6 Hexachlorobiphenyls	0.240	0.239	0.283	0.362	0%	16%	41%
Total PCBs	0.582	0.623	0.79	0.848	7%	30%	37%
Largemouth Bass							
PCB-052	0.023	0.054	0.231	0.021	81%	164%	-8%
PCB-153	0.348	0.161	0.198	0.276	-74%	-55%	-23%
Cl-4 Tetrachlorobiphenyls	0.149	0.175	0.502	0.146	16%	109%	-2%
Cl-5 Pentachlorobiphenyls	0.321	0.379	0.622	0.331	16%	64%	3%
Cl-6 Hexachlorobiphenyls	1.154	0.81	1.000	1.160	-35%	-14%	1%
Total PCBs	2.767	1.76	2.420	2.410	-44%	-13%	-14%

RPD = relative percent difference calculated as (predicted-observed)/average(predicted,observed)

green values indicate lowest RPD; blue values indicate within 50% of observed

Table 6-1. Results of Predicted versus Observed and Relative Percent Difference across Scenarios for the NSSC Site

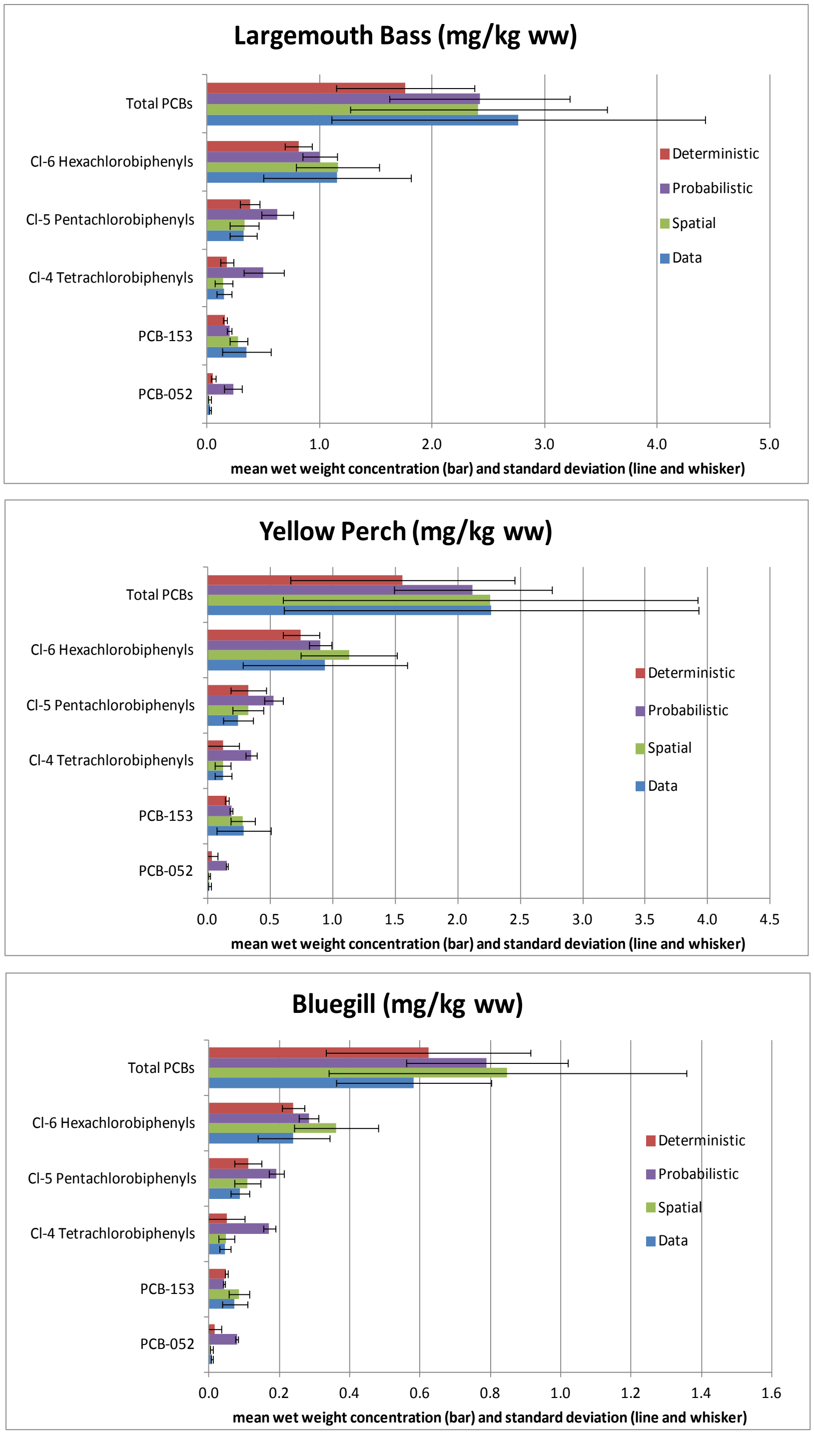


Figure 6-1. Results of Predicted vs. Observed across scenarios for the NSSC Site

Figure 6-1 and Table 6-1 provide the results of the model to data comparison for three of the four modeled species (no data were available for pumpkinseed), including largemouth bass, the predator species of most interest from a human health perspective, yellow perch, and bluegill. The lowest relative percent differences (RPDs) across scenarios are highlighted in green (Table 6-1), and comparisons within 50%, which indicate highly satisfactory model performance are shown in blue.

Taken together, Table 6-1 and Figure 6-1 show that across species and individual contaminant types, the Spatially-Explicit Model shows the most consistent and lowest RPDs across individual congeners, homolog groups, and total PCBs. However, the absolute difference across scenarios and contaminants is insignificant, save for the Deterministic Case, which consistently shows the worst performance relative to either the Probabilistic or Spatially-Explicit Cases. Nonetheless, the Spatially-Explicit Model shows either blue or green RPDs across all contaminants and species, in contrast to either of the other approaches, suggesting the spatially-explicit exposure characterization better captures the relationship between sediment and water exposures, fish foraging strategies, and PCB uptake. Figure 6-1 additionally shows the comparison of standard deviations across the scenarios, and again, the Spatially-Explicit Case performs better with respect to capturing the variance in the data in addition to capturing the central tendency. This can be important for subsequent ecological risk calculations that may require exposure distributions across the population rather than deterministic estimates of tissue concentrations, for example, using joint probability curves or other probabilistic risk methods.

6.2 TYNDALL AFB PERFORMANCE ASSESSMENT

The key performance criterion is predicted model results vs. observed tissue concentrations under each of the three scenarios.

6.1.2 PREDICTED VS. OBSERVED MODEL RESULTS

Table 6-2 summarizes the predicted model output under the three scenarios as compared to fish data for the Tyndall Site. The red values in the table represent the lowest RPD across scenarios. RPDs between 0% and 50% demonstrate excellent model performance and are highlighted in blue in Table 6-2.

Species and Area	Observed (mg/kg ww)	Deterministic Case (mg/kg ww)	Probabilistic (No Spatial) (mg/kg ww)	Spatially-Explicit Model Results (mg/kg ww)	RPD Deterministic	RPD Probabilistic	RPD Spatially-Explicit
Pinfish Area 1							
DDD	0.058	0.040	0.098	0.059	-37%	51%	1%
DDE	0.040	0.018	0.049	0.040	-77%	19%	-1%
DDT	0.017	0.023	0.042	0.050	27%	83%	96%
DDx	0.116	0.054	0.107	0.142	-73%	-8%	20%
Killifish Area 1							
DDD	0.149	0.105	0.258	0.147	-35%	53%	-2%
DDE	0.190	0.032	0.088	0.065	-142%	-73%	-98%
DDT	0.014	0.064	0.116	0.132	127%	156%	161%
DDx	0.353	0.138	0.275	0.301	-88%	-25%	-16%
Killifish Area 2							
DDD	0.304	0.752	1.890	0.474	85%	145%	44%
DDE	0.253	0.338	0.751	0.222	29%	99%	-13%
DDT	0.175	3.250	10.500	0.138	180%	193%	-23%
DDx	0.731	3.640	9.390	0.570	133%	171%	-25%
Killifish Areas 1 and 2							
DDD	0.248	0.752	1.890	0.474	101%	154%	63%
DDE	0.304	0.338	0.751	0.222	11%	85%	-31%
DDT	0.053	3.250	10.500	0.138	194%	198%	89%
DDx	0.605	3.640	9.390	0.570	143%	176%	-6%
Pinfish Area 5							
DDD	0.013	0.007	0.016	0.007	-59%	21%	-59%
DDE	0.014	0.018	0.031	0.173	27%	78%	171%
DDT	0.004	0.023	0.100	0.023	140%	184%	140%
DDx	0.031	0.033	0.155	0.034	8%	134%	10%
Killifish Area 5							
DDD	0.028	0.020	0.050	0.027	-33%	57%	-3%
DDE	0.053	0.032	0.055	0.226	-50%	3%	124%
DDT	0.007	0.071	0.323	0.069	163%	191%	162%
DDx	0.088	0.105	0.031	0.088	17%	-96%	0%

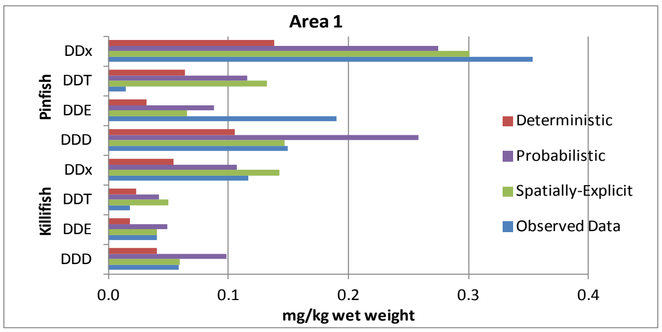
RPD = relative percent difference calculated as (predicted-observed)/average(predicted,observed)

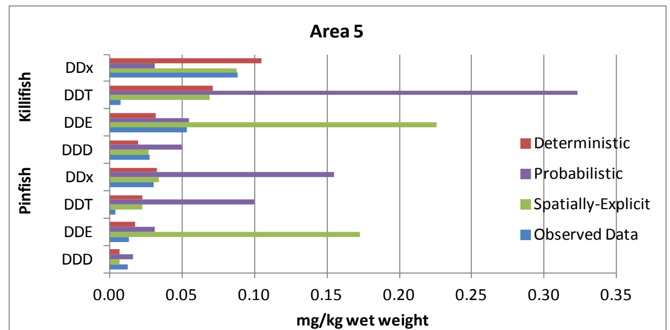
green values indicate lowest RPD; blue values indicate within 50% of observed

Table 6-2. Results of Predicted vs. Observed and Relative Percent Difference across Scenarios for the Tyndall AFB Site

In general, Table 6-2 shows that the majority of the blue and green comparisons are for the Spatially-Explicit Case, which indicates the most consistent predictions relative to observed data. For risk assessment purposes, particularly human health risks, results for DDD/DDE/DDT are typically combined and quantified as total DDx. In this context, the Spatially-Explicit Case performs optimally, within 20% across all sites and species, and represents excellent performance.

Unfortunately, the data available for this site are single samples of composite fish, precluding a comparison of variance between predicted and observed. However, graphical comparisons of predicted vs. observed are provided in Figure 6-2.





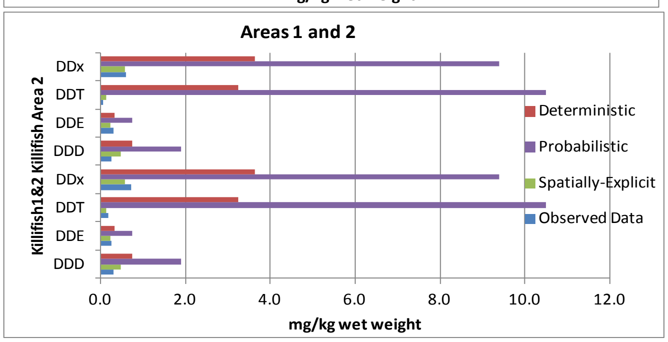


Figure 6-2. Results of Predicted vs. Observed across Scenarios for the Tyndall AFB Site

As shown in Table 6-2 and Figure 6-2, the probabilistic model performs particularly poorly for Areas 1 and 2 combined, largely a function of the high standard deviation in sediment concentrations attributable to the significant heterogeneity in concentrations across both areas. The spatially-explicit model tends to perform best, particularly in areas of spatial heterogeneity such as Area 1 and Areas 1 and 2 combined. By contrast, in Area 5, the advantages of the spatially-explicit approach are less evident. At sites with less spatial heterogeneity, (e.g., Area 5), a deterministic approach functions nearly as well.

Another observation from Table 6-2 and Figure 6-2 is that results for DDE are often under-predicted while results for DDT are over-predicted. One explanation for this is that DDE is a known metabolite of DDT in both fish and mammals. While the model allows for a metabolic term, data are insufficient to specify this term. Although it is possible to use the metabolic rate constant (currently set to zero, e.g., no metabolism) as a calibration parameter, this was not done for the current application. Further evidence for DDT metabolism is demonstrated by comparing the proportion of each isomer to total DDx across sediment and fish (Figure 6-3). The Y-axis shows the proportion of DDD, DDE and DDT in total DDx for fish and sediment across Areas. The red bar represents the percentage of total DDx represented by DDD, green is DDE and blue is DDT. The bars are mean percentages, with error bars described as one standard error from the mean.

This figure shows that while the proportion of DDD (red bars) is similar across fish and sediment samples within an Area, the proportions of DDE (green bars) and DDT (blue bars) across fish and sediment samples are essentially reversed. For example, the proportion of DDE in total DDx in fish from Area 1 is approximately 0.45 (DDE comprises 45% of total DDx), while it is closer to 0.1 (DDE comprises only 10% of total DDx) for sediment, suggesting either enrichment relative to sediment or metabolism of DDT to DDE within fish. Similarly, the blue bars, which represent the proportion of DDT in total DDx, differ significantly between fish and sediment within an Area. This figure also highlights differences across Areas at the Tyndall Site, particularly for sediment. Areas 1 and 2 show very similar patterns, while Area 5 is very different. Proportions for fish are more similar, but do show some differences, particularly in enrichment of DDE in Area 5 (greater than 50%) relative to Areas 1 and 2 (approximately 45%). These differences have implications for the modeling, since the same Log K_{ow} is used for a contaminant across areas (e.g., DDE has the same Log K_{ow} regardless of area).

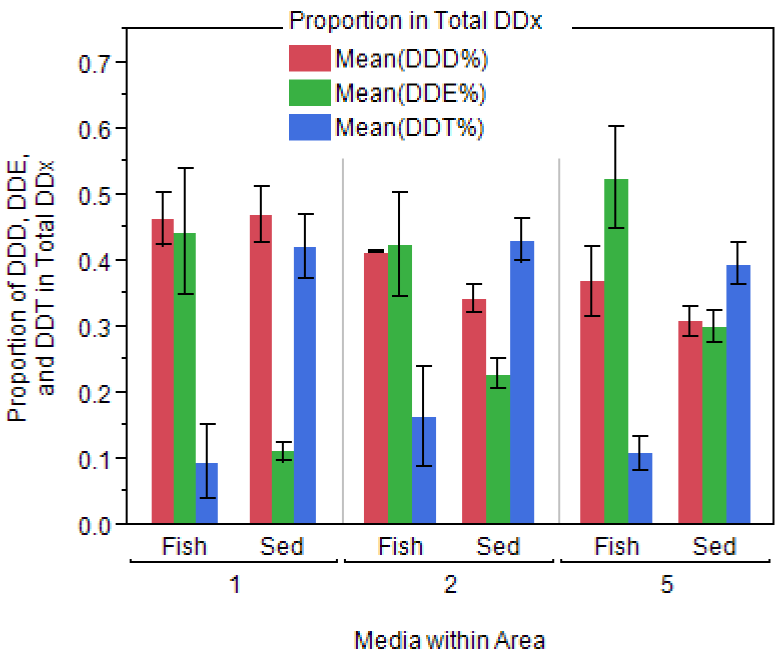


Figure 6-3. Data-based Proportion of DDD, DDE and DDT in total DDx in Fish and Sediment by Area (1, 2, and 5) at the Tyndall AFB Site

In its simplest terms, Log K_{ow} represents the relationship between sediment organic carbon and lipid in organisms, so that if the proportion of DDE changes across areas, the model has no way to capture that apparent difference in the relationship, given that feeding preferences, metabolic rates, etc. are also the same across areas.

6.3 DISCUSSION OF RESULTS

The procedure to develop these two site-specific applications involved using data typically available from an RI/FS or similar process. The approach was to parameterize the site-specific food webs using existing data augmented with information from the literature. Once these inputs were determined, they were consistently applied across scenarios, which differed only in their characterization of exposure concentrations. This included a Deterministic Case (deterministic SWAC, in both cases characterized by an arithmetic average); a Probabilistic Case (probabilistic sediment exposure concentrations but not spatially-explicit), and, a Spatially-Explicit Case. Both sites differed in their physical characteristics (NSSC is a freshwater lake while Tyndall AFB is an estuarine and brackish coastal system), and in the contaminants considered (PCBs and individual PCB congeners at the NSSC site; DDD/DDE/DDT at Tyndall AFB). Additionally, the spatial characteristics of exposure varied across scenarios, particularly at the Tyndall site. Area 5 is a relatively homogeneous area, with lower sediment concentrations, and essentially one single hot spot (SED175). Area 1 and Areas 1 and 2 together are highly heterogeneous, with sediment concentrations ranging from non-detectable to 100s of parts per million. The utility of the FR model in cases of heterogeneous contamination is evident in the results, which demonstrate the least value-added for Area 5 relative to other areas of the Tyndall Site and as compared to the NSSC Site. However, another factor to consider in the assessment for the Tyndall Site is that pinfish are largely (90%) tied to water rather than to sediment. Water concentrations were specified as point estimates across all scenarios (nominally set at approximately the detection level or less).

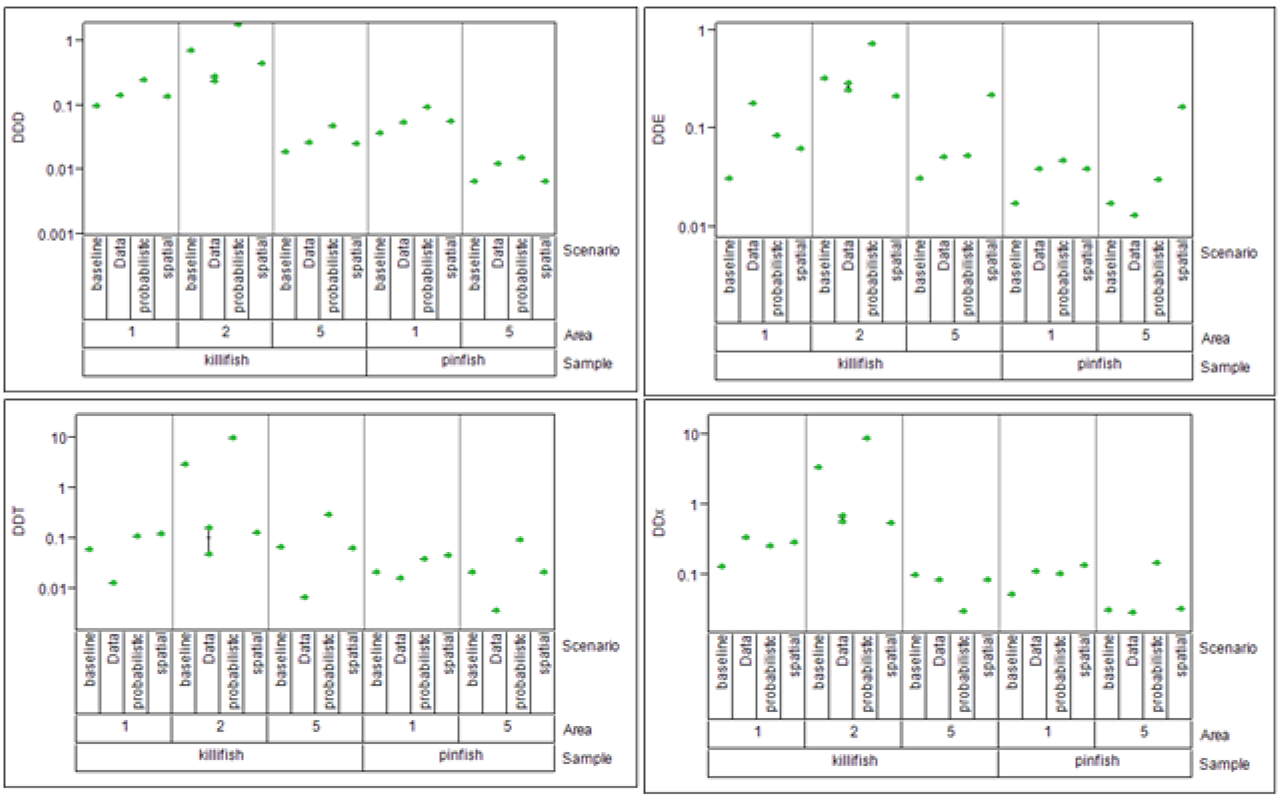


Figure 6-4. Comparison of Model Predictions to Site Data for the Tyndall AFB Site (note the log scale for ease of comparison)

Figures 6-4 and 6-5 provide another graphical view of the comparison between model predictions and site data for the Tyndall Site and NSSC Site, respectively. Note that Figure 6-4 is on a log scale for ease of comparison since several of the model predictions were so much higher (e.g., for the Deterministic and Probabilistic scenarios) than observed data. The values shown in Figure 6-5 are as follows: all data points in the dataset are presented. For model output across scenarios, the mean, 5th percentile, and 95th percentiles are presented. This figure shows that typically, the predicted 5th to 95th percentile ranges from the Spatially-Explicit scenario largely capture the range of observed data, and in all cases, compare most favorably relative to either the Deterministic or Probabilistic scenarios.

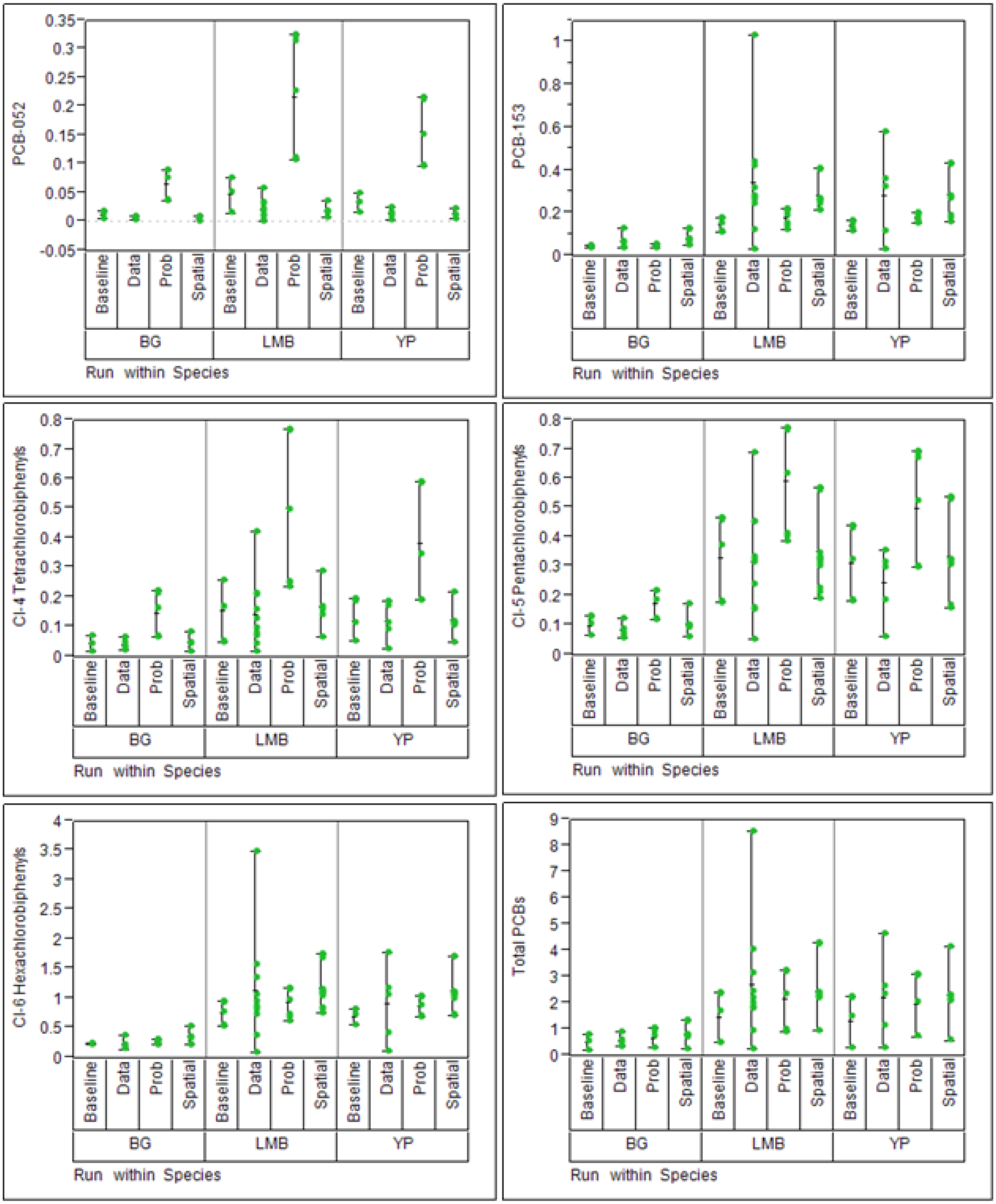


Figure 6-5. Comparison of Model Predictions to Site Data for the NSSC Site

6.3.1 Model Calibration and Verification

In general, site-specific application of a model requires calibration and verification (U.S. EPA 2005; 2009). Models are based on a combination of data combined with a scientific understanding of physical and chemical processes. Most of the equations in a model include numerical coefficients. To the extent that site data are available, some of the coefficients are based on the fit of the equations to data, and others are taken to be universal constants based on laboratory studies (e.g., growth rate in fish). Where site-specific data are limited, coefficients may be values from scientific literature. For example, the modeling framework presented here is based on the well-established mathematical framework developed by Gobas (1993) and further refined by Arnot and Gobas (2004). Calibration of a model is the process of adjusting its coefficients to attain optimal agreement between predicted values and actual site data. Most commonly, model calibration consists of fine-tuning the model to provide the best fit to site data. The model is then verified by running the calibrated model without adjusting any inputs or adjusted coefficients to an independent data set, either using data from a different time period or geographic location (within the same site), or by excluding a portion of the data set to be used to compare with the results. Calculated and actual values are compared, and if an acceptable level of agreement is achieved, the model is considered verified. If not, then further analysis of the model is performed, leading to refinements that should improve the accuracy of the model.

For both sites presented here, the initial model parameterization led to an acceptable comparison between predicted and observed tissue concentrations without a formal calibration. However, this does not necessarily represent a typical application; particularly for larger, more complex sediment sites for which calibration is usually required (Gustavson *et al.* 2011). Oftentimes, this is attributable to the availability of larger datasets, particularly those representing more than one point in time. In both the applications presented here, data were only available for one sampling time, thus, it is not possible to evaluate model performance over time, which would be an important criterion at sites for which greater temporal resolution in data are available, and for which potential model deficiencies with respect to calibration could be more evident. Site-specific model calibration focuses on adjustments to inputs that are potentially uncertain and for which the bounds on the data are generally wide.

An exhaustive discussion on model calibration and verification is beyond the scope of this document. However, much is known about sensitivity in modeling parameters for bioaccumulation models. For example, see von Stackelberg *et al.* 2002a; Gustavson *et al.* 2011; Barber 2008; Burkhard 1998; Ianuzzi *et al.* 1996; Imhoff *et al.* 2004), and site-specific model applications (most sites make their modeling documents publicly available, e.g., Hudson River, Duwamish, Portland Harbor, etc.). In general, bioaccumulation models are particularly sensitive to changes in Log K_{ow}, lipid content, total organic carbon, assimilation efficiency, growth rate, and feeding preferences, although the exact order of sensitivity will vary according to site-specific characteristics and data. Additional specific guidance on model calibration is given in U.S. EPA (2005) and associated references.

6.3.2 Implications for Risk Management

Both of these sites are not particularly highly contaminated, which to some extent limits the utility of a more complex spatially-explicit model. By and large, for both sites, the deterministic model performs reasonably well enough to support simplistic predictions of average fish tissue concentrations.

However, the site-wide average total PCB sediment concentration at NSSC (1.4 mg/kg) is well within cleanup levels and remedial objectives derived at other sites (see for example, a compilation of remedial objectives assembled by the Interstate Technology Regulatory Council at

http://www.itrcweb.org/contseds_remedy-selection/Default.htm#AppendixA/1AppendixACase Studies.htm%3FTocPath%3DAppendix%2520A.%2520Case%2520Studies%7C_____0; also the Sediment Management Workgroup hosts a Major Contaminated Sediment Sites Database at http://www.smwg.org/MCSS_Database/MCSS_Database_Docs.html); similarly, no cleanup has been proposed at the Tyndall Site on the basis of contaminants in fish or fish consumption. That presents a challenge with respect to demonstrating the clear benefits of a spatially-explicit approach, in that both of these sites will not require remedial activities based on fish consumption as an exposure pathway.

Nonetheless, irrespective of absolute concentrations, it is straightforward to demonstrate that an evaluation of remedial alternatives is facilitated through use of the spatially-explicit approach. In the deterministic case, implementation of a remedial alternative will require deriving a new site-wide average concentration, while in the spatially-explicit case, it is possible to more realistically simulate the impact of specific actions, such as removing hot spot areas or all areas above a certain threshold. But in order to use the model in this way, it is necessary to first demonstrate confidence in the predictions. At the NSSC site, the FR model consistently predicted tissue concentrations within 50% across all PCB congeners, homologs and total PCBs for largemouth bass, a top-level predator fish that would be the focus of decision making. The deterministic model was less consistent and did not perform as well on an individual congener basis, raising concerns about how well the model is really capturing exposures.

By definition, developing and evaluating remedial alternatives is a spatially-explicit process. Certain areas may be targeted for removal actions, or other management options such as capping. All of this spatial information will be lost when using deterministic approaches that rely on single, site-wide estimates of exposures.

7.0 COST ASSESSMENT

This section describes the costs associated with parameterizing and running the FR model. The cost assessment does not include costs associated with collecting the data, as these are assumed to occur regardless of whether the FR model is applied or not. In addition, the costs associated with developing GIS-based graphics of site concentrations are not included, as these would likely be generated whether or not a bioaccumulation model was being run. Therefore, only the costs associated with parameterizing and running the model are presented.

7.1 COST MODEL

The key costs associated with application of the model include creating the FR input files. This involves obtaining the input data through a combination of site-specific data already available and literature reviews. Table 7-1 provides a summary of these costs described in greater detail in the following subsections.

FishRand COST MODEL

Table 7-1. Cost Model for an Application of the FishRand Spatially-Explicit Model

Cost Element	Data Tracked During the Demonstration	Costs	
Baseline site characterization – use of existing GIS data	• Personnel required and associated labor • Assumes GIS-based site characterization already exists • Requires modeler to set up FR spatial files • Complexity of spatial characterization will increase costs	Modeler will typically spend two weeks organizing the spatially-explicit inputs, and total organic carbon, temperature etc. Assumes 80 hours @ $80/hr. A deterministic model, all things equal, would require at least 60 hours.	$6,400
Food web parameterization	Unit: $ per species • Labor per species in the food web; assumes literature review combined with site-specific data	Modeler or junior analyst will typically spend one week per species. Generally a minimum of three fish species. This effort would be required for a deterministic model.	$10, 000
Computer run-time	• Time required per run	• Not a direct cost	15 min – 1 hour
Calibration and verification	• Personnel time	• Most difficult to predict and variable cost	$1,500 - $8,000
Post-processing	Unit: $ per workbook • Macros can be written to facilitate Excel-based workbook linkages	Modeler or analyst will typically spend one day per run (assumes five chemicals, one site, five species)	$640

7.2 COST DRIVERS

Costs for developing input files for use of FishRand depend on the complexity of the application (e.g., complexity of the food web being modeled), and data availability (e.g., site-specific versus literature-based). The cost evaluation assumes that a conceptual model of aquatic food web exposures already exists as was the case for the two demonstration sites here. Cost estimates assume that the bioaccumulation model is being developed in conjunction with a suite of other site assessment tools and that appropriate data are already being collected as part of a larger site characterization process, such as an RI/FS or similar framework.

The least predictable and potentially most significant cost driver in any modeling application is the calibration and verification process. Different aquatic food webs might exist at complex sediment sites with different linked habitat areas (e.g., freshwater, estuarine, and marine). In addition, differences in population characteristics across locations might exist (e.g., specific species, feeding preferences, growth rates, etc.). Although no explicit calibration was required for the two demonstration sites presented herein, that may not represent a typical application. For example, development of the bioaccumulation model for the Hudson River Superfund Site (www.epa.gov/hudson) required extensive calibration, and that process resulted in some 40% of overall costs associated with bioaccumulation model development. That is an example of a site with over 20 years worth of fish tissue data, and measured sediment and water exposure concentrations for only a few of those years.

7.3 COST ANALYSIS

Bioaccumulation modeling applications include simple, steady-state, deterministic applications to probabilistic, and time-varying applications. The cost differential between parameterizing the FR model versus another model is greatest for the simplest approach as compared to a full FR application. As mentioned previously, the cost estimates developed here assume that the bioaccumulation model is only one part of a larger site evaluation process, and that bioaccumulation model development leverages ongoing data collection activities and does not require an independent dataset or separate sampling program.

The level of effort required to acquire the data necessary to parameterize the food web (e.g., feeding preferences, habitat use or attraction factors, and lipid and weight of the organisms) will depend on the overall complexity of the site, and should be proportional to the resources expended for other site characterization activities. There is no prescriptive proportion, but estimates based on professional experience suggest that something on the order of 20% of overall site characterization costs would be attributable to the bioaccumulation modeling.

Depending on the site complexity, there are options available for model parameterization that can be more expensive and correspondingly provide more information for decision making. For example, two key inputs, feeding preferences and habitat use (or foraging area) can either be based on literature values or professional judgment all the way to detailed, site-specific studies. Feeding preferences, whether site-specific or from the literature, are based on gut content analyses. Expending resources to evaluate gut contents from fish collected on-site may not be warranted for small sites. Similarly, different kinds of tag-recapture studies provide data on site fidelity and use for specific species.

Depending on the type of sensor used, and whether the data are temporally collated or simply obtained from two points in time, very detailed information can be gathered on where fish are spending their time, which can be directly incorporated to a spatially-explicit and probabilistic model like FishRand. Again, for large, complex sediment sites, the additional effort to develop site-specific information to support model development may be warranted given the potential expected costs of remediation or implementation of other management alternatives.

8.0 IMPLEMENTATION ISSUES

Implementing the FR model is uncomplicated given appropriate data inputs. However, the quality and quantity of data available from the site characterization process is a key consideration in the successful implementation of the model. In practice, data availability is a limiting factor with respect to model implementation. At many sites, data are not necessarily representative in time or space. Often, there is only one sampling event for sediment or fish or both, and the bioaccumulation model must capture the relationship between sediment exposures and resulting tissue concentrations based on this one sampling event. Similarly, often the bioaccumulation model is held accountable for potential limitations in understanding the relationship between sediment and water. For many, if not all, bioaccumulative contaminants, the assumption is that a bulk sediment concentration represents the relevant exposure metric with an incomplete understanding of 1) how sediment concentrations may be changing over time (e.g., net deposition, net erosion, and so on); 2) the relationship between sediment and water (e.g., low flow and highly dissolved concentrations at certain times of the year, or resuspension events that carry contaminants to other areas in either the dissolved or particulate phases), and 3) potential sources and flux mechanisms (e.g., groundwater recharge, bioturbation, and mechanisms for releasing "buried" sediments). These kinds of interactions would typically require hydrodynamic and fate and transport modeling. However, occasionally, the bioaccumulation model is expected to capture exposures that may not be truly understood from a fate and transport perspective.

A challenge in bioaccumulation modeling has been in understanding what is meant by true exposures. The FishRand model tries to overcome this limitation, and does so by: 1) providing a mechanism for characterizing spatial heterogeneity in sediment (and water) exposure concentrations, and 2) simulating fish movement probabilistically rather than by using static approaches including site averages, site-use factors, and similar deterministic adjustments. However, both foraging strategies of individual fish (e.g., spatial and temporal, in addition to appreciating what those prey items are, and whether they are primarily associated with sediment or water sources) combined with spatial heterogeneity in contamination contribute to population exposures. An understanding of species-specific fish biology is always desirable from a modeling perspective. Therefore, an implementation issue with respect to the model is how much site-specific data is available regarding fish biology. Tag-recapture studies and gut content analyses both provide important information relevant to the modeling. Oftentimes, these data are not obtained easily given limited resources (see above under Costs). However, knowledge gaps in these areas might represent a significant source of uncertainty when parameterizing the model.
In general, a site-specific application of any model involves model calibration and verification.

Calibration is the process of making adjustments to a small number of input parameters to achieve the best fit between predicted model output and monitoring data. Verification (referred to as validation by U.S. EPA 2009) is the process of running a calibrated model and comparing the results to an independent data set not used in model calibration. In practice, it is difficult to have enough data to accomplish both calibration and verification using independent data sets. Therefore, many bioaccumulation models combine calibration with verification in one step. Also, if sufficient data are available, another approach is to divide the data in half, and use one half for calibration and the other half for verification. Sometimes it is possible to apply the model in one location (e.g., river reach) for calibration, and use data from another reach or operable unit for model verification.

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APPENDICES

Appendix A: Points of Contact

POINT OF CONTACT Name	**ORGANIZATION Name Address**	**Phone Fax E-mail**	**Role in Project**
Katherine von Stackelberg	NEK Associates LTD, 12 Holton Street, Allston, MA 02134	Phone: (508) 596-4209 Email: kvon@nekassociates.com	PI for FishRand Model
Mark S. Johnson	U.S. Army Public Health Command, Toxicology Portfolio, 5158 Blackhawk Road Aberdeen Proving Ground, MD 21010	Phone: (410) 436-3980 DSN: 584-3980 Email: usarmy.apg.medcom-phc.mbx.tox-info@mail.mil	PI for Project
Mark A. Williams	U.S. Army Public Health Command, Toxicology Portfolio, 5158 Blackhawk Road Aberdeen Proving Ground, MD 21010	Phone: (410) 436-3980 DSN: 584-3980 Email: usarmy.apg.medcom-phc.mbx.tox-info@mail.mil	Co-PI for Project

Appendix B: Detailed Model Inputs and Outputs for the NSSC Site

Please refer to the attached PDF file.

