DEVELOPMENT OF A STANDARDIZED PROCESS FOR RANKING AND PRIORITIZING CONTAMINANTS IN THE CONTAMINANT ASSESSMENT PROCESS

by:

Sara Ward
U.S. Fish and Wildlife Service
Ecological Services
Raleigh, North Carolina

and

Dr. Damian Shea and Dr. Greg Cope
North Carolina State University
Department of Environmental and Molecular Toxicology
Raleigh, North Carolina

December 2005

PREFACE

This report describes work carried out under an interagency agreement between the U.S. Geological Survey (USGS) and the U.S. Fish and Wildlife Service (FWS) (IAG 1445-1A09-95-0179) to evaluate the process for ranking and prioritizing contaminants as part of the Contaminant Assessment Process (CAP) and is based on a task description developed by the USGS Biomonitoring of Environmental Status and Trends (BEST) Program (2000). Several individuals have contributed to this project and we wish to recognize their efforts. Jim Coyle and Chris Bunck of the USGS BEST Program along with the FWS's Division of Environmental Quality (DEQ) staff in Arlington (Mary Henry, George Noguchi, and Craig Moore) arranged initial project meetings and provided technical assistance and project oversight during the course of this work. Tom Augspurger of the FWS's Raleigh Field Office provided overall project coordination and technical expertise in the development of this report.

TABLE OF CONTENTS

APPENDICES

1.0 INTRODUCTION

1.1 Purpose and Overview

This report describes a more thorough evaluation of the process for ranking and prioritizing contaminants on Department of the Interior (DOI) lands identified through the Contaminant Assessment Process (CAP). The CAP is an electronic database of contaminant sources to, and receptors at risk on, DOI lands. The CAP methods are currently being used to inventory contaminant concerns on National Wildlife Refuges nationwide, and there is a desire to expand their scope by including a more rigorous contaminant prioritization scheme. This report explores the feasibility of the ranking and prioritization process discussed at the November 1999 meeting held between staff from the U.S. Geological Survey (USGS) Biomonitoring of Environmental Status and Trends (BEST) Program and the U.S. Fish and Wildlife Service (FWS) Division of Environmental Quality (DEQ). They desired development of a standardized, systematic process for screening-level estimation of risk posed by contaminants to resources managed by DOI. Further development of this process will also support the interpretation of regional assessment data collected by the BEST program. This work was conducted as described in the project proposal, *Development of a Standardized Process for Ranking and Prioritizing Contaminants in the Contaminant Assessment Process (CAP)* (Augspurger et al. 2001).

The need for a modified contaminant ranking and prioritizing system has evolved from the Idaho National Engineering and Environmental Laboratory (INEEL) approach where estimates of toxicity and exposure values were applied to the CAP in order to review and interpret contaminant issues on DOI lands (Figure 1-1). The goal of the ranking and prioritizing approach is to interpret information gathered in the CAP in order to develop cost-effective, focused, data collection plans for field sampling. A review of the initial INEEL approach concluded that significant variability in the toxicity and exposure value estimates assigned by various users led to inconsistent interpretations of CAP information. To address this problem, the USGS and FWS proposed a standardized ranking and prioritization system (hereafter referred to as the SRP approach) (Figure 1-2). The SRP approach includes the development of a standard set of toxicity and exposure values for potential contaminant-species interactions in order to improve the accuracy, consistency, and comparability of contaminant issues identified by CAP applications nationwide.

Due to the impracticality of compiling a database for all possible chemical/species interactions, we evaluated contaminant and species groupings for the SRP approach. For each contaminant class and species functional group, a surrogate chemical and species would be selected. Toxicity information for the model chemicals representing each chemical class will be provided for the surrogate species chosen to represent each functional classification of organisms. Those would be assembled into a toxicity estimation database. CAP users would hence have a new tool of standardized surrogate species toxicity reference values. Using these values, CAP users would then define refuge-specific exposure estimates for each model chemical-surrogate species pairing. To achieve an overall risk estimate for ranking and prioritizing contaminant concerns, the numeric value for the toxicity estimate would then be multiplied by the numeric value for the refuge-specific exposure estimate.