Fish: Pumpkinseed , Chemical: PCBs

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	7.56E-01	7.61E-01	4.53E-01	3.06E-01	9.40E-02	4.05E-01
2/1/2007	3/1/2007	1.02E+00	1.03E+00	1.14E+00	3.93E-01	1.54E-01	3.86E-01
3/1/2007	4/1/2007	1.14E+00	1.14E+00	1.27E+00	4.46E-01	1.99E-01	3.93E-01
4/1/2007	5/1/2007	1.19E+00	1.20E+00	1.33E+00	4.72E-01	2.23E-01	3.97E-01
5/1/2007	6/1/2007	1.22E+00	1.24E+00	1.37E+00	4.83E-01	2.33E-01	3.97E-01
6/1/2007	7/1/2007	1.22E+00	1.24E+00	1.38E+00	4.82E-01	2.32E-01	3.94E-01
7/1/2007	8/1/2007	1.23E+00	1.25E+00	1.38E+00	4.89E-01	2.39E-01	3.98E-01
8/1/2007	9/1/2007	1.23E+00	1.24E+00	1.38E+00	4.91E-01	2.41E-01	4.00E-01
9/1/2007	10/1/2007	1.22E+00	1.23E+00	1.38E+00	4.85E-01	2.35E-01	3.96E-01
10/1/2007	11/1/2007	1.23E+00	1.24E+00	1.38E+00	4.88E-01	2.38E-01	3.98E-01
11/1/2007	12/1/2007	1.23E+00	1.25E+00	1.38E+00	4.92E-01	2.42E-01	4.01E-01

Fish: Pumpkinseed , Chemical: PCB52

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	8.20E-03	7.90E-03	8.50E-03	3.20E-03	1.10E-05	3.97E-01
2/1/2007	3/1/2007	1.00E-02	9.70E-03	1.10E-02	3.80E-03	1.50E-05	3.75E-01
3/1/2007	4/1/2007	1.10E-02	1.00E-02	1.10E-02	4.10E-03	1.70E-05	3.80E-01
4/1/2007	5/1/2007	1.10E-02	1.00E-02	9.40E-03	4.20E-03	1.70E-05	3.80E-01
5/1/2007	6/1/2007	1.10E-02	1.00E-02	9.50E-03	4.20E-03	1.80E-05	3.82E-01
6/1/2007	7/1/2007	1.10E-02	1.10E-02	1.10E-02	4.20E-03	1.80E-05	3.80E-01
7/1/2007	8/1/2007	1.10E-02	1.00E-02	9.40E-03	4.20E-03	1.80E-05	3.84E-01

8/1/2007	9/1/2007	1.10E-02	1.00E-02	9.40E-03	4.20E-03	1.80E-05	3.83E-01
9/1/2007	10/1/2007	1.10E-02	1.00E-02	9.40E-03	4.20E-03	1.80E-05	3.84E-01
10/1/2007	11/1/2007	1.10E-02	1.00E-02	1.10E-02	4.20E-03	1.80E-05	3.84E-01
11/1/2007	12/1/2007	1.10E-02	1.00E-02	1.10E-02	4.20E-03	1.80E-05	3.82E-01

Fish: Pumpkinseed , Chemical: PCB153

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	7.20E-02	6.60E-02	4.00E-02	2.90E-02	8.30E-04	3.99E-01
2/1/2007	3/1/2007	1.02E-01	9.50E-02	8.70E-02	3.40E-02	1.20E-03	3.36E-01
3/1/2007	4/1/2007	1.17E-01	1.09E-01	1.00E-01	3.90E-02	1.50E-03	3.32E-01
4/1/2007	5/1/2007	1.24E-01	1.15E-01	1.06E-01	4.00E-02	1.60E-03	3.25E-01
5/1/2007	6/1/2007	1.27E-01	1.19E-01	1.09E-01	4.10E-02	1.70E-03	3.21E-01
6/1/2007	7/1/2007	1.28E-01	1.20E-01	1.10E-01	4.10E-02	1.70E-03	3.21E-01
7/1/2007	8/1/2007	1.29E-01	1.21E-01	1.11E-01	4.10E-02	1.70E-03	3.21E-01
8/1/2007	9/1/2007	1.28E-01	1.21E-01	1.11E-01	4.10E-02	1.70E-03	3.18E-01
9/1/2007	10/1/2007	1.29E-01	1.22E-01	1.12E-01	4.10E-02	1.70E-03	3.15E-01
10/1/2007	11/1/2007	1.29E-01	1.21E-01	1.11E-01	4.10E-02	1.70E-03	3.22E-01
11/1/2007	12/1/2007	1.29E-01	1.21E-01	1.12E-01	4.10E-02	1.70E-03	3.16E-01

Fish: Pumpkinseed , Chemical: Homolog4

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	6.40E-02	6.40E-02	6.90E-02	2.20E-02	4.70E-04	3.40E-01
2/1/2007	3/1/2007	7.90E-02	7.80E-02	8.60E-02	2.60E-02	6.90E-04	3.31E-01

3/1/2007	4/1/2007	8.50E-02	8.30E-02	9.20E-02	2.90E-02	8.50E-04	3.44E-01
4/1/2007	5/1/2007	8.60E-02	8.50E-02	9.40E-02	3.00E-02	8.70E-04	3.44E-01
5/1/2007	6/1/2007	8.60E-02	8.50E-02	9.50E-02	3.00E-02	9.20E-04	3.53E-01
6/1/2007	7/1/2007	8.60E-02	8.50E-02	9.50E-02	3.00E-02	9.20E-04	3.52E-01
7/1/2007	8/1/2007	8.70E-02	8.50E-02	7.40E-02	3.10E-02	9.40E-04	3.53E-01
8/1/2007	9/1/2007	8.60E-02	8.40E-02	7.40E-02	3.10E-02	9.40E-04	3.56E-01
9/1/2007	10/1/2007	8.60E-02	8.50E-02	9.50E-02	3.00E-02	9.10E-04	3.50E-01
10/1/2007	11/1/2007	8.70E-02	8.50E-02	9.50E-02	3.10E-02	9.30E-04	3.53E-01
11/1/2007	12/1/2007	8.70E-02	8.50E-02	9.50E-02	3.10E-02	9.30E-04	3.52E-01

Fish: Pumpkinseed , Chemical: Homolog5

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.06E-01	1.02E-01	1.10E-01	3.60E-02	1.30E-03	3.40E-01
2/1/2007	3/1/2007	1.44E-01	1.38E-01	1.26E-01	4.30E-02	1.90E-03	3.00E-01
3/1/2007	4/1/2007	1.61E-01	1.54E-01	1.41E-01	4.80E-02	2.30E-03	2.97E-01
4/1/2007	5/1/2007	1.68E-01	1.61E-01	1.48E-01	5.00E-02	2.50E-03	2.97E-01
5/1/2007	6/1/2007	1.70E-01	1.64E-01	1.50E-01	5.10E-02	2.60E-03	3.01E-01
6/1/2007	7/1/2007	1.71E-01	1.64E-01	1.50E-01	5.20E-02	2.70E-03	3.01E-01
7/1/2007	8/1/2007	1.71E-01	1.64E-01	1.51E-01	5.20E-02	2.70E-03	3.03E-01
8/1/2007	9/1/2007	1.71E-01	1.65E-01	1.51E-01	5.20E-02	2.70E-03	3.02E-01
9/1/2007	10/1/2007	1.71E-01	1.65E-01	1.51E-01	5.10E-02	2.60E-03	2.99E-01
10/1/2007	11/1/2007	1.71E-01	1.64E-01	1.50E-01	5.20E-02	2.70E-03	3.04E-01
11/1/2007	12/1/2007	1.70E-01	1.64E-01	1.50E-01	5.10E-02	2.60E-03	2.99E-01

Fish: Pumpkinseed , Chemical: Homolog6

	Central Tendency			Variability			

Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	3.22E-01	3.47E-01	3.64E-01	1.13E-01	1.30E-02	3.50E-01
2/1/2007	3/1/2007	4.48E-01	4.67E-01	4.93E-01	1.36E-01	1.80E-02	3.03E-01
3/1/2007	4/1/2007	5.11E-01	5.24E-01	5.56E-01	1.49E-01	2.20E-02	2.92E-01
4/1/2007	5/1/2007	5.34E-01	5.48E-01	5.81E-01	1.54E-01	2.40E-02	2.89E-01
5/1/2007	6/1/2007	5.46E-01	5.60E-01	5.94E-01	1.55E-01	2.40E-02	2.84E-01
6/1/2007	7/1/2007	5.50E-01	5.64E-01	5.99E-01	1.57E-01	2.50E-02	2.86E-01
7/1/2007	8/1/2007	5.54E-01	5.72E-01	6.05E-01	1.57E-01	2.50E-02	2.84E-01
8/1/2007	9/1/2007	5.56E-01	5.74E-01	6.06E-01	1.58E-01	2.50E-02	2.84E-01
9/1/2007	10/1/2007	5.55E-01	5.68E-01	6.04E-01	1.58E-01	2.50E-02	2.85E-01
10/1/2007	11/1/2007	5.53E-01	5.67E-01	6.01E-01	1.57E-01	2.50E-02	2.85E-01
11/1/2007	12/1/2007	5.56E-01	5.70E-01	6.03E-01	1.55E-01	2.40E-02	2.79E-01

Fish: Bluegill , Chemical: PCBs

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	4.86E-01	4.58E-01	5.19E-01	2.70E-01	7.30E-02	5.55E-01	1.67E-02	4.69E-01	5.03E-01
2/1/2007	3/1/2007	6.65E-01	6.38E-01	7.22E-01	3.81E-01	1.45E-01	5.73E-01	2.36E-02	6.41E-01	6.89E-01
3/1/2007	4/1/2007	7.63E-01	7.45E-01	8.41E-01	4.50E-01	2.03E-01	5.91E-01	2.79E-02	7.35E-01	7.91E-01
4/1/2007	5/1/2007	8.04E-01	7.89E-01	8.94E-01	4.81E-01	2.31E-01	5.98E-01	2.98E-02	7.74E-01	8.34E-01
5/1/2007	6/1/2007	8.25E-01	8.10E-01	9.19E-01	4.96E-01	2.46E-01	6.01E-01	3.07E-02	7.94E-01	8.56E-01
6/1/2007	7/1/2007	8.31E-01	8.19E-01	9.28E-01	5.00E-01	2.50E-01	6.02E-01	3.10E-02	8.00E-01	8.62E-01
7/1/2007	8/1/2007	8.39E-01	8.30E-01	9.40E-01	5.06E-01	2.56E-01	6.03E-01	3.14E-02	8.08E-01	8.70E-01
8/1/2007	9/1/2007	8.48E-01	8.41E-01	9.52E-01	5.10E-01	2.60E-01	6.01E-01	3.16E-02	8.16E-01	8.80E-01
9/1/2007	10/1/2007	8.46E-01	8.33E-01	9.45E-01	5.12E-01	2.62E-01	6.06E-01	3.17E-02	8.14E-01	8.78E-01
10/1/2007	11/1/2007	8.47E-01	8.44E-01	9.50E-01	5.09E-01	2.59E-01	6.01E-01	3.15E-02	8.15E-01	8.79E-01
11/1/2007	12/1/2007	8.48E-01	8.49E-01	9.53E-01	5.08E-01	2.58E-01	5.99E-01	3.15E-02	8.17E-01	8.79E-01

Fish: Bluegill , Chemical: PCB52

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	4.70E-03	4.40E-03	4.80E-03	2.20E-03	4.70E-06	4.65E-01	1.36E-04	4.56E-03	4.84E-03
2/1/2007	3/1/2007	5.80E-03	5.30E-03	4.70E-03	2.90E-03	8.20E-06	4.95E-01	1.80E-04	5.62E-03	5.98E-03
3/1/2007	4/1/2007	6.10E-03	5.70E-03	5.00E-03	3.10E-03	9.90E-06	5.13E-01	1.92E-04	5.91E-03	6.29E-03
4/1/2007	5/1/2007	6.20E-03	5.80E-03	5.00E-03	3.30E-03	1.10E-05	5.23E-01	2.05E-04	6.00E-03	6.40E-03
5/1/2007	6/1/2007	6.30E-03	5.80E-03	5.10E-03	3.30E-03	1.10E-05	5.25E-01	2.05E-04	6.10E-03	6.50E-03
6/1/2007	7/1/2007	6.30E-03	5.90E-03	5.10E-03	3.30E-03	1.10E-05	5.26E-01	2.05E-04	6.10E-03	6.50E-03
7/1/2007	8/1/2007	6.30E-03	5.80E-03	5.00E-03	3.40E-03	1.10E-05	5.34E-01	2.11E-04	6.09E-03	6.51E-03
8/1/2007	9/1/2007	6.30E-03	5.80E-03	5.10E-03	3.40E-03	1.10E-05	5.31E-01	2.11E-04	6.09E-03	6.51E-03
9/1/2007	10/1/2007	6.30E-03	5.80E-03	5.10E-03	3.30E-03	1.10E-05	5.28E-01	2.05E-04	6.10E-03	6.50E-03
10/1/2007	11/1/2007	6.30E-03	5.80E-03	5.10E-03	3.30E-03	1.10E-05	5.27E-01	2.05E-04	6.10E-03	6.50E-03
11/1/2007	12/1/2007	6.30E-03	5.80E-03	5.10E-03	3.40E-03	1.10E-05	5.30E-01	2.11E-04	6.09E-03	6.51E-03

Fish: Bluegill , Chemical: PCB153

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	4.40E-02	4.10E-02	2.30E-02	1.80E-02	3.20E-04	4.07E-01	1.12E-03	4.29E-02	4.51E-02
2/1/2007	3/1/2007	6.40E-02	6.00E-02	5.50E-02	2.30E-02	5.10E-04	3.51E-01	1.43E-03	6.26E-02	6.54E-02
3/1/2007	4/1/2007	7.60E-02	7.10E-02	6.50E-02	2.60E-02	6.50E-04	3.38E-01	1.61E-03	7.44E-02	7.76E-02
4/1/2007	5/1/2007	8.10E-02	7.70E-02	7.00E-02	2.70E-02	7.40E-04	3.34E-01	1.67E-03	7.93E-02	8.27E-02
5/1/2007	6/1/2007	8.40E-02	7.90E-02	7.20E-02	2.80E-02	7.60E-04	3.29E-01	1.74E-03	8.23E-02	8.57E-02
6/1/2007	7/1/2007	8.50E-02	8.00E-02	7.30E-02	2.80E-02	7.90E-04	3.31E-01	1.74E-03	8.33E-02	8.67E-02
7/1/2007	8/1/2007	8.60E-02	8.10E-02	7.40E-02	2.90E-02	8.10E-04	3.31E-01	1.80E-03	8.42E-02	8.78E-02

8/1/2007	9/1/2007	8.60E-02	8.10E-02	7.40E-02	2.90E-02	8.20E-04	3.32E-01	1.80E-03	8.42E-02	8.78E-02
9/1/2007	10/1/2007	8.70E-02	8.10E-02	7.40E-02	2.90E-02	8.40E-04	3.35E-01	1.80E-03	8.52E-02	8.88E-02
10/1/2007	11/1/2007	8.60E-02	8.10E-02	7.50E-02	2.80E-02	7.90E-04	3.26E-01	1.74E-03	8.43E-02	8.77E-02
11/1/2007	12/1/2007	8.60E-02	8.10E-02	7.40E-02	2.90E-02	8.10E-04	3.32E-01	1.80E-03	8.42E-02	8.78E-02

Fish: Bluegill , Chemical: Homolog4

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	3.60E-02	3.50E-02	3.90E-02	1.40E-02	2.00E-04	3.99E-01	8.68E-04	3.51E-02	3.69E-02
2/1/2007	3/1/2007	4.50E-02	4.30E-02	3.70E-02	1.90E-02	3.60E-04	4.25E-01	1.18E-03	4.38E-02	4.62E-02
3/1/2007	4/1/2007	4.80E-02	4.50E-02	3.90E-02	2.20E-02	4.70E-04	4.52E-01	1.36E-03	4.66E-02	4.94E-02
4/1/2007	5/1/2007	4.90E-02	4.70E-02	4.00E-02	2.20E-02	5.00E-04	4.60E-01	1.36E-03	4.76E-02	5.04E-02
5/1/2007	6/1/2007	4.90E-02	4.70E-02	4.00E-02	2.30E-02	5.30E-04	4.68E-01	1.43E-03	4.76E-02	5.04E-02
6/1/2007	7/1/2007	5.00E-02	4.70E-02	4.00E-02	2.30E-02	5.40E-04	4.68E-01	1.43E-03	4.86E-02	5.14E-02
7/1/2007	8/1/2007	5.00E-02	4.70E-02	4.00E-02	2.30E-02	5.50E-04	4.71E-01	1.43E-03	4.86E-02	5.14E-02
8/1/2007	9/1/2007	4.90E-02	4.70E-02	4.00E-02	2.30E-02	5.40E-04	4.70E-01	1.43E-03	4.76E-02	5.04E-02
9/1/2007	10/1/2007	5.00E-02	4.70E-02	4.00E-02	2.30E-02	5.50E-04	4.74E-01	1.43E-03	4.86E-02	5.14E-02
10/1/2007	11/1/2007	4.90E-02	4.70E-02	4.00E-02	2.30E-02	5.50E-04	4.74E-01	1.43E-03	4.76E-02	5.04E-02
11/1/2007	12/1/2007	4.90E-02	4.70E-02	4.00E-02	2.30E-02	5.30E-04	4.66E-01	1.43E-03	4.76E-02	5.04E-02

Fish: Bluegill , Chemical: Homolog5

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	6.30E-02	6.00E-02	3.80E-02	2.30E-02	5.10E-04	3.59E-01	1.43E-03	6.16E-02	6.44E-02
2/1/2007	3/1/2007	8.60E-02	8.20E-02	7.50E-02	2.80E-02	8.00E-04	3.27E-01	1.74E-03	8.43E-02	8.77E-02

3/1/2007	4/1/2007	9.80E-02	9.30E-02	8.50E-02	3.30E-02	1.10E-03	3.38E-01	2.05E-03	9.60E-02	1.00E-01
4/1/2007	5/1/2007	1.03E-01	9.80E-02	8.90E-02	3.50E-02	1.20E-03	3.40E-01	2.17E-03	1.01E-01	1.05E-01
5/1/2007	6/1/2007	1.05E-01	1.01E-01	9.20E-02	3.60E-02	1.30E-03	3.45E-01	2.23E-03	1.03E-01	1.07E-01
6/1/2007	7/1/2007	1.06E-01	1.02E-01	9.30E-02	3.70E-02	1.30E-03	3.44E-01	2.29E-03	1.04E-01	1.08E-01
7/1/2007	8/1/2007	1.07E-01	1.02E-01	9.30E-02	3.70E-02	1.40E-03	3.48E-01	2.29E-03	1.05E-01	1.09E-01
8/1/2007	9/1/2007	1.07E-01	1.03E-01	9.30E-02	3.70E-02	1.40E-03	3.45E-01	2.29E-03	1.05E-01	1.09E-01
9/1/2007	10/1/2007	1.07E-01	1.02E-01	9.30E-02	3.70E-02	1.40E-03	3.48E-01	2.29E-03	1.05E-01	1.09E-01
10/1/2007	11/1/2007	1.07E-01	1.02E-01	9.30E-02	3.70E-02	1.40E-03	3.49E-01	2.29E-03	1.05E-01	1.09E-01
11/1/2007	12/1/2007	1.08E-01	1.03E-01	9.40E-02	3.70E-02	1.40E-03	3.47E-01	2.29E-03	1.06E-01	1.10E-01

Fish: Bluegill , Chemical: Homolog6

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.96E-01	2.10E-01	2.21E-01	7.00E-02	4.90E-03	3.56E-01	4.34E-03	1.92E-01	2.00E-01
2/1/2007	3/1/2007	2.77E-01	2.82E-01	3.03E-01	9.20E-02	8.50E-03	3.32E-01	5.70E-03	2.71E-01	2.83E-01
3/1/2007	4/1/2007	3.24E-01	3.29E-01	3.52E-01	1.04E-01	1.10E-02	3.22E-01	6.45E-03	3.18E-01	3.30E-01
4/1/2007	5/1/2007	3.45E-01	3.47E-01	3.74E-01	1.14E-01	1.30E-02	3.30E-01	7.07E-03	3.38E-01	3.52E-01
5/1/2007	6/1/2007	3.54E-01	3.57E-01	3.84E-01	1.15E-01	1.30E-02	3.26E-01	7.13E-03	3.47E-01	3.61E-01
6/1/2007	7/1/2007	3.57E-01	3.57E-01	3.86E-01	1.19E-01	1.40E-02	3.33E-01	7.38E-03	3.50E-01	3.64E-01
7/1/2007	8/1/2007	3.59E-01	3.60E-01	3.88E-01	1.19E-01	1.40E-02	3.30E-01	7.38E-03	3.52E-01	3.66E-01
8/1/2007	9/1/2007	3.60E-01	3.59E-01	3.90E-01	1.19E-01	1.40E-02	3.31E-01	7.38E-03	3.53E-01	3.67E-01
9/1/2007	10/1/2007	3.61E-01	3.59E-01	3.90E-01	1.19E-01	1.40E-02	3.31E-01	7.38E-03	3.54E-01	3.68E-01
10/1/2007	11/1/2007	3.60E-01	3.58E-01	3.88E-01	1.20E-01	1.40E-02	3.34E-01	7.44E-03	3.53E-01	3.67E-01
11/1/2007	12/1/2007	3.62E-01	3.61E-01	3.91E-01	1.19E-01	1.40E-02	3.30E-01	7.38E-03	3.55E-01	3.69E-01

Fish: Yellow Perch , Chemical: PCBs

Central Tendency Variability

Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.36E+00	1.29E+00	1.49E+00	8.50E-01	7.23E-01	6.26E-01	5.27E-02	1.31E+00	1.41E+00
2/1/2007	3/1/2007	1.83E+00	1.72E+00	1.44E+00	1.20E+00	1.44E+00	6.56E-01	7.44E-02	1.76E+00	1.90E+00
3/1/2007	4/1/2007	2.05E+00	1.97E+00	2.28E+00	1.41E+00	2.00E+00	6.88E-01	8.74E-02	1.96E+00	2.14E+00
4/1/2007	5/1/2007	2.15E+00	2.04E+00	2.37E+00	1.51E+00	2.30E+00	7.05E-01	9.36E-02	2.06E+00	2.24E+00
5/1/2007	6/1/2007	2.22E+00	2.10E+00	2.45E+00	1.59E+00	2.54E+00	7.19E-01	9.85E-02	2.12E+00	2.32E+00
6/1/2007	7/1/2007	2.24E+00	2.12E+00	2.48E+00	1.62E+00	2.62E+00	7.22E-01	1.00E-01	2.14E+00	2.34E+00
7/1/2007	8/1/2007	2.26E+00	2.12E+00	2.50E+00	1.65E+00	2.71E+00	7.28E-01	1.02E-01	2.16E+00	2.36E+00
8/1/2007	9/1/2007	2.27E+00	2.11E+00	1.73E+00	1.65E+00	2.74E+00	7.30E-01	1.02E-01	2.17E+00	2.37E+00
9/1/2007	10/1/2007	2.26E+00	2.10E+00	1.71E+00	1.66E+00	2.76E+00	7.34E-01	1.03E-01	2.16E+00	2.36E+00
10/1/2007	11/1/2007	2.26E+00	2.10E+00	1.72E+00	1.66E+00	2.76E+00	7.35E-01	1.03E-01	2.16E+00	2.36E+00
11/1/2007	12/1/2007	2.26E+00	2.11E+00	2.50E+00	1.66E+00	2.75E+00	7.34E-01	1.03E-01	2.16E+00	2.36E+00

Fish: Yellow Perch , Chemical: PCB52

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.30E-02	1.20E-02	1.00E-02	6.20E-03	3.80E-05	4.87E-01	3.84E-04	1.26E-02	1.34E-02
2/1/2007	3/1/2007	1.40E-02	1.30E-02	1.20E-02	7.40E-03	5.50E-05	5.15E-01	4.59E-04	1.35E-02	1.45E-02
3/1/2007	4/1/2007	1.50E-02	1.40E-02	1.20E-02	7.90E-03	6.20E-05	5.31E-01	4.90E-04	1.45E-02	1.55E-02
4/1/2007	5/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.40E-05	5.36E-01	4.96E-04	1.45E-02	1.55E-02
5/1/2007	6/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.40E-05	5.36E-01	4.96E-04	1.45E-02	1.55E-02
6/1/2007	7/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.50E-05	5.37E-01	4.96E-04	1.45E-02	1.55E-02
7/1/2007	8/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.40E-05	5.37E-01	4.96E-04	1.45E-02	1.55E-02
8/1/2007	9/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.40E-05	5.37E-01	4.96E-04	1.45E-02	1.55E-02
9/1/2007	10/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.50E-05	5.37E-01	4.96E-04	1.45E-02	1.55E-02
10/1/2007	11/1/2007	1.50E-02	1.40E-02	1.20E-02	8.10E-03	6.50E-05	5.39E-01	5.02E-04	1.45E-02	1.55E-02
11/1/2007	12/1/2007	1.50E-02	1.40E-02	1.20E-02	8.00E-03	6.40E-05	5.37E-01	4.96E-04	1.45E-02	1.55E-02

Fish: Yellow Perch , Chemical: PCB153

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.49E-01	1.41E-01	7.50E-02	6.00E-02	3.60E-03	4.06E-01	3.72E-03	1.45E-01	1.53E-01
2/1/2007	3/1/2007	2.12E-01	1.99E-01	1.80E-01	7.70E-02	5.90E-03	3.61E-01	4.77E-03	2.07E-01	2.17E-01
3/1/2007	4/1/2007	2.49E-01	2.34E-01	2.12E-01	8.70E-02	7.60E-03	3.50E-01	5.39E-03	2.44E-01	2.54E-01
4/1/2007	5/1/2007	2.65E-01	2.51E-01	2.27E-01	9.20E-02	8.40E-03	3.46E-01	5.70E-03	2.59E-01	2.71E-01
5/1/2007	6/1/2007	2.75E-01	2.62E-01	2.37E-01	9.50E-02	9.00E-03	3.45E-01	5.89E-03	2.69E-01	2.81E-01
6/1/2007	7/1/2007	2.78E-01	2.64E-01	2.39E-01	9.60E-02	9.20E-03	3.45E-01	5.95E-03	2.72E-01	2.84E-01
7/1/2007	8/1/2007	2.80E-01	2.65E-01	2.40E-01	9.70E-02	9.40E-03	3.47E-01	6.01E-03	2.74E-01	2.86E-01
8/1/2007	9/1/2007	2.81E-01	2.65E-01	2.42E-01	9.70E-02	9.50E-03	3.47E-01	6.01E-03	2.75E-01	2.87E-01
9/1/2007	10/1/2007	2.80E-01	2.66E-01	2.41E-01	9.70E-02	9.50E-03	3.48E-01	6.01E-03	2.74E-01	2.86E-01
10/1/2007	11/1/2007	2.82E-01	2.64E-01	2.41E-01	9.90E-02	9.90E-03	3.53E-01	6.14E-03	2.76E-01	2.88E-01
11/1/2007	12/1/2007	2.83E-01	2.67E-01	2.43E-01	9.70E-02	9.50E-03	3.44E-01	6.01E-03	2.77E-01	2.89E-01

Fish: Yellow Perch , Chemical: Homolog4

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.00E-01	9.30E-02	5.90E-02	4.30E-02	1.90E-03	4.31E-01	2.67E-03	9.73E-02	1.03E-01
2/1/2007	3/1/2007	1.16E-01	1.06E-01	9.10E-02	5.50E-02	3.00E-03	4.72E-01	3.41E-03	1.13E-01	1.19E-01
3/1/2007	4/1/2007	1.20E-01	1.11E-01	9.40E-02	6.00E-02	3.60E-03	4.96E-01	3.72E-03	1.16E-01	1.24E-01
4/1/2007	5/1/2007	1.21E-01	1.11E-01	9.30E-02	6.10E-02	3.70E-03	5.06E-01	3.78E-03	1.17E-01	1.25E-01
5/1/2007	6/1/2007	1.21E-01	1.10E-01	9.30E-02	6.20E-02	3.80E-03	5.11E-01	3.84E-03	1.17E-01	1.25E-01
6/1/2007	7/1/2007	1.22E-01	1.10E-01	9.30E-02	6.20E-02	3.90E-03	5.14E-01	3.84E-03	1.18E-01	1.26E-01
7/1/2007	8/1/2007	1.22E-01	1.11E-01	9.40E-02	6.30E-02	3.90E-03	5.14E-01	3.90E-03	1.18E-01	1.26E-01

8/1/2007	9/1/2007	1.21E-01	1.10E-01	9.30E-02	6.20E-02	3.90E-03	5.13E-01	3.84E-03	1.17E-01	1.25E-01
9/1/2007	10/1/2007	1.21E-01	1.11E-01	9.40E-02	6.20E-02	3.90E-03	5.12E-01	3.84E-03	1.17E-01	1.25E-01
10/1/2007	11/1/2007	1.22E-01	1.11E-01	9.40E-02	6.20E-02	3.90E-03	5.13E-01	3.84E-03	1.18E-01	1.26E-01
11/1/2007	12/1/2007	1.21E-01	1.11E-01	9.30E-02	6.20E-02	3.90E-03	5.13E-01	3.84E-03	1.17E-01	1.25E-01

Fish: Yellow Perch , Chemical: Homolog5

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	2.03E-01	1.93E-01	1.37E-01	7.40E-02	5.50E-03	3.64E-01	4.59E-03	1.98E-01	2.08E-01
2/1/2007	3/1/2007	2.69E-01	2.57E-01	2.30E-01	9.40E-02	8.80E-03	3.49E-01	5.83E-03	2.63E-01	2.75E-01
3/1/2007	4/1/2007	2.98E-01	2.86E-01	2.56E-01	1.09E-01	1.20E-02	3.66E-01	6.76E-03	2.91E-01	3.05E-01
4/1/2007	5/1/2007	3.11E-01	2.97E-01	2.65E-01	1.18E-01	1.40E-02	3.79E-01	7.31E-03	3.04E-01	3.18E-01
5/1/2007	6/1/2007	3.17E-01	3.03E-01	2.69E-01	1.22E-01	1.50E-02	3.84E-01	7.56E-03	3.09E-01	3.25E-01
6/1/2007	7/1/2007	3.20E-01	3.07E-01	2.71E-01	1.24E-01	1.50E-02	3.87E-01	7.69E-03	3.12E-01	3.28E-01
7/1/2007	8/1/2007	3.20E-01	3.06E-01	2.71E-01	1.26E-01	1.60E-02	3.93E-01	7.81E-03	3.12E-01	3.28E-01
8/1/2007	9/1/2007	3.21E-01	3.07E-01	2.71E-01	1.27E-01	1.60E-02	3.94E-01	7.87E-03	3.13E-01	3.29E-01
9/1/2007	10/1/2007	3.23E-01	3.09E-01	2.73E-01	1.27E-01	1.60E-02	3.92E-01	7.87E-03	3.15E-01	3.31E-01
10/1/2007	11/1/2007	3.23E-01	3.09E-01	2.73E-01	1.27E-01	1.60E-02	3.93E-01	7.87E-03	3.15E-01	3.31E-01
11/1/2007	12/1/2007	3.23E-01	3.10E-01	2.74E-01	1.26E-01	1.60E-02	3.90E-01	7.81E-03	3.15E-01	3.31E-01

Fish: Yellow Perch , Chemical: Homolog6

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	6.45E-01	6.95E-01	7.29E-01	2.27E-01	5.20E-02	3.52E-01	1.41E-02	6.31E-01	6.59E-01
2/1/2007	3/1/2007	9.07E-01	9.31E-01	9.91E-01	2.89E-01	8.40E-02	3.19E-01	1.79E-02	8.89E-01	9.25E-01

3/1/2007	4/1/2007	1.04E+00	1.05E+00	1.13E+00	3.41E-01	1.16E-01	3.29E-01	2.11E-02	1.02E+00	1.06E+00
4/1/2007	5/1/2007	1.09E+00	1.10E+00	1.19E+00	3.59E-01	1.29E-01	3.29E-01	2.23E-02	1.07E+00	1.11E+00
5/1/2007	6/1/2007	1.12E+00	1.13E+00	1.22E+00	3.75E-01	1.41E-01	3.34E-01	2.32E-02	1.10E+00	1.14E+00
6/1/2007	7/1/2007	1.13E+00	1.13E+00	1.22E+00	3.81E-01	1.45E-01	3.36E-01	2.36E-02	1.11E+00	1.15E+00
7/1/2007	8/1/2007	1.14E+00	1.14E+00	1.24E+00	3.85E-01	1.48E-01	3.38E-01	2.39E-02	1.12E+00	1.16E+00
8/1/2007	9/1/2007	1.14E+00	1.14E+00	1.24E+00	3.90E-01	1.52E-01	3.42E-01	2.42E-02	1.12E+00	1.16E+00
9/1/2007	10/1/2007	1.13E+00	1.14E+00	1.23E+00	3.82E-01	1.46E-01	3.37E-01	2.37E-02	1.11E+00	1.15E+00
10/1/2007	11/1/2007	1.13E+00	1.13E+00	1.23E+00	3.86E-01	1.49E-01	3.41E-01	2.39E-02	1.11E+00	1.15E+00
11/1/2007	12/1/2007	1.14E+00	1.14E+00	1.23E+00	3.84E-01	1.48E-01	3.38E-01	2.38E-02	1.12E+00	1.16E+00

Fish: Largemouth Bass , Chemical: PCBs

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	9.45E-01	8.72E-01	4.67E-01	4.51E-01	2.03E-01	4.97E-01	2.80E-02	9.17E-01	9.73E-01
2/1/2007	3/1/2007	1.48E+00	1.40E+00	1.61E+00	6.58E-01	4.33E-01	4.60E-01	4.08E-02	1.44E+00	1.52E+00
3/1/2007	4/1/2007	1.86E+00	1.80E+00	2.08E+00	8.42E-01	7.08E-01	4.63E-01	5.22E-02	1.81E+00	1.91E+00
4/1/2007	5/1/2007	2.07E+00	2.04E+00	2.34E+00	9.54E-01	9.11E-01	4.70E-01	5.91E-02	2.01E+00	2.13E+00
5/1/2007	6/1/2007	2.22E+00	2.19E+00	2.51E+00	1.05E+00	1.09E+00	4.81E-01	6.51E-02	2.15E+00	2.29E+00
6/1/2007	7/1/2007	2.30E+00	2.27E+00	2.61E+00	1.08E+00	1.18E+00	4.82E-01	6.69E-02	2.23E+00	2.37E+00
7/1/2007	8/1/2007	2.33E+00	2.32E+00	2.66E+00	1.10E+00	1.22E+00	4.81E-01	6.82E-02	2.26E+00	2.40E+00
8/1/2007	9/1/2007	2.36E+00	2.33E+00	2.68E+00	1.12E+00	1.26E+00	4.84E-01	6.94E-02	2.29E+00	2.43E+00
9/1/2007	10/1/2007	2.39E+00	2.36E+00	2.70E+00	1.13E+00	1.27E+00	4.84E-01	7.00E-02	2.32E+00	2.46E+00
10/1/2007	11/1/2007	2.41E+00	2.34E+00	2.70E+00	1.14E+00	1.30E+00	4.87E-01	7.07E-02	2.34E+00	2.48E+00
11/1/2007	12/1/2007	2.41E+00	2.35E+00	2.70E+00	1.14E+00	1.30E+00	4.87E-01	7.07E-02	2.34E+00	2.48E+00

Fish: Largemouth Bass , Chemical: PCB52

	Central Tendency			Variability

Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.10E-02	9.90E-03	6.60E-03	4.90E-03	2.40E-05	4.65E-01	3.04E-04	1.07E-02	1.13E-02
2/1/2007	3/1/2007	1.60E-02	1.50E-02	1.30E-02	7.20E-03	5.20E-05	4.58E-01	4.46E-04	1.56E-02	1.64E-02
3/1/2007	4/1/2007	1.90E-02	1.80E-02	1.60E-02	9.10E-03	8.30E-05	4.83E-01	5.64E-04	1.84E-02	1.96E-02
4/1/2007	5/1/2007	2.00E-02	2.00E-02	2.20E-02	1.00E-02	1.00E-04	4.99E-01	6.20E-04	1.94E-02	2.06E-02
5/1/2007	6/1/2007	2.10E-02	2.00E-02	2.30E-02	1.10E-02	1.10E-04	5.06E-01	6.82E-04	2.03E-02	2.17E-02
6/1/2007	7/1/2007	2.10E-02	2.10E-02	2.40E-02	1.10E-02	1.20E-04	5.19E-01	6.82E-04	2.03E-02	2.17E-02
7/1/2007	8/1/2007	2.10E-02	2.10E-02	2.40E-02	1.10E-02	1.20E-04	5.20E-01	6.82E-04	2.03E-02	2.17E-02
8/1/2007	9/1/2007	2.20E-02	2.10E-02	2.40E-02	1.10E-02	1.30E-04	5.22E-01	6.82E-04	2.13E-02	2.27E-02
9/1/2007	10/1/2007	2.10E-02	2.10E-02	2.40E-02	1.10E-02	1.20E-04	5.23E-01	6.82E-04	2.03E-02	2.17E-02
10/1/2007	11/1/2007	2.10E-02	2.10E-02	2.40E-02	1.10E-02	1.20E-04	5.23E-01	6.82E-04	2.03E-02	2.17E-02
11/1/2007	12/1/2007	2.10E-02	2.10E-02	2.40E-02	1.10E-02	1.20E-04	5.21E-01	6.82E-04	2.03E-02	2.17E-02

Fish: Largemouth Bass , Chemical: PCB153

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	9.00E-02	8.40E-02	4.50E-02	3.60E-02	1.30E-03	4.06E-01	2.23E-03	8.78E-02	9.22E-02
2/1/2007	3/1/2007	1.52E-01	1.44E-01	1.30E-01	4.80E-02	2.30E-03	3.15E-01	2.98E-03	1.49E-01	1.55E-01
3/1/2007	4/1/2007	1.98E-01	1.89E-01	1.74E-01	5.70E-02	3.20E-03	2.88E-01	3.53E-03	1.94E-01	2.02E-01
4/1/2007	5/1/2007	2.25E-01	2.17E-01	2.00E-01	6.40E-02	4.10E-03	2.84E-01	3.97E-03	2.21E-01	2.29E-01
5/1/2007	6/1/2007	2.44E-01	2.36E-01	2.18E-01	6.90E-02	4.80E-03	2.84E-01	4.28E-03	2.40E-01	2.48E-01
6/1/2007	7/1/2007	2.57E-01	2.49E-01	2.29E-01	7.30E-02	5.40E-03	2.85E-01	4.52E-03	2.52E-01	2.62E-01
7/1/2007	8/1/2007	2.66E-01	2.57E-01	2.37E-01	7.60E-02	5.80E-03	2.85E-01	4.71E-03	2.61E-01	2.71E-01
8/1/2007	9/1/2007	2.72E-01	2.63E-01	2.44E-01	7.80E-02	6.00E-03	2.86E-01	4.83E-03	2.67E-01	2.77E-01
9/1/2007	10/1/2007	2.74E-01	2.66E-01	2.44E-01	7.90E-02	6.20E-03	2.87E-01	4.90E-03	2.69E-01	2.79E-01
10/1/2007	11/1/2007	2.77E-01	2.70E-01	2.49E-01	7.80E-02	6.10E-03	2.83E-01	4.83E-03	2.72E-01	2.82E-01
11/1/2007	12/1/2007	2.76E-01	2.68E-01	2.48E-01	7.80E-02	6.00E-03	2.82E-01	4.83E-03	2.71E-01	2.81E-01

Fish: Largemouth Bass , Chemical: Homolog4

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	8.30E-02	8.30E-02	5.20E-02	3.20E-02	1.00E-03	3.85E-01	1.98E-03	8.10E-02	8.50E-02
2/1/2007	3/1/2007	1.24E-01	1.23E-01	1.37E-01	4.70E-02	2.20E-03	3.78E-01	2.91E-03	1.21E-01	1.27E-01
3/1/2007	4/1/2007	1.46E-01	1.46E-01	1.63E-01	5.80E-02	3.40E-03	3.98E-01	3.59E-03	1.42E-01	1.50E-01
4/1/2007	5/1/2007	1.58E-01	1.56E-01	1.36E-01	6.60E-02	4.30E-03	4.17E-01	4.09E-03	1.54E-01	1.62E-01
5/1/2007	6/1/2007	1.64E-01	1.62E-01	1.40E-01	7.10E-02	5.00E-03	4.33E-01	4.40E-03	1.60E-01	1.68E-01
6/1/2007	7/1/2007	1.67E-01	1.63E-01	1.42E-01	7.30E-02	5.40E-03	4.40E-01	4.52E-03	1.62E-01	1.72E-01
7/1/2007	8/1/2007	1.68E-01	1.63E-01	1.42E-01	7.50E-02	5.60E-03	4.46E-01	4.65E-03	1.63E-01	1.73E-01
8/1/2007	9/1/2007	1.69E-01	1.65E-01	1.43E-01	7.50E-02	5.70E-03	4.46E-01	4.65E-03	1.64E-01	1.74E-01
9/1/2007	10/1/2007	1.69E-01	1.65E-01	1.44E-01	7.50E-02	5.70E-03	4.46E-01	4.65E-03	1.64E-01	1.74E-01
10/1/2007	11/1/2007	1.69E-01	1.65E-01	1.43E-01	7.60E-02	5.80E-03	4.51E-01	4.71E-03	1.64E-01	1.74E-01
11/1/2007	12/1/2007	1.69E-01	1.65E-01	1.43E-01	7.60E-02	5.70E-03	4.47E-01	4.71E-03	1.64E-01	1.74E-01

Fish: Largemouth Bass , Chemical: Homolog5

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	1.35E-01	1.29E-01	9.10E-02	4.90E-02	2.40E-03	3.65E-01	3.04E-03	1.32E-01	1.38E-01
2/1/2007	3/1/2007	2.18E-01	2.10E-01	1.91E-01	7.20E-02	5.20E-03	3.30E-01	4.46E-03	2.14E-01	2.22E-01
3/1/2007	4/1/2007	2.76E-01	2.67E-01	2.44E-01	9.10E-02	8.30E-03	3.29E-01	5.64E-03	2.70E-01	2.82E-01
4/1/2007	5/1/2007	3.11E-01	3.07E-01	3.34E-01	1.05E-01	1.10E-02	3.37E-01	6.51E-03	3.04E-01	3.18E-01
5/1/2007	6/1/2007	3.31E-01	3.28E-01	3.57E-01	1.14E-01	1.30E-02	3.45E-01	7.07E-03	3.24E-01	3.38E-01
6/1/2007	7/1/2007	3.42E-01	3.40E-01	3.70E-01	1.19E-01	1.40E-02	3.46E-01	7.38E-03	3.35E-01	3.49E-01
7/1/2007	8/1/2007	3.51E-01	3.47E-01	3.15E-01	1.23E-01	1.50E-02	3.50E-01	7.62E-03	3.43E-01	3.59E-01

8/1/2007	9/1/2007	3.57E-01	3.53E-01	3.20E-01	1.27E-01	1.60E-02	3.55E-01	7.87E-03	3.49E-01	3.65E-01
9/1/2007	10/1/2007	3.55E-01	3.52E-01	3.84E-01	1.27E-01	1.60E-02	3.57E-01	7.87E-03	3.47E-01	3.63E-01
10/1/2007	11/1/2007	3.57E-01	3.56E-01	3.89E-01	1.26E-01	1.60E-02	3.53E-01	7.81E-03	3.49E-01	3.65E-01
11/1/2007	12/1/2007	3.60E-01	3.58E-01	3.91E-01	1.28E-01	1.60E-02	3.56E-01	7.93E-03	3.52E-01	3.68E-01

Fish: Largemouth Bass , Chemical: Homolog6

	Central Tendency			Variability						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV	CL	LCL	95%UCL
1/1/2007	2/1/2007	4.11E-01	4.39E-01	2.12E-01	1.50E-01	2.20E-02	3.65E-01	9.30E-03	4.02E-01	4.20E-01
2/1/2007	3/1/2007	6.84E-01	6.92E-01	7.49E-01	2.13E-01	4.50E-02	3.11E-01	1.32E-02	6.71E-01	6.97E-01
3/1/2007	4/1/2007	8.77E-01	8.87E-01	9.53E-01	2.58E-01	6.70E-02	2.95E-01	1.60E-02	8.61E-01	8.93E-01
4/1/2007	5/1/2007	1.00E+00	1.01E+00	1.08E+00	2.97E-01	8.80E-02	2.96E-01	1.84E-02	9.82E-01	1.02E+00
5/1/2007	6/1/2007	1.08E+00	1.09E+00	1.17E+00	3.23E-01	1.05E-01	2.98E-01	2.00E-02	1.06E+00	1.10E+00
6/1/2007	7/1/2007	1.14E+00	1.14E+00	1.23E+00	3.41E-01	1.17E-01	3.01E-01	2.11E-02	1.12E+00	1.16E+00
7/1/2007	8/1/2007	1.16E+00	1.17E+00	1.26E+00	3.54E-01	1.25E-01	3.04E-01	2.19E-02	1.14E+00	1.18E+00
8/1/2007	9/1/2007	1.18E+00	1.18E+00	1.27E+00	3.60E-01	1.30E-01	3.06E-01	2.23E-02	1.16E+00	1.20E+00
9/1/2007	10/1/2007	1.18E+00	1.18E+00	1.27E+00	3.60E-01	1.30E-01	3.05E-01	2.23E-02	1.16E+00	1.20E+00
10/1/2007	11/1/2007	1.19E+00	1.20E+00	1.29E+00	3.66E-01	1.34E-01	3.08E-01	2.27E-02	1.17E+00	1.21E+00
11/1/2007	12/1/2007	1.19E+00	1.20E+00	1.29E+00	3.68E-01	1.36E-01	3.10E-01	2.28E-02	1.17E+00	1.21E+00

Food Item: Water Column Inverts , Chemical: PCBs

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
2/1/2007	3/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
3/1/2007	4/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
4/1/2007	5/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
5/1/2007	6/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
6/1/2007	7/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
7/1/2007	8/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
8/1/2007	9/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
9/1/2007	10/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
10/1/2007	11/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00
11/1/2007	12/1/2007	3.26E-01	1.46E-01	3.20E-03	6.85E-01	4.70E-01	2.10E+00

Food Item: Water Column Inverts , Chemical: PCB52

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
2/1/2007	3/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
3/1/2007	4/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
4/1/2007	5/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
5/1/2007	6/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
6/1/2007	7/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
7/1/2007	8/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01

8/1/2007	9/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
9/1/2007	10/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
10/1/2007	11/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01
11/1/2007	12/1/2007	1.30E-04	1.30E-04	1.10E-04	4.60E-05	2.10E-09	3.41E-01

Food Item: Water Column Inverts , Chemical: PCB153

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
2/1/2007	3/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
3/1/2007	4/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
4/1/2007	5/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
5/1/2007	6/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
6/1/2007	7/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
7/1/2007	8/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
8/1/2007	9/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
9/1/2007	10/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
10/1/2007	11/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01
11/1/2007	12/1/2007	1.80E-03	1.70E-03	1.50E-03	6.10E-04	3.70E-07	3.41E-01

Food Item: Water Column Inverts , Chemical: Homolog4

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
2/1/2007	3/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01

3/1/2007	4/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
4/1/2007	5/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
5/1/2007	6/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
6/1/2007	7/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
7/1/2007	8/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
8/1/2007	9/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
9/1/2007	10/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
10/1/2007	11/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01
11/1/2007	12/1/2007	1.50E-04	1.30E-04	8.70E-05	8.60E-05	7.40E-09	5.60E-01

Food Item: Water Column Inverts , Chemical: Homolog5

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
2/1/2007	3/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
3/1/2007	4/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
4/1/2007	5/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
5/1/2007	6/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
6/1/2007	7/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
7/1/2007	8/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
8/1/2007	9/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
9/1/2007	10/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
10/1/2007	11/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01
11/1/2007	12/1/2007	7.70E-04	5.10E-04	9.70E-05	6.80E-04	4.60E-07	8.91E-01

Food Item: Water Column Inverts , Chemical: Homolog6

	Central Tendency			Variability			

Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
2/1/2007	3/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
3/1/2007	4/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
4/1/2007	5/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
5/1/2007	6/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
6/1/2007	7/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
7/1/2007	8/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
8/1/2007	9/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
9/1/2007	10/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
10/1/2007	11/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01
11/1/2007	12/1/2007	1.10E-03	9.20E-04	2.60E-04	7.40E-04	5.50E-07	6.60E-01