1.2 Organization of Document

The following report is separated into five main sections to address tasks outlined in the original project proposal (Augspurger et al. 2001). Section 1.0 presents the introduction and a brief synoposis of the project. Section 2.0 of the report summarizes our evaluation of the proposed and existing ranking and prioritization approaches including a summary of critical data elements for the proposed SRP, professional perspectives, and a comprehensive review of existing chemical ranking and prioritization approaches. Section 3.0 presents a review of functional grouping systems for organisms and highlights two grouping systems appropriate for SRP applications. Section 4.0 includes a discussion of chemical classification and chemical ranking and scoring protocols and presents the results of an application of one chemical ranking approach using representative species outlined in the proposed functional grouping systems (in Section 3.0). Results and recommendations are provided in Section 5.0.

1.3 Reference for Section 1

Augspurger, T., Myers, S., Noguchi, G., and Henry, M. 2001. Project proposal to USGS-BRD. Development of a standardized process for ranking and prioritizing contaminants in the Contaminant Assessment Process (CAP). Department of the Interior. U.S. Fish and Wildlife Service.

INEEL Approach

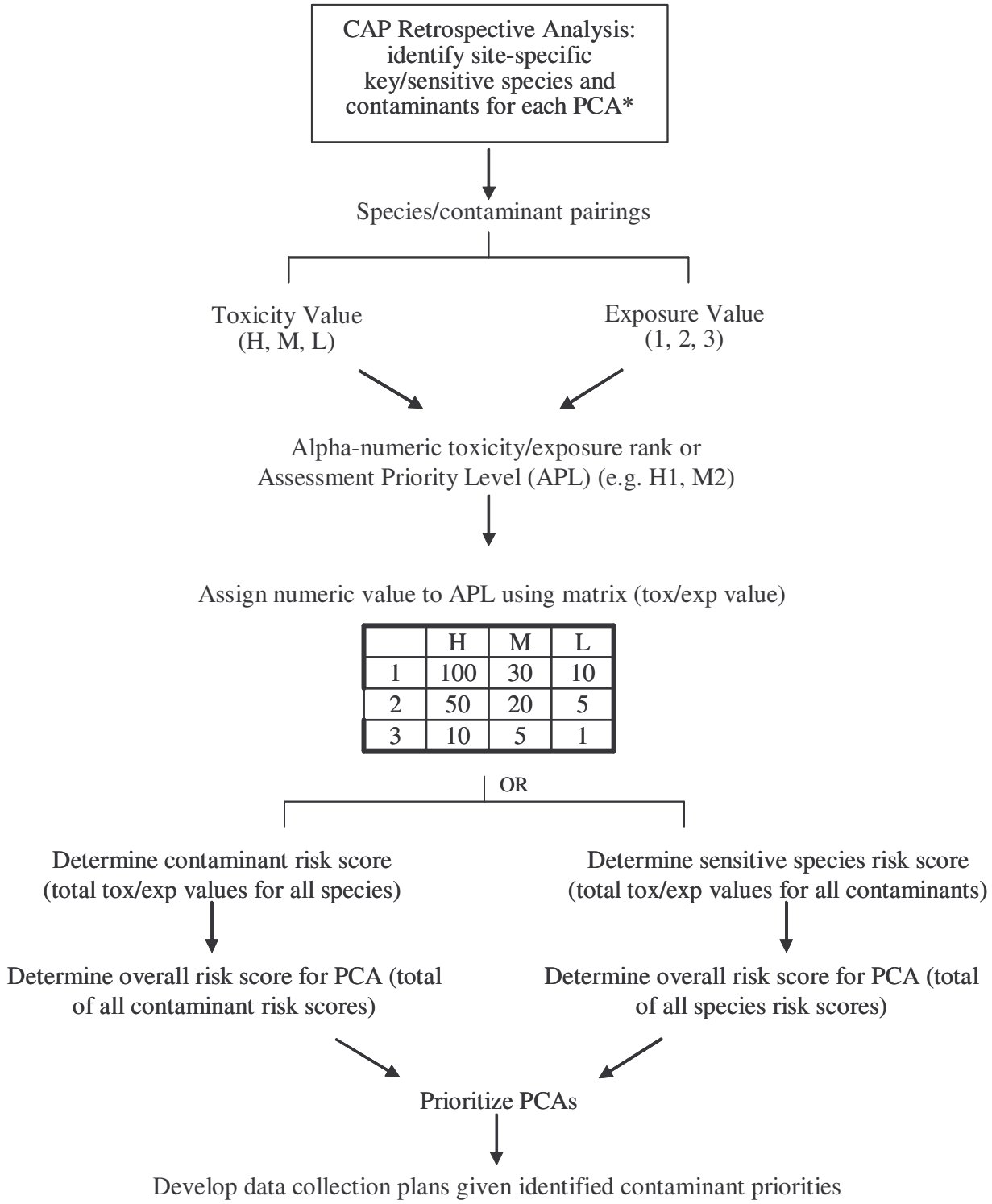


Figure 1-1. Diagram of approach proposed by INEEL

* PCA = potentially contaminated area

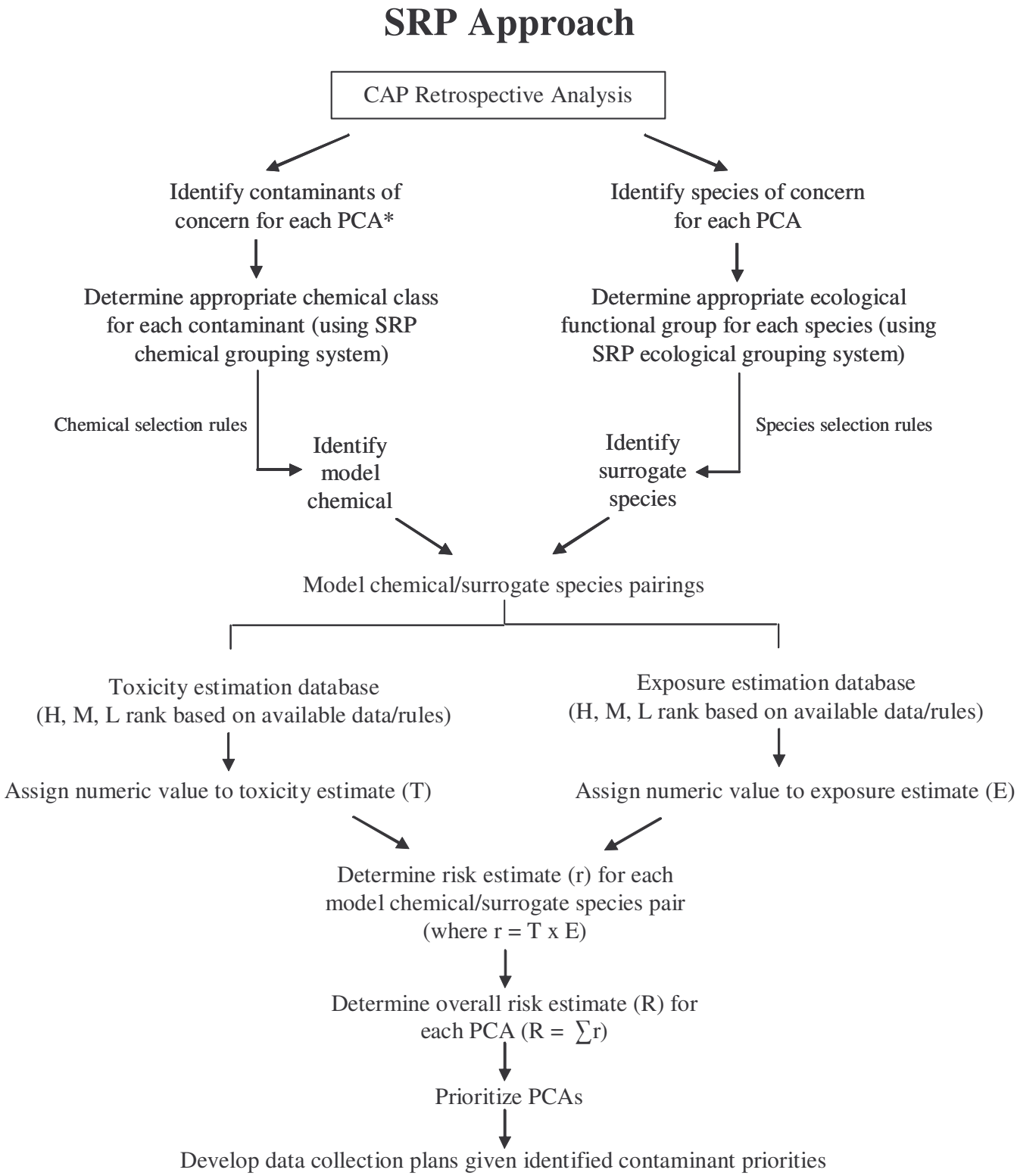


Figure 1-2. Diagram of proposed standard ranking and prioritization (SRP) approach

* PCA = potentially contaminated area

2.0 EVALUATION OF THE PROPOSED AND EXISTING RANKING AND PRIORITIZATION APPROACHES (TASK 1)

2.1 Review of the CAP Approach and Critical Data Elements