Food Item: Sediment Inverts , Chemical: PCBs

	Central Tendency			Variability			
Beginning	**Ending**	**Mean (ppm)**	**Median (ppm)**	**Mode (ppm)**	**Stdev (ppm)**	**Variance (p**	**CV**
1/1/2007	2/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
2/1/2007	3/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
3/1/2007	4/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
4/1/2007	5/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
5/1/2007	6/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
6/1/2007	7/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
7/1/2007	8/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
8/1/2007	9/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
9/1/2007	10/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
10/1/2007	11/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01
11/1/2007	12/1/2007	1.36E+01	1.17E+01	7.31E+00	1.07E+01	1.14E+02	7.83E-01

Food Item: Sediment Inverts , Chemical: PCB52

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
2/1/2007	3/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
3/1/2007	4/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
4/1/2007	5/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
5/1/2007	6/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
6/1/2007	7/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
7/1/2007	8/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
8/1/2007	9/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
9/1/2007	10/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
10/1/2007	11/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01
11/1/2007	12/1/2007	1.50E-01	1.32E-01	1.15E-01	9.20E-02	8.50E-03	6.15E-01

Food Item: Sediment Inverts , Chemical: PCB153

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
2/1/2007	3/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
3/1/2007	4/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
4/1/2007	5/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
5/1/2007	6/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
6/1/2007	7/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
7/1/2007	8/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01

8/1/2007	9/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
9/1/2007	10/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
10/1/2007	11/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01
11/1/2007	12/1/2007	1.08E+00	9.81E-01	8.60E-01	6.31E-01	3.98E-01	5.85E-01

Food Item: Sediment Inverts , Chemical: Homolog4

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
2/1/2007	3/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
3/1/2007	4/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
4/1/2007	5/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
5/1/2007	6/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
6/1/2007	7/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
7/1/2007	8/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
8/1/2007	9/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
9/1/2007	10/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
10/1/2007	11/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01
11/1/2007	12/1/2007	8.54E-01	7.89E-01	6.97E-01	4.39E-01	1.92E-01	5.13E-01

Food Item: Sediment Inverts , Chemical: Homolog5

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
2/1/2007	3/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01

3/1/2007	4/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
4/1/2007	5/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
5/1/2007	6/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
6/1/2007	7/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
7/1/2007	8/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
8/1/2007	9/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
9/1/2007	10/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
10/1/2007	11/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01
11/1/2007	12/1/2007	1.51E+00	1.34E+00	1.19E+00	8.57E-01	7.35E-01	5.66E-01

Food Item: Sediment Inverts , Chemical: Homolog6

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
1/1/2007	2/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
2/1/2007	3/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
3/1/2007	4/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
4/1/2007	5/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
5/1/2007	6/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
6/1/2007	7/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
7/1/2007	8/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
8/1/2007	9/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
9/1/2007	10/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
10/1/2007	11/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01
11/1/2007	12/1/2007	4.62E+00	4.10E+00	3.60E+00	2.69E+00	7.23E+00	5.82E-01

FishRand Basic Inputs

Advanced Options

X	Site contains hotspots
	Fish abundance in the site changes due to migration
	Apply user-specified parameters for bioaccumulation
	Use predefined tissue concentrations for food items
	Use site specific measurements for validation
X	Separate contribution of uncertainty and variability
	Apply Cleanup Levels

Model Name:

Natick Site

Model Description:

Spatially explicit Natick application

Monte Carlo Simulation Parameters

Sample Size for Uncertainty:	0.00E+00
Sample Size for Variability:	1.00E+02
Sample Size for Diet Loop:	1.00E+01

Total number of food items: 2.00E+00

Total number of fish: 4.00E+00

Statistical Options

X	Central Tendency: Mean
X	Central Tendency: Median
X	Central Tendency: Mode
	Central Tendency: Geometric Mean
X	Variability: Standard Deviation
X	Variability: Variance
X	Variability: Coefficient of Variation

Variability: Geometric Standard Deviation
Uncertainty: Standard Error of the Mean
Uncertainty: Upper Confidence Limit 95.0%
Probability of Mean > 0.000000
Full table of percentiles for Food Tissue Concentration (wet weight)
Full table of percentiles for Food Tissue Concentration (lipid normalized)
Full table of percentiles for Fish Tissue Concentration (wet weight)
Full table of percentiles for Fish Tissue Concentration (lipid normalized)

All Chemicals of Concern

Name	***CASRN***	***LogKow Distribution***	
PCBs		type: normal	
		mean	6.60E+00
		stdev	7.70E-01
		min	4.10E+00
		max	9.10E+00
PCB52		type: point estimate	
		value	5.93E+00
PCB153		type: point estimate	
		value	7.05E+00
Homolog4		type: triangular	
		min	5.45E+00
		mode	5.96E+00
		max	6.43E+00
Homolog5		type: triangular	
		min	5.72E+00
		mode	6.39E+00
		max	7.52E+00
Homolog6		type: triangular	

min	6.24E+00
mode	6.80E+00
max	7.31E+00

Food Items

Name	***Medium***	***Lipid % Distribution***		***Reference***
Water Column Inverts	water	type: triangular		
		min	5.00E-01	
		mode	1.20E+00	
		max	3.00E+00	
Sediment Inverts	sediment	type: triangular		
		min	1.80E+00	
		mode	3.10E+00	
		max	4.70E+00	

Fish Species Information

Fish	***Weight Distribution (g)***		***Lipid % Distribution***		***Reference***
	type: triangular		type: triangular		
Pumpkinseed	min	3.40E+01	min	1.00E+00	[Ref# 6]
	mode	4.20E+01	mode	2.00E+00	
	max	4.70E+01	max	2.90E+00	
	type: triangular		type: triangular		
Bluegill	min	7.00E+01	min	8.00E-02	[Ref# 7]
	mode	9.80E+01	mode	6.10E-01	
	max	1.35E+02	max	2.80E+00	
	type: triangular		type: triangular		
Yellow Perch	min	5.00E+01	min	1.10E-01	
	mode	1.34E+02	mode	4.30E-01	

	max	1.75E+02	max	1.10E+00	
	type: normal		type: normal		
Largemouth Bass	mean	5.26E+02	mean	8.30E-01	[Ref# 8]
	stdev	1.86E+02	stdev	9.40E-01	
	min	2.73E+02	min	5.00E-02	
	max	9.65E+02	max	4.43E+00	

Fish Diets

Fish Name	***Diet Item Names***		***Percent in Diet***
Pumpkinseed [Ref# 6]	Plankton Diet Items	Sediment Inverts	3.00E+01
		Water Column Inverts	7.00E+01
	Fish Diet Items	NONE	
Bluegill [Ref# 7]	Plankton Diet Items	Sediment Inverts	2.00E+01
		Water Column Inverts	7.00E+01
	Fish Diet Items	Pumpkinseed	1.00E+01
Yellow Perch	Plankton Diet Items	Water Column Inverts	2.00E+01
		Sediment Inverts	7.00E+01
	Fish Diet Items	Pumpkinseed	1.00E+01
Largemouth Bass [Ref# 8]	Plankton Diet Items	Sediment Inverts	5.00E+01
	Fish Diet Items	Pumpkinseed	4.00E+01
		Bluegill	0.00E+00
		Yellow Perch	1.00E+01

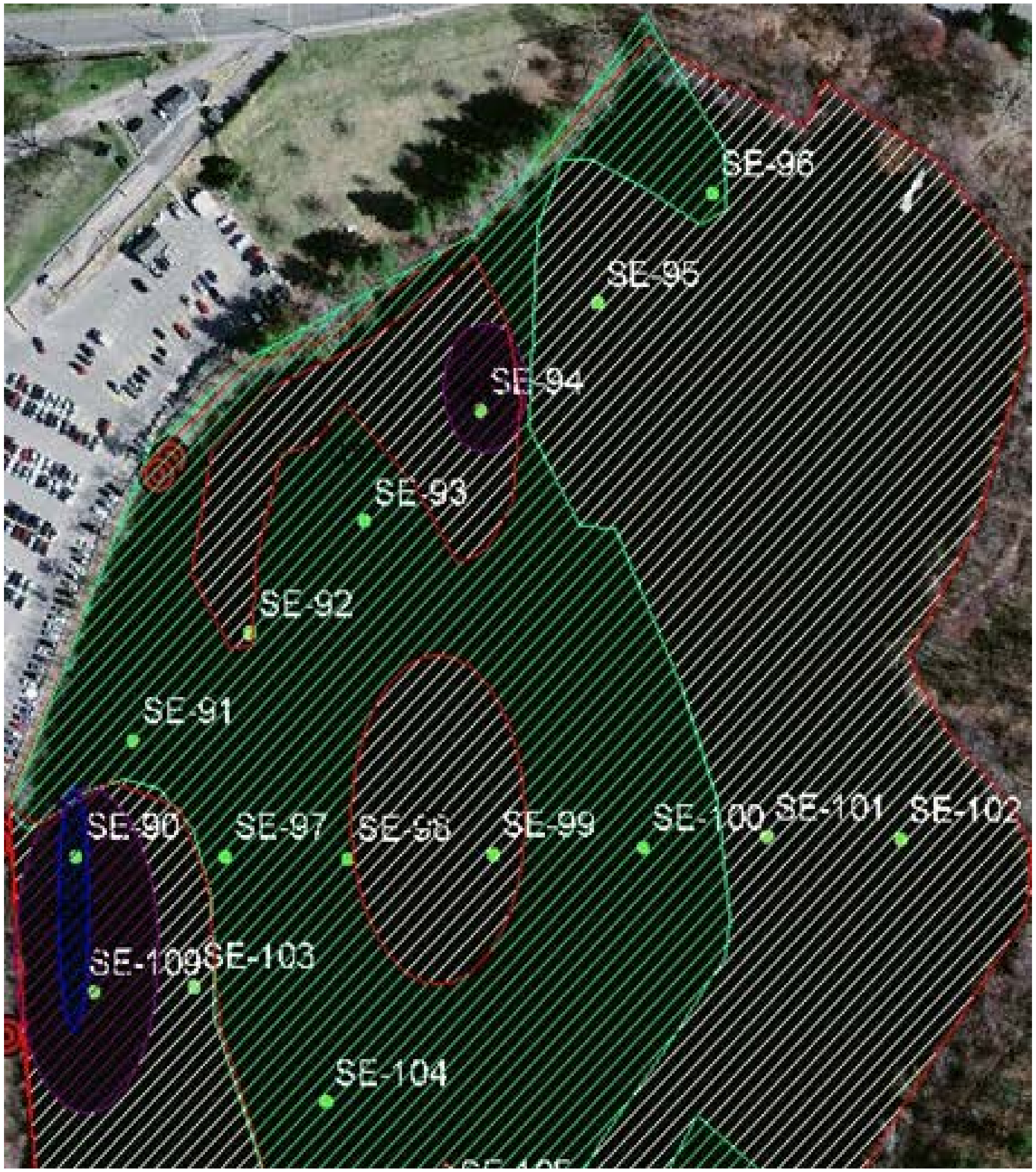
FishRand Inputs Report

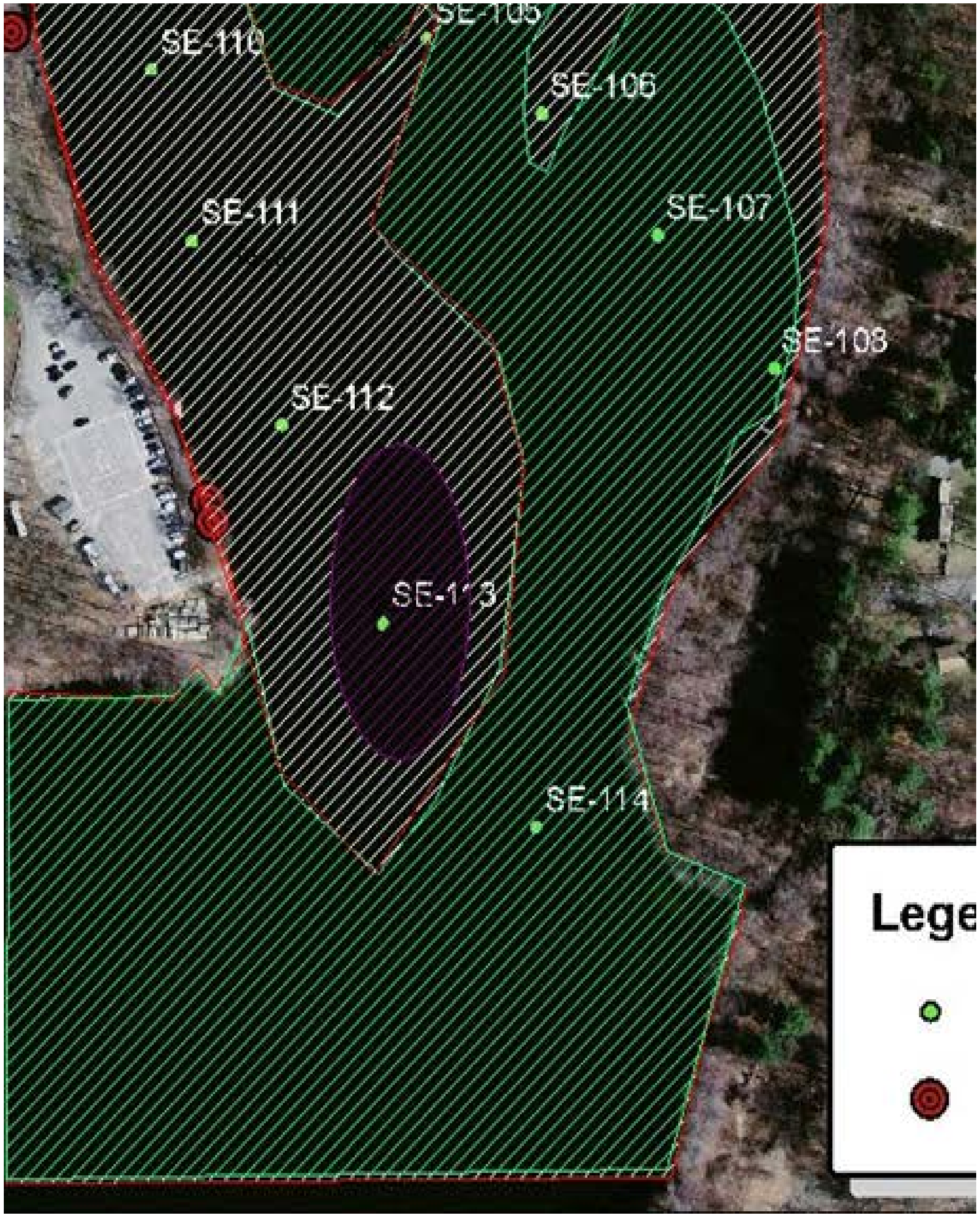
Time Scale

Seasons/Period	***# of Days***
1/1/2007	3.10E+01
2/1/2007	2.80E+01
3/1/2007	3.10E+01
4/1/2007	3.00E+01
5/1/2007	3.10E+01
6/1/2007	3.00E+01
7/1/2007	3.10E+01
8/1/2007	3.10E+01
9/1/2007	3.00E+01
10/1/2007	3.10E+01
11/1/2007	3.00E+01

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: Site





Scale in horizontal (E-W) direction (m): 1.12E+03

Scale in vertical (N-S) direction (m): 2.50E+03

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.00E-01
2/1/2007	point estimate	value	3.00E-01
3/1/2007	point estimate	value	3.00E-01
4/1/2007	point estimate	value	3.00E-01
5/1/2007	point estimate	value	3.00E-01
6/1/2007	point estimate	value	3.00E-01
7/1/2007	point estimate	value	3.00E-01
8/1/2007	point estimate	value	3.00E-01
9/1/2007	point estimate	value	3.00E-01
10/1/2007	point estimate	value	3.00E-01
11/1/2007	point estimate	value	3.00E-01
12/1/2007	point estimate	value	3.00E-01

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE96

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E+00
2/1/2007	point estimate	value	1.00E+00
3/1/2007	point estimate	value	1.00E+00
4/1/2007	point estimate	value	1.00E+00
5/1/2007	point estimate	value	1.00E+00
6/1/2007	point estimate	value	1.00E+00
7/1/2007	point estimate	value	1.00E+00
8/1/2007	point estimate	value	1.00E+00
9/1/2007	point estimate	value	1.00E+00
10/1/2007	point estimate	value	1.00E+00

11/1/2007	point estimate	value	1.00E+00
12/1/2007	point estimate	value	1.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE100

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	2.00E+00
2/1/2007	point estimate	value	2.00E+00
3/1/2007	point estimate	value	2.00E+00
4/1/2007	point estimate	value	2.00E+00
5/1/2007	point estimate	value	2.00E+00
6/1/2007	point estimate	value	2.00E+00
7/1/2007	point estimate	value	2.00E+00
8/1/2007	point estimate	value	2.00E+00
9/1/2007	point estimate	value	2.00E+00
10/1/2007	point estimate	value	2.00E+00
11/1/2007	point estimate	value	2.00E+00
12/1/2007	point estimate	value	2.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE99

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.00E+00
2/1/2007	point estimate	value	1.00E+00
3/1/2007	point estimate	value	1.00E+00
4/1/2007	point estimate	value	1.00E+00
5/1/2007	point estimate	value	1.00E+00
6/1/2007	point estimate	value	1.00E+00
7/1/2007	point estimate	value	1.00E+00
8/1/2007	point estimate	value	1.00E+00

9/1/2007	point estimate	value	1.00E+00
10/1/2007	point estimate	value	1.00E+00
11/1/2007	point estimate	value	1.00E+00
12/1/2007	point estimate	value	1.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE92

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.00E+00
2/1/2007	point estimate	value	3.00E+00
3/1/2007	point estimate	value	3.00E+00
4/1/2007	point estimate	value	3.00E+00
5/1/2007	point estimate	value	3.00E+00
6/1/2007	point estimate	value	3.00E+00
7/1/2007	point estimate	value	3.00E+00
8/1/2007	point estimate	value	3.00E+00
9/1/2007	point estimate	value	3.00E+00
10/1/2007	point estimate	value	3.00E+00
11/1/2007	point estimate	value	3.00E+00
12/1/2007			

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE94

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	4.00E+00
2/1/2007	point estimate	value	4.00E+00
3/1/2007	point estimate	value	4.00E+00
4/1/2007	point estimate	value	4.00E+00

5/1/2007	point estimate	value	4.00E+00
6/1/2007	point estimate	value	4.00E+00
7/1/2007	point estimate	value	4.00E+00
8/1/2007	point estimate	value	4.00E+00
9/1/2007	point estimate	value	4.00E+00
10/1/2007	point estimate	value	4.00E+00
11/1/2007	point estimate	value	4.00E+00
12/1/2007	point estimate	value	4.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE110

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.00E+00
2/1/2007	point estimate	value	3.00E+00
3/1/2007	point estimate	value	3.00E+00
4/1/2007	point estimate	value	3.00E+00
5/1/2007	point estimate	value	3.00E+00
6/1/2007	point estimate	value	3.00E+00
7/1/2007	point estimate	value	3.00E+00
8/1/2007	point estimate	value	3.00E+00
9/1/2007	point estimate	value	3.00E+00
10/1/2007	point estimate	value	3.00E+00
11/1/2007	point estimate	value	3.00E+00
12/1/2007	point estimate	value	3.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE113

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	4.00E+00
2/1/2007	point estimate	value	4.00E+00
3/1/2007	point estimate	value	4.00E+00
4/1/2007	point estimate	value	4.00E+00
5/1/2007	point estimate	value	4.00E+00
6/1/2007	point estimate	value	4.00E+00
7/1/2007	point estimate	value	4.00E+00
8/1/2007	point estimate	value	4.00E+00
9/1/2007	point estimate	value	4.00E+00
10/1/2007	point estimate	value	4.00E+00
11/1/2007	point estimate	value	4.00E+00
12/1/2007	point estimate	value	4.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE109

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	4.00E+00
2/1/2007	point estimate	value	4.00E+00
3/1/2007	point estimate	value	4.00E+00
4/1/2007	point estimate	value	4.00E+00
5/1/2007	point estimate	value	4.00E+00
6/1/2007	point estimate	value	4.00E+00
7/1/2007	point estimate	value	4.00E+00
8/1/2007	point estimate	value	4.00E+00
9/1/2007	point estimate	value	4.00E+00
10/1/2007	point estimate	value	4.00E+00
11/1/2007	point estimate	value	4.00E+00
12/1/2007	point estimate	value	4.00E+00

Chemical Concentrations

Chemical: PCBs Medium: sediment Area: SE90

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	9.00E+00
2/1/2007	point estimate	value	9.00E+00
3/1/2007	point estimate	value	9.00E+00
4/1/2007	point estimate	value	9.00E+00
5/1/2007	point estimate	value	9.00E+00
6/1/2007	point estimate	value	9.00E+00
7/1/2007	point estimate	value	9.00E+00
8/1/2007	point estimate	value	9.00E+00
9/1/2007	point estimate	value	9.00E+00
10/1/2007	point estimate	value	9.00E+00
11/1/2007	point estimate	value	9.00E+00
12/1/2007	point estimate	value	9.00E+00

Chemical Concentrations

Chemical: PCBs Medium: water Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E+00
2/1/2007	point estimate	value	1.00E+00
3/1/2007	point estimate	value	1.00E+00
4/1/2007	point estimate	value	1.00E+00
5/1/2007	point estimate	value	1.00E+00
6/1/2007	point estimate	value	1.00E+00
7/1/2007	point estimate	value	1.00E+00
8/1/2007	point estimate	value	1.00E+00
9/1/2007	point estimate	value	1.00E+00

10/1/2007	point estimate	value	1.00E+00
11/1/2007	point estimate	value	1.00E+00
12/1/2007	point estimate	value	1.00E+00

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.00E-03
2/1/2007	point estimate	value	1.00E-03
3/1/2007	point estimate	value	1.00E-03
4/1/2007	point estimate	value	1.00E-03
5/1/2007	point estimate	value	1.00E-03
6/1/2007	point estimate	value	1.00E-03
7/1/2007	point estimate	value	1.00E-03
8/1/2007	point estimate	value	1.00E-03
9/1/2007	point estimate	value	1.00E-03
10/1/2007	point estimate	value	1.00E-03
11/1/2007	point estimate	value	1.00E-03
12/1/2007	point estimate	value	1.00E-03

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE96

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.30E-02
2/1/2007	point estimate	value	1.30E-02
3/1/2007	point estimate	value	1.30E-02
4/1/2007	point estimate	value	1.30E-02
5/1/2007	point estimate	value	1.30E-02
6/1/2007	point estimate	value	1.30E-02

7/1/2007	point estimate	value	1.30E-02
8/1/2007	point estimate	value	1.30E-02
9/1/2007	point estimate	value	1.30E-02
10/1/2007	point estimate	value	1.30E-02
11/1/2007	point estimate	value	1.30E-02
12/1/2007	point estimate	value	1.30E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE100

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	2.10E-02
2/1/2007	point estimate	value	2.10E-02
3/1/2007	point estimate	value	2.10E-02
4/1/2007	point estimate	value	2.10E-02
5/1/2007	point estimate	value	2.10E-02
6/1/2007	point estimate	value	2.10E-02
7/1/2007	point estimate	value	2.10E-02
8/1/2007	point estimate	value	2.10E-02
9/1/2007	point estimate	value	2.10E-02
10/1/2007	point estimate	value	2.10E-02
11/1/2007	point estimate	value	2.10E-02
12/1/2007	point estimate	value	2.10E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE94

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	5.20E-02
2/1/2007	point estimate	value	5.20E-02

3/1/2007	point estimate	value	5.20E-02
4/1/2007	point estimate	value	5.20E-02
5/1/2007	point estimate	value	5.20E-02
6/1/2007	point estimate	value	5.20E-02
7/1/2007	point estimate	value	5.20E-02
8/1/2007	point estimate	value	5.20E-02
9/1/2007	point estimate	value	5.20E-02
10/1/2007	point estimate	value	5.20E-02
11/1/2007	point estimate	value	5.20E-02
12/1/2007	point estimate	value	5.20E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE99

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.30E-02
2/1/2007	point estimate	value	1.30E-02
3/1/2007	point estimate	value	1.30E-02
4/1/2007	point estimate	value	1.30E-02
5/1/2007	point estimate	value	1.30E-02
6/1/2007	point estimate	value	1.30E-02
7/1/2007	point estimate	value	1.30E-02
8/1/2007	point estimate	value	1.30E-02
9/1/2007	point estimate	value	1.30E-02
10/1/2007	point estimate	value	1.30E-02
11/1/2007	point estimate	value	1.30E-02
12/1/2007	point estimate	value	1.30E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE92

Concentration Distributions (mg/kg dry weight)

Time Period	Type	Parameter	Values
1/1/2007	point estimate	value	3.00E-02
2/1/2007	point estimate	value	3.00E-02
3/1/2007	point estimate	value	3.00E-02
4/1/2007	point estimate	value	3.00E-02
5/1/2007	point estimate	value	3.00E-02
6/1/2007	point estimate	value	3.00E-02
7/1/2007	point estimate	value	3.00E-02
8/1/2007	point estimate	value	3.00E-02
9/1/2007	point estimate	value	3.00E-02
10/1/2007	point estimate	value	3.00E-02
11/1/2007	point estimate	value	3.00E-02
12/1/2007	point estimate	value	3.00E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE110

Concentration Distributions (mg/kg dry weight)

Time Period	Type	Parameter	Values
1/1/2007	point estimate	value	3.00E-02
2/1/2007	point estimate	value	3.00E-02
3/1/2007	point estimate	value	3.00E-02
4/1/2007	point estimate	value	3.00E-02
5/1/2007	point estimate	value	3.00E-02
6/1/2007	point estimate	value	3.00E-02
7/1/2007	point estimate	value	3.00E-02
8/1/2007	point estimate	value	3.00E-02
9/1/2007	point estimate	value	3.00E-02
10/1/2007	point estimate	value	3.00E-02
11/1/2007	point estimate	value	3.00E-02
12/1/2007	point estimate	value	3.00E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE109

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	5.20E-02
2/1/2007	point estimate	value	5.20E-02
3/1/2007	point estimate	value	5.20E-02
4/1/2007	point estimate	value	5.20E-02
5/1/2007	point estimate	value	5.20E-02
6/1/2007	point estimate	value	5.20E-02
7/1/2007	point estimate	value	5.20E-02
8/1/2007	point estimate	value	5.20E-02
9/1/2007	point estimate	value	5.20E-02
10/1/2007	point estimate	value	5.20E-02
11/1/2007	point estimate	value	5.20E-02
12/1/2007	point estimate	value	5.20E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE90

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	6.80E-02
2/1/2007	point estimate	value	6.80E-02
3/1/2007	point estimate	value	6.80E-02
4/1/2007	point estimate	value	6.80E-02
5/1/2007	point estimate	value	6.80E-02
6/1/2007	point estimate	value	6.80E-02
7/1/2007	point estimate	value	6.80E-02
8/1/2007	point estimate	value	6.80E-02
9/1/2007	point estimate	value	6.80E-02
10/1/2007	point estimate	value	6.80E-02
11/1/2007	point estimate	value	6.80E-02

12/1/2007	point estimate	value	6.80E-02

Chemical Concentrations

Chemical: PCB52 Medium: sediment Area: SE113

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	6.80E-02
2/1/2007	point estimate	value	6.80E-02
3/1/2007	point estimate	value	6.80E-02
4/1/2007	point estimate	value	6.80E-02
5/1/2007	point estimate	value	6.80E-02
6/1/2007	point estimate	value	6.80E-02
7/1/2007	point estimate	value	6.80E-02
8/1/2007	point estimate	value	6.80E-02
9/1/2007	point estimate	value	6.80E-02
10/1/2007	point estimate	value	6.80E-02
11/1/2007	point estimate	value	6.80E-02
12/1/2007	point estimate	value	6.80E-02

Chemical Concentrations

Chemical: PCB52 Medium: water Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02

10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE96

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-01
2/1/2007	point estimate	value	1.00E-01
3/1/2007	point estimate	value	1.00E-01
4/1/2007	point estimate	value	1.00E-01
5/1/2007	point estimate	value	1.00E-01
6/1/2007	point estimate	value	1.00E-01
7/1/2007	point estimate	value	1.00E-01

8/1/2007	point estimate	value	1.00E-01
9/1/2007	point estimate	value	1.00E-01
10/1/2007	point estimate	value	1.00E-01
11/1/2007	point estimate	value	1.00E-01
12/1/2007	point estimate	value	1.00E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE100

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.73E-01
2/1/2007	point estimate	value	1.73E-01
3/1/2007	point estimate	value	1.73E-01
4/1/2007	point estimate	value	1.73E-01
5/1/2007	point estimate	value	1.73E-01
6/1/2007	point estimate	value	1.73E-01
7/1/2007	point estimate	value	1.73E-01
8/1/2007	point estimate	value	1.73E-01
9/1/2007	point estimate	value	1.73E-01
10/1/2007	point estimate	value	1.73E-01
11/1/2007	point estimate	value	1.73E-01
12/1/2007	point estimate	value	1.73E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE94

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.06E-01
2/1/2007	point estimate	value	3.06E-01
3/1/2007	point estimate	value	3.06E-01

4/1/2007	point estimate	value	3.06E-01
5/1/2007	point estimate	value	3.06E-01
6/1/2007	point estimate	value	3.06E-01
7/1/2007	point estimate	value	3.06E-01
8/1/2007	point estimate	value	3.06E-01
9/1/2007	point estimate	value	3.06E-01
10/1/2007	point estimate	value	3.06E-01
11/1/2007	point estimate	value	3.06E-01
12/1/2007	point estimate	value	3.06E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE99

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-01
2/1/2007	point estimate	value	1.00E-01
3/1/2007	point estimate	value	1.00E-01
4/1/2007	point estimate	value	1.00E-01
5/1/2007	point estimate	value	1.00E-01
6/1/2007	point estimate	value	1.00E-01
7/1/2007	point estimate	value	1.00E-01
8/1/2007	point estimate	value	1.00E-01
9/1/2007	point estimate	value	1.00E-01
10/1/2007	point estimate	value	1.00E-01
11/1/2007	point estimate	value	1.00E-01
12/1/2007	point estimate	value	1.00E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE92

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.06E-01

2/1/2007	point estimate	value	3.06E-01
3/1/2007	point estimate	value	3.06E-01
4/1/2007	point estimate	value	3.06E-01
5/1/2007	point estimate	value	3.06E-01
6/1/2007	point estimate	value	3.06E-01
7/1/2007	point estimate	value	3.06E-01
8/1/2007	point estimate	value	3.06E-01
9/1/2007	point estimate	value	3.06E-01
10/1/2007	point estimate	value	3.06E-01
11/1/2007	point estimate	value	3.06E-01
12/1/2007	point estimate	value	3.06E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE110

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.06E-01
2/1/2007	point estimate	value	3.06E-01
3/1/2007	point estimate	value	3.06E-01
4/1/2007	point estimate	value	3.06E-01
5/1/2007	point estimate	value	3.06E-01
6/1/2007	point estimate	value	3.06E-01
7/1/2007	point estimate	value	3.06E-01
8/1/2007	point estimate	value	3.06E-01
9/1/2007	point estimate	value	3.06E-01
10/1/2007	point estimate	value	3.06E-01
11/1/2007	point estimate	value	3.06E-01
12/1/2007	point estimate	value	3.06E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE109

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	3.70E-01
2/1/2007	point estimate	value	3.70E-01
3/1/2007	point estimate	value	3.70E-01
4/1/2007	point estimate	value	3.70E-01
5/1/2007	point estimate	value	3.70E-01
6/1/2007	point estimate	value	3.70E-01
7/1/2007	point estimate	value	3.70E-01
8/1/2007	point estimate	value	3.70E-01
9/1/2007	point estimate	value	3.70E-01
10/1/2007	point estimate	value	3.70E-01
11/1/2007	point estimate	value	3.70E-01
12/1/2007	point estimate	value	3.70E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE90

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	5.00E-01
2/1/2007	point estimate	value	5.00E-01
3/1/2007	point estimate	value	5.00E-01
4/1/2007	point estimate	value	5.00E-01
5/1/2007	point estimate	value	5.00E-01
6/1/2007	point estimate	value	5.00E-01
7/1/2007	point estimate	value	5.00E-01
8/1/2007	point estimate	value	5.00E-01
9/1/2007	point estimate	value	5.00E-01
10/1/2007	point estimate	value	5.00E-01
11/1/2007	point estimate	value	5.00E-01
12/1/2007	point estimate	value	5.00E-01

Chemical Concentrations

Chemical: PCB153 Medium: sediment Area: SE113

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	3.70E-01
2/1/2007	point estimate	value	3.70E-01
3/1/2007	point estimate	value	3.70E-01
4/1/2007	point estimate	value	3.70E-01
5/1/2007	point estimate	value	3.70E-01
6/1/2007	point estimate	value	3.70E-01
7/1/2007	point estimate	value	3.70E-01
8/1/2007	point estimate	value	3.70E-01
9/1/2007	point estimate	value	3.70E-01
10/1/2007	point estimate	value	3.70E-01
11/1/2007	point estimate	value	3.70E-01
12/1/2007	point estimate	value	3.70E-01

Chemical Concentrations

Chemical: PCB153 Medium: water Area: Site

Concentration Distributions (ng/L)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE96

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-01
2/1/2007	point estimate	value	1.00E-01
3/1/2007	point estimate	value	1.00E-01
4/1/2007	point estimate	value	1.00E-01
5/1/2007	point estimate	value	1.00E-01
6/1/2007	point estimate	value	1.00E-01
7/1/2007	point estimate	value	1.00E-01
8/1/2007	point estimate	value	1.00E-01
9/1/2007	point estimate	value	1.00E-01
10/1/2007	point estimate	value	1.00E-01
11/1/2007	point estimate	value	1.00E-01
12/1/2007	point estimate	value	1.00E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE100

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.73E-01
2/1/2007	point estimate	value	1.73E-01
3/1/2007	point estimate	value	1.73E-01
4/1/2007	point estimate	value	1.73E-01
5/1/2007	point estimate	value	1.73E-01
6/1/2007	point estimate	value	1.73E-01
7/1/2007	point estimate	value	1.73E-01
8/1/2007	point estimate	value	1.73E-01
9/1/2007	point estimate	value	1.73E-01
10/1/2007	point estimate	value	1.73E-01
11/1/2007	point estimate	value	1.73E-01
12/1/2007	point estimate	value	1.73E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE94

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.30E-01
2/1/2007	point estimate	value	3.30E-01
3/1/2007	point estimate	value	3.30E-01
4/1/2007	point estimate	value	3.30E-01
5/1/2007	point estimate	value	3.30E-01
6/1/2007	point estimate	value	3.30E-01
7/1/2007	point estimate	value	3.30E-01
8/1/2007	point estimate	value	3.30E-01
9/1/2007	point estimate	value	3.30E-01
10/1/2007	point estimate	value	3.30E-01
11/1/2007	point estimate	value	3.30E-01
12/1/2007	point estimate	value	3.30E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE99

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.00E-01
2/1/2007	point estimate	value	1.00E-01
3/1/2007	point estimate	value	1.00E-01
4/1/2007	point estimate	value	1.00E-01
5/1/2007	point estimate	value	1.00E-01
6/1/2007	point estimate	value	1.00E-01
7/1/2007	point estimate	value	1.00E-01
8/1/2007	point estimate	value	1.00E-01
9/1/2007	point estimate	value	1.00E-01
10/1/2007	point estimate	value	1.00E-01
11/1/2007	point estimate	value	1.00E-01
12/1/2007	point estimate	value	1.00E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE92

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.50E-01
2/1/2007	point estimate	value	2.50E-01
3/1/2007	point estimate	value	2.50E-01
4/1/2007	point estimate	value	2.50E-01
5/1/2007	point estimate	value	2.50E-01
6/1/2007	point estimate	value	2.50E-01
7/1/2007	point estimate	value	2.50E-01
8/1/2007	point estimate	value	2.50E-01
9/1/2007	point estimate	value	2.50E-01
10/1/2007	point estimate	value	2.50E-01
11/1/2007	point estimate	value	2.50E-01
12/1/2007	point estimate	value	2.50E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE110

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	2.50E-01
2/1/2007	point estimate	value	2.50E-01
3/1/2007	point estimate	value	2.50E-01
4/1/2007	point estimate	value	2.50E-01
5/1/2007	point estimate	value	2.50E-01
6/1/2007	point estimate	value	2.50E-01
7/1/2007	point estimate	value	2.50E-01
8/1/2007	point estimate	value	2.50E-01
9/1/2007	point estimate	value	2.50E-01
10/1/2007	point estimate	value	2.50E-01
11/1/2007	point estimate	value	2.50E-01
12/1/2007	point estimate	value	2.50E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE109

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.30E-01
2/1/2007	point estimate	value	3.30E-01
3/1/2007	point estimate	value	3.30E-01
4/1/2007	point estimate	value	3.30E-01
5/1/2007	point estimate	value	3.30E-01
6/1/2007	point estimate	value	3.30E-01
7/1/2007	point estimate	value	3.30E-01
8/1/2007	point estimate	value	3.30E-01
9/1/2007	point estimate	value	3.30E-01
10/1/2007	point estimate	value	3.30E-01
11/1/2007	point estimate	value	3.30E-01
12/1/2007	point estimate	value	3.30E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE90

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.30E-01
2/1/2007	point estimate	value	1.30E-01
3/1/2007	point estimate	value	1.30E-01
4/1/2007	point estimate	value	1.30E-01
5/1/2007	point estimate	value	1.30E-01
6/1/2007	point estimate	value	1.30E-01
7/1/2007	point estimate	value	1.30E-01
8/1/2007	point estimate	value	1.30E-01
9/1/2007	point estimate	value	1.30E-01
10/1/2007	point estimate	value	1.30E-01
11/1/2007	point estimate	value	1.30E-01
12/1/2007	point estimate	value	1.30E-01

Chemical Concentrations

Chemical: Homolog4 Medium: sediment Area: SE113

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.50E-01
2/1/2007	point estimate	value	2.50E-01
3/1/2007	point estimate	value	2.50E-01
4/1/2007	point estimate	value	2.50E-01
5/1/2007	point estimate	value	2.50E-01
6/1/2007	point estimate	value	2.50E-01
7/1/2007	point estimate	value	2.50E-01
8/1/2007	point estimate	value	2.50E-01
9/1/2007	point estimate	value	2.50E-01
10/1/2007	point estimate	value	2.50E-01
11/1/2007	point estimate	value	2.50E-01
12/1/2007	point estimate	value	2.50E-01

Chemical Concentrations

Chemical: Homolog4 Medium: water Area: Site

Concentration Distributions (ng/L)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE96

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***

1/1/2007	point estimate	value	1.60E-01
2/1/2007	point estimate	value	1.60E-01
3/1/2007	point estimate	value	1.60E-01
4/1/2007	point estimate	value	1.60E-01
5/1/2007	point estimate	value	1.60E-01
6/1/2007	point estimate	value	1.60E-01
7/1/2007	point estimate	value	1.60E-01
8/1/2007	point estimate	value	1.60E-01
9/1/2007	point estimate	value	1.60E-01
10/1/2007	point estimate	value	1.60E-01
11/1/2007	point estimate	value	1.60E-01
12/1/2007	point estimate	value	1.60E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE100

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.50E-01
2/1/2007	point estimate	value	2.50E-01
3/1/2007	point estimate	value	2.50E-01
4/1/2007	point estimate	value	2.50E-01
5/1/2007	point estimate	value	2.50E-01
6/1/2007	point estimate	value	2.50E-01
7/1/2007	point estimate	value	2.50E-01
8/1/2007	point estimate	value	2.50E-01
9/1/2007	point estimate	value	2.50E-01
10/1/2007	point estimate	value	2.50E-01
11/1/2007	point estimate	value	2.50E-01
12/1/2007	point estimate	value	2.50E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE94

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	5.80E-01
2/1/2007	point estimate	value	5.80E-01
3/1/2007	point estimate	value	5.80E-01
4/1/2007	point estimate	value	5.80E-01
5/1/2007	point estimate	value	5.80E-01
6/1/2007	point estimate	value	5.80E-01
7/1/2007	point estimate	value	5.80E-01
8/1/2007	point estimate	value	5.80E-01
9/1/2007	point estimate	value	5.80E-01
10/1/2007	point estimate	value	5.80E-01
11/1/2007	point estimate	value	5.80E-01
12/1/2007	point estimate	value	5.80E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE99

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.60E-01
2/1/2007	point estimate	value	1.60E-01
3/1/2007	point estimate	value	1.60E-01
4/1/2007	point estimate	value	1.60E-01
5/1/2007	point estimate	value	1.60E-01
6/1/2007	point estimate	value	1.60E-01
7/1/2007	point estimate	value	1.60E-01
8/1/2007	point estimate	value	1.60E-01
9/1/2007	point estimate	value	1.60E-01
10/1/2007	point estimate	value	1.60E-01
11/1/2007	point estimate	value	1.60E-01
12/1/2007	point estimate	value	1.60E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE92

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	3.80E-01
2/1/2007	point estimate	value	3.80E-01
3/1/2007	point estimate	value	3.80E-01
4/1/2007	point estimate	value	3.80E-01
5/1/2007	point estimate	value	3.80E-01
6/1/2007	point estimate	value	3.80E-01
7/1/2007	point estimate	value	3.80E-01
8/1/2007	point estimate	value	3.80E-01
9/1/2007	point estimate	value	3.80E-01
10/1/2007	point estimate	value	3.80E-01
11/1/2007	point estimate	value	3.80E-01
12/1/2007	point estimate	value	3.80E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE110

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.80E-01
2/1/2007	point estimate	value	3.80E-01
3/1/2007	point estimate	value	3.80E-01
4/1/2007	point estimate	value	3.80E-01
5/1/2007	point estimate	value	3.80E-01
6/1/2007	point estimate	value	3.80E-01
7/1/2007	point estimate	value	3.80E-01
8/1/2007	point estimate	value	3.80E-01
9/1/2007	point estimate	value	3.80E-01
10/1/2007	point estimate	value	3.80E-01
11/1/2007	point estimate	value	3.80E-01
12/1/2007	point estimate	value	3.80E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE109

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	5.80E-01
2/1/2007	point estimate	value	5.80E-01
3/1/2007	point estimate	value	5.80E-01
4/1/2007	point estimate	value	5.80E-01
5/1/2007	point estimate	value	5.80E-01
6/1/2007	point estimate	value	5.80E-01
7/1/2007	point estimate	value	5.80E-01
8/1/2007	point estimate	value	5.80E-01
9/1/2007	point estimate	value	5.80E-01
10/1/2007	point estimate	value	5.80E-01
11/1/2007	point estimate	value	5.80E-01
12/1/2007	point estimate	value	5.80E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE90

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	6.00E-01
2/1/2007	point estimate	value	6.00E-01
3/1/2007	point estimate	value	6.00E-01
4/1/2007	point estimate	value	6.00E-01
5/1/2007	point estimate	value	6.00E-01
6/1/2007	point estimate	value	6.00E-01
7/1/2007	point estimate	value	6.00E-01
8/1/2007	point estimate	value	6.00E-01
9/1/2007	point estimate	value	6.00E-01
10/1/2007	point estimate	value	6.00E-01
11/1/2007	point estimate	value	6.00E-01
12/1/2007	point estimate	value	6.00E-01

Chemical Concentrations

Chemical: Homolog5 Medium: sediment Area: SE113

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	5.80E-01
2/1/2007	point estimate	value	5.80E-01
3/1/2007	point estimate	value	5.80E-01
4/1/2007	point estimate	value	5.80E-01
5/1/2007	point estimate	value	5.80E-01
6/1/2007	point estimate	value	5.80E-01
7/1/2007	point estimate	value	5.80E-01
8/1/2007	point estimate	value	5.80E-01
9/1/2007	point estimate	value	5.80E-01
10/1/2007	point estimate	value	5.80E-01
11/1/2007	point estimate	value	5.80E-01
12/1/2007	point estimate	value	5.80E-01