As a foundation for expanding the CAP approach to include the SRP approach (either as part of the CAP data management system or as a stand alone decision support tool), the CAP process was implemented on two refuges in North Carolina (one with recognized contaminant issues and another where contaminant issues were minor). A review of completed CAP reports nationwide was also conducted. During the review of completed CAP reports for refuge areas nationwide, particular emphasis was focused on the ability of the existing data management system to support the data needs of the SRP approach for CAP (e.g., the surrogate-based ecological functional grouping and chemical classification systems). For the ecological functional grouping system and the chemical classification system, a review of required data elements was conducted. The following sections evaluate the CAP approach, existing data elements, critical data elements for SRP development, and potential limitations of the present data management system for CAP based on those critical data elements.

2.2 Completion of North Carolina CAP Projects

Two CAP projects were completed in North Carolina as the basis for developing an understanding of the complexities of the CAP approach on a refuge with documented contaminant concerns (Alligator River National Wildlife Refuge (NWR)) and a refuge with limited contaminant inputs and low potential for impacts to trust resources (Cedar Island NWR). Completion of these projects provided a foundation for better understanding of the CAP approach, the CAP data management system and associated data elements, and potential uses for information maintained in the CAP data management system. As part of these projects, background information about the refuges was collected and reviewed, interviews were conducted (with refuge staff, professionals with expertise or additional understanding of refuge resources and potential contaminant concerns), and site reconnaissance was conducted. Familiarity with the data elements of the CAP data management system was achieved during the information entry phase of the CAP projects. Establishing this foundation as a CAP user was important to adequately review CAP reports nationwide, the next project component.