Chemical Concentrations

Chemical: Homolog5 Medium: water Area: Site

Concentration Distributions (ng/L)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: Site

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	2.00E-02
2/1/2007	point estimate	value	2.00E-02
3/1/2007	point estimate	value	2.00E-02
4/1/2007	point estimate	value	2.00E-02
5/1/2007	point estimate	value	2.00E-02
6/1/2007	point estimate	value	2.00E-02
7/1/2007	point estimate	value	2.00E-02
8/1/2007	point estimate	value	2.00E-02
9/1/2007	point estimate	value	2.00E-02
10/1/2007	point estimate	value	2.00E-02
11/1/2007	point estimate	value	2.00E-02
12/1/2007	point estimate	value	2.00E-02

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE96

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	4.00E-01
2/1/2007	point estimate	value	4.00E-01
3/1/2007	point estimate	value	4.00E-01
4/1/2007	point estimate	value	4.00E-01
5/1/2007	point estimate	value	4.00E-01
6/1/2007	point estimate	value	4.00E-01
7/1/2007	point estimate	value	4.00E-01
8/1/2007	point estimate	value	4.00E-01
9/1/2007	point estimate	value	4.00E-01
10/1/2007	point estimate	value	4.00E-01
11/1/2007	point estimate	value	4.00E-01
12/1/2007	point estimate	value	4.00E-01

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE100

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	8.60E-01
2/1/2007	point estimate	value	8.60E-01
3/1/2007	point estimate	value	8.60E-01
4/1/2007	point estimate	value	8.60E-01
5/1/2007	point estimate	value	8.60E-01
6/1/2007	point estimate	value	8.60E-01
7/1/2007	point estimate	value	8.60E-01
8/1/2007	point estimate	value	8.60E-01
9/1/2007	point estimate	value	8.60E-01
10/1/2007	point estimate	value	8.60E-01
11/1/2007	point estimate	value	8.60E-01
12/1/2007	point estimate	value	8.60E-01

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE94

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.40E+00
2/1/2007	point estimate	value	1.40E+00
3/1/2007	point estimate	value	1.40E+00
4/1/2007	point estimate	value	1.40E+00
5/1/2007	point estimate	value	1.40E+00
6/1/2007	point estimate	value	1.40E+00
7/1/2007	point estimate	value	1.40E+00
8/1/2007	point estimate	value	1.40E+00
9/1/2007	point estimate	value	1.40E+00
10/1/2007	point estimate	value	1.40E+00
11/1/2007	point estimate	value	1.40E+00
12/1/2007	point estimate	value	1.40E+00

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE99

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	6.80E-01
2/1/2007	point estimate	value	6.80E-01
3/1/2007	point estimate	value	6.80E-01
4/1/2007	point estimate	value	6.80E-01
5/1/2007	point estimate	value	6.80E-01
6/1/2007	point estimate	value	6.80E-01
7/1/2007	point estimate	value	6.80E-01
8/1/2007	point estimate	value	6.80E-01
9/1/2007	point estimate	value	6.80E-01
10/1/2007	point estimate	value	6.80E-01
11/1/2007	point estimate	value	6.80E-01
12/1/2007	point estimate	value	6.80E-01

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE92

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E+00
2/1/2007	point estimate	value	1.00E+00
3/1/2007	point estimate	value	1.00E+00
4/1/2007	point estimate	value	1.00E+00
5/1/2007	point estimate	value	1.00E+00
6/1/2007	point estimate	value	1.00E+00
7/1/2007	point estimate	value	1.00E+00
8/1/2007	point estimate	value	1.00E+00
9/1/2007	point estimate	value	1.00E+00
10/1/2007	point estimate	value	1.00E+00
11/1/2007	point estimate	value	1.00E+00
12/1/2007	point estimate	value	1.00E+00

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE110

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.00E+00
2/1/2007	point estimate	value	1.00E+00
3/1/2007	point estimate	value	1.00E+00
4/1/2007	point estimate	value	1.00E+00
5/1/2007	point estimate	value	1.00E+00
6/1/2007	point estimate	value	1.00E+00
7/1/2007	point estimate	value	1.00E+00
8/1/2007	point estimate	value	1.00E+00
9/1/2007	point estimate	value	1.00E+00
10/1/2007	point estimate	value	1.00E+00
11/1/2007	point estimate	value	1.00E+00
12/1/2007	point estimate	value	1.00E+00

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE109

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.80E+00
2/1/2007	point estimate	value	1.80E+00
3/1/2007	point estimate	value	1.80E+00
4/1/2007	point estimate	value	1.80E+00
5/1/2007	point estimate	value	1.80E+00
6/1/2007	point estimate	value	1.80E+00
7/1/2007	point estimate	value	1.80E+00
8/1/2007	point estimate	value	1.80E+00
9/1/2007	point estimate	value	1.80E+00
10/1/2007	point estimate	value	1.80E+00
11/1/2007	point estimate	value	1.80E+00
12/1/2007	point estimate	value	1.80E+00

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE90

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***

1/1/2007	point estimate	value	2.00E+00
2/1/2007	point estimate	value	2.00E+00
3/1/2007	point estimate	value	2.00E+00
4/1/2007	point estimate	value	2.00E+00
5/1/2007	point estimate	value	2.00E+00
6/1/2007	point estimate	value	2.00E+00
7/1/2007	point estimate	value	2.00E+00
8/1/2007	point estimate	value	2.00E+00
9/1/2007	point estimate	value	2.00E+00
10/1/2007	point estimate	value	2.00E+00
11/1/2007	point estimate	value	2.00E+00
12/1/2007	point estimate	value	2.00E+00

Chemical Concentrations

Chemical: Homolog6 Medium: sediment Area: SE113

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.80E+00
2/1/2007	point estimate	value	1.80E+00
3/1/2007	point estimate	value	1.80E+00
4/1/2007	point estimate	value	1.80E+00
5/1/2007	point estimate	value	1.80E+00
6/1/2007	point estimate	value	1.80E+00
7/1/2007	point estimate	value	1.80E+00
8/1/2007	point estimate	value	1.80E+00
9/1/2007	point estimate	value	1.80E+00
10/1/2007	point estimate	value	1.80E+00
11/1/2007	point estimate	value	1.80E+00
12/1/2007	point estimate	value	1.80E+00

Chemical Concentrations

Chemical: Homolog6 Medium: water Area: Site

Concentration Distributions (ng/L)

Time Period	*Type*	*Parameter*	*Values*

1/1/2007	point estimate	value	1.00E-02
2/1/2007	point estimate	value	1.00E-02
3/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
5/1/2007	point estimate	value	1.00E-02
6/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
8/1/2007	point estimate	value	1.00E-02
9/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
11/1/2007	point estimate	value	1.00E-02
12/1/2007	point estimate	value	1.00E-02

Fishrand Advanced Inputs

Uncertain and Variable Parameters

Uncertain Parameters

None

Variable Parameters

Log Octanol-Water Partitioning Coefficient (Log Kow)
Food Item Lipid Percents
Fish Lipid Percents
Fish Weights
Sediment Organic Carbon Percent
Water Temperature

Water Temperature

Time Period	Site		Water Temperature (Celcius) SE96	
1/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
2/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
3/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
4/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
5/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
6/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
7/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
8/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01

	max	1.80E+01	max	1.80E+01
9/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
10/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
11/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01
12/1/2007	type: triangular		type: triangular	
	min	8.00E+00	min	8.00E+00
	mode	1.20E+01	mode	1.20E+01
	max	1.80E+01	max	1.80E+01

Total Organic Carbon in Sediment (TOC)

Location	*Sediment TOC (%) Distribution*	
Site	type: point estimate	
	value	1.00E+00
SE96	type: normal	
	mean	1.70E+00
	stdev	6.70E-01
	min	1.10E-01
	max	3.80E+00

Fish Attraction Factors

Fish: **Pumpkinseed**

Location/Area	*Attraction Factor*

Site	type: point estimate	
	value	0.00E+00
SE96	type: point estimate	
	value	1.00E+00

Fish Attraction Factors

Fish: **Bluegill**

Location/Area	*Attraction Factor*	
Site	type: point estimate	
	value	0.00E+00
SE96	type: point estimate	
	value	1.00E+00

Fish Attraction Factors

Fish: **Yellow Perch**

Location/Area	*Attraction Factor*	
Site	type: point estimate	
	value	0.00E+00
SE96	type: point estimate	
	value	1.00E+00

Fish Attraction Factors

Fish: **Largemouth Bass**

Location/Area	*Attraction Factor*	
Site	type: point estimate	
	value	0.00E+00
SE96	type: point estimate	
	value	1.00E+00

Fishrand Input References

TOC

REF# 5

Fish Species Information

Pumpkinseed

REF# 6

FS report, Table 3-2, 2007 data

Bluegill

REF# 7

FS Report, Table 3-2, 2007 data

Largemouth Bass

REF# 8

FS Report, 2007 data Table 3-2

Appendix C: Detailed Model Inputs and Outputs for the Tyndall AFB Site

Please refer to the attached PDF file.

Fish: Killifish , Chemical: DDD

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.43E-01	1.20E-01	1.06E-01	1.07E-01	1.76E-01	3.10E-02	1.23E+00
4/1/2007	7/1/2007	1.54E-01	1.28E-01	1.67E-01	1.16E-01	1.87E-01	3.50E-02	1.22E+00
7/1/2007	10/1/2007	1.47E-01	1.21E-01	1.67E-01	1.05E-01	1.95E-01	3.80E-02	1.32E+00
10/1/2007	1/1/2008	1.46E-01	1.21E-01	1.38E-01	1.05E-01	1.90E-01	3.60E-02	1.31E+00
1/1/2008	4/1/2008	1.55E-01	1.29E-01	1.44E-01	1.16E-01	1.92E-01	3.70E-02	1.24E+00
4/1/2008	7/1/2008	1.46E-01	1.21E-01	1.66E-01	1.05E-01	1.91E-01	3.60E-02	1.31E+00
7/1/2008	10/1/2008	1.48E-01	1.21E-01	1.39E-01	1.05E-01	1.95E-01	3.80E-02	1.32E+00

Fish: Killifish , Chemical: DDE

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	3.90E-02	3.20E-02	3.40E-02	3.30E-02	3.80E-02	1.40E-03	9.66E-01
4/1/2007	7/1/2007	5.60E-02	4.50E-02	4.90E-02	4.80E-02	5.10E-02	2.60E-03	9.03E-01
7/1/2007	10/1/2007	6.30E-02	5.10E-02	5.50E-02	5.30E-02	5.80E-02	3.30E-03	9.08E-01
10/1/2007	1/1/2008	6.30E-02	5.20E-02	4.20E-02	5.40E-02	5.70E-02	3.20E-03	9.05E-01
1/1/2008	4/1/2008	6.50E-02	5.30E-02	5.70E-02	5.60E-02	5.70E-02	3.20E-03	8.82E-01
4/1/2008	7/1/2008	6.30E-02	5.40E-02	5.00E-02	5.50E-02	5.60E-02	3.20E-03	8.87E-01
7/1/2008	10/1/2008	6.40E-02	5.40E-02	5.00E-02	5.50E-02	5.70E-02	3.20E-03	8.88E-01

Fish: Killifish , Chemical: DDT

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.23E-01	1.00E-01	7.90E-02	1.05E-01	1.06E-01	1.10E-02	8.67E-01
4/1/2007	7/1/2007	1.27E-01	1.03E-01	8.20E-02	1.09E-01	1.08E-01	1.20E-02	8.48E-01
7/1/2007	10/1/2007	1.27E-01	1.04E-01	9.60E-02	1.10E-01	1.08E-01	1.20E-02	8.46E-01
10/1/2007	1/1/2008	1.27E-01	1.04E-01	9.60E-02	1.10E-01	1.07E-01	1.20E-02	8.43E-01
1/1/2008	4/1/2008	1.27E-01	1.03E-01	9.50E-02	1.09E-01	1.07E-01	1.10E-02	8.46E-01
4/1/2008	7/1/2008	1.28E-01	1.05E-01	9.70E-02	1.11E-01	1.08E-01	1.20E-02	8.40E-01
7/1/2008	10/1/2008	1.30E-01	1.07E-01	8.60E-02	1.13E-01	1.07E-01	1.20E-02	8.24E-01

Fish: Killifish , Chemical: DDx

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	2.29E-01	1.32E-01	1.00E-02	1.33E-01	3.12E-01	9.80E-02	1.36E+00
4/1/2007	7/1/2007	2.74E-01	1.50E-01	1.20E-02	1.57E-01	3.61E-01	1.30E-01	1.32E+00
7/1/2007	10/1/2007	3.01E-01	1.56E-01	1.20E-02	1.68E-01	3.83E-01	1.47E-01	1.28E+00
10/1/2007	1/1/2008	2.98E-01	1.53E-01	1.00E-02	1.63E-01	3.85E-01	1.48E-01	1.29E+00
1/1/2008	4/1/2008	2.99E-01	1.54E-01	1.20E-02	1.66E-01	3.85E-01	1.48E-01	1.29E+00
4/1/2008	7/1/2008	2.99E-01	1.54E-01	1.20E-02	1.66E-01	3.85E-01	1.49E-01	1.29E+00
7/1/2008	10/1/2008	3.02E-01	1.53E-01	1.20E-02	1.68E-01	3.86E-01	1.49E-01	1.28E+00

Fish: Pinfish , Chemical: DDD

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	5.90E-02	4.30E-02	3.80E-02	4.40E-02	6.90E-02	4.80E-03	1.17E+00
4/1/2007	7/1/2007	5.90E-02	4.30E-02	3.80E-02	4.40E-02	6.90E-02	4.80E-03	1.17E+00
7/1/2007	10/1/2007	5.90E-02	4.30E-02	3.80E-02	4.40E-02	6.90E-02	4.80E-03	1.17E+00
10/1/2007	1/1/2008	5.90E-02	4.30E-02	3.80E-02	4.40E-02	6.90E-02	4.80E-03	1.17E+00
1/1/2008	4/1/2008	5.90E-02	4.30E-02	4.70E-02	4.40E-02	6.90E-02	4.80E-03	1.16E+00
4/1/2008	7/1/2008	5.90E-02	4.30E-02	4.70E-02	4.40E-02	6.90E-02	4.80E-03	1.17E+00
7/1/2008	10/1/2008	5.90E-02	4.30E-02	4.70E-02	4.40E-02	6.90E-02	4.80E-03	1.16E+00

Fish: Pinfish , Chemical: DDE

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	3.70E-02	2.50E-02	2.70E-02	2.70E-02	4.00E-02	1.60E-03	1.07E+00
4/1/2007	7/1/2007	4.00E-02	2.70E-02	2.50E-02	3.00E-02	4.20E-02	1.70E-03	1.05E+00
7/1/2007	10/1/2007	4.00E-02	2.80E-02	3.00E-02	3.00E-02	4.20E-02	1.80E-03	1.06E+00
10/1/2007	1/1/2008	4.00E-02	2.80E-02	2.50E-02	3.00E-02	4.20E-02	1.80E-03	1.04E+00
1/1/2008	4/1/2008	4.00E-02	2.70E-02	3.00E-02	3.00E-02	4.20E-02	1.80E-03	1.05E+00
4/1/2008	7/1/2008	4.00E-02	2.80E-02	2.50E-02	3.00E-02	4.20E-02	1.80E-03	1.05E+00
7/1/2008	10/1/2008	4.00E-02	2.80E-02	2.50E-02	3.00E-02	4.20E-02	1.80E-03	1.04E+00

Fish: Pinfish , Chemical: DDT

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	5.00E-02	2.50E-02	1.70E-03	2.50E-02	8.90E-02	7.80E-03	1.77E+00
4/1/2007	7/1/2007	5.00E-02	2.50E-02	1.90E-03	2.50E-02	8.80E-02	7.80E-03	1.77E+00
7/1/2007	10/1/2007	5.00E-02	2.50E-02	1.90E-03	2.50E-02	8.80E-02	7.80E-03	1.76E+00
10/1/2007	1/1/2008	5.00E-02	2.50E-02	1.90E-03	2.50E-02	8.80E-02	7.80E-03	1.76E+00
1/1/2008	4/1/2008	5.00E-02	2.50E-02	1.90E-03	2.50E-02	8.80E-02	7.80E-03	1.76E+00
4/1/2008	7/1/2008	5.00E-02	2.50E-02	1.90E-03	2.50E-02	8.80E-02	7.80E-03	1.76E+00
7/1/2008	10/1/2008	5.00E-02	2.50E-02	1.90E-03	2.50E-02	8.80E-02	7.80E-03	1.76E+00

Fish: Pinfish , Chemical: DDx

	Central Tendency				Variability			
Beginning	Ending	Mean (ppm)	Median (ppm	Mode (ppm)	GM (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.29E-01	6.00E-02	2.20E-03	5.90E-02	2.21E-01	4.90E-02	1.72E+00
4/1/2007	7/1/2007	1.41E-01	6.50E-02	2.30E-03	6.50E-02	2.36E-01	5.60E-02	1.67E+00
7/1/2007	10/1/2007	1.42E-01	6.50E-02	2.30E-03	6.50E-02	2.40E-01	5.70E-02	1.69E+00
10/1/2007	1/1/2008	1.42E-01	6.50E-02	2.30E-03	6.40E-02	2.39E-01	5.70E-02	1.69E+00
1/1/2008	4/1/2008	1.40E-01	6.50E-02	2.30E-03	6.40E-02	2.38E-01	5.70E-02	1.71E+00
4/1/2008	7/1/2008	1.37E-01	6.50E-02	2.30E-03	6.30E-02	2.36E-01	5.60E-02	1.73E+00
7/1/2008	10/1/2008	1.36E-01	6.50E-02	2.30E-03	6.30E-02	2.36E-01	5.60E-02	1.74E+00

Food Item: Pelagic , Chemical: DDD

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01
4/1/2007	7/1/2007	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01
7/1/2007	10/1/2007	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01
10/1/2007	1/1/2008	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01
1/1/2008	4/1/2008	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01
4/1/2008	7/1/2008	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01
7/1/2008	10/1/2008	1.60E-07	1.70E-07	1.80E-07	4.30E-08	1.90E-15	2.71E-01

Food Item: Pelagic , Chemical: DDE

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01
4/1/2007	7/1/2007	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01
7/1/2007	10/1/2007	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01
10/1/2007	1/1/2008	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01
1/1/2008	4/1/2008	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01
4/1/2008	7/1/2008	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01
7/1/2008	10/1/2008	1.10E-06	1.10E-06	7.30E-07	3.10E-07	9.90E-14	2.80E-01

Food Item: Pelagic , Chemical: DDT

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01
4/1/2007	7/1/2007	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01
7/1/2007	10/1/2007	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01
10/1/2007	1/1/2008	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01
1/1/2008	4/1/2008	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01
4/1/2008	7/1/2008	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01
7/1/2008	10/1/2008	1.40E-07	1.10E-07	8.50E-08	6.30E-08	4.00E-15	4.69E-01

Food Item: Pelagic , Chemical: DDx

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01
4/1/2007	7/1/2007	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01
7/1/2007	10/1/2007	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01
10/1/2007	1/1/2008	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01
1/1/2008	4/1/2008	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01
4/1/2008	7/1/2008	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01
7/1/2008	10/1/2008	1.60E-07	1.10E-07	3.80E-08	1.50E-07	2.40E-14	9.57E-01

Food Item: Benthos , Chemical: DDD

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01
4/1/2007	7/1/2007	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01
7/1/2007	10/1/2007	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01
10/1/2007	1/1/2008	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01
1/1/2008	4/1/2008	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01
4/1/2008	7/1/2008	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01
7/1/2008	10/1/2008	3.31E+00	3.19E+00	2.80E+00	1.21E+00	1.46E+00	3.64E-01

Food Item: Benthos , Chemical: DDE

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01
4/1/2007	7/1/2007	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01
7/1/2007	10/1/2007	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01
10/1/2007	1/1/2008	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01
1/1/2008	4/1/2008	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01
4/1/2008	7/1/2008	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01
7/1/2008	10/1/2008	4.72E-01	4.56E-01	3.12E-01	1.65E-01	2.70E-02	3.49E-01

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01
4/1/2007	7/1/2007	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01
7/1/2007	10/1/2007	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01
10/1/2007	1/1/2008	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01
1/1/2008	4/1/2008	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01
4/1/2008	7/1/2008	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01
7/1/2008	10/1/2008	2.97E+00	2.84E+00	2.33E+00	1.43E+00	2.04E+00	4.81E-01

	Central Tendency						
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
1/1/2007	4/1/2007	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01
4/1/2007	7/1/2007	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01
7/1/2007	10/1/2007	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01
10/1/2007	1/1/2008	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01
1/1/2008	4/1/2008	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01
4/1/2008	7/1/2008	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01
7/1/2008	10/1/2008	5.37E+00	5.32E+00	3.22E+00	1.67E+00	2.80E+00	3.12E-01

FishRand Basic Inputs

Advanced Options

X	Site contains hotspots
	Fish abundance in the site changes due to migration
	Apply user-specified parameters for bioaccumulation
	Use predefined tissue concentrations for food items
	Use site specific measurements for validation
X	Separate contribution of uncertainty and variability
	Apply Cleanup Levels

Model Name: Tyndall Area 1

Model Description:

Area 1 Tyndall

Monte Carlo Simulation Parameters

Sample Size for Uncertainty:	0.00E+00
Sample Size for Variability:	1.00E+04
Sample Size for Diet Loop:	1.00E+04
Total number of food items:	2.00E+00
Total number of fish:	2.00E+00

Statistical Options

X	Central Tendency: Mean
X	Central Tendency: Median
X	Central Tendency: Mode
X	Central Tendency: Geometric Mean
X	Variability: Standard Deviation
X	Variability: Variance
X	Variability: Coefficient of Variation
	Variability: Geometric Standard Deviation
	Uncertainty: Standard Error of the Mean
	Uncertainty: Upper Confidence Limit 95.0%
	Probability of Mean > 0.000000
	Full table of percentiles for Food Tissue Concentration (wet weight)
	Full table of percentiles for Food Tissue Concentration (lipid normalized)
	Full table of percentiles for Fish Tissue Concentration (wet weight)
	Full table of percentiles for Fish Tissue Concentration (lipid normalized)

All Chemicals of Concern

Name	***CASRN***	***LogKow Distribution***	
DDD		type: triangular	
		min	6.02E+00
		mode	6.10E+00
		max	6.20E+00
DDE		type: normal	
		mean	6.96E+00
		stdev	1.10E-02

		min	6.30E+00
		max	7.00E+00
DDT		type: normal	
		mean	6.00E+00
		stdev	4.50E-02
		min	4.89E+00
		max	6.91E+00
DDx		type: triangular	
		min	4.30E+00
		mode	6.02E+00
		max	6.91E+00

Food Items

Name	***Medium***	***Lipid % Distribution***		***Reference***
Pelagic	water	type: triangular		
		min	5.00E-01	
		mode	1.00E+00	
		max	2.00E+00	
Benthos	sediment	type: triangular		
		min	1.00E+00	
		mode	2.00E+00	
		max	4.00E+00	

Fish Species Information

Fish	***Weight Distribution (g)***		***Lipid % Distribution***		***Reference***
	type: triangular		type: triangular		
Killifish	min	2.50E+01	min	3.00E-01	
	mode	1.50E+02	mode	7.00E-01	
	max	2.00E+02	max	1.00E+00	
	type: triangular		type: triangular		
Pinfish	min	2.00E+00	min	3.00E-01	
	mode	5.00E+00	mode	5.00E-01	
	max	1.00E+01	max	7.00E-01	

Fish Diets

Fish Name	***Diet Item Names***		***Percent in Diet***
Killifish	Plankton Diet Items	Benthos	9.00E+01
		Pelagic	1.00E+01
	Fish Diet Items	NONE	
Pinfish	Plankton Diet Items	Benthos	7.00E+01
		Pelagic	3.00E+01
	Fish Diet Items	NONE	

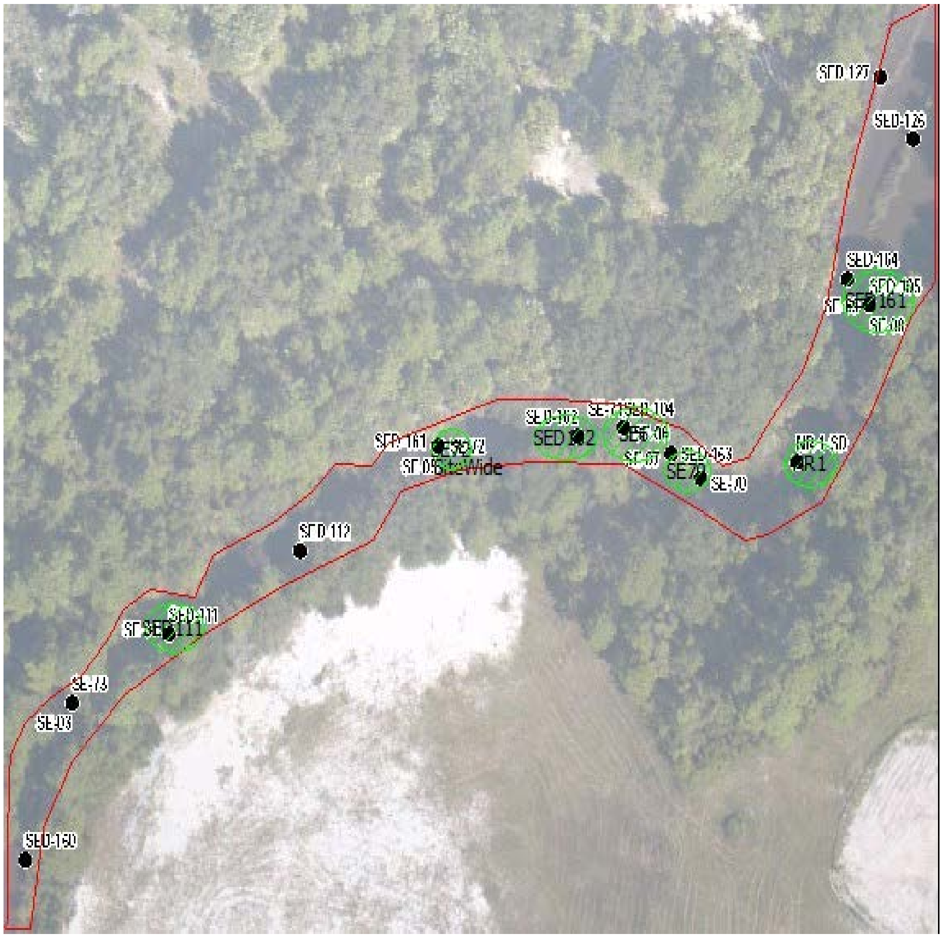
FishRand Inputs Report

Time Scale

Seasons/Period	***# of Days***
1/1/2007	9.00E+01
4/1/2007	9.10E+01
7/1/2007	9.20E+01
10/1/2007	9.20E+01
1/1/2008	9.10E+01
4/1/2008	9.10E+01
7/1/2008	9.20E+01

Chemical Concentrations

Chemical: DDD Medium: sediment Area: Site



Scale in horizontal (E-W) direction (m): 1.14E+03

Scale in vertical (N-S) direction (m): 9.48E+02

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.04E-01
4/1/2007	point estimate	value	1.04E-01
7/1/2007	point estimate	value	1.04E-01
10/1/2007	point estimate	value	1.04E-01
1/1/2008	point estimate	value	1.04E-01
4/1/2008	point estimate	value	1.04E-01
7/1/2008	point estimate	value	1.04E-01
10/1/2008	point estimate	value	1.04E-01

Chemical Concentrations

Chemical: DDD Medium: sediment Area: NR1

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.11E-01
4/1/2007	point estimate	value	3.11E-01
7/1/2007	point estimate	value	3.11E-01
10/1/2007	point estimate	value	3.11E-01
1/1/2008	point estimate	value	3.11E-01
4/1/2008	point estimate	value	3.11E-01
7/1/2008	point estimate	value	3.11E-01
10/1/2008	point estimate	value	3.11E-01

Chemical Concentrations

Chemical: DDD Medium: sediment Area: SE6

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.04E+00
4/1/2007	point estimate	value	1.04E+00
7/1/2007	point estimate	value	1.04E+00
10/1/2007	point estimate	value	1.04E+00
1/1/2008	point estimate	value	1.04E+00
4/1/2008	point estimate	value	1.04E+00
7/1/2008	point estimate	value	1.04E+00
10/1/2008	point estimate	value	1.04E+00

Chemical Concentrations

Chemical: DDD Medium: sediment Area: SED111

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.60E+00
4/1/2007	point estimate	value	1.60E+00
7/1/2007	point estimate	value	1.60E+00
10/1/2007	point estimate	value	1.60E+00
1/1/2008	point estimate	value	1.60E+00
4/1/2008	point estimate	value	1.60E+00
7/1/2008	point estimate	value	1.60E+00
10/1/2008	point estimate	value	1.60E+00

Chemical Concentrations

Chemical: DDD Medium: sediment Area: SE70

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	8.30E-01
4/1/2007	point estimate	value	8.30E-01
7/1/2007	point estimate	value	8.30E-01
10/1/2007	point estimate	value	8.30E-01
1/1/2008	point estimate	value	8.30E-01

4/1/2008	point estimate	value	8.30E-01
7/1/2008	point estimate	value	8.30E-01
10/1/2008	point estimate	value	8.30E-01

Chemical Concentrations

Chemical: DDD Medium: sediment Area: SED162

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-02
4/1/2007	point estimate	value	1.00E-02
7/1/2007	point estimate	value	1.00E-02
10/1/2007	point estimate	value	1.00E-02
1/1/2008	point estimate	value	1.00E-02
4/1/2008	point estimate	value	1.00E-02
7/1/2008	point estimate	value	1.00E-02
10/1/2008	point estimate	value	1.00E-02

Chemical Concentrations

Chemical: DDD Medium: sediment Area: SE72

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.10E-02
4/1/2007	point estimate	value	2.10E-02
7/1/2007	point estimate	value	2.10E-02
10/1/2007	point estimate	value	2.10E-02
1/1/2008	point estimate	value	2.10E-02
4/1/2008	point estimate	value	2.10E-02
7/1/2008	point estimate	value	2.10E-02
10/1/2008	point estimate	value	2.10E-02

Chemical Concentrations

Chemical: DDD Medium: sediment Area: SED161

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	9.60E-02
4/1/2007	point estimate	value	9.60E-02
7/1/2007	point estimate	value	9.60E-02
10/1/2007	point estimate	value	9.60E-02
1/1/2008	point estimate	value	9.60E-02
4/1/2008	point estimate	value	9.60E-02
7/1/2008	point estimate	value	9.60E-02
10/1/2008	point estimate	value	9.60E-02

Chemical Concentrations

Chemical: DDD Medium: water Area: SiteWide

Concentration Distributions (ng/L)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-05
4/1/2007	point estimate	value	1.00E-05
7/1/2007	point estimate	value	1.00E-05

10/1/2007	point estimate	value	1.00E-05
1/1/2008	point estimate	value	1.00E-05
4/1/2008	point estimate	value	1.00E-05
7/1/2008	point estimate	value	1.00E-05
10/1/2008	point estimate	value	1.00E-05

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SiteWide

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.80E-02
4/1/2007	point estimate	value	1.80E-02
7/1/2007	point estimate	value	1.80E-02
10/1/2007	point estimate	value	1.80E-02
1/1/2008	point estimate	value	1.80E-02
4/1/2008	point estimate	value	1.80E-02
7/1/2008	point estimate	value	1.80E-02
10/1/2008	point estimate	value	1.80E-02

Chemical Concentrations

Chemical: DDE Medium: sediment Area: NR1

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.10E-01
4/1/2007	point estimate	value	1.10E-01
7/1/2007	point estimate	value	1.10E-01
10/1/2007	point estimate	value	1.10E-01
1/1/2008	point estimate	value	1.10E-01
4/1/2008	point estimate	value	1.10E-01
7/1/2008	point estimate	value	1.10E-01
10/1/2008	point estimate	value	1.10E-01

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SE6

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.24E-01
4/1/2007	point estimate	value	2.24E-01
7/1/2007	point estimate	value	2.24E-01
10/1/2007	point estimate	value	2.24E-01
1/1/2008	point estimate	value	2.24E-01
4/1/2008	point estimate	value	2.24E-01
7/1/2008	point estimate	value	2.24E-01
10/1/2008	point estimate	value	2.24E-01

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SED111

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.50E-01

4/1/2007	point estimate	value	1.50E-01
7/1/2007	point estimate	value	1.50E-01
10/1/2007	point estimate	value	1.50E-01
1/1/2008	point estimate	value	1.50E-01
4/1/2008	point estimate	value	1.50E-01
7/1/2008	point estimate	value	1.50E-01
10/1/2008	point estimate	value	1.50E-01

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SE70

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.30E-02
4/1/2007	point estimate	value	1.30E-02
7/1/2007	point estimate	value	1.30E-02
10/1/2007	point estimate	value	1.30E-02
1/1/2008	point estimate	value	1.30E-02
4/1/2008	point estimate	value	1.30E-02
7/1/2008	point estimate	value	1.30E-02
10/1/2008	point estimate	value	1.30E-02

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SED162

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	5.00E-03
4/1/2007	point estimate	value	5.00E-03
7/1/2007	point estimate	value	5.00E-03
10/1/2007	point estimate	value	5.00E-03
1/1/2008	point estimate	value	5.00E-03
4/1/2008	point estimate	value	5.00E-03
7/1/2008	point estimate	value	5.00E-03
10/1/2008	point estimate	value	5.00E-03

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SE72

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	4.00E-03
4/1/2007	point estimate	value	4.00E-03
7/1/2007	point estimate	value	4.00E-03
10/1/2007	point estimate	value	4.00E-03
1/1/2008	point estimate	value	4.00E-03
4/1/2008	point estimate	value	4.00E-03
7/1/2008	point estimate	value	4.00E-03
10/1/2008	point estimate	value	4.00E-03

Chemical Concentrations

Chemical: DDE Medium: sediment Area: SED161

Concentration Distributions (mg/kg dry weight)

Time Period	Type	Parameter	Values
1/1/2007	point estimate	value	3.40E-02
4/1/2007	point estimate	value	3.40E-02
7/1/2007	point estimate	value	3.40E-02
10/1/2007	point estimate	value	3.40E-02
1/1/2008	point estimate	value	3.40E-02
4/1/2008	point estimate	value	3.40E-02
7/1/2008	point estimate	value	3.40E-02
10/1/2008	point estimate	value	3.40E-02

Chemical Concentrations

Chemical: DDE Medium: water Area: SiteWide

Concentration Distributions (ng/L)

Time Period	Type	Parameter	Values
1/1/2007	point estimate	value	1.00E-05
4/1/2007	point estimate	value	1.00E-05
7/1/2007	point estimate	value	1.00E-05
10/1/2007	point estimate	value	1.00E-05
1/1/2008	point estimate	value	1.00E-05
4/1/2008	point estimate	value	1.00E-05
7/1/2008	point estimate	value	1.00E-05
10/1/2008	point estimate	value	1.00E-05

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SiteWide

Concentration Distributions (mg/kg dry weight)

Time Period	Type	Parameter	Values
1/1/2007	point estimate	value	1.06E-01
4/1/2007	point estimate	value	1.06E-01
7/1/2007	point estimate	value	1.06E-01
10/1/2007	point estimate	value	1.06E-01
1/1/2008	point estimate	value	1.06E-01
4/1/2008	point estimate	value	1.06E-01
7/1/2008	point estimate	value	1.06E-01
10/1/2008	point estimate	value	1.06E-01

Chemical Concentrations

Chemical: DDT Medium: sediment Area: NR1

Concentration Distributions (mg/kg dry weight)

Time Period	Type	Parameter	Values
1/1/2007	point estimate	value	1.70E+00
4/1/2007	point estimate	value	1.70E+00
7/1/2007	point estimate	value	1.70E+00
10/1/2007	point estimate	value	1.70E+00
1/1/2008	point estimate	value	1.70E+00
4/1/2008	point estimate	value	1.70E+00
7/1/2008	point estimate	value	1.70E+00
10/1/2008	point estimate	value	1.70E+00

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SE6

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	3.36E-01
4/1/2007	point estimate	value	3.36E-01
7/1/2007	point estimate	value	3.36E-01
10/1/2007	point estimate	value	3.36E-01
1/1/2008	point estimate	value	3.36E-01
4/1/2008	point estimate	value	3.36E-01
7/1/2008	point estimate	value	3.36E-01
10/1/2008	point estimate	value	3.36E-01

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SED111

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.90E-01
4/1/2007	point estimate	value	2.90E-01
7/1/2007	point estimate	value	2.90E-01
10/1/2007	point estimate	value	2.90E-01
1/1/2008	point estimate	value	2.90E-01
4/1/2008	point estimate	value	2.90E-01
7/1/2008	point estimate	value	2.90E-01
10/1/2008	point estimate	value	2.90E-01

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SE70

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.70E-02
4/1/2007	point estimate	value	2.70E-02
7/1/2007	point estimate	value	2.70E-02
10/1/2007	point estimate	value	2.70E-02
1/1/2008	point estimate	value	2.70E-02
4/1/2008	point estimate	value	2.70E-02
7/1/2008	point estimate	value	2.70E-02
10/1/2008	point estimate	value	2.70E-02

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SED162

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.35E-01
4/1/2007	point estimate	value	1.35E-01
7/1/2007	point estimate	value	1.35E-01
10/1/2007	point estimate	value	1.35E-01
1/1/2008	point estimate	value	1.35E-01
4/1/2008	point estimate	value	1.35E-01
7/1/2008	point estimate	value	1.35E-01

10/1/2008	point estimate	value	1.35E-01

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SE72

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	6.00E-03
4/1/2007	point estimate	value	6.00E-03
7/1/2007	point estimate	value	6.00E-03
10/1/2007	point estimate	value	6.00E-03
1/1/2008	point estimate	value	6.00E-03
4/1/2008	point estimate	value	6.00E-03
7/1/2008	point estimate	value	6.00E-03
10/1/2008	point estimate	value	6.00E-03

Chemical Concentrations

Chemical: DDT Medium: sediment Area: SED161

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	5.60E-01
4/1/2007	point estimate	value	5.60E-01
7/1/2007	point estimate	value	5.60E-01
10/1/2007	point estimate	value	5.60E-01
1/1/2008	point estimate	value	5.60E-01
4/1/2008	point estimate	value	5.60E-01
7/1/2008	point estimate	value	5.60E-01
10/1/2008	point estimate	value	5.60E-01

Chemical Concentrations

Chemical: DDT Medium: water Area: SiteWide

Concentration Distributions (ng/L)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	1.00E-05
4/1/2007	point estimate	value	1.00E-05
7/1/2007	point estimate	value	1.00E-05
10/1/2007	point estimate	value	1.00E-05
1/1/2008	point estimate	value	1.00E-05
4/1/2008	point estimate	value	1.00E-05
7/1/2008	point estimate	value	1.00E-05
10/1/2008	point estimate	value	1.00E-05

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SiteWide

Concentration Distributions (mg/kg dry weight)

Time Period	*Type*	*Parameter*	*Values*
1/1/2007	point estimate	value	2.28E-01
4/1/2007	point estimate	value	2.28E-01
7/1/2007	point estimate	value	2.28E-01
10/1/2007	point estimate	value	2.28E-01
1/1/2008	point estimate	value	2.28E-01

4/1/2008	point estimate	value	2.28E-01
7/1/2008	point estimate	value	2.28E-01
10/1/2008	point estimate	value	2.28E-01

Chemical Concentrations

Chemical: DDx Medium: sediment Area: NR1

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	2.20E+00
4/1/2007	point estimate	value	2.20E+00
7/1/2007	point estimate	value	2.20E+00
10/1/2007	point estimate	value	2.20E+00
1/1/2008	point estimate	value	2.20E+00
4/1/2008	point estimate	value	2.20E+00
7/1/2008	point estimate	value	2.20E+00
10/1/2008	point estimate	value	2.20E+00

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SE6

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.60E+00
4/1/2007	point estimate	value	1.60E+00
7/1/2007	point estimate	value	1.60E+00
10/1/2007	point estimate	value	1.60E+00
1/1/2008	point estimate	value	1.60E+00
4/1/2008	point estimate	value	1.60E+00
7/1/2008	point estimate	value	1.60E+00
10/1/2008	point estimate	value	1.60E+00

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SED111

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	2.04E+00
4/1/2007	point estimate	value	2.04E+00
7/1/2007	point estimate	value	2.04E+00
10/1/2007	point estimate	value	2.04E+00
1/1/2008	point estimate	value	2.04E+00
4/1/2008	point estimate	value	2.04E+00
7/1/2008	point estimate	value	2.04E+00
10/1/2008	point estimate	value	2.04E+00

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SE70

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.23E-01
4/1/2007	point estimate	value	1.23E-01
7/1/2007	point estimate	value	1.23E-01

10/1/2007	point estimate	value	1.23E-01
1/1/2008	point estimate	value	1.23E-01
4/1/2008	point estimate	value	1.23E-01
7/1/2008	point estimate	value	1.23E-01
10/1/2008	point estimate	value	1.23E-01

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SED162

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	2.70E-02
4/1/2007	point estimate	value	2.70E-02
7/1/2007	point estimate	value	2.70E-02
10/1/2007	point estimate	value	2.70E-02
1/1/2008	point estimate	value	2.70E-02
4/1/2008	point estimate	value	2.70E-02
7/1/2008	point estimate	value	2.70E-02
10/1/2008	point estimate	value	2.70E-02

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SE72

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	3.20E-02
4/1/2007	point estimate	value	3.20E-02
7/1/2007	point estimate	value	3.20E-02
10/1/2007	point estimate	value	3.20E-02
1/1/2008	point estimate	value	3.20E-02
4/1/2008	point estimate	value	3.20E-02
7/1/2008	point estimate	value	3.20E-02
10/1/2008	point estimate	value	3.20E-02

Chemical Concentrations

Chemical: DDx Medium: sediment Area: SED161

Concentration Distributions (mg/kg dry weight)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	6.91E-01
4/1/2007	point estimate	value	6.91E-01
7/1/2007	point estimate	value	6.91E-01
10/1/2007	point estimate	value	6.91E-01
1/1/2008	point estimate	value	6.91E-01
4/1/2008	point estimate	value	6.91E-01
7/1/2008	point estimate	value	6.91E-01
10/1/2008	point estimate	value	6.91E-01

Chemical Concentrations

Chemical: DDx Medium: water Area: SiteWide

Concentration Distributions (ng/L)

Time Period	***Type***	***Parameter***	***Values***
1/1/2007	point estimate	value	1.00E-05

4/1/2007	point estimate	value	1.00E-05
7/1/2007	point estimate	value	1.00E-05
10/1/2007	point estimate	value	1.00E-05
1/1/2008	point estimate	value	1.00E-05
4/1/2008	point estimate	value	1.00E-05
7/1/2008	point estimate	value	1.00E-05
10/1/2008	point estimate	value	1.00E-05

Water Temperature

Time Period	Site	Water Temperature (Celcius)
1/1/2007	type: point estimate	
	value	1.20E+01
4/1/2007	type: point estimate	
	value	1.20E+01
7/1/2007	type: point estimate	
	value	1.20E+01
10/1/2007	type: point estimate	
	value	1.20E+01
1/1/2008	type: point estimate	
	value	1.20E+01
4/1/2008	type: point estimate	
	value	1.20E+01
7/1/2008	type: point estimate	
	value	1.20E+01
10/1/2008	type: point estimate	
	value	1.20E+01

Total Organic Carbon in Sediment (TOC)

Location	Sediment TOC (%) Distribution	
SiteWide	type: normal	
	mean	1.68E+00
	stdev	2.39E+00
	min	2.00E-01
	max	9.10E+00

Fish Attraction Factors

Fish: Killifish

Location/Area	Attraction Factor	
SiteWide	type: point estimate	
	value	1.00E+00

Fish: Pinfish

Location/Area	Attraction Factor	
SiteWide	type: point estimate	
	value	1.00E+00

Appendix D: Original Sediment and Fish Data for the Natick and Tyndall Sites

This Appendix presents the original data used to support the bioaccumulation modeling.

Sediment Data

Individual sediment sampling locations are aggregated in different ways to generate polygons depending on which method chosen by the analyst. A feature of the FR program is the ability to take advantage of GIS-based methods for generating exposure profiles for aquatic receptors, although in earlier versions of the model (including the version used for this report), the linkage between exposure concentrations as depicted in FR and GIS-based outputs was manual, requiring the additional step of manually transferring polygons (or grids) to FR. Sediment samples are taken at particular locations and interpolation methods are used to predict the values in unsampled locations and to generate maps with the user-preferred GIS program. A number of different interpolation methods are available and depend on different underlying mathematical and statistical models and assumptions. Therefore, somewhat different results and polygon shapes can be obtained depending on which interpolation method is chosen as well as the user-specified contour interval. Most kriging tools in commonly used GIS programs (e.g., ARCGIS, QGIS) interactively analyze the spatial behavior of contaminant concentrations to identify the best estimation method for generating the output surface. Some of these methods include trend surface, Thiessen polygons, TIN (Triangular Irregular Network), IDW (Inverse Distance Weighting), and different kinds of kriging.

Fish Data

For statistical comparisons, fish data may be aggregated in different ways depending on the scope and complexity of the site as well as fish life history. Sometimes fish samples are taken as composites, while other times individual fish will be sampled. For the purposes of FR, the goal is to identify samples that represent the same population of fish (e.g., adult white perch from one river) that are likely to experience substantially similar food web exposures over similar spatial and temporal scales (e.g., similar feeding preferences and prey availability).

Natick Site

Sediment data for the Natick Site was obtained from ICF International, Inc. 2008. Final Fall 2007 Fish and Sediment Sampling Program Memorandum for the primary area of interest, Pegan Cove (identified as “Main Stormwater Outfall) during 2007. The polygons were reproduced from Figure 4-1 of this report (Figure 3 in the original document). The extracted data appear in Table D-1. The “polygon” column shows the correspondence between the original data and the FishRand designated polygons in Table 5-3. One polygon highlighted in blue in Figure 4-1 (Figure 3 in the original document) showed a total PCB concentration of between 8-9 mg/kg near the outfall. There was no corresponding data point for that – the closest was SE-90 with a total PCB concentration near 1.0 mg/kg. Nonetheless, SE-90 was designated as the polygon for that location.

TOC was input as a site-wide distribution using all data across Pegan Cove. Measured TOC in Pegan Cove was very high, roughly 18% or 0.18. However, below approximately the upper 5 cm, sediment cores consist of largely peat (Gschwend, personal communication, 2014), apparently due to a bog that was almost completely subsumed during past management activities at the site. Studies show the bioavailability of sediment-associated contaminants sorbed to peat may be significantly less than other forms of organic carbon (McLeod et al. 2004). Preliminary model runs using site-specific fish lipid, weight and sediment concentrations, and typical benthos lipid composition (obtained from US EPA http://www.epa.gov/oppefed1/models/water/kabam/kabam_user_guide_appendix_c.html#C3) led to predicted fish tissue concentrations that differed from observed tissue concentrations by an order of magnitude, suggesting a disconnect between partitioning behavior in the environment and subsequent food web exposures. However, operationally, the FR model code only allows the user to input and edit the effective total organic carbon. Thus, the TOC distribution for this site was adjusted by an order of magnitude based on best professional judgment of site conditions.

Table D-1: Sediment Data for the Natick Site (from Appendix B, starting at page B-97 of ICF International, 2008)

LOCID	Polygon	Installation	Site	Interval	SampleDate	Analyte	Result	Flag	Units
SE-100	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	130	J	ug/Kg
SE-100	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	250	J	ug/Kg
SE-100	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	680	J	ug/Kg
SE-100	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	21.3	J	ug/Kg
SE-100	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	152	J	ug/Kg
SE-100		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	200000		mg/kg
SE-100	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1700	J	ug/Kg
SE-101	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	77	J	ug/Kg
SE-101	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	130	J	ug/Kg

SE-101	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	260	J	ug/Kg
SE-101	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	11.3	J	ug/Kg
SE-101	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	52.4	J	ug/Kg
SE-101		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	190000		mg/kg
SE-101	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	720	J	ug/Kg
SE-102	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	40	J	ug/Kg
SE-102	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	66	J	ug/Kg
SE-102	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	170	J	ug/Kg
SE-102	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	5.95	J	ug/Kg
SE-102	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	37.8	J	ug/Kg
SE-102		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	120000		mg/kg
SE-102	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	460	J	ug/Kg
SE-103	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	190	J	ug/Kg
SE-103	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	390	J	ug/Kg
SE-103	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	1000	J	ug/Kg

SE-103	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	31.8	J	ug/Kg
SE-103	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	201	J	ug/Kg
SE-103		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	180000		mg/kg
SE-103	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2400	J	ug/Kg
SE-104	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	87	J	ug/Kg
SE-104	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	180	J	ug/Kg
SE-104	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	460	J	ug/Kg
SE-104	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	14.7	J	ug/Kg
SE-104	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	94.1	J	ug/Kg
SE-104		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	180000		mg/kg
SE-104	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1200	J	ug/Kg
SE-105	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	160	J	ug/Kg
SE-105	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	350	J	ug/Kg
SE-105	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	880	J	ug/Kg
SE-105	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	27.4	J	ug/Kg

SE-105	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	176	J	ug/Kg
SE-105		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	140000		mg/kg
SE-105	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2200	J	ug/Kg
SE-106	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	36	J	ug/Kg
SE-106	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	71	J	ug/Kg
SE-106	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	220	J	ug/Kg
SE-106	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	5.88	J	ug/Kg
SE-106	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	46.2	J	ug/Kg
SE-106		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	230000	J	mg/kg
SE-106	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	520	J	ug/Kg
SE-107	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	150	J	ug/Kg
SE-107	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	330	J	ug/Kg
SE-107	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	860	J	ug/Kg
SE-107	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	25.2	J	ug/Kg
SE-107	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	173	J	ug/Kg

SE-107		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	150000		mg/kg
SE-107	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2100	J	ug/Kg
SE-108	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	77	J	ug/Kg
SE-108	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	160	J	ug/Kg
SE-108	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	360	J	ug/Kg
SE-108	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	15.6	J	ug/Kg
SE-108	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	74.2	J	ug/Kg
SE-108		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	230000		mg/kg
SE-108	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	950	J	ug/Kg
SE-109	SE109	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	170	J	ug/Kg
SE-109	SE109	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	340	J	ug/Kg
SE-109	SE109	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	880	J	ug/Kg
SE-109	SE109	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	30.7	J	ug/Kg
SE-109	SE109	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	185	J	ug/Kg
SE-109		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	180000		mg/kg

SE-109	SE109	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2200	J	ug/Kg
SE-110	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	200	J	ug/Kg
SE-110	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	410	J	ug/Kg
SE-110	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	1100	J	ug/Kg
SE-110	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	30.3	J	ug/Kg
SE-110	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	234	J	ug/Kg
SE-110		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	200000		mg/kg
SE-110	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2600	J	ug/Kg
SE-111	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	170	J	ug/Kg
SE-111	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	370	J	ug/Kg
SE-111	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	1000	J	ug/Kg
SE-111	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	30.9	J	ug/Kg
SE-111	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	220	J	ug/Kg
SE-111		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	190000		mg/kg
SE-111	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2500	J	ug/Kg

SE-112	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	170	J	ug/Kg
SE-112	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	380	J	ug/Kg
SE-112	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	1000	J	ug/Kg
SE-112	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	32.6	J	ug/Kg
SE-112	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	216	J	ug/Kg
SE-112		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	130000		mg/kg
SE-112	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2500	J	ug/Kg
SE-113	SE113	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	250	J	ug/Kg
SE-113	SE113	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	580	J	ug/Kg
SE-113	SE113	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	1800	J	ug/Kg
SE-113	SE113	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	67.4	J	ug/Kg
SE-113	SE113	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	370	J	ug/Kg
SE-113		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	150000		mg/kg
SE-113	SE113	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	4100	J	ug/Kg
SE-114	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	120	J	ug/Kg

SE-114	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	230	J	ug/Kg
SE-114	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	590	J	ug/Kg
SE-114	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	23.1	J	ug/Kg
SE-114	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	114	J	ug/Kg
SE-114		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	200000		mg/kg
SE-114	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1500	J	ug/Kg
SE-121	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	70	J	ug/Kg
SE-121	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	110	J	ug/Kg
SE-121	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	280	J	ug/Kg
SE-121	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	12.2	J	ug/Kg
SE-121	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	56.5	J	ug/Kg
SE-121	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	730	J	ug/Kg
SE-122	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	210	J	ug/Kg
SE-122	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	320	J	ug/Kg
SE-122	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	810	J	ug/Kg

SE-122	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	34	J	ug/Kg
SE-122	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	177	J	ug/Kg
SE-122	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	2200	J	ug/Kg
SE-123	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	150	J	ug/Kg
SE-123	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	290	J	ug/Kg
SE-123	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	780	J	ug/Kg
SE-123	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	25.4	J	ug/Kg
SE-123	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	173	J	ug/Kg
SE-123	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	1900	J	ug/Kg
SE-124	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	66	J	ug/Kg
SE-124	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	140	J	ug/Kg
SE-124	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	370	J	ug/Kg
SE-124	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	9.67	J	ug/Kg
SE-124	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	74.7	J	ug/Kg
SE-124	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	950	J	ug/Kg

SE-125	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	89	J	ug/Kg
SE-125	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	210	J	ug/Kg
SE-125	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	420	J	ug/Kg
SE-125	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	13.1	J	ug/Kg
SE-125	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	87.3	J	ug/Kg
SE-125	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	1100	J	ug/Kg
SE-126	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	82	J	ug/Kg
SE-126	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	190	J	ug/Kg
SE-126	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	470	J	ug/Kg
SE-126	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	12.4	J	ug/Kg
SE-126	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	96.6	J	ug/Kg
SE-126	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	1200	J	ug/Kg
SE-127	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-4 Tetrachlorobiphenyls	140	J	ug/Kg
SE-127	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-5 Pentachlorobiphenyls	390	J	ug/Kg
SE-127	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Cl-6 Hexachlorobiphenyls	1100	J	ug/Kg

SE-127	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-052	22.7	J	ug/Kg
SE-127	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	PCB-153	227	J	ug/Kg
SE-127	SE110	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-2 in	23-Oct-07	Total PCBs	2700	J	ug/Kg
SE-90	SE90	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	180	J	ug/Kg
SE-90	SE90	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	250	J	ug/Kg
SE-90	SE90	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	530	J	ug/Kg
SE-90	SE90	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	33.1	J	ug/Kg
SE-90	SE90	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	101	J	ug/Kg
SE-90		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	120000		mg/kg
SE-90	SE90	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1400	J	ug/Kg
SE-91	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	130	J	ug/Kg
SE-91	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	240	J	ug/Kg
SE-91	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	650	J	ug/Kg
SE-91	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	19.6	J	ug/Kg
SE-91	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	142	J	ug/Kg

SE-91		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	140000		mg/kg
SE-91	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1600	J	ug/Kg
SE-92	SE92	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	170	J	ug/Kg
SE-92	SE92	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	300	J	ug/Kg
SE-92	SE92	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	850	J	ug/Kg
SE-92	SE92	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	23.3	J	ug/Kg
SE-92	SE92	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	193	J	ug/Kg
SE-92		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	230000		mg/kg
SE-92	SE92	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	2200	J	ug/Kg
SE-93	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	92	J	ug/Kg
SE-93	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	180	J	ug/Kg
SE-93	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	500	J	ug/Kg
SE-93	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	12.6	J	ug/Kg
SE-93	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	111	J	ug/Kg
SE-93		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	210000		mg/kg

SE-93	SE100	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1300	J	ug/Kg
SE-94	SE94	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	330	J	ug/Kg
SE-94	SE94	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	570	J	ug/Kg
SE-94	SE94	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	1400	J	ug/Kg
SE-94	SE94	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	51.5	J	ug/Kg
SE-94	SE94	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	306	J	ug/Kg
SE-94		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	210000		mg/kg
SE-94	SE94	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	3600	J	ug/Kg
SE-95	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	15	J	ug/Kg
SE-95	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	23	J	ug/Kg
SE-95	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	56	J	ug/Kg
SE-95	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	2.45	J	ug/Kg
SE-95	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	11.9	J	ug/Kg
SE-95		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	380000		mg/kg
SE-95	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	150	J	ug/Kg

SE-96	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	84	J	ug/Kg
SE-96	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	160	J	ug/Kg
SE-96	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	390	J	ug/Kg
SE-96	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	12.5	J	ug/Kg
SE-96	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	86.8	J	ug/Kg
SE-96		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	140000	J	mg/kg
SE-96	SE96	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1000	J	ug/Kg
SE-97	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	120	J	ug/Kg
SE-97	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	210	J	ug/Kg
SE-97	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	520	J	ug/Kg
SE-97	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	18.9	J	ug/Kg
SE-97	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	107	J	ug/Kg
SE-97		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	300000		mg/kg
SE-97	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	1400	J	ug/Kg
SE-98	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	81	J	ug/Kg

SE-98	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	120	J	ug/Kg
SE-98	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	180	J	ug/Kg
SE-98	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	12.7	J	ug/Kg
SE-98	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	35.5	J	ug/Kg
SE-98		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	130000		mg/kg
SE-98	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	560	J	ug/Kg
SE-99	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-4 Tetrachlorobiphenyls	38	J	ug/Kg
SE-99	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-5 Pentachlorobiphenyls	69	J	ug/Kg
SE-99	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Cl-6 Hexachlorobiphenyls	210	J	ug/Kg
SE-99	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-052	5.93	J	ug/Kg
SE-99	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	PCB-153	45	J	ug/Kg
SE-99		U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	TOC	120000		mg/kg
SE-99	SE99	U.S Army Natick Soldier Systems Center (NSSC)	Main Stormwater Outfall	0-6 in	11-Oct-07	Total PCBs	510	J	ug/Kg

Fish contaminant data were also obtained from ICF International (2008) and represent sampling during October 2007. “Three fish species (largemouth bass, bluegill, and yellow perch) were collected and analyzed during the program. Bluegill and yellow perch were analyzed whole body, and largemouth bass were filleted in the field with fillet (skin-on) and offal portions analyzed separately. Largemouth bass were retained for sampling only if they were greater than 12 inches long, the legal size limit for catching this species in Massachusetts. There are no size limits imposed by the State of Massachusetts for bluegill or yellow perch. Therefore, the sizes of bluegill and yellow perch targeted and analyzed in this study (approximately 4 to 8 inches in length) were consistent with size classes taken by anglers reported in the Draft Lake Cochituate Angler Survey Report (ICF International, January 9, 2006; ICF International 2008, p. 2). Further details can be found in that document. For modeling, the largemouth bass offal and fillet samples were combined to obtain results for whole fish.

Lipid and weight data were obtained for fish across all sampling locations, while PCB concentration data were used only from fish from Pegan Cove (MSO). Lipid and weight data are shown in Table D-2 (Tables 1 through 3 in ICF International [2008]). The original data are found in Appendix B (starting on page B-1) of ICF International (2008).

Table D-2: Fish Lipid and Weight Data for the Natick Site

Location	Sample ID	Length (cm)	Weight (g)	Percent Lipids	Total PCBs (mg/kg)	Fish
MSO (FS-75)	FX075ABG	17.7	120	0.130	0.93	Bluegill
	FX075BBG	14.0	70	0.175	0.38	Bluegill
	FX075FBG	16.8	100	0.394	0.54	Bluegill
	FX075KBG	17.0	95	1.430	0.64	Bluegill
	FX075MBG	18.5	130	2.220	0.42	Bluegill
Route 135 Culvert (FS-76)	FX076FBG	19.5	135	2.770	0.25	Bluegill
	FX076GBG	19.2	130	0.200	0.29	Bluegill
	FX076HBG	19.5	130	0.601	0.38	Bluegill
	FX076IBG	17.8	105	0.112	0.18	Bluegill
	FX076JBG	17.1	90	0.324	0.14	Bluegill
Fisk Pond (FS-77)	FX077ABG	17.5	90	0.075	0.15	Bluegill
	FX077BBG	16.8	85	0.184	0.20	Bluegill
	FX077CBG	16.0	80	0.209	0.12	Bluegill
	FX077DBG	15.3	65	0.182	0.16	Bluegill
	FX077EBG	13.3	45	0.115	0.19	Bluegill

MSO (FS-75)	FX075CYP	13.8	50	0.331	0.33	Yellow Perch
	FX075GYP	25.3	165	0.630	2.4	Yellow Perch
	FX075HYP	25.5	160	0.107	4.7	Yellow Perch
	FX075IYP	26.5	155	0.194	2.7	Yellow Perch
	FX075JYP	21.0	100	0.494	1.2	Yellow Perch
Route 135 Culvert (FS-76)	FX076AYP	26.0	150	0.735	0.85	Yellow Perch
	FX076BYP	25.3	155	1.060	1.3	Yellow Perch
	FX076CYP	24.0	130	0.445	0.60	Yellow Perch
	FX076DYP	23.0	125	0.726	1.6	Yellow Perch
	FX076EYP	21.0	90	0.138	0.99	Yellow Perch
Fisk Pond (FS-77)	FX077FYP	25.1	170	0.163	0.37	Yellow Perch
	FX077GYP	25.5	175	0.513	0.62	Yellow Perch
	FX077HYP	24.6	150	0.239	0.43	Yellow Perch
	FX077IYP	19.7	75	0.270	0.24	Yellow Perch
	FX077JYP	24.0	155	0.444	0.62	Yellow Perch

Table D-3 shows the PCB concentrations in fish tissue (original data in Appendix B of ICF International [2008]).

Table D-3: PCB Concentration in Fish Tissue (individual whole fish, skin on)

YELLOW PERCH	**PCB-052**	**PCB-153**	**Cl-4 Tetrachloro biphenyls**	**Cl-5 Pentachloro biphenyls**	**Cl-6 Hexachloro biphenyls**	**Total PCBs**	**Percent Lipids**
	mg/kg ww	mg/kg ww	mg/kg ww	mg/kg ww	mg/kg ww	mg/kg ww	%
FX075CYP	0.005	0.035	0.030	0.066	0.140	0.330	0.331
FX075GYP	0.018	0.329	0.120	0.320	1.100	2.400	0.630
FX075HYP	0.016	0.587	0.190	0.360	1.800	4.700	0.107
FX075IYP	0.013	0.368	0.099	0.300	1.200	2.700	0.194
FX075JYP	0.028	0.125	0.180	0.190	0.450	1.200	0.494
BLUEGILL							
FX075ABG	0.006	0.132	0.037	0.130	0.410	0.930	0.130
FX075BBG	0.005	0.044	0.028	0.062	0.160	0.380	0.175
FX075FBG	0.008	0.065	0.052	0.080	0.210	0.540	0.394

FX075KBG	0.012	0.074	0.069	0.092	0.250	0.640	1.430
FX075MBG	0.007	0.048	0.040	0.071	0.170	0.420	2.220
LMB							
FX075DLMF	0.013	0.279	0.085	0.245	0.850	1.890	0.340
FX075ELMF	0.014	0.269	0.101	0.327	0.885	2.030	0.197
FX075LLMF	0.060	1.040	0.425	0.692	3.510	8.600	0.736
FX075NLMF	0.012	0.125	0.074	0.161	0.407	0.977	1.559
FX075PLMF	0.035	0.425	0.214	0.459	1.379	3.190	1.071
FX075QLMF	0.026	0.288	0.163	0.336	0.968	2.270	0.666
FX075RLMF	0.004	0.035	0.024	0.056	0.115	0.283	0.638
FX075SLMF	0.020	0.325	0.134	0.318	1.085	2.500	0.755
FX075TLMF	0.037	0.447	0.218	0.456	1.590	4.080	0.171
FX075ULMF	0.006	0.251	0.047	0.164	0.748	1.850	0.242

All concentrations are for whole body, skin-on, individual fish

Tyndall Site

Noblis, Inc. provided what information they could for this site, including a few electronic tables developed to support the ecological risk assessment (we were not able to obtain the actual document, but the tables are provided here), which included fish tissue concentrations. Noblis, Inc., provided a draft feasibility study (electronically) as well as a set of Excel spreadsheets containing sediment concentrations, along with GIS-based summaries sent as images. Sampling locations were provided in the feasibility study (Figure 1-6) as well as individual figures (it was not specified from which report, but they are attached here for convenience as Figures 1-6).

The Tyndall site consists of five discreet sampling areas (Figure 1). Fish were only caught from Areas 1, 2, and 5 as shown in Table D-4 (received electronically and identified as Table 7-5 from the ecological risk assessment). The Areas are described as:

- Area 1 (Upper Reach of Southwest Branch): This area represents approximately 720 linear feet of stream with a width of 15 to 30 feet. The upper reach of the Southwest Branch comprises small isolated communities of needlerush and cordgrass. The approximate total area is 19,000 square feet or 0.2 acres.
- Area 2 (Lower Reach of Southwest Branch): This area represents approximately 570 linear feet of stream with a width of 35 to 200 feet. The lower reach of the Southwest Branch in this area is bounded on the western side by a significant needlerush community. The approximate total area is 75,000 square feet or 1.7 acres.

- Area 5 (Northern Portion of Shoal Point Bayou): This area represents the northern extent of Shoal Point Bayou to its discharge point into East Bay. The area is approximately 2,200 feet long in a north-south direction, and the width varies from 350 to 500 feet. Area 5 is bounded by relatively narrow needlerush communities on the east, west, and northeast. The approximate total area is 1,000,000 square feet or 23 acres.

Noblis personnel involved in the sampling assisted in identifying the corresponding Areas (last column of Table D-4) based on local knowledge of fish populations. Fish caught in the lower portion of Area 1 are unlikely to leave that area, but fish caught in Area 2 near the "border" with Area 1 would be likely to forage over both Areas 1 and 2 (Noblis, Inc., personal communication, 2013). Fish caught in Area 5 are expected to stay in that area.

Sediment data were made available as an Excel spreadsheet and provided in Table D-5. An Area-wide average was calculated using all the data for that Area; individual sample numbers in Table 5-6 refer to individual samples as presented in Table D-5. A distribution for TOC was estimated for each Area (or combined, for Areas 1 and 2) based on the data in Table D-5.

Table D-4: Summary of Fish Tissue Data Samples and Locations for Tyndall AFB

Sample ID	Adjacent Sediment Sample Locations	Species	Number of Fish Collected	Total Weight of Fish Collected (g)	Range of Fish Length (cm)			Area
Reference - Smack Bayou								
OT029-SMB-SE-1	NS	Pinfish	60	285	5.1	-	9.3	
OT029-SMB-SE-2	SE-2	Gulf killifish	28	263	--		--	
Fred Bayou								
OT029-SE-05	SE-3, SE-4, SE-5, and SE-6	Pinfish	29	150.1	5.1	-	8.6	1
OT029-SE-06	SE-3, SE-4, SE-5, SE-6, SE-7, and SE-8	Gulf killifish	25	138.5	5.1	-	8.9	1
OT029-SE-11 [A]	SE-10, SE-11, and SE-14	Gulf killifish	13	126.9	7.0	-	12.7	1,2
OT029-SE-11 [A]	SE-10, SE-11, and SE-14	Longnose killifish	10	25.3	3.8	-	6.4	1,2
OT029-SE-12	SE-8, SE-9, SE-10 and SE-12	Gulf killifish	21	201.3	5.7	-	11.4	1,2
OT029-SE-27 [B]	SE-33 and SE-34	Gulf killifish	12	67.7	6.4	-	9.9	5
OT029-SE-48 [B]	SE-34	Gulf killifish	12	77.1	6.7	-	10.5	5
OT029-SE-48	SE-34	Pinfish	30	166.9	5.4	-	8.6	5

-- Not available.
NS = Not sampled.
A - Gulf and longnose killifish from OT029-SE-11were combined for analysis.
B - Gulf killifish from OT029-SE-27 and OT029-SE-48 were combined for analysis.

The original fish data, consisting of composites, are presented in Table 4-1 of the report and repeated here for convenience (Table D-6, including footnotes).

Table D-5: Surface Sediment Data for Tyndall AFB

Station ID	Sample	Area	DDD	DDE	DDT	DDx	Total Organic Carbon (9060)
			µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
OT029-SE-03-00	SE3	1	160	53	190	403	2600000
OT029-SE-03-02	SE3	1	2.4	2.4	27	31.8	8140000
OT029-SE-03-02-a	SE3	1	6.4	2.1	2.1	10.6	200000
OT029-SE-04	SE4	1	360	24	93	477	3170000
OT029-SE-05-00	SE5	1	720	100	200	1020	31500000
OT029-SE-05-01	SE5	1	100	22	27	149	200000
OT029-SE-06-00	SE6	1	210	15	640	865	1620000
OT029-SE-06-01	SE6	1	62	9.4	44	115.4	NA
OT029-SE-06-02	SE6	1	3900	870	580	5350	NA
OT029-SE-06-02	SE6	1	3	1.1	82	86.1	19200000
OT029-SE-07-00	SE7	1	110	14	30	154	2250000
OT029-SE-08-00	SE8	1	230	34	220	484	4130000
OT029-SE-08-01	SE8	1	140	16	310	466	NA
OT029-SE-08-02	SE8	1	81	17	43	141	NA
OT029-SE-08-02	SE8	1	110	21	277	408	200000
OT029-SE-69-2	SE69	1	17	2.2	4	23.2	11200000
OT029-SE-70-2	SE70	1	56	11	24	91	93100000
OT029-SE-72-2	SE72	1	21	4.3	6.7	32	NA
OT029-SE-73-2	SE73	1	5.1	5.3	5.3	15.7	29500000
OT029-SE-73-2-a	SE73	1	4.6	4.6	4.6	13.8	27300000
OT029-SED-104	SED104	1	75.5	10.8	37.7	124	NA
OT029-SED-104a	SED104	1	65.6	21.4	7.2	94.2	NA
OT029-SED-105	SED105	1	38.6	8.2	11	57.8	NA
OT029-SED-111-1	SED111	1	1600	150	290	2040	NA
OT029-SED-112-1	SED112	1	78.3	16.7	260	355	NA
OT029-SED-160-1	SED160	1	176	42.4	226	444.4	NA
OT029-SED-161-1	SED161	1	96.9	33.7	560	690.6	NA
OT029-SED-162-1	SED162	1	10.4	3	13.5	26.9	NA
OT029-SED-163-1	SED163	1	19.6	4.9	43.7	68.2	NA
OT029-NR-1-SD	NR1	1	311	110	1790	2211	NA
OT029-SE-09-00	SE9	2	65	100	1100	1265	966000
OT029-SE-10-00	SE10	2	53	22	21	96	7220000
OT029-SE-11-00	SE11	2	58	16	130	204	2880000
OT029-SE-11-01	SE11	2	87	25	280	392	NA
OT029-SE-11-01-a	SE11	2	130	27	210	367	NA
OT029-SE-11-01	SE11	2	44	40	40	124	3260000
OT029-SE-11-02	SE11	2	1000	240	260	1500	NA

OT029-SE-12-00	SE12	2	93	26	87	206	2920000
OT029-SE-63-2	SE63	2	4.4	4.4	4.4	13.2	12700000
OT029-SE-64-2	SE64	2	4	4	4	12	19300000
OT029-SE-65-2	SE65	2	130	23	570	723	173000000
OT029-SE-66-2	SE66	2	4.2	4.2	4.2	12.6	9410000
OT029-SE-67-2	SE67	2	57	9	7.4	73.4	10200000
OT029-SE-68-2	SE68	2	19	6	6.7	31.7	28900000
OT029-SE-74-2	SE74	2	2.2	4.6	6.3	13.1	8170000
OT029-SED-103	SED103	2	40.7	9.4	2.1	52.2	NA
OT029-SED-120-0.25	SED120	2	1020	519	28800	30339	NA
OT029-SED-120-1	SED120	2	1670	1150	5210	8030	NA
OT029-SED-121-0.25	SED121	2	1370	462	499	2331	NA
OT029-SED-121-1	SED121	2	2670	1280	267	4217	NA
OT029-SED-122-0.25	SED122	2	243	137	1000	1380	NA
OT029-SED-122-1	SED122	2	39.3	41.7	10.2	91.2	NA
OT029-SED-123-0.25	SED123	2	366	304	15700	16370	NA
OT029-SED-123-1	SED123	2	2890	338	9820	13048	NA
OT029-SED-124-0.25	SED124	2	121	170	1610	1901	NA
OT029-SED-124-1	SED124	2	1160	494	2730	4384	NA
OT029-SED-126-1	SED126	2	1510	716	3360	5586	NA
OT029-SED-126-2	SED126	2	137	350	200	687	NA
OT029-SED-127-1	SED127	2	603	150	647	1400	NA
OT029-SED-127-2	SED127	2	860	220	978	2058	NA
OT029-SED-128-2	SED128	2	34.5	20.1	10.2	64.8	NA
OT029-SED-129-2	SED129	2	51	90	18	159	NA
OT029-SED-130-1	SED130	2	695	383	186	1264	NA
OT029-SED-130-2	SED130	2	30	29	33	92	NA
OT029-SED-131-1	SED131	2	10.7	7	3.4	21.1	NA
OT029-SED-131-2	SED131	2	68.1	32.8	93.9	194.8	NA
OT029-SED-132-1	SED132	2	279	144	409	832	NA
OT029-SED-132-2	SED132	2	645	282	1300	2227	NA
OT029-SED-133-1	SED133	2	0.86	0.78	8.6	10.24	NA
OT029-SED-133-2	SED133	2	1.8	0.65	2	4.45	NA
OT029-SED-134-1	SED134	2	2930	389	4790	8109	NA
OT029-SED-134-2	SED134	2	1760	460	2050	4270	NA
OT029-SED-135-1	SED135	2	1370	530	1330	3230	NA
OT029-SED-135-2	SED135	2	1330	370	679	2379	NA
OT029-SED-136-1	SED136	2	18.6	8	51.1	77.7	NA
OT029-SED-136-2	SED136	2	6.1	2.9	5.5	14.5	NA

OT029-SED-137-1	SED137	2	471	369	36	876	NA
OT029-SED-137-2	SED137	2	164	131	34.5	329.5	NA
OT029-SED-138-1	SED138	2	128	72.5	30	230.5	NA
OT029-SED-138-2	SED138	2	8.3	32.6	4.2	45.1	NA
OT029-SED-139-1	SED139	2	10500	2600	35000	48100	NA
OT029-SED-149-1	SED149	2	73.2	76.1	41.9	191.2	NA
OT029-SED-149-2	SED149	2	80.2	93	8.6	181.8	NA
OT029-SED-149-3	SED149	2	32.8	33	1.4	67.2	NA
OT029-SED-150-1	SED150	2	1520	132	3210	4862	NA
OT029-SED-150-2	SED150	2	244	66.2	41.3	351.5	NA
OT029-SED-150-3	SED150	2	29.2	6.6	7.2	43	NA
OT029-SED-151-1	SED151	2	2220	1650	7910	11780	NA
OT029-SED-151-2	SED151	2	203	97.4	1850	2150.4	NA
OT029-SED-151-3	SED151	2	36	19	150	205	NA
OT029-SED-152-2	SED152	2	2860	249	62900	66009	NA
OT029-SED-152-3	SED152	2	6190	574	87800	94564	NA
OT029-SED-152-4	SED152	2	4520	463	68300	73283	NA
OT029-SED-165-1	SED165	2	32.4	23.9	53.9	110.2	NA
OT029-SED-166-1	SED166	2	42.7	24.3	120	187	NA
OT029-SED-167-1	SED167	2	55.5	30.2	1200	1285.7	NA
OT029-NR-2-SD	NR2	2	264	142	266	672	NA
OT029-NR-3-SD	NR3	2	11400	3250	4140	18790	NA
OT029-SED-194-01	SED194	2	21.8	53	12.2	87	20700000
OT029-SED-194-02	SED194	2	0.49	1.9	0.3	2.69	28300000
OT029-SB-195-01	SED195	2	5.7	44.6	20.8	71.1	21400000
OT029-SB-195-02	SED195	2	0.73	0.23	0.18	1.14	2520000
OT029-SED-194-01	SED194	2	21.8	53	12.2	87	20700000
OT029-SED-194-02	SED194	2	0.49	1.9	0.3	2.69	28300000
OT029-SED-212-01	SED212	2	6	15	23	44	4900000
OT029-SED-212-02	SED212	2	7.4	2.8	3.7	13.9	2000000
OT029-SE-26-00	SE26	5	160	160	4600	4920	40200000
OT029-SE-26-02	SE26	5	2	0.44	2	4.44	200000
OT029-SE-29-00	SE29	5	55	16	280	351	21400000
OT029-SE-29-01	SE29	5	89	60	25	174	NA
OT029-SE-29-02	SE29	5	16	11	4.4	31.4	NA
OT029-SE-29-02	SE29	5	0.83	2.1	1	3.93	200000
OT029-SE-30-00	SE30	5	130	120	58	308	61000000
OT029-SE-30-01	SE30	5	50	14	547	611	200000
OT029-SE-31-00	SE31	5	16	2.2	3.7	21.9	7070000
OT029-SE-32-00	SE32	5	20	50	290	360	32200000
OT029-SE-33-00	SE33	5	19	13	26	58	2150000
OT029-SE-33-00-a	SE33	5	29	15	12	56	2380000
OT029-SE-34-00	SE34	5	5.2	3.4	9.6	18.2	1890000

OT029-SE-35-00	SE35	5	1.7	0.92	3.4	6.02	1270000
OT029-SE-36-00	SE36	5	6.3	2.2	3	11.5	8020000
OT029-SE-36-02	SE36	5	2.8	2.8	0.88	6.48	200000
OT029-SE-37-00	SE37	5	15	7.1	6.8	28.9	8660000
OT029-SE-37-01	SE37	5	33	9.9	75	117.9	NA
OT029-SE-37-02	SE37	5	37	18	31	86	NA
OT029-SE-37-02	SE37	5	2.2	2.4	2	6.6	200000
OT029-SE-38-00	SE38	5	2	1.4	3.5	6.9	2540000
OT029-SE-38-00-a	SE38	5	19	21	260	300	2130000
OT029-SE-39-00	SE39	5	1.1	1.4	1.7	4.2	1850000
OT029-SE-40-00	SE40	5	15	3.6	130	148.6	3120000
OT029-SE-41-00	SE41	5	93	93	11	197	105000000
OT029-SE-41-01	SE41	5	42	29	3.1	74.1	NA
OT029-SE-41-02	SE41	5	74	50	9.9	133.9	NA
OT029-SE-41-02	SE41	5	2	2	2	6	200000
OT029-SE-42-00	SE42	5	6.7	2.6	2.1	11.4	1780000
OT029-SE-43-00	SE43	5	19	15	12	46	5740000
OT029-SE-44-00	SE44	5	11	37	9.8	57.8	6930000
OT029-SE-48-01	SE48	5	2.1	1.4	30	33.5	200000
OT029-SE-32-2	SE32	5	22	36	50	108	109000
OT029-SE-33-2	SE33	5	32	8	97	137	5770000
OT029-SE-38-2	SE38	5	3.7	3.7	3.7	11.1	111000
OT029-SE-40-2	SE40	5	2.9	1.4	46	50.3	111000
OT029-SE-49-2	SE49	5	55	26	49	130	61300000
OT029-SE-50-2	SE50	5	95	62	250	407	42800000
OT029-SE-51-2	SE51	5	3	3.9	3.9	10.8	2100000
OT029-SE-52-2	SE52	5	3.7	3.7	3.7	11.1	8320000
OT029-SE-53-2	SE53	5	8.7	8.7	8.7	26.1	57000000
OT029-SE-54-2	SE54	5	3.6	3.6	3.6	10.8	108000
OT029-SE-55-2	SE55	5	3.5	3.5	3.5	10.5	105000
OT029-SE-56-2	SE56	5	24	15	7	46	129000
OT029-SED-170-01	SED170	5	0.51	4.2	0.75	5.46	115000
OT029-SED-171-01	SED171	5	0.096	0.049	1.5	1.645	111000
OT029-SED-172-01	SED172	5	0.092	0.049	0.4	0.541	112000
OT029-SED-173-01	SED173	5	1.5	5.9	5.5	12.9	115000
OT029-SED-174-01	SED174	5	0.2	1.5	0.55	2.25	105000
OT029-SED-175-01	SED175	5	515	92.3	297	904.3	17800000
OT029-SED-175-02	SED175	5	19.3	4.2	8.9	32.4	7010000
OT029-SED-176-01	SED176	5	12	1.5	0.16	13.66	32900000
OT029-SED-177-01	SED177	5	0.18	0.43	0.27	0.88	113000
OT029-SED-178-01	SED178	5	58.6	30.2	5.2	94	2640000
OT029-SED-179-01	SED179	5	0.13	0.45	0.17	0.75	112000
OT029-SED-180-01	SED180	5	0.19	1.2	0.28	1.67	111000

OT029-SED-181-01	SED181	5	0.95	1	1.3	3.25	113000
OT029-SED-182-01	SED182	5	1.1	1.4	1.6	4.1	111000
OT029-SED-183-01	SED183	5	0.13	1	0.18	1.31	112000
OT029-SED-183-01-a	SED183	5	0.31	2.5	2.6	5.41	113000
OT029-SED-183-02	SED183	5	0.093	0.14	0.09	0.323	113000
OT029-SED-200-01	SED200	5	7.5	5.3	22	34.8	41000000
OT029-SED-200-02	SED200	5	0.71	0.31	1.6	2.62	1200000
OT029-SED-201-01	SED201	5	6.9	27	68	101.9	5900000
OT029-SED-201-02	SED201	5	50	120	8	178	3200000
OT029-SED-201-02-a	SED201	5	9.8	45	7.3	62.1	1800000

NA - No samples available

Table D-6: Fish Tissue Data for Tyndall AFB

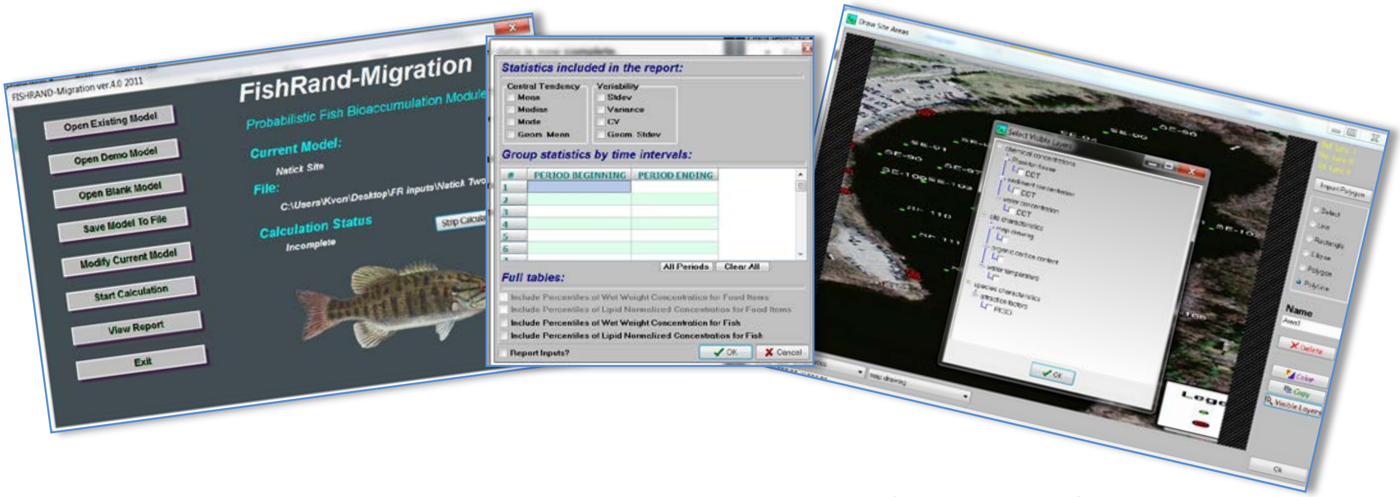
Fish Species		Study Area											
Location		Pinfish		Pinfish		Gulf Killifish		Gulf & Longnose Killifish		Gulf Killifish		Gulf Killifish	
Sample ID		**OT029-SE-05 (Area 1)**		**OT029-SE-48 (Area 5)**		**OT029-SE-06 (Area 1)**		**OT029-SE-11 (Area 2)**		**OT029-SE-12 (Areas 1 & 2)**		**OT029-SE-27 (Area 5)**	
Analyte	**Units**	**Result**		**Result**		**Result**		**Result**		**Result**		**Result**	
Pesticides													
4,4'-DDD	mg/kg	0.058	P/J/HG	0.013	P/J/H	0.149	/J/HG	0.3036	/J/HG	0.248	/J/HG	0.028	/J/HG
4,4'-DDE	mg/kg	0.04	P/J/HG	0.014	P/J/H	0.19	/J/HG	0.253	/J/HG	0.304	/J/HG	0.053	/J/HG
4,4'-DDT	mg/kg	0.017	P/J/HG	0.004	P/J/H	0.014	J/J/HG	0.1746	/J/HG	0.053	J/J/HG	0.007	P/J/H
Total DDX	mg/kg	0.116		0.031		0.353		0.7312		0.605		0.088	
Miscellaneous													
Lipids	%	0.72		0.31		0.33		0.76		0.39		0.54	
Moisture	%	72.5		75.3		75.1		75		75		75.3	

Notes:
All concentrations are based on dry weight.
NA = Not analyzed.
ND = Not detected.
* Average concentration based on detected concentrations and use of one-half the reporting limit as the concentration for non-detects.
[A] - Analytical results were detected but "L" flagged and not considered site-related per EPA data evaluation guidance. A proxy value of 1/2 the reporting limit is shown.
G = Surrogate recovery less than 10%.
H = Holding time exceeded by more than 2X.
J = Indicates estimated value. It is used when the data indicates the presence of an analyte above the method detection limit (MDL) yet lower than the reporting limit.
P = This qualifier is used for pesticide/Aroclor target analytes where there is greater than 25% difference for the detected concentration between GC columns.

Appendix E: User's Guide to the FishRand-Migration (FR-M) Probabilistic Bioaccumulation Module User's Manual Version 4.0

A PDF document of the FishRand User's Guide, produced by E. Risk Sciences, LLP, Warren Pinnacle Consulting, Inc., is attached.

E Risk Sciences, LLP
Warren Pinnacle Consulting, Inc.



FishRand-Migration (FR-M) Probabilistic Bioaccumulation Module

User's Manual Version 4.0

March 2012

FISHRAND-MIGRATION (FR-M)
Probabilistic Fish Bioaccumulation Module

USER'S MANUAL
Version 4.0

March, 2012

Prepared By:

E Risk Sciences, LLP

12 Holton Street
Allston, MA 02134

Programming By:

Warren Pinnacle Consulting, Inc.

P.O. Box 315
Waitsfield, VT 05673

TABLE OF CONTENTS

List of Acronyms

BAF	BioAccumulation Factor (ratio of lipid-normalized tissue concentration to freely dissolved water concentration)
BP	Bioaccumulation Parameters
BSAF	Biota Sediment Accumulation Factor (ratio of lipid-normalized benthic invertebrate tissue concentration to TOC-normalized sediment concentration)
COC	Chemical of Concern
EH	Exposure History
FR-M	FishRand-Migration
K_{ow}	Octanol Water Partition Coefficient
PDF	Probability Density Function
TOC	Total Organic Carbon
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

1 Preface

This *FISHRAND-MIGRATION Probabilistic Fish Bioaccumulation Module - User's Manual*, outlines the mathematical framework for the modeling approach, presents the equations and operational mechanics of the model, and provides stepwise user instructions.