2.3 Screening of Nationwide CAP Reports for Refuge Areas

A total of 113 completed CAP reports were reviewed to determine if the information needs of a SRP system could be satisfied by the current CAP format, or if modification of the existing system would be necessary. These CAP reports were selected for review based on the summary statistics for completed CAP reports available online (https://ecos.fws.gov/cap_summaries/cap_summaries.html?module=123) in August 2001.

2.3.1 Critical Data Elements for the Species Grouping System

A system for classifying organisms into functional groups is a primary component of the proposed SRP approach. For each functional group in this system, representative species would be identified based on several selection criteria. This ecological functional grouping system coupled with toxicity information for the surrogate identified in the chemical classification system forms the basis for a toxicity estimation database with qualitative descriptors of high, medium, and low hazard, or toxicity (with associated numeric values). Information regarding the species at risk at a site is essential to support the SRP approach. For a given site, a complete list of potential receptors is a critical data element in the ecological functional grouping component of the SRP approach (see Section 3.0 for more information). For each species potentially at risk, a suitable surrogate based on species identified for each function grouping must be identified. Additionally, information about other species with similar phylogeny is desired. For example, in cases where toxicity data is not readily available for a given surrogate organism/surrogate chemical pairing, the investigator should substitute a species within the same genus. If toxicity information is still lacking, a search for toxicity data for a species in the next-higher category (e.g., genus followed by family, order, class, phylum) of the hierarchal biological classification system must be conducted.

Currently, the CAP data management system includes several fields where information about species potentially at risk is reported (e.g., species assessment section, biotic transport pathways section, and individual narrative fields where species impacts can be detailed); however, there is not a specific field for potential receptors in the "potentially contaminated area, report" section. It is recommended that a specific data entry field, "receptors potentially affected", be added to the 'potentially contaminated areas' reporting screen. Ideally, for each receptor listed, links to taxonomic information for that organism and related species would be provided so that the primary investigator could make informed decisions regarding the species surrogate/chemical surrogate pairings. More detailed information regarding the ecological functional grouping system, the rules for surrogate selection, and the development of toxicity estimates is provided in Section 3.0.

2.3.2 Critical Data Elements for the Chemical Classification System

In the proposed chemical classification system component of the SRP approach, contaminants would be grouped into a limited number of classes for which physical and chemical characteristic profiles would be developed. A model chemical would be chosen for each chemical class based on various selection criteria (e.g., toxicity, availability of ecotoxicological information for the surrogate species identified in the ecological functional classification system, etc.) Several fields are available within the existing CAP data management system to support the data needs of potential chemical classification systems. These were reviewed to see if changes in the format of CAP may be necessary to ensure that consistent contaminant information is available.

A review of the contaminant classes frequently identified in completed CAP reports was conducted. This information provides a foundation for 1) the development of the chemical

classification system (e.g., to identify frequently identified contaminants of concern for which data may not be readily available and to assure that chemicals identified as known problems on DOI lands are adequately addressed in the proposed chemical classification system) and 2) the potential refinement of the existing CAP data management system to better address the data needs of the SRP approach. Completed CAP reports were reviewed to assemble the list of contaminant issues reported in Table 2-1. These CAP reports were selected for review based on the summary statistics for completed CAP reports available online in August 2001 (https://ecos.fws.gov/cap_summaries/cap_summaries.html?module=123) using the "contaminant concerns by refuge" function for each region.

2.3.2.1 Identification of Frequently Selected Contaminant Concerns

Individual CAP reports completed for refuges nationwide were screened to identify where potential data gaps exist or may arise (e.g., chemicals for which limited toxicity information exists) in developing a toxicity matrix. The existing CAP data management system provides a list of contaminant classifications (in a pick-list format) for contaminant specialists to choose from when characterizing contaminant concerns. Some of these classifications are specific to one contaminant (e.g. aluminum, mercury, fluoride), while several contaminant classifications are broad (e.g., toxic materials, organochlorines, petroleum products). This review focused on broad contaminant classes in the CAP data management system, in particular, so that individual contaminant issues that have been reported by contaminant specialists as known problems on refuges nationwide could be determined. By identifying specific contaminants mentioned in the text of CAP reports for which a broad contaminant class was selected, potential data gaps and limitations of the existing system was established. Table 2-1 illustrates specific contaminant concerns identified by contaminant specialists in reports where a broad contaminant class was selected.

2.3.2.2 Reporting Discrepancies

While there are over 70,000 chemicals in commerce, Table 2-1 indicates that CAP users specifically identified only about 30 inorganic and 100 organic chemicals as concerns on DOI lands when broad contaminant categories were selected. Any SRP approach should emphasize the current use herbicides and insecticides which represent the most common concerns. A small list of specific chemicals may also lend support to developing specific toxicological profiles for these compounds (an option to weigh against the inherent generic nature of toxicity estimates in a surrogate chemical SRP approach).

During this review process, several discrepancies in the reporting of contaminant information for individual refuges were identified. While reporting discrepancies are not likely to impede the development of a chemical classification system for the SRP approach, they potentially undermine the overall goals of the CAP approach (which is the basis for the ranking and prioritizing process). The CAP approach strives to standardize the documentation and assessment of contaminant threats to lands and biota. The data management system, in particular, is intended to document CAP findings, enhance the Service's institutional memory, and support informed management decisions. Consistent and accurate reporting of contaminant

data, therefore, is fundamental to the CAP approach. Reporting discrepancies discovered during the review of completed CAP reports are described in detail below in Table 2-2**.**

Under Reporting of Contaminant Concerns (False Negative)