Drawing from user-defined input parameters, FISHRAND-MIGRATION (FR-M) is a software tool to estimate body burdens of organic chemicals in fish under current and future exposure scenarios. Based on the Gobas (1993 and 1995) modeling approach, FR-M is a mechanistic, time-varying exposure model that employs mass balance principles, species-specific foraging and life history data, site-specific chemistry and biological characteristics to predict population distributions of aquatic food web concentrations and associated uncertainty. The user enters data on biota-sediment accumulation factors for infaunal organisms, lipid content, chemical concentrations in associated physical media, total organic carbon in sediment, chemical assimilation efficiency, fish residence time and octanol water partition coefficients. FR-M also accounts for the influence of species-specific migratory and foraging behaviors and spatial heterogeneity of contamination and habitat quality to incorporate greater realism into exposure estimates.

2 INTRODUCTION

2.1 Background

The FishRand-Migration (FR-M) model is a spatially-explicit aquatic bioaccumulation model originally developed to support decision making at the Hudson River Superfund Site (assuming single, non-spatially explicit reach-wide exposure concentrations in sediment and water) and used to compare remedial alternatives (and no action) on the basis of predicted fish tissue concentrations. Since its original development, the model has been expanded and augmented to include a spatially-explicit component to better characterize exposures for migratory and wide-ranging fish species.

The sediment and water concentrations of contaminants to which aquatic organisms are exposed in areas of localized contamination are a function of spatial factors together with species biology. Species with overlapping foraging areas may experience significantly different contaminant exposures from the same site due to local variability in species behavior and contaminant distributions as they overlap with preferred foraging and migratory areas. Predicted exposure estimates and subsequent human health and ecological risk projections typically assume static exposures of receptors to contaminant concentrations characterized by descriptive statistics such as a mean or maximum. The level of health protection is unknown, and the results may not be representative of actual exposures experienced by aquatic organisms in a dynamic system. In addition, these static exposures do not account for uncertainty and variability in the underlying input parameters.

The FR model assumes that the fish caught by anglers or ecological receptors are sampled from a population of fish, and so every individual fish can be thought of as coming from a population distribution. Computationally, this assumption leads to a set of nested Monte-Carlo subroutines shown in Figure 2. Conceptually, the FR-M model begins by defining a hypothetical population of fish. These fish are randomly placed on the modeling grid according to the model input parameters. The fish are allowed to forage over the grid (within their defined foraging areas) for the time period specified by the analyst. At the end of that time period (e.g., one week or one month), all the fish are "gathered up" and again randomly dispersed over the modeling grid. For each time interval, the predicted body burden of the individual fish contributes to the population distribution. Strictly speaking, the FR-M model does not track individual fish; individual fish are represented mathematically by the number of simulations specified by the analyst (e.g., the number of Monte Carlo draws).

The modeling grid in FR_M is defined by a map that can be imported from a variety of graphical formats such as JPEG or GIF files. Contaminant concentrations in sediment and water and physical locations are defined on the map as modeling zones using a polygon drawing tool. The user specifies the aquatic food web, which can include benthic and pelagic invertebrates, phytoplankton, forage fish, and piscivorous fish. The mathematical engine for the model is based on the Gobas model developed by Dr. Frank Gobas and colleagues at Simon Frasier

University (Gobas, 1993; Gobas et al., 1995; 1999; Gobas and Wilcoxson, 2003; Arnot and Gobas, 2004).

Fish, like terrestrial receptors, are known to preferentially forage in particular areas based on features of the landscape (e.g., particular substrates, presence of specific kinds of aquatic vegetation, physical disturbances, such as fallen trees, etc.). The FR-M model allows fish to be "attracted" to these physically defined features again using the map-based polygon tool. In this case, the random dispersal of fish over the modeling grid is weighted toward these attractive areas (e.g., the probability that the fish will land near these areas is increased rather than completely random). It is possible to define attraction factors using analogous methods to the habitat suitability index utilized in terrestrial systems, but there are no formal methods or databases incorporated in FR-M (e.g., the analyst must make this determination outside the software).

FR-M predicts fish body burdens in aquatic food webs given site-specific exposure conditions. One key aspect to this is having an understanding of the relationship between sediment and water. Although fish are primarily exposed to bioaccumulative contaminants through sediment sources, there can be significant dynamics that allow sediments to release contaminants, for example, through various flux mechanisms resulting from disequilibrium between sediment and water, which may be important to capture with respect to exposure. FR-M is not a sediment fate and transport model – these issues need to be addressed outside the FR realm.

FR allows users to specify probability distributions for model inputs, and users can specify whether an input predominantly contributes to "uncertainty" or population "variability." Uncertainty and variability should be viewed separately in risk assessment because they have different implications to regulators and decision makers (Thompson and Graham, 1996). For example, there is "true" uncertainty (e.g., lack of knowledge) in the estimated concentrations of sediment and water to which aquatic organisms are exposed. Concurrently, there is variability across inputs -- stochasticity -- contributing to contaminant bioaccumulation. Variability is a population measure, and provides a context for a deterministic point estimate (e.g., average or reasonable maximum exposure). Variability typically cannot be reduced, only better characterized and understood. In contrast, uncertainty represents unknown but often measurable quantities. Typically, uncertainty can be reduced by obtaining additional measurements of the uncertain quantity. Quantitatively separating uncertainty and variability allows an analyst to determine the fractile of the population for which a specified risk occurs and the uncertainty bounds or confidence interval around that predicted risk (von Stackelberg et al., 2002b). If uncertainty is large relative to variability (i.e., it is the primary contributor to the range of risk estimates) and if the differences in cost among management alternatives are high, additional collection and evaluation of information can be recommended before making management decisions for contaminated sediments. On the other hand, including variability in risk estimates allows decision makers to quantitatively evaluate the likelihood of risks both above and below selected reference values or conditions (for example, average risks as compared to 95th percentile risks).

2.2 Purpose and Scope

The FR-M model provides a more realistic simulation of how population exposures in aquatic food webs occur by developing a probabilistic analytical framework that simulates random fish movements over a grid or polygon map, and allows for fish congregating or preferentially feeding in particular areas within the study area through the use of user-defined modeling zones. The model also allows fish to move in and out of the modeling grid if that reflects their particular life histories. The probabilistic framework provides population estimates of tissue concentrations with associated uncertainty that provide greater flexibility for analysts in estimating subsequent human health and ecological risks.

2.3 Application

FR-M can be a valuable tool for ecological and human health risk assessors. The model can be used to estimate aquatic food web concentrations under different scenarios. The impact of different remedial strategies can be explored by applying sediment clean-up levels. The time-varying features in the model enhance the analytical and risk management power.

2.4 Installation and Requirements

FR-M requires Windows and Microsoft Excel (2003 or higher) for the report viewer. FR-M requires 100 MB of free hard drive space for most calculations. The required hard drive space required is dependent on the complexity of the user-defined model. FR-M generates output files in Microsoft Excel; **when generating output files, the user should not work, open, or save any other Excel files**.

If previous versions of FishRand or FR-M are installed, run the uninstall function to remove these versions before installing the latest version. In addition, after removing the program, confirm that all program files have been deleted from the Program Files folder on your computer (e.g., C:\ drive).

FR-M is distributed in a self-extracting setup file. Within this file, click on setup.exe to install the program. The setup will create a desktop shortcut and move files to the appropriate folders. Project-specific data files may be stored in any folder.

3 MODEL STRUCTURE

3.1 Overview

FR-M uses time-varying water and sediment concentration data to generate fish tissue concentrations[1]. The model is constructed using a set of compartments. The two primary diet compartments are pelagic biota (both invertebrate and phytoplankton) and benthic

[1] NOTE: Fish tissue concentrations are simulated in the same way regardless of position in the food chain

invertebrates. Tissue concentrations are assumed to be in equilibrium with the media concentrations, i.e. pelagic biota tissue concentrations are assumed to be in equilibrium with dissolved water concentrations and benthic invertebrate body burden concentrations are assumed to be in equilibrium with sediment concentrations (USEPA 2000). Depending on the specific diet preferences, forage fish consume biota from the two compartments. There can be multiple types for each compartment, e.g., worms, mollusks, shrimp, phytoplankton, etc. Piscivorous fish consume biota from these two compartments as well as forage fish, depending on species-specific diet preferences. Chemical uptake can occur through the diet or through the water column for both forage fish and piscivorous fish. Conceptually, the various inputs and outputs of FR-M are summarized in Figure 1.

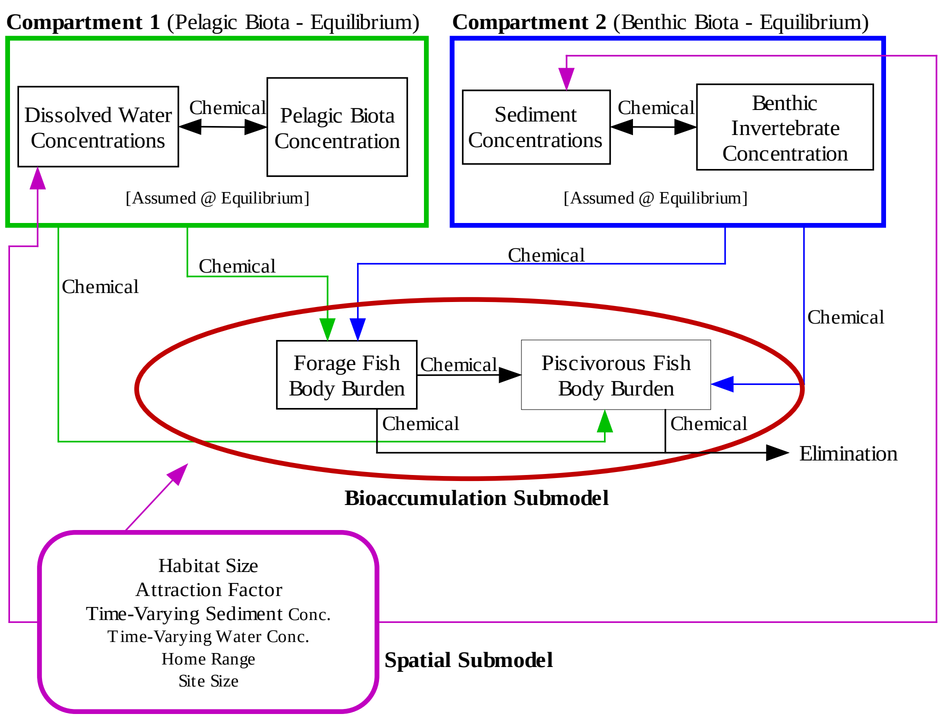


Figure 1. Schematic summary of calculation pathways within FISHRAND

In addition to assessing the bioaccumulation of chemicals, FR-M contains a spatial submodel. The spatial submodel improves the realism of the modeling process by incorporating foraging behaviors that may impact exposure. The spatial submodel includes:

a consideration of seasonal migration (relative abundance);

a consideration of the influence of home range size compared to the size of the site (home range in meters);

a consideration of the influence of habitat quality on exposure expressed as differential attraction to certain areas within the site (species-specific attraction factors); and, the influence of time-varying concentrations on the species exposure given the seasonal movements and impacts of habitat quality on foraging (tine-varying and spatially-defined sediment and water input concentrations).

In the sections that follow, the model structure is described in more detail. As mentioned previously, the FR-M model is based on the Gobas model (Gobas, 1993; Gobas et al. 1995; 1999). The FR-M model has been applied to specific projects (USEPA 2000) and is also discussed in von Stackelberg et al. (2002a,b) and Linkov et al. (2002).

3.2 Equilibrium Partitioning (Prey Item Calculations)

The base of the food web, including pelagic and benthic invertebrates and plankton (e.g., zooplankton, phytoplankton) assumes that these compartments are in equilibrium with either sediment or water, depending on the dominant exposure route. Pelagic invertebrate and phytoplankton concentrations are estimated using equilibrium partitioning based on a freely dissolved water concentration, while benthic invertebrates are related to dry weight sediment concentrations. FR-M provides three options for generating invertebrate tissue and plankton concentrations. They include:

Entry (or selection) of a Biota Sediment Accumulation Factor (BSAF) for sediment or Bioaccumulation Factor (BAF) for water. Time-varying tissue concentrations are calculated using the BSAF and time-varying sediment concentrations or BAF and time-varying water concentrations;

Estimation through equilibrium partitioning from sediment (BSAF=1) or water (BAF = 1) to tissue, yielding time-varying tissue concentrations that track the sediment OR water concentration; and,

Input of co-located tissue and sediment (or water) concentrations (measured data). Such sets of measured tissue concentrations and medium concentrations are usually time independent (i.e. time varying tissue measurements are not collected on the same time scale as time-varying sediment or water measurements). All pairs of measured medium and tissue concentrations (or BAF/BSAF values estimated from measurements) are assigned equal statistical weights and are used to construct a mixture distribution of BAF/BSAF reflecting central tendency and measurement uncertainty in BAF/BSAF.

The US Army Corps of Engineers provides guidance regarding bioaccumulation testing (USEPA/USACE 1991). The equilibrium partitioning models for phytoplankton and pelagic invertebrate tissue concentration estimation use the octanol water partition coefficient (Log K_{ow}) in combination with the lipid content and freely dissolved water concentration. For sediment dwelling organisms, the percent lipid, total organic carbon, and chemical concentration in sediment are applied.

3.3 Bioaccumulation Submodel

Time-varying biota tissue chemical concentrations are calculated using the following differential equation:

$$\frac{dC_f}{dt} = k_1 * C_{wd} + k_d * C_{diet} - (k_2 + k_e + k_m + k_g) * C_{fish}$$

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 (μg/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_{fish} = concentration in fish (μg/kg)

3.4 Rate Constants

Four rate constants are required for model operation. Gobas (1993) discusses each in detail. The rate constants include chemical uptake via water and the diet, the fecal egestion rate and a growth rate constant. The equations for each are presented below and are discussed in greater detail in Gobas (1993; 1995) and Arnot and Gobas (2004). Several of the coefficients for these rate constants can be user modified based on site-specific and species-specific data.

3.4.1 Direct Uptake from Water

This rate constant is used to estimate the rate at which chemicals in water cross the gill interface and includes a gill ventilation rate as well as a cross gill diffusion rate. The equation is:

$$K_1 = \frac{1}{V_f / Q_w + V_f / Q_L * K_{ow}}$$

where:

k_1 = gill uptake rate (d^{-1})
K_{ow} = octanol/water partition coefficient
Q_w = transport rate in the aqueous phase (L/day)
Q_L = transport rate in the lipid phase (L/day)
V_f = fish weight in kg (described by a distribution in FR-M)

The two transport rates are described by:

$Q_w = 88.3 * V_f^{0.6}$

$Q_L = Q_w/100$

The gill elimination rate is described by:

$$k_2 = \frac{k_1}{L_{fish} * K_{ow}}$$

where:

L_{fish} = fish lipid content

3.4.2 Uptake from Prey Consumption

The rate at which chemicals in prey items are transported into a consumer is dependent on the food ingestion rate, the rate of diffusion across the intestinal wall, and the fecal egestion rate. Gobas (1993) assumes that the efficiency of the uptake from food is related to the transport of the chemical in aqueous and lipid phases within the gut.

$$K_d = \frac{E_d * F_d}{V_f}$$

where:

k_d = dietary uptake rate constant (d^{-1})
E_d = uptake efficiency (unitless)
F_d = food ingestion rate (kg food/day)
V_f = fish weight (kg)

The uptake efficiency, E_d, is defined by:

$$E_d = \frac{1}{5.3x10^{-8} * K_{ow} + 2.3}$$

The food ingestion rate, F_d in [kg food/day] is defined by:

$F_d = 0.022 * V_f^{0.85} * e^{0.06T}$

where:

F_d = food ingestion rate (kg food/day)
V_f = fish weight (kg) (described by a distribution in FR-M)
T = monthly mean water temperature (deg C)

3.4.3 Fecal Egestion Rate Constant

The rate at which biota release waste is defined by:

$k_e = 0.2 * k_d$

where:

k_e = fecal egestion rate (d^{-1})
k_d = dietary uptake rate constant (d^{-1})

3.4.4 Growth Rate Constant

FR-M uses the growth rate constant presented in the original Gobas Model (1993). It is defined by:

For temperatures greater than 10°C (T>10°C), the growth rate constant, k_g, is given by:

$K_g = 0.01 * V_f^{-0.2}$

Where:
V_f = fish weight (kg) (User input)

For temperatures less than or equal to10°C (T≤10°C), the growth rate constant, k_g, is given by:

$K_g = 0.002 * V_f^{-0.2}$

3.5 Spatial Submodel

The spatial submodel is described in detail in Linkov et al. (2002) and von Stackelberg et al. (2002b). The method is derived from an approach originally formulated for terrestrial habitats (Freshman and Menzie, 1996). The spatial submodel employs fish foraging behaviors to calculate the probability that a fish will be exposed to a chemical concentration in water and/or sediment. The spatial submodel uses time-varying sediment and water chemical concentrations, size of the site and so-called "hotspots" or modeling zones, attraction factors, migration habits of the fish, and fish home range sizes to evaluate the probability that a fish will be exposed to chemicals in the site.

A polygon tool is used to define hot spots and other spatially-dependent inputs within the study area.

The concentrations of chemicals in sediment (C_s) and in water (C_{wd}), water temperature, and sediment organic carbon content are considered as random variables described by data-based parametric probability distributions. In addition, the variability associated with the migratory habits of the fish population as well as the possible differential attractiveness of particular areas within the site are taken into account. Finally, population heterogeneity in bioaccumulation by individual fish is modeled in the bioaccumulation submodel.

The variability of chemical accumulation in the population of fish has two independent origins: 1) variability associated with the migratory and foraging strategy of each individual fish in the population (resulting in variable exposure histories); and, 2) variability in the parameters associated with chemical uptake for each individual fish. Accordingly, the model is based on the following general decomposition of the probabilities:

$$PDF(C_f \mid t) = \int\limits_{\substack{Exposure \\ Histories}} \int\limits_{\substack{Bioaccumulation \\ parameters}} PDF(C_f \mid t, EH, BP) \cdot dP(EH) \cdot dP(BP) \qquad (1)$$

where:

PDF(C$_f$ | t) = probability density function (PDF) of chemical concentration in fish (C_f) accumulated at each time period *t*

EH = exposure history: the time series of chemical concentrations in local sediments and water, prior to the time period *t* (based on the migratory and localized foraging history of the fish)

BP = the set of individual bioaccumulation parameters

PDF(C$_f$ | t,EH,BP) = conditional PDF of chemical concentration in fish given the exposure history *EH* and a set of values of the bioaccumulation parameters *BP* d$P(EH)$ = the probability of given exposure history *EH*

d$P(BP)$ = the probability of given set of values of the bioaccumulation parameters *BP*

The integral in equation (1) employs a Monte Carlo assessment to generate random realizations of exposure histories (EH), i.e. random fish locations within the site or outside of the site, and bioaccumulation features (BP), i.e. random values for the parameters affecting assimilation and elimination of chemicals.

In addition to capturing the impact of migratory behaviors on exposure, the spatial submodel also incorporates the impact of heterogeneous chemical distribution across the site. Areas with a unique chemical distribution compared to the remainder of the site are referred to as modeling zones. Differential attraction to defined modeling zones versus the remainder of the site is captured through the application of an attraction factor. Using attraction factors, the probability of finding a fish within a particular modeling zone compared to finding a fish within the remainder of the site is defined by:

$$\text{Prob(modeling zone)} = \frac{AF_i * MZ_i^{\ 2}}{S^2 + \sum_{i=1}^{N} AF_i \times MZ_i^{\ 2}}$$

where:

AF_i = attraction factor (unitless; ratio of abundance within hotspot to abundance outside of the i-th modeling zone)
MZ_i^2 = i-th modeling zone area (km^2)
S^2 = site background (site without defined modeling zones) area (km^2)

3.6 Population Distributions and Associated Uncertainty

Parameters within FR-M are categorized as either variable (reflect population heterogeneity or stochasticity) or uncertain (reflect a lack of knowledge attributable to precision and bias) (von Stackelberg et al. 2002a). FR-M employs distributions to define model parameters; but point estimates may also be applied. Inputs may be defined as predominantly uncertain (e.g. Log K_{ow}, organic carbon, chemical concentrations, etc.) or variable (e.g. percent lipid, body weight, water temperature, etc.), but not both. As shown in Figure 2, FR-M then employs a nested Latin Hypercube/Monte Carlo approach to quantitatively evaluate uncertainty and variability. In this approach, uncertainty and variability are assessed separately (Cohen et al. 1996; Burmaster and Wilson 1996; von Stackelberg et al. 2002a). The nested Monte Carlo approach holds uncertain values constant and then runs the model by selecting values from the distributions for variable parameters for a user-selected number of iterations. Then another set of values are selected from the distribution for uncertain parameters, the values are again held constant while the variable parameter loop is completed. This nested Monte Carlo analysis continues until the specified number of iterations for the uncertain parameters are completed. Each set of iterations repeats across time periods.

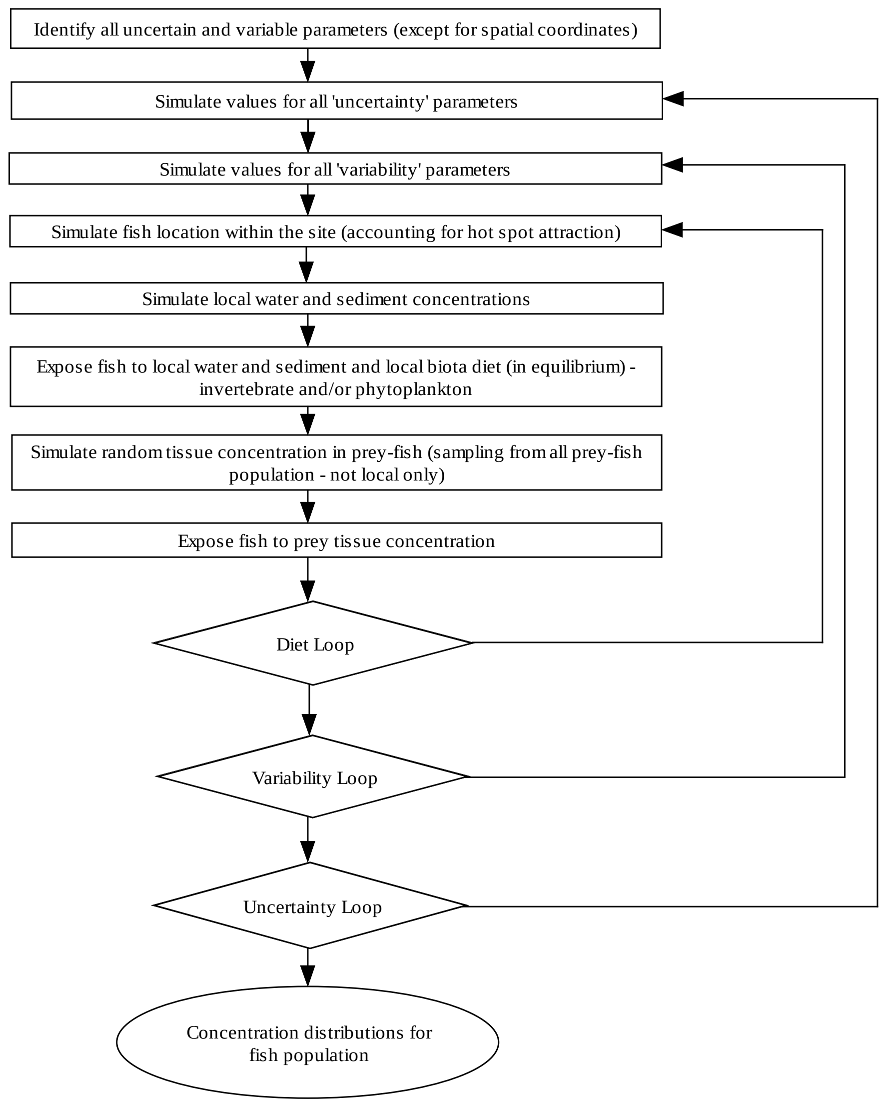
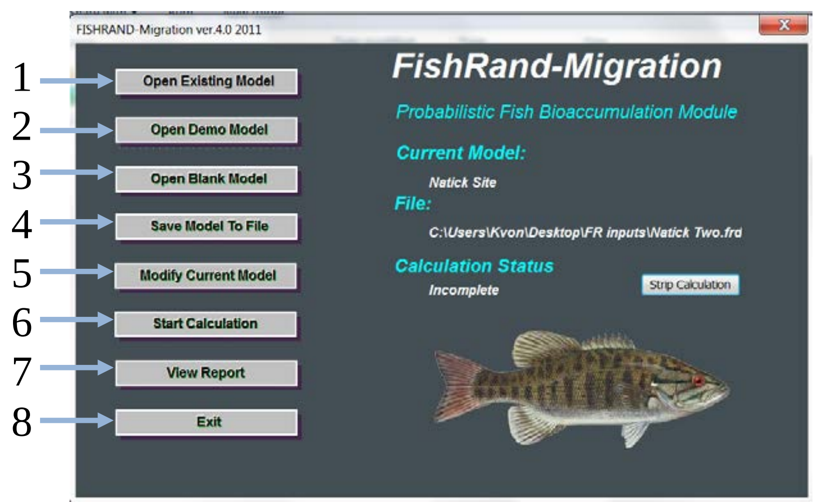


Figure 2. Nested Monte Carlo Approach Schematic

In addition to the variability loop discussed above, there is also an internal simulation loop capturing variability in prey body burdens (forage fish with an exposure history that is not correlated with the exposure of the piscivorous fish) and generating spatial simulations for fish positions within the site with corresponding body burdens of local biota (invertebrates and plankton).

4 Stepwise Instructions

FR-M is organized around the home screen. From this screen a user may open existing models, save a model to a file, open a demonstration model, create a new model, modify the open model, start/run calculations and view reports. Each function is operated by directly clicking on the button/icon of interest. In addition, this screen reports the name of the current model (data from previous FR-M activity remains loaded until a user selects a new dataset to load or create from a blank input). FR-M is designed with an integrated guided input interface. The interface directs the user to enter specific pieces of information required to operate the model correctly. The guided input, in addition to other functions is accessed via the home screen. The function of each button on this screen is:



Open Existing Model (1): If a model data set has already been started and saved to an external file, this button allows a user to reopen that file and modify inputs, complete inputs, run the calculation and view the report;

Open Demo Model (2): FR-M includes two demonstration data sets. Access these datasets while learning how to use FR-M. Each dataset includes different combinations of inputs and modeling options to illustrate model functionality;

Open Blank Model (3): To load a blank model file and begin a new project, click this button;

Save Model to File (4): This button provides a user with an opportunity to save the input files, as well as the calculation file (after running the model), to an external file;

Modify Current Model (5): When opening an existing data file or returning to an active file, this button is used to access and modify the inputs in the file in the guided input;

Start Calculation (6): After data entry is complete, the model may be run. In order to run the model, *Finish* must have been clicked within the guided input to confirm that data entry is complete. A set of calculation options are available to the user (discussed in detail in the Sections that follow);

View Report (7): After completing the calculations, the *View Report* button generates a summary report including inputs, tabular results and graphical results. Users are offered a number of statistical and summary options (discussed in detail in the Sections that follow); and,

Exit (8): To close the model, click *Exit*. Note: save all model data and outputs prior to exiting the program.

In addition to the function buttons on the home screen, additional information is provided to the user.

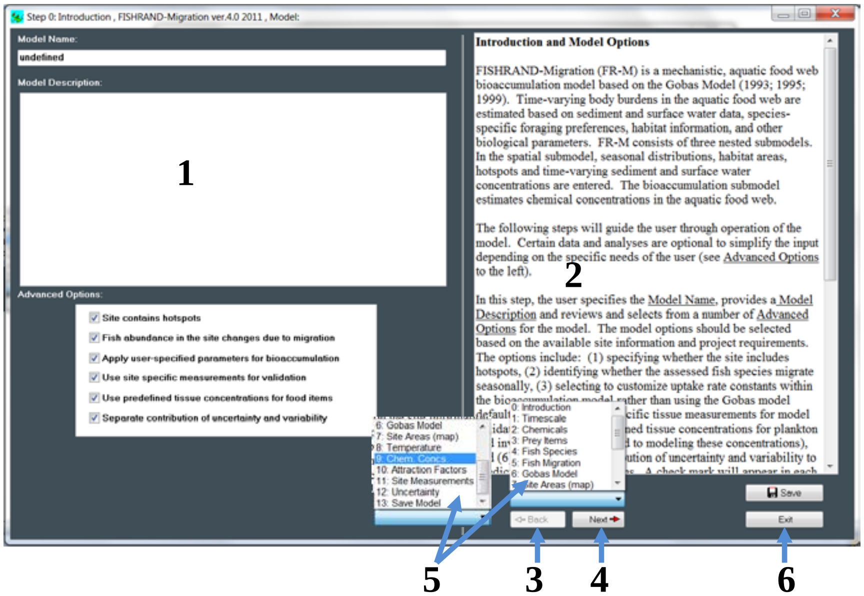
Current Model (9): This is the name of active model. The name is entered in the initial guided input step;

File (10): The file name is also provided to assist users in tracking which data set is active at any given time;

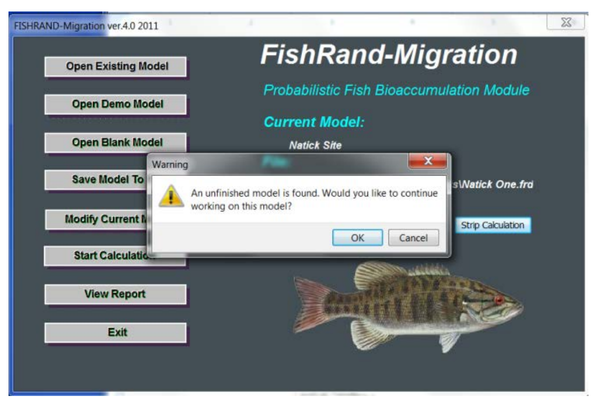
Is Calculation Complete (11): Before a report can be generated, the calculations must be completed. This information box indicates whether the model has been run for the current input file.

Each screen in the guided input requires the user to supply specific inputs needed to run the model. Users are given the opportunity to determine the complexity of each model run, which is dependent on the specific question being framed, the available data and user preferences. As a result, the number of steps in a specific guided input series is customized based on the desired level of complexity and/or flexibility selected by the user. The number of guided input steps will vary depending on the parameters that a user selects (from 8 to 14 steps) (see Section 3.1 for additional detail). Use of parameters such as migratory characteristics of the assessed species or the presence of hotspots is optional. The guided input is used to populate the model. Once completed, the user will exit the guided input and initiate model calculations from the FR-M home screen.

In the following sections, the input screen and a description of the input data for each step are provided. For organizational purposes, we list all possible guided input steps; note that the exact number of steps depends on the number of advanced options chosen by the user. The program will modify the step numbers depending on which parameters apply to a given model run.



The general structure of the guided input screens is displayed to the left. Data entry fields occupy the left-hand side of the screen **(1)**, while step-specific guidance text describing the required data is provided on the right-hand side of the screen **(2)**. On some input screens, clicking on a data entry screen on the left-hand side of the screen will activate an additional data entry pop-up on the right-hand side. A user can toggle between the guidance text and the pop-up data entry window. The *Back* **(3)** and *Next* **(4)** buttons are used to navigate between guided input steps. All guided input steps are available from every screen (**5**). *Save* and *Exit* (**6**) are also available from every screen. They differ in how they save the data. *Save* will always lead to a dialog box asking the user to name the file, while *Exit* will bring the user back to the main menu and will save all data entry up to that point in the "current model" – if that is a model that has been opened from a file, or previously saved, clicking on *Exit* from any screen will automatically overwrite the file contents and save data entry up to that point to the current file without notifying the user that a file could be overwritten. FR-M stores all data input while working on an active data set – if that dataset has not been named, FR-M will recover data entry from an unfinished temporary file and users will be given the option of continuing to work on this data file if it is not actively saved. This is shown in the figure below. To summarize:



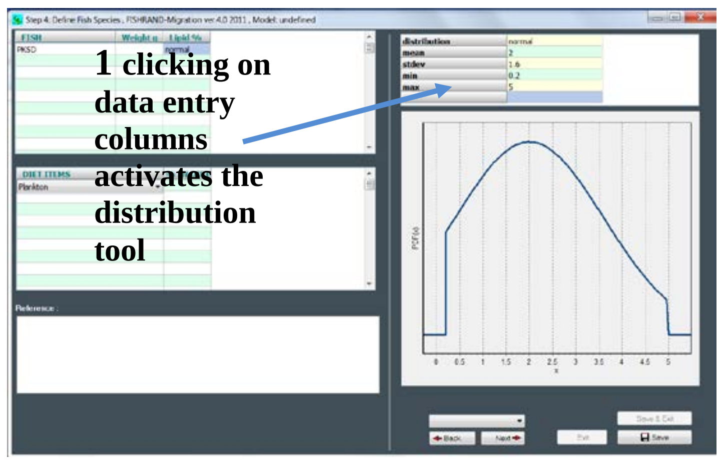
Save: this option is available on each input screen and allows a user to save the data entered through the guided input step *preceding* the active step to an external file. Data entry must be completed in order to run the model, but this feature allows a user to backup work, create duplicate input files, etc.

Exit: this option will exit guided input and return to the main screen *without saving* the current input to a file; current input are still available and before opening another file or exiting, the user will be prompted to "continue working on this model?" as shown in the figure above.

Upon exiting the guided input, the *Save As* dialog pops up only if the model is created from scratch. If an external file is already assigned to the model data (due to previous saving or opening of external files), on *Exit* this external file is updated without any additional warnings or dialogs. The external model file will have the extension: *.FRD.

Because FR-M will not run correctly if inputs are not entered correctly, the program contains input alerts. If a user misses an input in any step, an alert will appear when *Next* is clicked. Users will not be permitted to advance to the next step until all inputs have been supplied.

4.1 Deterministic vs. Probabilistic Inputs

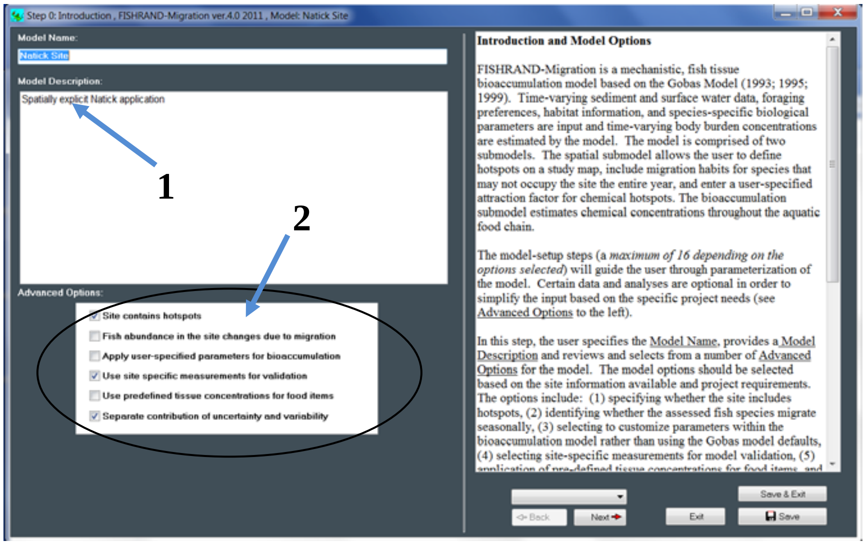


For almost all input variables, users may enter data as point estimates or as distributions, if data allow. Distribution types include uniform, triangular, normal and lognormal. This tool allows a user to select a distribution and displays the required inputs for each specific distribution. A figure of the data distribution is also generated. The tool is accessed by clicking on the value cell on the left side of the screen (**1**). If the input data have a spatial reference, a user may click on the input name to display a map of the data locations. Distributions are parameterized as follows:

- Uniform (min, max); minimum and maximum in native units (e.g., not transformed in any way)
- Normal (μ,σ); mean and standard deviation in native units (e.g., not transformed in any way)
- Triangular (min, mode, max); minimum, likeliest value, and maximum value in native units (e.g., not transformed in any way)
- Lognormal (μ,σ); mean and standard deviation of the natural log transformed data (e.g., LN[x])

4.2 Introduction and Model Option Selection

The first step in the process is to customize the specific model run. Users may select from a number of advanced model options depending on the data available, the project needs, site complexity and the global model run assumptions. FR-M is designed to accommodate a range of different site conditions and parameters. In this step the user creates a model name **(1)** and provides a model description. The model name entered in this step appears on the home screen.



Below the name and description, a user may review and select among six advanced options.

The options **(2)** include:

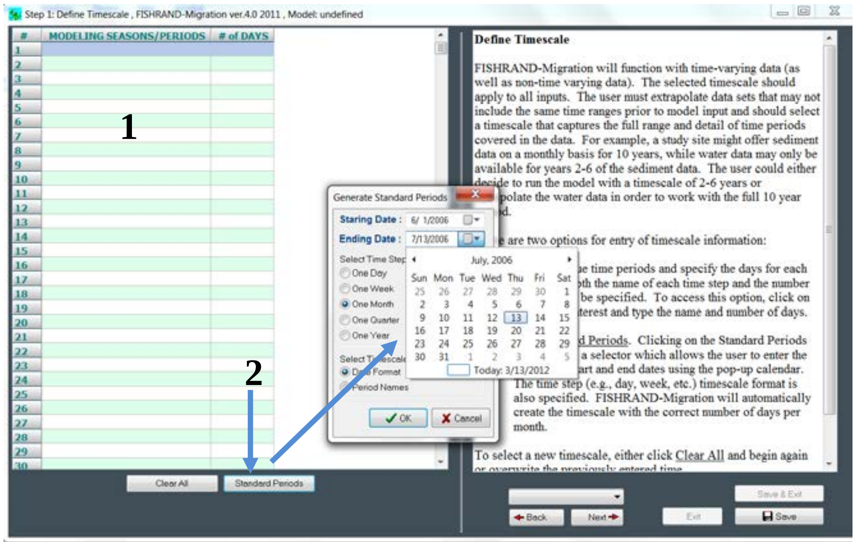
- *Site contains hotspots*: This option allows users to define modeling zones within the study area using a map-based input together with a drawing tool. This option assumes spatial heterogeneity across key inputs, analogous to "hotspots";
- *Fish abundance in the site changes due to migration*: This option allows users to specify seasonal migration habits within the fish abundance parameter;
- *Apply user-specific parameters for bioaccumulation*: This option allows users to modify the rate constants in the bioaccumulation model;
- *Use site specific measurements for validation*: This option allows users to automate comparisons between predicted and observed tissue concentrations to visually evaluate model performance;
- *Use predefined tissue concentrations for food items*: This option allows users to enter data for invertebrate and plankton concentrations rather than using equilibrium partitioning to calculate those; and/or,
- *Separate contribution of uncertainty and variability*: This option allows users to specify individual inputs as contributing primarily to uncertainty (lack of knowledge) or variability (population heterogeneity or stochasticity).

The user may select a subset or all of these options by placing a "✓" in the appropriate selection box. By default, none of these options are selected. The format and number of steps that follow will be determined based on the selection of these options. The step numbers that follow in this User Guide assume that all options have been selected.

When finished specifying the model run name and options, click *Next* to move to the next Step.

4.3 Define Timescale

FR-M accepts time-varying input data, and if time-steps are entered, FR-M requires all inputs to follow the same timescale. For example, if annual sediment data are for a five year period, and water concentrations are available monthly over several, but not all, of those years, the user would specify a monthly timescale and enter the same sediment concentration across the 12 months in the year. The user would also need to fill in the missing water data (the program will not fill in missing data automatically. A user may enter specific time periods and the number of days in each period **(1)**.

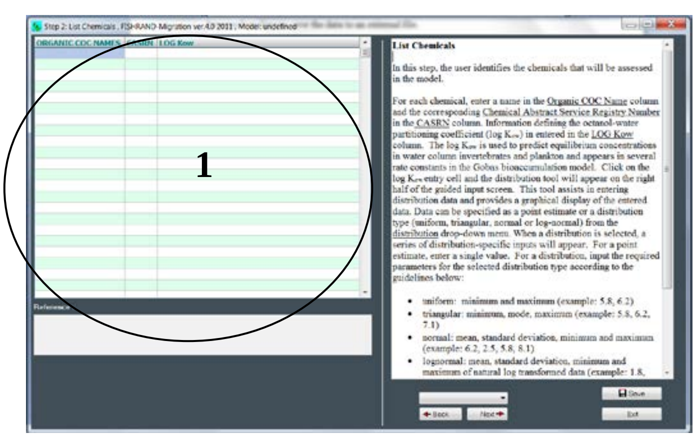


A user may also generate standard periods. By clicking on *Standard Periods* **(2)**, a pop-up selector tool is activated. Using this tool a user enters the starting and ending date, the time step increment (e.g. day, week, month), and the format for the timescale, either date or period names. FR-M will round the time period to the nearest time step increment, e.g. if the time step is one month and a user enters 1/10/04 to 1/25/05, the ending month will be 12/10/04 representing the last complete month.

When the user is collecting data for application in FR-M, he or she should consider standardizing time periods for all data sets. If the time periods differ across data sets, the user is required to reconcile the differences before using FR-M because FR-M will only accept input data with consistent time periods and time steps.

When finished entering inputs for this Step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.4 List Chemicals

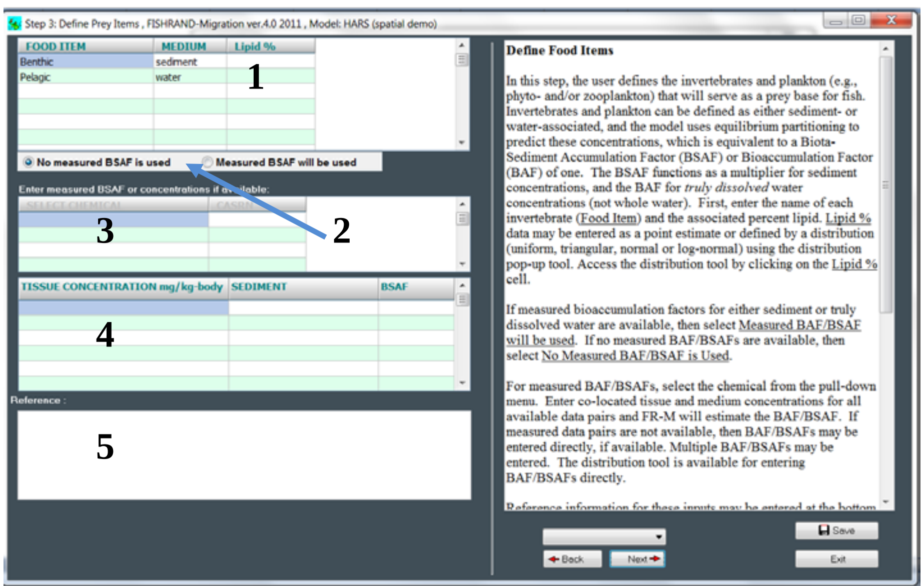


In this step a user names the chemicals that will be assessed in FR-M. The chemical name, chemical abstract service number (CASRN) and the Log octanol water partition coefficient (LogK_{ow}) are entered (**1**). The Log K_{ow} data may be entered as a point estimate, or as a distribution (uniform, triangular, normal, lognormal). When a user clicks on the Log K_{ow} entry cell, the distribution input tool opens. This tool allows a user to select a distribution and displays the required inputs for each specific distribution. A figure of the data distribution is also generated. A single run in FR-M will include all chemicals listed in this step.

When finished entering inputs for this Step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.5 Define Prey Items

In this step, prey items such as pelagic or benthic invertebrates, or different kinds of plankton (e.g., phytoplankton) are defined. First **(1)** enter the name of each food item, the medium in which it is found (primary habitat either water or sediment, but not both) and the percent lipid. Percent lipid may be entered as a point estimate or as a distribution. To activate the distribution tool, click on the lipid input cell **(1)**.