One discrepancy identified by the review of CAP reports is that the total number of "potentially impacted areas" for a given contaminant class listed in the summary statistics for completed CAPs does not match the number of refuges for which that class was selected in the refuge CAP reports. For example, a total of six refuges in Region 1 were identified as "potentially impacted areas" affected by "other organics" in the CAP summary statistics section; however, review of the individual reports shows that this particular contaminant class was not selected in the CAP contaminant pick list for four out of the six refuges reported. In the remaining two refuge CAP reports, the category "other organics" was selected in the report and specific contaminants were cited in the report narrative sections. According to Tim Kern of the Midcontinent Ecological Science Center (MESC) Technology Applications Team, this discrepancy is most likely due to the query function of the CAP summary statistics database. The summary statistics report retrieves data from several sources in addition to the CAP data management system. For example, the "other organics" class was not mentioned in the CAP report for Humbolt Bay National Wildlife Refuge in Region 1, but was selected in 3 additional reports (the refuge management information system (RMIS) report, California state data, and a salmon contaminant report) that were queried to develop the summary statistics report. This discrepancy is problematic because it reflects a contradiction between reports archived in the ECOS system. The frequency of this data reporting discrepancy is illustrated in Table 2-2 where the total number of "potentially impacted areas" (Total) for a given contaminant class is shown relative to the number of refuges for which the particular contaminant class was not identified (NI) in the CAP report.

Table 2-1. Specific contaminants concerns identified for broad contaminant classes in all CAPs (n = 113) completed as of September 2001

Broad CAP (Picklist) Categories	Specific Contaminant Issues Identified in CAP Reports
Airborne Gaseous Pollutants	natural gas, SO_2, inorganics, ozone, ammonia, VOCs, NOx, CO, hydrocarbons
Airborne Particulates	Pb, SO_2, As, Zn, road dust, Cu and lime mine waste, waste/refuse
Carbamates	dithiocarbamate, aldicarb, cycloate, carbaryl
Color	none reported
Dissolved Solids	irrigation drain water, waste water treatment plant discharge, septic-related, agricultural runoff
Heavy Metals	Al, As, B, Ca, Cd, Cu, Cr, Fe, Hg, Li, Mo, Mn, Na, Ni, Pb, Sb, Se, V, Zn, butyltins
Nutrients–Other than Sewage	unionized ammonia, ammonia, phosphates, nitrates
Organochlorines	DDT, DDE, DDD, toxaphene, endrin, alpha chlordane, chlordane, oxychlordane, dichloropropene, cis-1,2-DCE, 11DCE, mirex, dieldrin, heptachlorepoxide, nonaclor, pentachlorophenol, methoxychlor, lindane
Organophosphates	temephos, naled, phorate, famphur, parathion, methidathion, tribufos
Other Inorganics	irrigation drainwater trace metals, As, B, mine tailings (Zn and Cu ore), butyltins, V, Ni
Other Organics	dibenzofurans, aliphatics (chain oils, waxes), benzene-soluble compounds,
Other Pesticides[1]	methoprene, rotenone, 2,4-D, 2,4,5-T, carbofuran, metaldehyde, mineral oil, glyphosate, dicamba, chlorothal-dimethyl, fenuron, desmedipham, thiophanate methyl, manzoceb, difenzoquat, zinc phosphide, sodium fluoroacetate, acrolein, aluminum phosphide, bentazon, quizalofop-P-tefuryl, trifluralin, ethalfluralin, clethodim, imazamox, pendimethalin, sethoxydim, thifensulfuron-methyl, fenoxyaprop-P-ethyl, lactofen, imazethapyr, diclofop-methyl, clopyralid, MCPA, bromoxynil, triflusulfuron-methyl, fentin hydroxide, benomyl, acetochlor, atrazine, bromoxynil, clopyralid, Doubleplay (dicontinued acetochlor and EPTC mixture), nicosulfuron, chlorothalonil, picloram, DCPA, aquabec (silvex, discontinued), imazapyr, imazaquin, flumetsulam, Dual (metolachlor, discontinued), imazameth, alachlor, fluazifop-butyl, norflurazon, clomazone, fluometuron, Triox, Damminix, indrum
Petroleum Products	diesel, crude oil, fuel products, PAHs, gasoline, oils, lubricants, petroleum hydrocarbons, BTEX, methanol, hydraulic oil, motor oil
Polyaromatic Hydrocarbons	fuel, oil, crude oil, xylene, styrene
Polychlorinated Biphenyls	none reported
Radioactive Materials	Americium-241
Settleable Solids	none reported
Solvents	paint and paint waste, chlorinated hydrocarbon solvents, benzene, toluene, xylene, triethylene glycol, ethylbenzene
Suspended Solids	none reported
Synthetic Pyrethroids	fenvalerate
Total Solids	none reported
Toxic Materials	acrolein, petroleum products (diesel), plastics, metals, road salt, chemicals
Trace Elements	Al, As, Cd, Cr, Cu, Hg, Mn, Pb, Se, Zn
Urea and other Organic Nitrogen Compounds	urea, ammonia fertilizer
Volatile Suspended Solids	none reported
Water Quality Parameters	water temperature, dissolved oxygen, chlorophyll, ammonia, bacteria, salinity, nutrients, pesticides, sedimentation, pH, turbidity, fecal coliform, chemical oxygen demand, biological oxygen demand

[1] pyrenes, phenanthrene, Triox, Damminix, and indrum were also listed as pesticides concerns

Table 2-2. Completed CAP summary statistics for broad contaminant classes

Contaminant Class	CAP Reporting Statistics for Potentially Impacted Areas					Percent Totals for Potentially Impacted Areas			
	NI	NS	NC	S	Total	NI	NS	NC	S
Airborne Gaseous Pollutants	32	14	8	6	60	53	23	13	10
Airborne Particulates	23	19	0	4	46	50	41	0	9
Carbamates	3	12	0	2	17	18	71	0	12
Color	2	0	0	0	2	100	0	0	0
Dissolved Solids	14	6	0	5	25	56	24	0	20
Heavy Metals	12	20	0	20	52	23	38	0	38
Nutrients--Other than Sewage	17	22	0	4	43	40	51	0	9
Organochlorines	12	20	0	12	44	27	45	0	27
Organophosphates	10	23	0	4	37	27	62	0	11
Other Inorganics	7	5	1	8	30	23	17	3	27
Other Organics	14	11	1	7	41	34	27	2	17
Other Pesticides	7	24	0	23	69	10	35	0	33
Petroleum Products	13	25	17	10	65	20	38	26	15
Polyaromatic Hydrocarbons	16	18	2	3	39	41	46	5	8
Polychlorinated Biphenyls	4	15	1	0	20	20	75	5	0
Radioactive Materials	9	3	2	1	15	60	20	13	7
Settleable Solids	8	6	0	0	14	57	43	0	0
Solvents	17	5	2	4	28	61	18	7	14
Suspended Solids	16	6	1	0	23	70	26	4	0
Synthetic Pyrethroids	2	8	0	2	12	17	67	0	17
Total Solids	9	1	0	0	10	90	10	0	0
Toxic Materials	6	5	2	3	16	38	31	13	19
Trace Elements	11	12	0	6	29	38	41	0	21
Urea and Other Organic N Compounds	6	7	0	1	14	43	50	0	7
Volatile Suspended Solids	4	1	0	0	5	80	20	0	0
Water Quality Parameters	13	18	3	10	44	30	41	7	23

NI = not identified (contaminant class not selected from pick list in CAP report)

NS = not specified (contaminant class selected in CAP report but specific contaminant not specified)

NC = no known contamination problem (contaminant class selected due to potential affects of spills or background atmospheric deposition--no existing contaminant problem)

S = identified (contaminant class selected in CAP report and specific contaminant specified)

Total = total number of "potentially impacted areas" (refuges that are potentially affected by a given contaminant class according to the CAP summary statistics report)

During the review of CAP reports for this analysis, there were several occasions where a given contaminant concern (e.g. use of urea for deicing) was cited in the narrative section of the CAP report but the corresponding contaminant classification (urea and other nitrogen compounds) was not selected from the pick list. Although a specific concern is documented in the report narrative, this contaminant problem will not be captured in the nationwide totals because the summary statistics query function does not retrieve information from narrative sections. This is an additional discrepancy that could result in an underestimation of contaminant threats on refuges when compiling summary statistics. The frequency of this under-reporting occurrence is unknown and is subsequently not included in Table 2-2.