Next, specify whether measured BAF data will be used **(2)**. Click either 'No measured BAF is used' OR 'Measured BAF will be used'. If no measured BAF data are used, then the model will estimate food item tissue concentrations using equilibrium partitioning.

If measured BAF values or matching tissue and medium concentrations are available, then highlight the chemical **(3)**. Next, either enter a tissue and medium concentration combination or the BAF **(4)**. A user may enter multiple tissue-medium concentration combinations. Depending on the form of the entered data, FR-M will develop a distribution of BAF/BSAFs from the values and simulate random BAF/BSAFs from the group of entered data **(4)**.

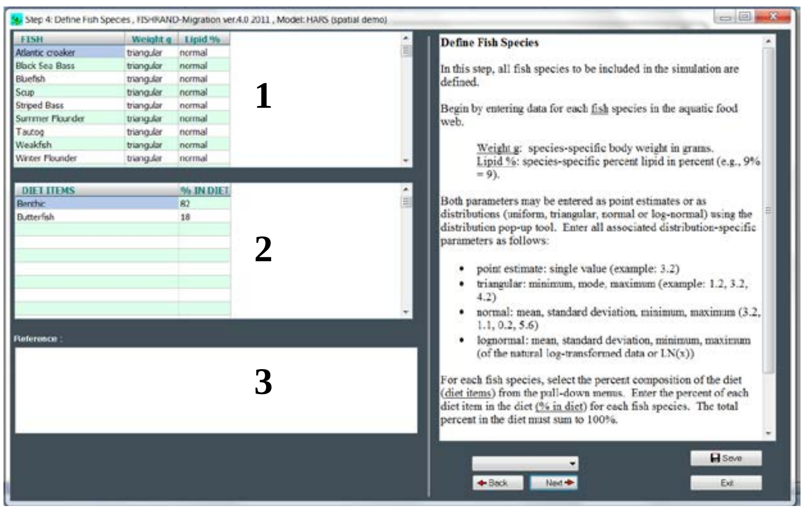
Finally, in this Step a user may record reference information **(5)**. Any text entered here will be tracked and printed on the model report for this data set. Each user determines the format and style of text entered in this section.

When finished entering inputs for this Step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.6 Define Fish Species

In this step a user defines the fish species for the FR-M model runs. Tissue concentrations will be estimated for each species entered in this section. In addition to the species name, FR-M requires each species weight, percent lipid and diet composition.

First, enter the fish name (**1**). Users may enter scientific names or common names. Second, enter the body weight in grams. Similar to other data parameters, users may elect to enter a body weight distribution. By clicking on the data entry cell for weight, users access the distribution tool. Third, enter the percent lipid for the fish (**1**).



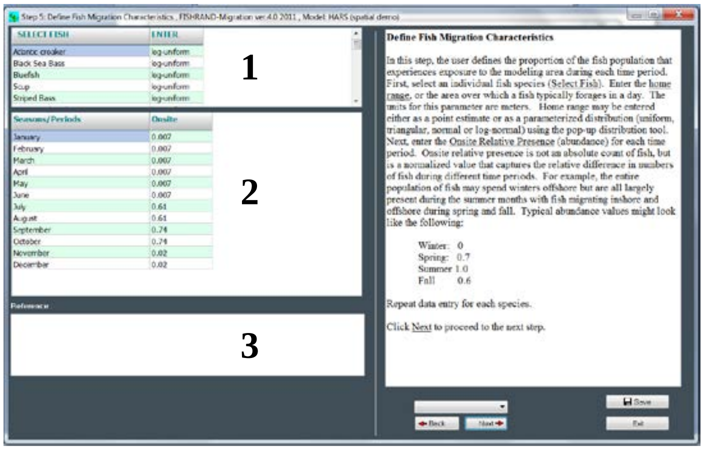
After entering the weight and lipid data, a user characterizes the diet for each fish species. With the species of interest highlighted at the top of the entry screen, select the species comprising the diet and enter the percent of each species in the diet **(2)**. The only diet items available in the pull-down menu are those entered in the previous step. If a diet item is missing, return to the previous step using the *Back* key, enter the new item, then return to this step and select it. The total percent in diet for each fish species must equal 100% before a user may move to the next step.

Finally, reference text may be entered in a user-defined format for output in the report **(3)**.

When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.7 Define Fish Migration Characteristics (OPTIONAL)

In this step, fish migration characteristics are entered based on relative abundance as a proportion of the total population. First, select a fish species from the set entered in the previous Step **(1)**. Enter the home range (in meters) for that species. Next, enter the relative abundance for the previously defined seasons or time periods (from Step 1) **(2)**. Abundance, in this case, is defined as relative because it is simply providing an estimate of the likelihood that a species will be found in the site during any given time period/season compared to likelihood of being found during the other time periods. One of the selected time periods should have the maximum relative abundance. Users may choose to enter data as relative to 1, 100 or any other maximum value, with the remaining time periods being a fraction of the maximum – e.g. 0.5 or 50 in the example.



Finally, reference text may be entered in a user-defined format for output in the report **(3)**.

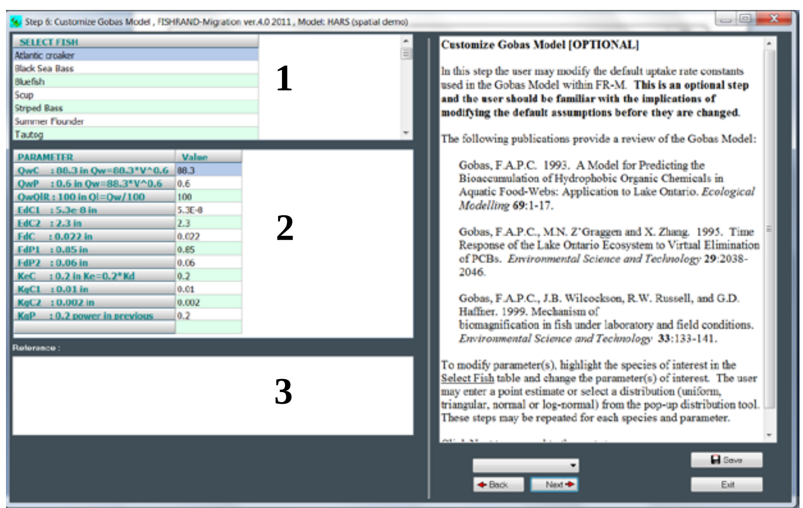
When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.8 Customize Gobas Model (OPTIONAL)

For advanced users who are familiar with the underlying Gobas model structure, the default rate constants may be modified in this step. For detailed bioaccumulation model background information please review Gobas (1993; 1995; 1999).

The parameters may be modified on a species-by-species basis. Select the species **(1)** and then modify the parameters **(2).** Each parameter may be entered either as a point estimate or as a parameterized distribution. References may also be added at the bottom of the screen (**3**).

Caution should be used when modifying the default model parameters.

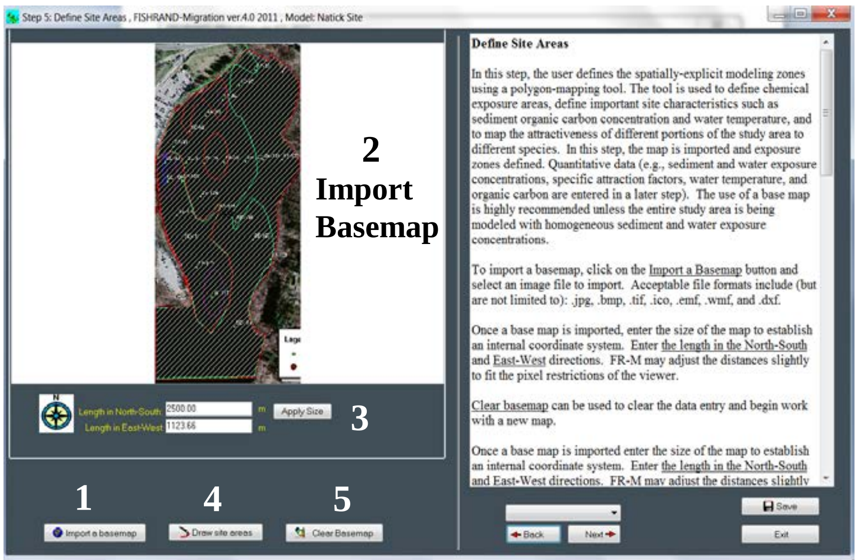


When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.9 Define Site Area and Modeling Zones (OPTIONAL)

A polygon-mapping tool is applied to define the modeling zones within the study area. The tool is used to characterize the chemistry and habitats of a site on a user-supplied base map. Users can define chemical exposure areas and map the attractiveness of different portions of the site using this polygon drawing tool. FR-M does not link directly to GIS files but allows users to import a base map across a variety of graphical formats, and then essentially draw modeling zones that define chemical concentrations, attraction factors, total organic carbon, miscellaneous site features, and/or water temperature. In this step, a base map is imported **(1)** and modeling zones are defined. In subsequent guided input steps, quantitative attributes that apply to each modeling zone, such chemical concentrations, organic carbon, and attraction factors will be entered for each of the modeling zones.

<u>*Define Site Areas Screen*</u>

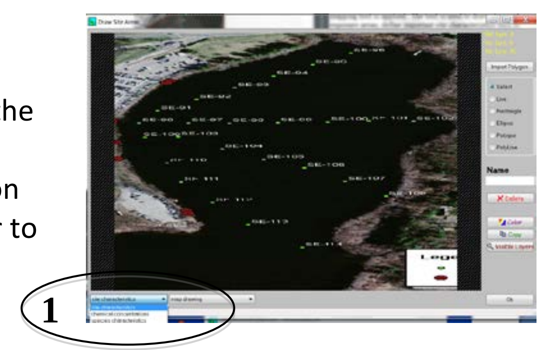


The first step is to Import the base map. Click on the *Import a Basemap* button **(1)** and select an image file to import **(2)**. There are a number of acceptable file formats including, but not limited to: .jpg, .bmp, .tif, .ico, .emf, .wmf, and .dxf.

Once a base map is imported, enter the size of the map to establish an internal coordinate system **(3)** in the model. Enter the length in meters in the North-South and East-West directions. FR-M tracks the pixel numbers and may suggest a correction to the entered measurements if warranted. If you know the size of the map, enter the lengths in meters in the data entry boxes and click *Apply Size*. To clear map work and begin again, click *Clear Basemap* **(4)**.

The next step is to define modeling zones by drawing shapes (e.g., polygons, rectangles, etc.) to define site chemistry and attraction factors. A modeling zone is defined as an area over which the particular input is the same. The size, position and shape are all user-defined based on the available data. Begin by clicking on the *Draw Site Areas* **(5)** button on the *Define Site Areas Screen*. This will open the *Draw Site Areas Tool*.

<u>Draw Site Areas Tool</u>

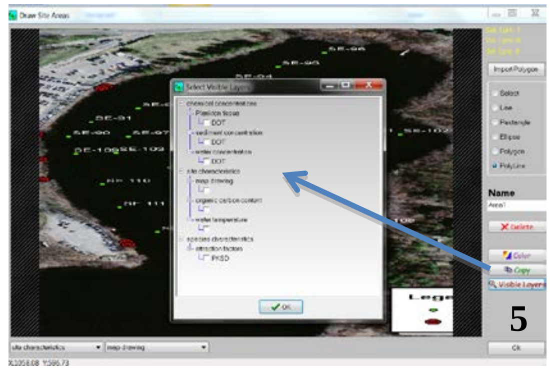


There are three pull-down menus at the bottom of the Drawing Tool screen **(1)**. The category of data to be entered is selected from the first pull down menu (on the far left hand side of the window) allowing a user to identify the type of polygon to be drawn/defined; options include: *site characteristics, chemical* *concentrations,* or *species characteristics*. When a selection is made, the options in the other two pull down menus will be options specific to the first selection. For example, if a user chooses *chemical concentrations*, then the options in the second pull down menu will be *sediment concentration* or *water concentration* and the third pull down menu will include a list of all of the chemicals of concern.

Depending on which option the user selects, the second pull-down menu offers another series of choices. For *site characteristics*, a user may draw polygons representing *sediment organic carbon concentration*, *water temperature* or *map drawings*, e.g. other site features including underground structures, etc. For the *chemical characteristics* option, users select either *sediment* or *water concentration* in the second menu. For the species characteristics option, users are asked to define species-specific *attraction factors*.

Once the type of polygon is selected, then the user draws applicable modeling zones. Note: actual values associated with each modeling zone are not entered on this screen. Modeling zones are defined by polygons or other shapes, and each modeling zone/shape is assigned a unique name, either automatically or by user entry. If the site includes the entire map, then proceed to define modeling zones; background concentrations (all areas not covered by a specifically defined modeling zone) are characterized in a future step and do not require any specific name. However, if the site is smaller than the map area (e.g., there are land areas), then modeling zone drawing should begin with a polygon or other shape around the study area (e.g., waterbody). **It is very important to define the attraction factor for this zone as 1 for all species (otherwise fish will be exposed on land).** Polygon drawing continues from large to small, nesting each smaller polygon within larger polygons as applicable. Modeling zones may intersect and overlap. The value for any given location is the value of the last shape drawn over an area.

Various drawing methods are available (e.g. ellipse, rectangle, polygon – free form) **(2).** After drawing each polygon, the program will assign a default name; for organizational and presentation purposes, user defined names may be substituted for any default name **(3)**. User-specified names should be unique identifiers and will be used to reference the polygon in future data entry steps. The user can click on *Select* **(4)** then click on a modeling zone to modify the name after the shape has been drawn and saved. *Select* is also used to delete modeling zones (*Select* and then click *Delete* (**5**)) and to move locations after a polygon has been drawn. The color of each polygon can also be modified **(5)**.



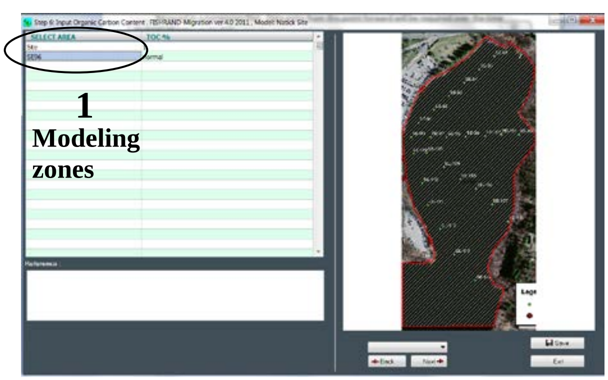
A copy function allows a user to copy previously drawn polygons to additional screens in the *Draw Site Areas* window **(5)**. For example, if chemical concentration contours are the same for all chemicals, then a user can draw one set of modeling zones and copy them for each chemical.

For each medium-chemical combination draw all polygons representing the different concentrations across the landscape. To guide polygon drawing a user may classify a layer as a visible layer (**5**). Visible layers appear in the background of the other drawing tool input screens. These layers are assumed to be useful guides to drawing other modeling zones and shapes. For example, a user may draw important site features under *site characteristics>map* drawing. These features may be landmarks required to draw the chemical and/or habitat polygons. The visible layer (**5**) tool provides users with the opportunity to display layers throughout the drawing tool screens.

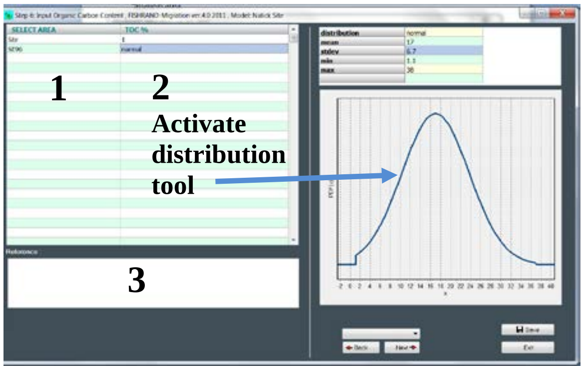
Click *Ok* when all modeling zones have been identified to return to the main screen for this step. Reminder: Quantitative values associated with modeling zones are assigned in subsequent steps.

When modeling zone drawing is complete, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file). Data entry from this point forward will be required over the time scale specified initially, and for each modeling zone.

4.10 Input Organic Carbon Content



In this step, users enter the total organic carbon (TOC) content of the sediment. The previous step defined one or more modeling zones for TOC, which may or may not be the same as the modeling zones for sediment concentrations. The modeling zone names entered previously will appear in the left-hand column *Select Area* **(1)**. Note that the modeling zone names that appear on this screen will only be the shapes defined for TOC assignment in the previous step. The area name "Site" is automatically generated and represents the entire map area. For some sites this may represent background, while for other sites this area may be outside of the analysis area.

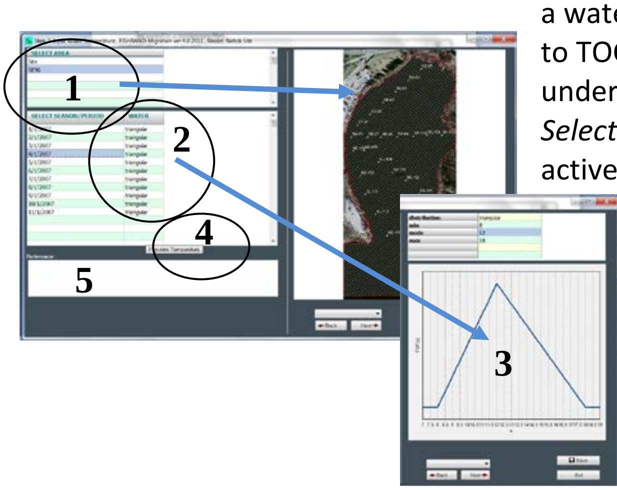


First, highlight an area **(1)**. When the name of a modeling zone is highlighted, a map will appear on the right-hand side of the screen with the selected shape highlighted (red boundary line in the figure on the previous page). Next, click on the *TOC %* value cell **(2)**. This will activate the distribution tool. Enter a point estimate TOC value or define the TOC by parameterizing a distribution. After entering TOC data, supply reference information for the data in a user-defined format **(3)**.

When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.11 Input Water Temperature

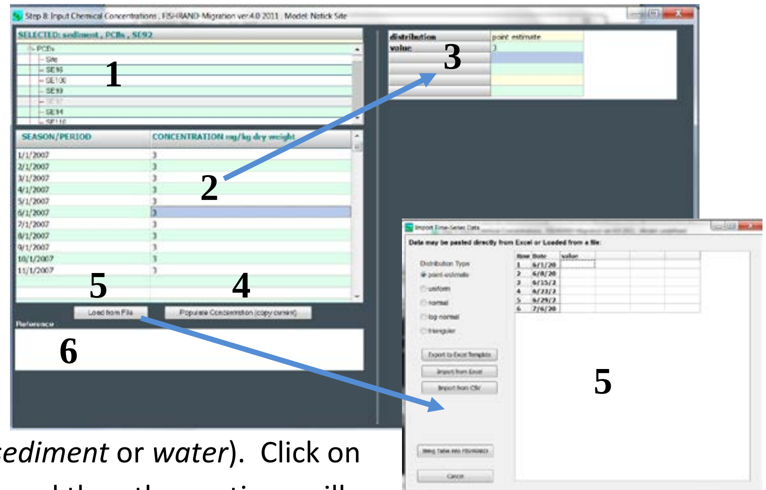
Water temperature is required for the Gobas model and is entered in this step. If modeling zones specific to water temperature were defined in previous steps, then the user should enter a water temperature for each modeling zone. Similar to TOC entry, highlight the modeling zone of interest under *Select Area* and the associated time step under *Select Season/Period* **(1)** and a map illustrating the active shape will appear on the right-hand side of the screen. Enter data by clicking on the *Water Temperature* cell (**2**). A user may enter a point estimate or, using the distribution tool (**3**), parameterize the appropriate distribution. Temperature data must be entered for each time step initially specified, and the *Populate Temperature* **(4)** button can be used to populate the data from the first cell across all time periods if water temperature does not change over time. The same temperature data will be populated whether defined as a point estimate or as a distribution. Enter user-defined references in the space provided (**5**).



When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

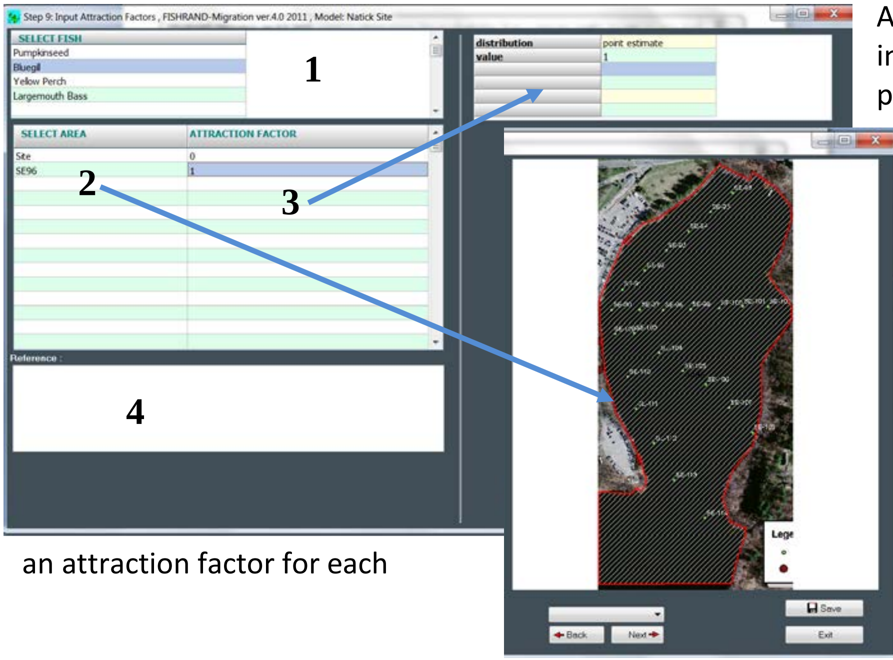
4.12 Input Chemical Concentration

Entering chemical concentration data is similar to the temperature and TOC data entry described in previous steps. Users may enter chemical concentration data for sediment, surface water, or biota (or some combination). If modeling zones specific to the media and the chemical type were defined in previous steps, then a chemical concentration will have to be entered for each modeling zone and chemical-media combination. Similar to TOC and water temperature entry, highlight the modeling zone name of interest **(1)**. In this case the display presents a tier of data entry options (**1**). The top tier is the medium (*sediment* or *water*). Click on the **+** icon next to the medium of interest and the other options will appear below. Next, click on the chemical name and click through each defined modeling zone and enter time-varying chemistry data for each period (**2**). When a modeling zone is highlighted, a map will appear in the right hand window to orient the user (not shown). Chemistry data may be entered as a point estimate or as a distribution (**3)**. Click on the value entry cell to activate the distribution tool. For sites without time-varying chemical concentration data, a button is available to populate all time steps with the data entered in the first cell (**4**). Enter data for the first time step, then click *Populate Concentration* (**4**) to fill in all remaining time steps with the same entry. For biota, a user also selects whether the entered data are lipid normalized or entered on a wet weight basis. The selection window is below the data entry window. Alternatively, time-series data may be imported from an external file through the *Load from File* (5) button, which activates a dialog box with a number of options for importing data from Excel. Users can also export a template to Excel, particularly for entering distributions, which provides the exact format for the selected distribution type that FR-M requires. Finally, enter user-defined references in the space provided (**6**).



When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.13 Input Attraction Factors



Attraction factors are used to increase or decrease the probability that a species will forage in one modeling zone compared to other modeling zones. This is used to specify habitat or foraging areas within a study area that are particularly attractive to fish. If modeling zones specific to attraction factors were defined in previous steps, then enter an attraction factor for each species and each area.

Begin by highlighting the fish species of interest (**1**). Next, select the modeling zone name of interest **(2)**. A map illustrating the active polygon will appear on the right-hand side of the screen (**2**). To select the target modeling zone, click on the name in the table or click directly on the target area on the map. A user may enter a point estimate attraction factor or, using the distribution tool (**3**), parameterize the appropriate distribution for each modeling zone.

Enter user-defined references in the space provided (**4**).

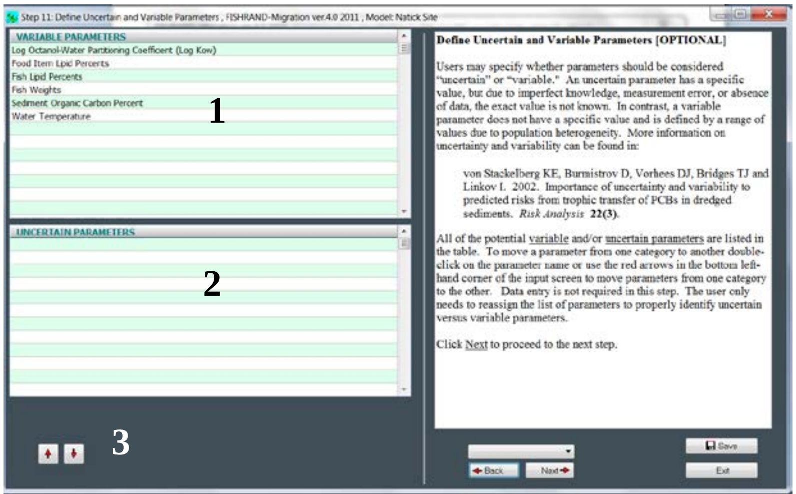
When finished entering inputs for this step, click *Next* to proceed with input entry, *Save* to save the data to an external file, or *Exit* to return to the main menu (data entry up to that point will be saved in a temporary file).

4.14 Input Site Specific Measurements (OPTIONAL)

This option is not functional in the current version of FR-M, but will be added in future releases. For some studies, the user may obtain site-specific fish tissue measurements. These data would be entered into the model for comparison to model results and model calibration/validation.

4.15 Define Uncertain and Variable Parameters (OPTIONAL)

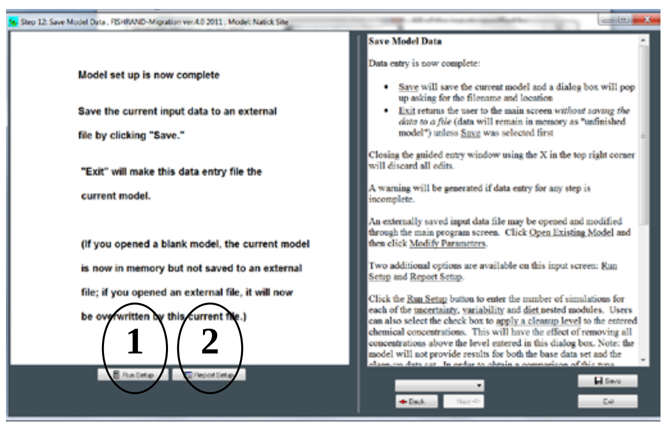
For assessment of uncertainty and variability in the model, a user may specify which parameters are uncertain and which parameters are variable. An uncertain parameter has a specific value, but due to a lack of knowledge, measurement error or a lack of data, the exact number is not known. In contrast, a variable parameter does not have a specific value. Variable parameters have a range of values and they vary due to the heterogeneity inherent in populations.

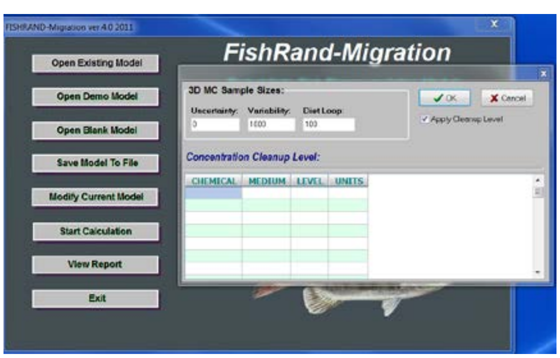


All of the inputs specified by distributions will be listed in the top table (**1**). To move a parameter from the variable **(1)** to uncertain table **(2)** or vice versa, select a parameter and click on the up or down arrow (**3**). Users may want to review von Stackelberg *et al*. (2002a) for additional background on uncertain and variable parameters and analysis of uncertainty and variability.

4.16 Running Model Simulations

The final screen of the guided setup allows users to define the number of simulations for each nested loop by clicking on *Run Setup* (**1**). This dialog box will automatically open again when clicking on *Start Calculation* on the main screen. Users may also select report output options under *Report Setup* (**2**) on this screen or *View Report* from the main screen (assuming the model has been run). Detailed information for that dialog box can be found in the next section.

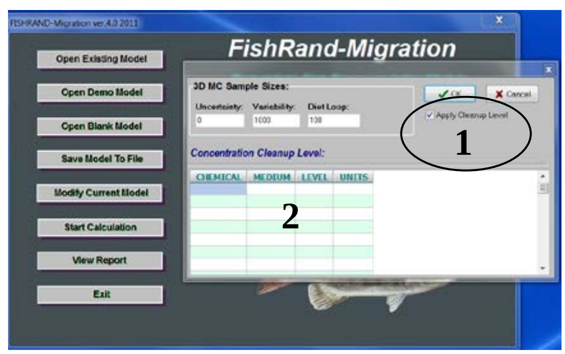




Clicking *Start Calculation* from the main screen or *Run Setup* from this screen brings up the dialog box shown to the left. If data entry is not complete, the following warning message will be generated: "Input for this model was not finished" and the user must click on *Modify Current Model* from the main menu to complete data entry. Following successful data entry, click on *Save* and then *Exit*. Then click *Start Calculation* again.

This will open the Run Model options box shown on the previous page. In this box a user may select the sample sizes for the uncertainty, variability, and diet loops. These functions will only operate if data have been entered as distributions and categorized as either uncertain or variable. As illustrated in Figure 2, FR-M employs a nested Latin Hypercube/Monte Carlo approach for sampling distributions for uncertain and variable parameters. The *Uncertainty Sample Size* refers to number of times that the uncertain parameter distributions will be sampled and, therefore, the number of simulations in the model run. The *Variability Sample Size* may also be specified by the user and refers to the number of times that the variable parameter distributions will be sampled. In general, a higher number of simulations is better, but the increase comes at a computational cost in time. Typical values for these cells range between 100 and 1000. One strategy is to run the model specifying a higher number of samples and then running it again with a lower number and comparing the results to verify that stability in the outputs have been achieved. Finally, a user may specify the diet sample size (*Diet Loop*). Forage fish are exposed to variable diet items (benthic and pelagic invertebrates and phytoplankton), therefore a distribution of diet concentrations is developed. Variability in diet may be explored by specifying the diet sample size or diet averaging time. Because fish diets are variable and the chemical concentrations of diet items are variable depending on where forage fish, invertebrates, or phytoplankton are exposed, the chemical concentrations of predator fish should also reflect diet variability. A typical value for this cell is 10 or higher.

In addition, a user may choose to modify the input dataset to assess the impact of cleanup levels on fish tissue chemical concentrations. First, check off *Apply Cleanup Level* (**1**). Next, choose the chemical, medium and cleanup level/concentration (**2**). The units in the program are fixed and will appear automatically in the units column depending on the medium selected. Any unit adjustments will have to be made externally. The cleanup tool modifies the current data set for the active model run by truncating all input distributions at the level(s) specified in this screen.



The tool does not permanently modify the dataset and the model will only generate the results for the cleaned site data when this function is selected. To run the model under current conditions, deselect this function.

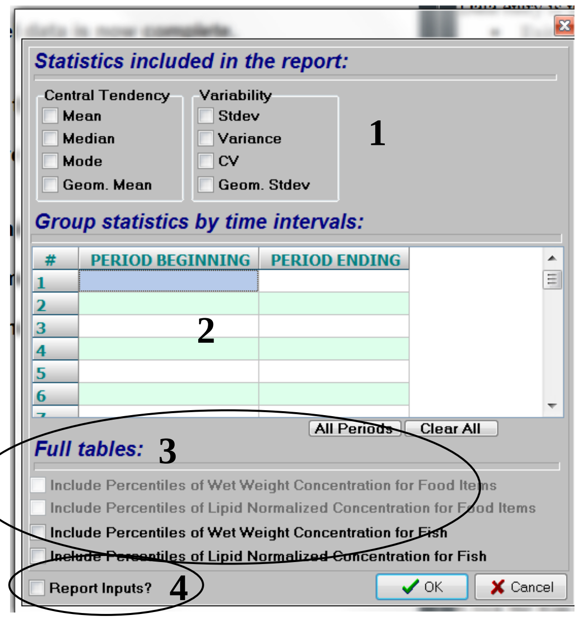
Finally, click <u>Run</u> to complete the calculations. FR-M will run for all chemical and species combinations.

FR-M includes a run status bar. Because some model runs can be very complex depending on the number of assessed chemicals, species and sites, model runs may require many hours. The tool provides the user with feedback on Total Time, Elapsed Time and Remaining Time. These estimates are generated after the model has run for a few minutes.

4.17 Report Viewers

FR-M employs Microsoft Excel to generate simulation reports. After completing the simulation, Click on *View Report* at the main menu.

A report may consist of multiple Excel Worksheets and Workbooks depending on the user-defined content. When a user clicks *View Report*, a statistical selector pops-up. This screen provides the user with a number of reporting options. Because FR-M output is generated in Microsoft Excel, modeling results may be readily copied and pasted into any statistical program for additional assessment.



To begin the report generation process, select the summary statistics to include in the report (**1**). Users may define specific averaging times over which to generate output statistics (**2**). The overall data table will include results across all time periods, but summary statistics can be generated over specific time-periods. For example, a user may elect to evaluate the full time period and also each season independently. The time periods are selected using pull-down menus and one time period may overlap with others. The user also selects the tables to include in the output reports (**3**); a separate output workbook is generated for each of these options. A user may select wet weight or lipid normalized tissue concentration output and view results for prey items and/or the receptor fish species. Finally, a user may elect to include the inputs in the output report using the check box (**4**). Click OK to generate the custom report; an example of a partial summary table is provided to the left.

Fish: Pumpkinseed , Chemical: PCBs

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (ppm)	CV
10/1/07	1/1/08	2.26E+00	2.00E+00	6.41E-01	1.80E+00	3.23E+00	7.96E-01
1/1/08	4/1/08	2.42E+00	2.16E+00	5.06E-01	1.89E+00	3.56E+00	7.81E-01
4/1/08	7/1/08	2.43E+00	2.17E+00	5.26E-01	1.89E+00	3.57E+00	7.77E-01

Fish: Pumpkinseed , Chemical: PCB52

	Central Tendency			Variability			
Beginning	Ending	Mean (ppm)	Median (ppm)	Mode (ppm)	Stdev (ppm)	Variance (p	CV
10/1/07	1/1/08	2.20E-02	2.30E-02	2.60E-03	1.70E-02	2.90E-04	7.83E-01
1/1/08	4/1/08	2.30E-02	2.40E-02	2.40E-03	1.60E-02	2.70E-04	7.23E-01
4/1/08	7/1/08	2.30E-02	2.40E-02	2.10E-03	1.60E-02	2.60E-04	7.08E-01

If the user has selected one or more of the "Include Percentiles" checkboxes shown above (**3**), several additional output files are generated. **Important: Do not work in Excel or open and close any Excel files while FR-M is generating output percentiles.** FR-M generates population distributions of predicted tissue concentrations with our without associated uncertainty depending on whether parameters were specified as uncertain and/or variable. The predicted body burden at the 10th percentile of variability is interpreted as the concentration experienced by 10% of the population or less. If none of the user inputs were specified as “uncertain”, then this would be the only distribution that FR generates. However, when there are uncertain parameters, FR fixes those parameters first, then runs variability loops. The looping is repeated a user-specified number of times with another set of uncertain parameters each time. Upon completion of the model run, there will be as many different “variability” curves representing uncertainty as were specified in *Run Setup*. Each variability percentile has an associated uncertainty distribution. The uncertainty distribution is interpreted as the percent confidence in the variability percentile.

Across the top of the table, a user will see the uncertainty percentiles with each variability percentile underneath (**1**) for each time period specified in the user-defined timescale. In the example below, the 90th percentile uncertainty distributions are shown for all the variability percentiles. We are 90% confident that 90% of the largemouth bass population will experience a predicted body burden of 6.21 mg/kg or less.

1

PCB (total) wet weight normalized Large Mouth Bass,ppm													
Percentile unc.	90%												
Percentile var.	0%	2.50%	5%	10%	25%	50%	75%	90%	95%	97.50%	100%	Mean	Stdev
Time,years													
2/15/77	7.69E-01	7.76E-01	8.19E-01	8.50E-01	8.70E-01	9.21E-01	9.71E-01	1.02E+00	1.09E+00	1.11E+00	1.45E+00	9.32E-01	9.06E-02
3/15/77	2.19E+00	2.27E+00	2.36E+00	2.43E+00	2.58E+00	[illegible]	2.93E+00	3.18E+00	3.32E+00	3.44E+00	6.11E+00	2.81E+00	4.28E-01
4/15/77	4.07E+00	4.12E+00	4.27E+00	4.32E+00	4.61E+00	5.03E+00	5.45E+00	6.21E+00	6.71E+00	7.18E+00	1.54E+01	5.26E+00	1.23E+00
5/15/77	6.27E+00	6.39E+00	6.66E+00	6.81E+00	7.48E+00	7.99E+00	8.59E+00	9.64E+00	1.02E+01	1.07E+01	2.21E+01	8.27E+00	1.69E+00
6/15/77	8.88E+00	8.94E+00	9.10E+00	9.43E+00	1.02E+01	1.10E+01	1.17E+01	1.27E+01	1.34E+01	2.10E+01	2.38E+01	1.13E+01	2.31E+00
7/15/77	1.20E+01	1.22E+01	1.28E+01	1.31E+01	1.40E+01	1.52E+01	1.65E+01	1.77E+01	1.86E+01	2.33E+01	3.41E+01	1.56E+01	2.80E+00
8/15/77	2.48E+01	2.49E+01	2.55E+01	2.61E+01	2.71E+01	3.00E+01	3.16E+01	3.37E+01	3.54E+01	3.61E+01	4.59E+01	2.99E+01	3.30E+00
9/15/77	3.38E+01	3.44E+01	3.47E+01	3.61E+01	3.77E+01	3.98E+01	4.25E+01	4.50E+01	4.57E+01	5.05E+01	5.61E+01	4.04E+01	3.86E+00
10/15/77	3.34E+01	3.37E+01	3.44E+01	3.52E+01	3.66E+01	3.84E+01	4.02E+01	4.26E+01	4.44E+01	4.54E+01	5.07E+01	3.87E+01	3.04E+00
11/15/77	2.62E+01	2.67E+01	2.69E+01	2.75E+01	2.89E+01	3.04E+01	3.22E+01	3.44E+01	3.71E+01	3.81E+01	9.11E+01	3.15E+01	6.35E+00
12/15/77	2.50E+01	2.50E+01	2.55E+01	2.61E+01	2.72E+01	2.86E+01	3.08E+01	3.29E+01	3.52E+01	3.59E+01	9.21E+01	2.99E+01	6.53E+00
1/15/78	2.34E+01	2.37E+01	2.43E+01	2.46E+01	2.57E+01	2.71E+01	2.90E+01	3.16E+01	3.28E+01	3.43E+01	8.58E+01	2.83E+01	6.08E+00
2/15/78	2.22E+01	2.24E+01	2.30E+01	2.35E+01	2.46E+01	2.56E+01	2.75E+01	2.98E+01	3.07E+01	3.28E+01	8.10E+01	2.68E+01	5.73E+00
3/15/78	2.15E+01	2.16E+01	2.21E+01	2.28E+01	2.36E+01	2.46E+01	2.64E+01	2.82E+01	2.91E+01	3.28E+01	7.68E+01	2.58E+01	5.46E+00
4/15/78	2.09E+01	2.10E+01	2.14E+01	2.19E+01	2.26E+01	2.37E+01	2.54E+01	2.70E+01	2.80E+01	3.11E+01	7.16E+01	2.47E+01	5.02E+00
5/15/78	2.07E+01	2.07E+01	2.11E+01	2.18E+01	2.26E+01	2.35E+01	2.51E+01	2.63E+01	2.74E+01	3.09E+01	6.64E+01	2.44E+01	4.56E+00

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Appendix F: Publication Summarizing the 2010 Workshop Results

The following paper and the accompanying editorial, summarize in detail the proceedings and results of the workshop.

1. Wickwire T., et al. (2010). Spatially Explicit Ecological Exposure Models: A Rationale for and Path Toward Their Increased Acceptance and Use. Integrated Environmental Assessment and Management 7: 1-11.
2. Hope BK., et al. (2011). The Need for Increased Acceptance and Use of Spatially Explicit Wildlife Exposure Models. Integrated Environmental Assessment and Management 7: 156-157.

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Critical Review

Spatially Explicit Ecological Exposure Models: A Rationale for and Path Toward Their Increased Acceptance and Use

Theodore Wickwire,† Mark S Johnson,‡ Bruce K Hope,§, and Marc S Greenberg||*

†Exponent, Inc., Maynard, Massachusetts 01754, USA
‡Health Effects Research, US Army Public Health Command, Aberdeen Proving Ground, Aberdeen 21010-5403, Maryland
§Oregon Department of Environmental Quality, Portland, Oregon 97204-1390, USA
||Environmental Response Team, US Environmental Protection Agency, Edison 08837, New Jersey

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ABSTRACT

Spatially explicit wildlife exposure models have been developed to integrate chemical concentrations dispersed in space and time, heterogeneous habitats of varying qualities, and foraging behaviors of wildlife to give more realistic wildlife exposure estimates for ecological risk assessments. These models not only improve the realism of wildlife exposure estimates, but also increase the efficiency of remedial planning. However, despite being widely available these models are rarely used in baseline (definitive) ecological risk assessments. A lack of precedent for their use, misperceptions about models in general and spatial models in particular, non-specific or no enabling regulations, poor communication, and uncertainties regarding inputs are all impediments to greater use of such models. An expert workshop was convened as part of an Environmental Security Technology Certification Program Project to evaluate current applications for spatially-explicit models and consider ways such model could bring increased realism to ecological exposure assessments. Specific actions (e.g., greater accessibility and innovation in model design, increased communication with and training opportunities for decision makers and regulators, explicit consideration during assessment planning and problem formulation, etc.) were discussed as mechanisms to increase the use of these valuable and innovative modeling tools. The intent of this workshop synopsis is to highlight for the ecological risk assessment community both the value and availability of a wide range of spatial models and to recommend specific actions that may help to increase their acceptance and use by ecological risk assessment practitioners. Integr Environ Assess Manag 2011;7:1–11. © 2011 SETAC

Keywords: Wildlife exposure models   Spatially explicit   Area use factors   Remedial decisions

INTRODUCTION

Exposure is critical in understanding the likelihood for adverse health effects to wildlife populations from environmental contamination. Wildlife experience the environment relative to species-specific life history constraints (e.g. habitat) which may overlap with variation in environmental contamination. Consideration of space in an environmental context is crucial, where significant resources are devoted to defining the nature and extent of contamination. Models contribute to environmental assessments from early site analyses through remedial planning, implementation and monitoring. Accounting for spatially explicit relationships is an integral component in many of the most frequently applied fate and transport models, e.g., WASP (Gonenc et al. 2005); WASTOX (Connolly and Winfield 1994); BASINS (Chigbu et al. 2007). Despite broad acceptance of fate and transport models that include spatial components, ecological risk assessments rarely consider the influences of habitat and contamination in a quantitative spatial context meaningful to an assemblage of individuals (populations).

Models provide scientists with the opportunity to increase the value of data collected at a particular contaminated site by facilitating additional research into alternative scenarios, leveraging data collected for predictions in areas lacking data and, when combined with non site-specific data, increasing the efficiency of future direct sampling by highlighting data gaps and clarifying data needs. Ecologists are challenged to incorporate increasingly realistic wildlife exposure scenarios in their work. Models that incorporate species- and site-specific data, and where spatial interactions between environmental contamination and habitat preferences are made transparent and accessible, provide increased realism and enhance predictive capabilities. Recognition of the importance of spatial relationships in environmental assessments is not new. Early ecological risk assessment guidance documents discuss the importance of considering spatial characteristics in an assessment (USEPA 1997, 1998). In this context, these models are of value to risk assessors, environmental managers, and decision makers because of their ability to incorporate important spatial considerations related to exposure into risk characterization, and also to identify uncertainties associated with risk estimates. The challenge is to reach consensus among model developers, risk assessors, and regulators (and within each group, as well as among individuals who work in all three areas) regarding appropriate applications for new models. In addition, if consensus can be reached regarding the use of a spatially explicit model, then a project team must identify the appropriate model, model inputs and assumptions, and have a clear understanding about how the results may be interpreted before results are generated.

As part of an Environmental Security Technology Certification Program (ESTCP) project focusing on spatially explicit wildlife exposure model demonstration and testing, a workshop of U.S. Army, U.S. Environmental Protection

* To whom correspondence may be addressed: hope.bruce@deq.state.or.us
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Agency (USEPA), state regulators, and private sector researchers was convened to evaluate current applications of available spatially explicit wildlife exposure models and approaches for increasing future use of such models. The workshop focused on collecting insights with respect to 4 key questions: 1) What are spatially-explicit wildlife exposure models and why are they valuable? 2) How have such models been applied? 3) Are there regulatory impediments to their use? and 4) What are the limitations of these models and how could they be improved? On the basis of detailed discussions during the 2-day workshop, a set of recommendations was developed using these important tools to estimate wildlife exposures. Although there are numerous applications (e.g., natural resource damage assessment, land-use planning) for these models, here, we concentrated on their applications within the ecological risk assessment (ERA) process—from initial screening assessment through remediation—with respect to contaminated sites. The following summary of our discussions during the workshop is intended to encourage ecological risk assessors to make greater use of spatially explicit exposure models and to provide recommendations for increasing the acceptance and use of such models in ecological risk assessments.

SPATIALLY EXPLICIT EXPOSURE MODELS

Spatially explicit relationships have been considered in site assessments in many forms for many years (Freshman and Menzie 1996; Wickwire and Menzie 2003; Hope 2004; Gaines et al. 2005). Historically, ecological risk assessors have accounted for species-specific spatial requirements using the home range (area over which a species' activities occur, excluding migration) or foraging area (area over which food is sought (USEPA 1993). The traditional approach is to either assume that the entire site represents a species' "home range" or apply an area use factor (AUF) (USEPA 1997). The AUF adjusts exposure on the basis of how much time an individual spends on-site versus off-site and is thus a measure of relative exposure. Putting a small site in combination with a large home range wildlife receptor typically results in a very small AUF. Although this approach considers use of noncontaminated areas by wildlife, it tends to be nonspecific with respect to habitat suitability and has the appearance of being a somewhat arbitrary adjustment in the absence of a consideration of habitat suitability and/or availability. Additionally, erroneously applied differences between "lifetime" home range and daily home range can significantly affect the calculation of a daily exposure estimate. Despite its limitations and uncertainties, the AUF does represent an attempt to integrate spatial considerations into an assessment and is generally an improvement on simply assuming a site is, regardless of the availability of any quality habitat and of a receptor's foraging range, the only area within which a receptor can and does forage.

Approaches for incorporating habitat heterogeneity and preferences into wildlife exposure models vary from no specific accounting to a detailed characterization of the habitat at a user-defined spatial resolution. The designation of habitat versus no habitat is important in and of itself, but there are also gradations in quality among the different habitats in an area that, if properly represented, could improve both exposure estimates and the subsequent hazard assessment. There are habitat models that define habitat suitability for a given species in terms of a habitat suitability index (HIS) (USGS 2010). Including habitat variability and the preference-guided behaviors of receptors in an exposure model increases its realism and ensures that wildlife exposure across a site is influenced by habitat quality and that no exposure occurs in areas devoid of suitable habitat.

In contrast to traditional approaches that evaluate wildlife exposures with no, or only a limited (e.g., AUF), consideration of space and time, spatially explicit wildlife exposure models integrate the spatial determinants of biological activity, physical habitat suitability, and/or chemical variability in various media. As a result, these exposure models capture aspects of spatial (and behavioral) variability typically absent from more traditional wildlife exposure assessments. Chemical concentrations, for example, can vary widely across a site, and not necessarily in any relation to habitat type or suitability. Habitat suitability varies as well, and in many cases, habitat type and suitability vary over much larger spatial scales than does chemical contamination in specific media (e.g., soil, sediment, surface water). Capturing the intersection of habitat, media-specific chemical contamination, and wildlife receptor activity is the goal of exposure modeling. Spatially explicit exposure models increase the realism of that modeling by increasing the resolution of the calculation. By defining the spatial grid over which exposure occurs to reflect variability in both chemical contamination and habitat suitability, the variability in the exposure of each individual receptor can be captured. Some models employ algorithms that emulate movements of wildlife across the landscape guided by habitat suitability. Each day, additional exposures occur and are recorded for each individual. Ultimately, an average or high-end exposure can be estimated reflecting all of the daily exposures. Additionally, many individuals or a virtual (statistical) population may be included in the modeled exposure estimate for the additional benefit of capturing the variability of exposure and, subsequently, of risk These models offer assessors the opportunity to explore how known behaviors overlay with the available habitat and media-specific chemical concentrations to better understand variability in the system. Ultimately, exposure estimates from these models are not estimated based on a single areal average, but rather as a statistic based on numerous model runs representing many individuals over time and space.

Value of these models

Although the goal of this communication is not to review or recommend any particular spatially explicit exposure model, there is value in understanding how spatial considerations have been incorporated into wildlife exposure assessments historically and the variety of such models that are currently available (Loos et al. 2010). These models can be used to better inform risk assessors and risk managers at all stages of a site remediation project, including:

Problem formulation. Often boundaries and operational units are established based on non-ecological factors, such as hydrogeology, property lines, or contaminant sources or distribution. Although these are important considerations, habitat suitability should be considered as an important scaling factor overlaid on these other site demarcations. Spatially explicit models, when used early in the assessment planning stages, can help to focus the assessment on areas where contamination is most likely to intersect with wildlife habitat and foraging ranges, thus minimizing exposure estimates that are unrealistically improbable. By considering the importance of habitat early in the assessment process, its evaluation can be included in the field sampling plan, evaluated during the larger field program, and, ultimately, the remedial plan.

Risk analysis and estimation. Workshop participants generally agreed that these models are more consistent with baseline (definitive) rather than screening assessments given the relative high investment in model parameterization and operation. However, during both screening (hazard) assessments and baseline (definitive) risk assessments, spatially explicit models can be employed in some capacity to determine what, if any, species might be subject to site-related exposures and what areas of a site are likely to be the most problematic. For example, the Spatially Explicit Exposure Model (SEEM) was used effectively to evaluate several bird species with different life histories, and all of management concern, at the Eureka Mills Superfund Site in Utah (USFWS 2009). Logical recommendations regarding risk management at the site were made based on variability in the results in combination with considerations regarding land use and the spatial extent and nature of habitat and chemical contamination. Spatially explicit models allow risk assessors to: 1) Generate more realistic exposure estimates accounting for variability in habitat; 2) Account for species-specific exposure across a heterogeneous landscape by integrating actual wildlife behaviors, thereby capturing a perspective lost when relying only on site-wide average- or maximum-based risk estimates; 3) Avoid misleading results from use of a site-wide average-based risk estimate which might propagate errors such as remediation focused in areas where habitat is insufficient to even support wildlife; and 4) Efficiently suggest a protective risk management solution by both extending the context to consider exposures at ecologically relevant scales rather than operational or legal scales and by narrowing the focus of an analysis to the species that are most sensitive and susceptible based on the presence and orientation of favorable habitats.

Feasibility study/remedial planning. When a remediation project reaches the feasibility study/remedial planning stage, spatially explicit exposure models can be used to assess how different patterns of remedial activities could influence exposure and risk. Through iterative modeling, risk managers can arrive at a remedial solution that balances habitat loss (if any) against needed reductions in chemical concentrations. As there is no necessary correlation between static chemical concentrations in environmental media and habitat, it may be possible to craft remedies that do not significantly impact wildlife habitat. Remedial activities may also have direct costs to wildlife and can result in adverse impacts to specific species. Although there is an historical tendency to choose the most protective solution, the environmental benefits of *appropriate* actions that are based on more accurate prediction of exposures and risk should achieve the desired level of protection more efficiently. The role of a spatially explicit model is not to provide an absolute answer, but rather to capture a range of possible answers to serve as the basis for informed decision-making.

Risk communication. Maps are traditionally an excellent medium for communicating complex assessment results and spatially explicit models typically include map-based features. As a risk communication tool, spatially explicit exposure models can provide diverse groups of interested parties (i.e., stakeholders) with important data in a form that can be readily grasped and acted upon. Decisions regarding which areas to clean-up, how much, and why can be facilitated and expedited when the options are presented visually. Ten acres of prime habitat may have no relevance (or too much relevance) until it is considered within the larger context of the surrounding landscape and the spatial location of possible remedial actions. Mapping tools within the models can also be used to forecast and display risk based on changing site conditions.

Examples of available models

A number of currently available models provide risk assessors with varying capabilities for assessing wildlife exposure to site-related chemicals given a consideration of habitat quality and availability. Table 1 provides an overview and comparison of a subset of available wildlife exposure models. These models have different development histories and, although many were constructed for a specific purpose or project, many are flexible enough to potentially be useful (as is or modified) for other applications. Most of the currently available wildlife models include some sort of movement of the individuals across the landscape, guided by a set of user-defined, and, where possible, species-specific movement rules (Hope 2005; Loos et al. 2010). Otherwise these models vary in terms of the exposure media (water, soil, sediment, etc.) considered, the type of output offered (deterministic [point estimates] or probabilistic [distributions]), and how space is represented for landscape characterization(as a fixed grid of cells or pixel-based, which provides greater flexibility in terms of scale characterization). Some of these models are currently being used for regulatory purposes. For example, the Animal Landscape and Man Simulation System (ALMaSS), a probabilistic individual-based population model, in which the individuals move around the defined landscape based on user assumptions and species-specific behaviors (Topping et al. 2003; Sibly et al. 2005; Dalkvist et al. 2009), has been used in Europe to review the registration of agrochemicals and the influence of new government policies. Similarly, HexSim which is an individual-based, spatially explicit model for evaluating terrestrial wildlife population dynamics and interactions, currently under development by USEPA (Lawler and Schumaker 2004).

Following are two examples of how spatial model outputs might benefit risk assessors and risk managers.

Example 1: Deterministic versus probabilistic approaches. This example compares exposure estimates for songbird species exposed to lead at two small arms ranges made with a deterministic model and site-wide statistics to those generated with SEEM, a spatially explicit wildlife exposure model with probabilistic outputs (Johnson et al. 2007). Avian dietary exposure was estimated with SEEM, which considers the spatial relationships of habitat and receptors, and a deterministic point estimate method with no spatial or habitat considerations. Exposure criteria used for each species were identical for each model. Exposure estimates from both

Table 1. Comparison of spatially explicit exposure models

Model name and description	Key features*	Exposure estimates	Effect endpoint(s)	Spatial representation
ALMaSS (Animal Landscape and Man Simulation System) A landscape scale, spatially-explicit, agent based simulation system for investigating the effect of changes in landscape structure and management on the population size and distribution of animals. Developer - C. Topping et al. 2003.	OM - Yes - based on assumptions and observed behavior. PE - Yes. P/D - Probabilistic. NCS - Food availability, starvation, human disturbance(e.g. plowing, mowing).	Daily Dose (mg/kg/d) Internal concentration (mg/kg)	Population level (abundance, growth rate, persistence, spatial distribution)	Rectangular grid 1 cell = 1 m^2 Area = 100 km^2 10^4 X 10^4 cells Mapping: Spatial characterization within the model on user-supplied base map
RSEM (Resource Selection Exposure Model) A GIS-based model for predicting exposure of midsized wildlife species to soil contamination. Developer - Chow et al. 2005; Gaines et al. 2005.	OM - No PE - Multiple individuals of a statistical population. P/D - Probabilistic. NCS - No.	Daily Dose (mg/kg/d)	Individual level (compare to LOAEL) with compilation of results for population	Hexagonal grid 1 hexagon = 7.8 ha Area = 778 km^2 100 × 100 cells Mapping: Interacts with independent GIS layers
SE⁴M (Spatially and bioEnergetically Explicit terrestrial Ecological Exposure Model) A spatially explicit, random walk model for exploring the influence of spatial and bioenergetic factors on a receptor's acquisition of energy and contaminant tissue residues. Developer - Hope 2001, 2005.	OM - Yes, based on behavior described in the literature. PE - No, individual based - simulation. P/D - Probabilistic. NCS - Food & habitat availability	Internal concentration (mg/kg)	Individual level (tissue residues and energy balances)	Rectangular grid 1 cell = 0.1 ha Area = 1.69 ha 13 × 13 cells Mapping: Spatial characterization within the model on user-supplied base map
SpaCE (Spatially Explicit Cumulative Exposure Model) A spatially explicit, random walk model for assessing dietary exposure of terrestrial vertebrates to cumulative chemical stressors. Developer - Loos et al. 2006; Schipper et al. 2008 (see also Eco-Space: Loos et al., 2009).	OM - Yes, based on assumptions and behavior described in the literature. PE - No, individual based - simulation. P/D - n/a. NCS - No.	Average concentration in food (mg/kg) Internal concentration (mg/kg)	Individual level (comparison with NOECs)	Rectangular grid 1 cell = 25 m^2 Area = 5.6 km^2 913 × 247 cells Mapping: Spatial characterization within the model on user-supplied base map
WBM (Wading Bird Model) A model to assess dietary contaminant exposure of interacting individuals of a wading bird colony. Developer - Wolff 1994; Matsinos and Wolff 2003.	OM - Yes, based on assumptions and on observed behavior. PE - Yes. P/D - n/a. NCS - Food availability.	Internal concentration (mg/kg)	Individual level (foraging efficiency, reproduction success) Population level (colony survival)	Rectangular grid 1 cell = 6.25 ha Area = 1600 km^2 160 × 160 cells Mapping: Spatial characterization within the model

(Continued)

TABLE 1. (*Continued*)

Model name and description	Key features*	Exposure estimates	Effect endpoint(s)	Spatial representation
SEEM (Spatially Explicit Exposure Model) A spatially explicit, rule-based foraging model for assessing dietary exposure of terrestrial vertebrates to cumulative chemical stressors. Developer - U.S. Army and Exponent.	OM - Yes - based on two general foraging strategies described in the literature and implemented as movement rules. PE - Yes, but depends on assumptions and approach; can be a statistical population. P/D - Probabilistic, using 1-D Monte Carlo. NCS - No.	Daily dose (mg/kg/d) Model period dose statistics	Statistical population level (LOAEL/NOAEL based comparisons	Fixed 25 × 25 cell grid User defined polygons are drawn for site chemistry and habitat suitability. Polygon data are translated into a fixed grid for calculations using area-weighted averaging to arrive at a value for each cell. Mapping: Spatial characterization within the model on user-supplied base map
FR-M (FishRand-Migration) A spatially-explicit dynamic aquatic bioaccumulation model (using 3-D Monte Carlo). Developer - U.S. Army Corps of Engineers.	OM - Yes; probabilistic framework that ''reseats'' fish with each simulation. PE - Yes. P/D - Probabilistic, using 3-D Monte Carlo. NCS - No.	Internal concentration (mg/kg)	Individual level (tissue concentration only)	User defined. Mapping: Spatial characterization within the model on user-supplied base map
QEAFDCHN A spatially-explicit, time-varying model for fish migration. Developer - QEA (now AnchorQEA).	OM - Yes, but not explicitly spatial. PE - No. P/D - Deterministic. NCS - No.	Internal concentration (mg/kg)	Individual level (body burdens)	User defined. Mapping: Internal calculations only
HexSim (formerly PATCH) A spatially-explicit, individual-based, multi-species model designed for simulating terrestrial wildlife population dynamics and interactions. Developer - U.S. EPA (http://www.epa.gov/wed/pages/models/hexsim/index.htm)	OM - Yes - based on assumptions. PE - Yes. P/D - Probabilistic. NCS - Habitat quality.	None	Population level (abundance & distribution)	User-defined hexangular grid. Mapping: Interacts with independent GIS layers
RAMAS GIS A metapopulation modeling platform for exposure analysis, population viability analysis and extinction risk assessment. Developer - Applied Biomathematics (http://www.ramas.com/ramas.htm)	OM - Yes - based on assumptions. PE - Yes. P/D - Probabilistic. NCS - Habitat quality & location.	None	Population level (abundance & distribution)	User-defined rectangular grid Mapping: Links directly to user-supplied GIS software

(*Continued*)

TABLE 1. (Continued)

Model name and description	Key features*	Exposure estimates	Effect endpoint(s)	Spatial representation
3MRA (Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment) A system of models for conducting screening-level risk-based assessments of potential human and ecological health risks resulting from chronic exposure to chemicals released fr + om + B65 land-based waste management units (WMUs). Developer - U.S. EPA Center for Exposure Assessment Modeling (CEAM) (http://www.epa.gov/ceampubl/mmedia/3mra/index.html)	OM - No (?) PE - Yes. P/D - Deterministic (probabilistic in FRAMES). NCS - Habitat influences exposure.	Daily dose (mg/kg-day)	Statistical population level (HQs based on mortality, growth, survival, reproductive success)	Rectangular grid 100 × 100 m cells Mapping: Uses external GIS layers within an internal GIS
AQUATOX An ecosystem simulation model for aquatic systems which predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants. Developer - U.S. EPA (http://www.epa.gov/waterscience/models/aquatox/)	OM - Yes, pre-specified by user. PE - Yes (as biomass). P/D - Both options available. NCS - Yes (DO, suspended & bedded sediment).	External exposure Internal dose	A large variety of both individual and population level endpoints	Linked Segments Thermal stratification Flexible scale Mapping: No mapping component, however the program can pull data from BASINS, EPA's GIS and water quality modeling system
MEERC models Individual-based methods to simulate spatial movements of fish schools through the water column. Developer - Multiscale Experimental Ecosystem Research Center (http://hpl.umces.edu/meerc/models.htm)	OM - n/a. PE - n/a. P/D - n/a. NCS - n/a.	Water circulation Nutrients	Evaluate how spatially homogeneous vs heterogeneous ecosystems respond differently to perturbations (simulating mesocosms), and how ecological effects differ from pulse versus press predation by schooling fish	
SADA (Spatial Analysis and Decision Assistance) integrated modules for visualization, geospatial analysis, statistical analysis, human health risk assessment, ecological risk assessment, cost/benefit analysis, sampling design, and decision analysis. Developer - University of Tennessee (http://www.tiem.utk.edu/~sada/index.shtml)	OM - No. PE - No (based on benchmark screening of individuals). P/D - n/a. NCS - n/a.	Daily Dose (mg/kg/d)	Individual level (benchmark screening)	User-defined Includes a geospatial estimator (e.g. kriging) Mapping: Includes internal mapping tool and also accepts externally generated GIS layers

*Key Features:
OM = organism movement; PE = population endpoint; P/D = probabilistic and/or deterministic; n/a = not applicable; NCS = nonchemical stressors.

models were compared to lead dietary dose based toxicity reference value (TRV) using a hazard quotient methodology. These results were then compared to a site-specific risk estimate developed from blood lead data collected on-site. The investigators concluded that SEEM modeling results were more closely aligned with the risk estimate generated from the directly measured blood lead concentrations (Figure 1). SEEM also made a daily maximum calculation for each individual to ensure that acute thresholds are not exceeded. In contrast, the conventional deterministic risk estimates were significantly higher than both the spatially explicit and directly measured risk estimates (Johnson et al. 2007). An additional benefit is that the SEEM can be summarized as a probability of exceeding a TRV, based on Monte Carlo–generated means for each individual over time (Figure 2). This probability distribution is more than a simple hazard classification, and is the type of information consistent with a risk assessment (Tannenbaum et al. 2003).

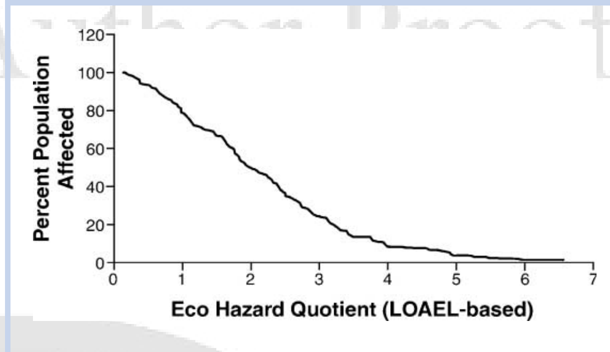

Figure 2. Output from the SEEM model showing the percentage of a statistical population experiencing a given mean hazard quotient, based on a lowest-observed-adverse-effect-level (LOAEL) toxicity reference value (TRV). An increasingly smaller percentage of the population experiences increasingly larger hazard quotients (adapted from Johnson et al. 2007).

Example 2: Risk management decision-making. Because spatially explicit models require users to collect spatially-specific chemical and habitat suitability data, these models can be redeployed during risk management to evaluate how different remedial options may influence risk to wildlife, due to changes in both chemical concentrations and habitat due to remedial actions, thus allowing risk management plans to be fine tuned to meet site-specific goals, including the protection of wildlife. For example, remedial managers may be considering different cleanup options. A brief description of possible options and the benefits and costs of each is provided in Table 2. Habitat use affects exposure estimates. Areas with higher contamination may not be seen as presenting a risk if not used by valued receptors. Conversely, areas of high habitat use combined with relatively high contamination may result in very high exposure and risk estimates. Virtual risk management of various remedial alternatives can be conducted and compared efficiently using these models and optimal solutions for remediation can be determined through iterative model runs.

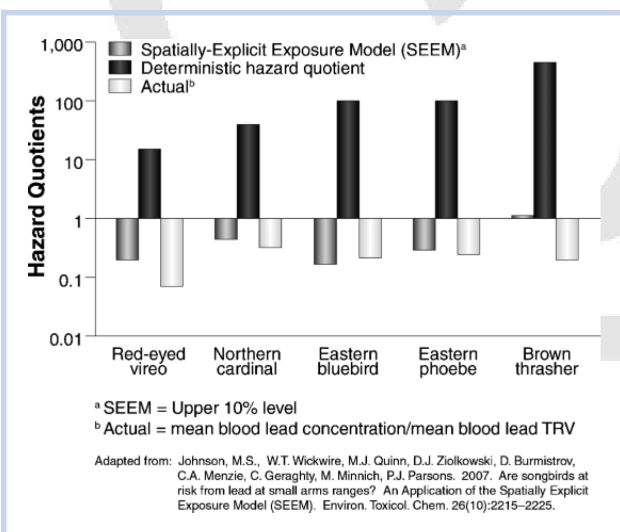

Figure 1. Comparison of hazard quotients determined using measured values, a deterministic reasonable maximum exposure (RME) method, and a spatially-explicit exposure model (SEEM). Note that SEEM produces estimates more aligned with measured values than does the deterministic RME method (adapted from Johnson et al. 2007).

REGULATORY IMPEDIMENTS TO USE

Although workshop participants could not identify any specific regulatory restrictions on the application of spatially explicit wildlife exposure models, a number of impediments to the application of such models were identified. These include few precedents for their use, misguided perceptions as to their purpose, traditional regulatory practices, when such models are considered during the site assessment process, and specific technical concerns, including the quality of input data. Each impediment is discussed briefly below.

Few precedents for use

Though the models have been available, discussed, and updated for years, there are few examples of their application in risk assessments for regulatory purposes. Although the current use of AUFs illustrates that spatial factors are being given consideration in some risk assessments, attempts to use exposure estimates based on more detailed, and possibly more realistic, characterizations of habitat suitability have largely been met with concern. Recently, however, SEEM was used with success at the Eureka Mills Superfund site in Utah (USFWS 2009). This former mining site was divided into 8 exposure areas varying from 15 to 69 hectares in size, and 23 unique exposure/habitat areas were defined. To support the spatially explicit calculations employed by SEEM, Thiesson polygons were used to assign surface soil concentration values to every sample collection point on the site. Exposure profiles for 5 songbird species were developed and assessed. The results corroborated life history attributes and were used in a weight of evidence approach to characterize risk.

Misperceptions as to purpose

Spatially explicit exposure models can be perceived, incorrectly, as simply a means to ''dilute'' exposure estimates so that subsequent risk estimates are lower and less ''protective'' remedial options are favored. However, simply basing remedial decisions on a protective, rather than a predictive, model may not result in actual protection of wildlife populations. Active remediation (e.g., soil excavation

Table 2. Summary of costs and benefits relative to various remedial options

Remedial option	Benefits	Costs
Site-Wide Removal: Remove all soils with a contaminant concentration greater than a specific preliminary remediation goal (PRG).	Public perception – clean the entire site	No consideration of habitat quality or replacement; potential unnecessary loss of habitat and indirect wildlife harm; high costs associated with remediation.
Hotspot Removal: Remediate a few hotspot areas. A reduced acreage of habitat removed, but some elevated locations of a chemical may remain on the site.	More focused clean-up areas – potentially lower cost	Habitat quality not considered; potential unnecessary loss of habitat and indirect wildlife harm; high costs
Risk-Based Balanced Remediation: targeted soil remediation to ensure population protections while balancing conservation of habitat; arrive at the best protective plan through iterative risk management planning.	Protect the wildlife population – save key habitat when possible; Arrive at a defensible approach using transparent cost-benefit analysis; visualize landscape changes and their influence before remediation begins.	Public perception may be that pollution is not being fully addressed. Managers have the information to illustrate important choices and trade-offs between removal, habitat preservation, and habitat restoration.

with attendant removal of overlying vegetation [i.e., habitat], dredging of sediment) comes at a cost, specifically in the reduction in habitat use during restoration, which can be especially significant to threatened and endangered species where habitat is the often the primary regulating factor (Wilcove et al. 1998). Other misperceptions include believing that modeling cannot possibly provide useful outputs because it requires so little investment of time, data, or resources or that using a model will lead to protracted and burdensome disputes about parameter values, disputes that will slow progress toward actual remediation.

Regulatory practices

Few precedents for use, in combination with these misperceptions, has made regulators hesitant to specifically support use of spatially explicit models. In addition, there is an expectation on the part of many regulators that risk assessments will, for simplicity and consistency with common practice, incorporate default, nonspatial, protective (reasonable maximum), nonprobabilistic approaches. Although they predate recent advancements in spatially explicit models, current guidance documents do not specifically preclude or endorse the use of spatially explicit models; but do, however, tend to focus on spatially neutral approaches. Larger framework statements about risk assessment do recognize the need for more flexible and realistic exposure tools and some risk assessments have given limited consideration to spatial factors through the use of AUFs. However, as mentioned previously, approaches that realistically capture the variability in both habitat and chemical distribution are rarely used or discussed.

Timing of inclusion in the assessment process

Although spatially explicit methods are not suitable for every risk assessment, they can add value to baseline (or definitive) assessments at larger, more complex sites, particularly those involving highly valued habitats and ecological receptors (e.g., critical habitat, endangered species). They can be of assistance only if their role and data needs are given consideration early in the assessment process, and ideally during planning or problem formulation phases. It is extremely hard to retrofit the data needs of a spatially explicit model into an assessment once the project plan has been finalized and field work has commenced in a non–spatially explicit manner. Therefore, during the initial stages of an assessment, preliminary data should be collected that may allow spatially explicit exposure models to be of value to the baseline or definitive assessment. Following identification of assessment and measurement endpoints, specific and pertinent data can be collected that will help delineate habitat suitability as well as assist in better characterizing the extent of chemical contamination. Often, these data are not extensive nor is obtaining them particularly burdensome—habitat suitability indices typically require only 2 to 4 data for their calculation. Often these data can be gleaned from existing data: Natural Resource Management Plans, aerial photography, or limited field surveys.

Technical concerns

Although use of spatially explicit models can raise a number legitimate of technical and data quality concerns, these concerns should not be used as excuses for not employing such models where they might otherwise add value to an assessment. Some typical technical concerns, and means for their possible resolution, are outlined below.

Determination of suitability. Habitat suitability is an important component of many spatial models and its determination can be contentious, particularly when a species-specific HSI model does not already exist. Although suitability is most effectively by an ecologist or by natural resource personnel who have worked with the receptor and know its habitat requirements well, a consensus may be also reached through course habitat suitability assignments (e.g., high, medium, low) based on species presence data.

Assessment population size. The size (as the number of model iterations) of the assessment (statistical) population can affect the shape of the distribution of output values, with the curve becoming ''smoother'' as more and more individuals are modeled. An inclination to use the most accurate population size often results in a ''saw-toothed'' curve, which is hard to interpret. One solution is to use a high estimate of population size combined with a series of iterations to achieve the best exposure estimate for the individuals of the population.

Assessment area. Reducing the assessment area to include only ''hot spots'' (small areas with very high contaminant concentrations) may reduce the population size to a few (perhaps unrealistically few) individuals. Conversely, expanding the assessment area to include substantial areas with habitat but without contamination is often criticized as an attempt to ''dilute'' exposure estimates. Workshop participants agreed that species-specific life history criteria combined with relevant population information could be used to select an assessment area. That is, the area of exposure should be determined after careful consideration of the habitat available for utilization by a population during an exposure period (e.g., a season). Assessors are advised to take receptor's requirements into consideration, and consult with stakeholders, to determine an optimal assessment area (stakeholder involvement may be needed to allow for data collection on adjoining private lands).

RECOMMENDATIONS FOR INCREASING USE

Balance complexity with accessibility

As many model developers know, finding the proper balance between a feature-rich model, user accessibility, and transparency for decision makers is one of the more challenging steps in the model design process. Users may include risk assessors, environmental engineers, and biologists. Decision makers may include risk managers and policy makers and, by extension, the constituencies to which they respond. Users must be able to easily describe to decision makers and stakeholders the features of the model and how it works—that it is not simply a black box. The optimal choice generally is a model that is no more complicated than necessary to inform the regulatory decision. The challenge for designers is how to achieve the stated goals in a transparent, accessible model. Selection of a model and its features requires, for example, a well-defined objective, an understanding of technical possibilities, close communication with the user community, understanding monetary constraints, and distribution method. Close and frequent communication with the user community and decision makers is necessary to ensure that an appropriate balance of features and complexity is achieved as these improvements are included.

Enhanced guidance with examples and case studies

Even if the design of the model is intuitive, a user-friendly, clear, and comprehensive guidance manual provides a foundation for new users. Step-by-step instructions are important, but examples of applications and model outputs, along with well-documented case studies, will likely be the most encouraging and useful to new users. Case studies offer the opportunity to state a specific question, illustrate how the model is setup to answer that question, demonstrate how data are entered and results generated, and how the results were interpreted for and used by risk managers. The tendency to create a guidance document early on in the process with little attention to the application and with no plan for guidance updates leads to models that are applied by the developers but few others. Guidance documents can be considered living documents, and developers should consider updating them on a routine basis including the incorporation of user input. One of the most frequently mentioned concerns about spatially explicit models is that they are ''fixed'' to produce lower estimates of exposure and risk than are deterministic (point estimate) models. There is no better way to dispel this mistaken belief, and convey the value of a model, than to provide examples of real-world applications. Case study examples might include an example of an analysis made with data collected while considering habitat compared to one made with data collected only from chemical hot spots. The value of comparative case studies is their being able to demonstrate why results differ between different approaches to risk estimation. By presenting detailed examples, potential new users can see what data and assumptions underlie the differing estimates. Case studies can also be used to illustrate how iterative models runs can be used to focus in on the most effective and efficient remedial solution.

Emphasize earlier consideration in the process

One of the historic limitations on the use of spatially-explicit models has been the timing of their introduction into the assessment process. If they are introduced to a project at all, it is too often after study areas within the site (e.g., operable units) have been delineated without consideration of habitat. It is often unclear at a site *a priori* how habitat availability and chemical concentrations interacts might influence wildlife exposures—the highest chemical concentrations may not be colocated with habitat, rendering wildlife exposures negligible or, conversely, highly attractive habitat could harbor sufficient contamination to pose a problem with prolonged exposure. Earlier consideration of a spatially explicit model's data needs may provide insights into the need for specific sampling in order to understand the potential exposures. Identifying these needs early in the assessment process allows for coordination with other sampling that is planned for the site. It can be prohibitively resource intensive to remobilize a project's workforce simply to gather habitat data. If, however, these models were introduced at the beginning of the assessment process, during the planning and problem formulation phases, then study areas could be demarcated so as to ensure collection, congruent with collection of all other site-specific data, of habitat data supportive of a spatially explicit assessment, thereby avoiding the impediment of remobilization costs.

Increase interactions with the regulatory community

Increased appropriate use of spatially explicit models would be greatly encouraged if the results from such models were shown to be useful to and accepted by regulatory decision makers. Even if such models are not specifically recognized in existing regulatory guidance, their use by regulators to solve specific problems would likely lead to their use within the wider environmental community. Working collaboratively with the regulatory community to develop new guidance would also help align model products with the expectations of the various agencies who may ultimately provide oversight at sites seeking to use spatially explicit models. Increasing opportunities for hands-on training with direct access to the models, as well as including regulators on peer review panels, may also model visibility and assist in understanding needed improvements in modeling features, approaches, and assumptions. External, independent reviews are another way to increase awareness within the regulatory community of models and their uses. The Center for Exposure Assessment Modeling (USEPA 2010) offers an existing option for formalized review and distribution through appropriate regulatory agencies.

Expanded communication with risk community

Developers of spatially explicit models need to identify and employ consistent communication channels to alert risk assessors to the availability of these models and any updates them, as well as to receive feedback from users as to model performance and applications. Some avenues for communication between developers and users are briefly discussed below. More than 1 of these channels may need to be used on a consistent basis if effective bilateral communications are to occur.

New media such as Web site blogs and listservs also provide the opportunity to more directly communicate with users and encourage new applications.

Publications. Publications are the traditional platform for presenting technical information about new models, the results of research using them, as well as case studies using model results. Publications can, depending on the nature and extent of their reader base, be important tools for reaching a large and varied groups, encompassing both users and decision makers. A publication series focused on different spatially explicit models and their applications would help increase the visibility of these tools and provide a focal point for comparisons of functionality and features.

Conferences. Conferences offer a venue where it is possible to reach a large number of people at one time, present the latest findings and developments, obtain real-time feedback, and offer hands-on demonstrations. Conferences should, ideally, include a diversity of environmental practitioners from regulators to consultants, researchers and industrial representatives. The opportunity for real-time interactions among a number of different practitioners and decision makers allows for valuable feedback while expanding the number of risk assessors who are comfortable with the models.

Other recommendations. Workshop participants discussed and generally agreed upon a number of other ideas for improving the utility and utilization of spatially explicit models, including (in no specific order): 1) Providing linkages to conventional, preferably widely available, GIS applications, as more sophisticated geospatial tools and geostatistical approaches may be better at delineating the extent of both contamination and habitats; 2) Ability to easily adjust exposure calculation algorithms; 3) Polygon-specific adjustments to site-specific soil bioavailability values; 4) Use bioaccumulation regression equations to estimate food uptake; 5) Adding interactions between individuals and predator/prey relationships for greater realism; 6) Including life history parameters for various life stages; 7) Harmonizing output from these models with those from human health assessments, because some spatially explicit models provide results that are directly (e.g., FishRand-Migration estimates fish body burdens for human consumption) and indirectly (early indications of stressed sentinel populations) applicable to human health; and 8) Further research is needed to corroborate model estimates with field measures.

SUMMARY

Workshop participants reached a consensus on spatially explicit wildlife exposure models being an important tool for increasing the predictive power of ecological risk assessments, and for improving the effectiveness and efficiency of risk management decisions. The participants also agreed that developers have not yet succeeded in fostering widespread acceptance and application of these models. By increasing model visibility in both the regulatory and risk assessment communities, opportunities will be identified and the existing models can be more directly tuned to meet users' needs and expectations. Ultimately, as more sites use these models, they will gain greater acceptance. Additional research aimed corroborating model results with field observations will be key to user acceptance, allowing for these important tools to gain greater application in baseline ecological risk assessments. The models are valuable throughout the different stages in the assessment process, but increasing the acceptance and use of these models will require a concerted effort by developers and regulators. Ultimately, the goal of increasing the realism of ecological assessments can be attained with a balanced and thoughtful integration of spatially explicit wildlife models.

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The Need for Increased Acceptance and Use of Spatially Explicit Wildlife Exposure Models

Bruce K Hope,† W Theodore Wickwire,‡ and Mark S Johnson§*

†Oregon[Q1] Department of Environmental Quality, 811 SW Sixth Avenue, Portland, Oregon 97204, USA
‡Exponent, Inc., Maynard, Massachusetts, USA
§Health Effects Research, US Army Public Health Command, Fort Sam Houston, Texas

(Submitted 7 September 2010; Accepted 5 October 2010)

Letter to the Editor

DEAR SIR:

When estimating and characterizing risks posed by chemical stressors, assessors must capture wildlife exposures to chemicals in either abiotic or biotic media. The scientific and regulatory communities generally recognize that the relative spatial positions of wildlife and contaminated media can strongly influence estimates of exposure and hence of risk. It is rare, however, to find an ecological risk assessment that explicitly considers spatial relationships of contact and habitat use in estimating exposure potential. The common practice is to assume that: 1) an exposed individual moves randomly across an exposure area, thus allowing the area-averaged media concentration to be used to estimate the true average concentration contacted over time; 2) equal time is spent throughout the exposure area; and 3) measures of individual exposure are equally applicable to a local population of that species. This approach ignores all information about the relative spatial patterns of contaminants or wildlife, and of wildlife behavior. Wildlife typically have more specific habitat requirements and preferences, more circumscribed foraging areas, and a greater variety of reasons for exclusion from, or containment within, areas where exposure to chemical contaminants is a possibility. Moreover, this averaging approach provides no measure of variability among individuals within a population, and hence produces a single value from which decisions are made. This suggests that more accurate, and possibly more ecologically realistic, ecological risk assessments would result if the relative spatial relationship of receptors, their habitats, and contaminants were routinely considered and quantified. By extension, any decision based on such an ecological risk assessment would also be both better informed and more ecologically relevant.

A 2-day workshop was convened with 14 participants from the US Army, US Environmental Protection Agency (USEPA), state agencies, and private sector researchers and consultants to evaluate applications of currently available spatially explicit wildlife exposure models and to discuss use, limitations, and potential improvements. [The workshop was held in March 2010 in Menlo Park, CA. It was sponsored by the Department of Defense, under the auspices of the Environmental Security Technology Certification Program, for the purpose of evaluating current applications of available spatially explicit wildlife exposure models and discussing ways to increase their use in risk assessments.] Although spatially explicit models are used for research purposes (Loos et al. 2010), our focus was on increasing their use in regulatory decision-making. Workshop participants reached a consensus that such models are an important tool for increasing the realism of ecological risk assessments and for improving the effectiveness and efficiency of risk management actions. The participants also agreed that, to date, developers have not succeeded in fostering widespread acceptance and application of the models. Discussion focused on collecting insights with respect to a set of key questions: 1) Are these models available and have they been applied?; 2) What are the limitations of these models and how could they be improved?; 3) What is their value in the context of an ecological risk assessment?; and, 4) What are the regulatory impediments to their use? On the basis of in-depth discussions during this workshop, it was agreed that: 1) Such models are available and have been applied in specific instances; 2) The models have both technical and procedural limitations, many of which could be alleviated through additional research and testing; 3) They can add value to an ecological risk assessment by giving risk managers (decision-makers) ecologically relevant insights into interactions between stressors, receptors, habitat, and remedial goals and objectives; and 4) Despite the absence of specific legal or statutory restrictions, lack of precedents (i.e., documented prior regulatory uses) and concerns about risk prediction rather than a protective screening assessment has led to a hesitancy on the part of regulators to specifically endorse the use of spatially explicit models.

Although the application of area use factors (an area use factor accounts for the size of a study area relative to the size of a wildlife receptor's home range [Suter 2007]) indicates a rudimentary willingness to consider spatial factors, attempts at more detailed incorporation of receptor behavior and preferences, habitat suitability, stressor heterogeneity, and the resultant exposures have largely been met with hesitance. This hesitancy appears to stem from a preference for the ''simple'' threshold screening approach that has come to dominate USEPA and state guidance during the past 20 years, as well as cost and schedule considerations on the part of regulated entities that discourage doing more than is minimally necessary to pass regulatory muster, regardless of how any lack of representative information might subsequently hamper or bias decision-making. Recently, however, 1 such model (the Spatially Explicit Exposure Model [SEEM]) was used to successfully estimate ecological risk at the Eureka Mills Superfund site (Wickwire et al. 2004; USFWS 2009). More examples of successful use and regulatory acceptance at major sites will be needed to establish the precedents to both allow and encourage use of spatially explicit models. It is possible, but not assured, that regulatory acceptance would be greater for spatially explicit

* To whom correspondence may be addressed: hope.bruce@deq.state.or.us
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models that met criteria established by the USEPA's Center for Environmental Assessment and Modeling, which evaluates the utility and effectiveness, availability of adequate documentation, degree of acceptance and application by users, and adherence to good software development practices of a model.

Although federal and state guidance documents do not specifically preclude or endorse the use of spatially explicit models, there is, in general, a tendency on the part of risk managers (and their constituencies) to prefer screening assessments that rely on static, nonspatial, nonprobabilistic (point estimate) methods and conservative generic assumptions. The use of a more ecologically representative exposure model can be misrepresented as an attempt to under-represent (i.e., ''dilute'') these ''protective'' screening estimates simply to support outcomes that are less burdensome for the responsible party. The assumption is that a higher estimate based on a single, site-wide exposure statistic and a number of simplifying, but untested, assumptions is a ''better'' predictor of actual exposures than an estimate, particularly a lower estimate, obtained with a model. Recent research appears to refute this assumption that a lower model estimate should be automatically suspect. Johnson et al. (2007) compared estimates of wildlife exposure to lead made with a nonspatial model to those obtained from a spatially explicit probabilistic model (SEEM). They concluded that SEEM results were more closely aligned with directly measured blood lead concentrations than were estimates made with the nonspatial model, which typically produced exposure estimates significantly higher than measured exposures. Additional similar studies for other species and ecosystems will be necessary to further validate SEEMs. Overcoming the misconception that such models systematically, and perhaps intentionally, under-represent actual wildlife exposures will be a critically important step in fostering greater use of SEEMs.

The utility of a spatially explicit assessment for informing decision-makers will vary depending on the nature of the problem under investigation and the decision context. It is possible to include spatial considerations in screening assessments (those intended to narrow the scope of subsequent assessments) through use, for example, of an area use factor. Generally, however, the increased information demands of a spatially explicit analysis will restrict its use to definitive risk assessments (those intended to provide the basis for management decisions [Suter 2007]). Given the vast differences between study areas and decision contexts, it is not possible to make absolute a priori statements as to whether a spatial analysis would be of use or not. The decision to include such methods in an assessment should be based on the outcome of planning and problem formulation processes that are the essential precursors of informative assessments. Appropriately greater use of spatially explicit techniques will also require a change in the informal policies, or perhaps just loose practices, that have encouraged decisions for even large, ecologically complex areas to be influenced by estimates from screening assessments. It bears repeating that ''...estimates of risk, produced solely for screening or risk-ranking purposes, have too often been used inappropriately as a definitive basis for decision-making. Such use might be attractive to decision-makers, but it seriously distorts the intentions of risk assessors who produce the estimates.'' (NRC 1994). A firm and clear policy to use definitive risk assessments, and not screening assessments, to inform management decisions for ecologically complex situations would promote both greater use of spatially explicit methods and provide decision-makers with more ecologically meaningful decisions.

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