Reporting Specificity

The review of completed CAP reports for which broad contaminant classes had been selected revealed another potential limitation in the development of a chemical classification system. In many of the completed CAPs, a contaminant category was selected in the pick list and a specific contaminant of concern was identified in the subsequent narrative explanation; however, most completed CAPs reviewed did not provide additional information concerning the nature of the contaminant problem.

To some extent, additional contaminant information in the narrative section may be absent because a specific contaminant of concern has not yet been identified at the site. In the data management system for CAP, contaminants are selected from a pick list and information about the contamination level is requested. Contamination levels 1 (known contaminant sources and documented contaminant problems) and 2 (known sources and presence) are the only designated categories for which the presence of a contaminant is known. For contamination level 3 (known sources, suspected presence) and contamination level 4 (no known sources other than atmospheric deposition), specific contaminants of concern may not be known. In CAP reports where contamination level 1, 2, or 3 were selected, a rationale for selection of these categories is requested in the field "description of area and importance to study". This field does not require that a list of contaminants of potential concern be included and they are sometimes not provided even when known.

Additional detail and specificity in reporting contaminant concerns would benefit both the CAP approach and the development of a SRP system. Because CAP is intended as a standardized approach for documenting and assessing threats posed by contaminants to DOI resources, it would appear essential to document not only broad classes of contaminants known to affect a given area, but also to convey site-specific contaminant concerns when known as part of the CAP report. In addition, a complete list of contaminants known to affect refuges nationwide could guide the development of representative chemical classes and surrogates for the ranking and prioritizing system. Information about the number and type of chemicals found on refuges for which toxicological data is not readily available would also allow assessment of potential data gaps in any species versus chemical toxicity matrix developed to support consistent rankings. Table 2-2 illustrates the number of completed CAP reports where a given contaminant class was selected but a specific contaminant concern was not specified (NS).

Over Reporting of Contaminant Concerns (False Positive)

An additional reporting discrepancy results (typically in Section 9–Spill Sensitive Areas of the data management system) when contamination level 4 (no known sources other than atmospheric deposition) is selected and several contaminant classifications are identified as associated with the site. In this case, the contaminant classifications highlighted reflect those compounds that are likely to impact an area in the event of a spill, not contaminants that are known or even suspected to be present at the site. When summary statistics are compiled for all completed CAP reports, the contaminant pick lists are queried for information about contaminant threats on refuges. Consequently, those areas where a contaminant class was selected based solely on a potential spill threat are included in the total number of areas potentially impacted by a given contaminant class. This can result in an overestimation of the number of refuges actually affected by specific contaminant classes. Table 2-2 shows the number of completed CAP reports where a given contaminant class was selected, but no existing contamination (NC) problem exists at the site (e.g., the contaminant class was selected due to potential affects of spills or background atmospheric deposition).

Overestimation of contaminant impacts to refuges also results when more than one contaminant classification is selected for one known contaminant problem. For example, lead contamination can be captured by the selection of multiple contaminant categories (e.g., lead, heavy metals, trace elements, toxic materials, etc.) in the contaminant classification pick list. When summary information is compiled for all completed CAP reports, the potential impact of one contaminant problem is magnified based on the number of categories that are selected as representative of the given contaminant issue. The frequency of this overestimation and overall effect of this reporting discrepancy cannot be determined and is not included in the results shown in Table 2-2.

2.3.2.3 Potential Refinement of the Existing Data Management System

To ensure that consistent contaminant information is available for ranking and prioritizing contaminant concerns, refinement of the existing data management system for CAP to address the reporting discrepancies described above should be considered. Common reporting concerns include lack of specificity in documentation of contaminant concerns and both under- and over-reporting of existing contaminant problems. The following recommended modifications to the existing CAP data management system are based on observations made during the review of over 100 completed CAP reports:

- The data management system for CAP would be strengthened by 1) increasing the specificity of the contaminant classifications available for selection in the pick list (e.g., limit the number of broad categories) and 2) providing a detailed description of the contaminant categories in the pick list field including common contaminants and species of concern related to each given category. Providing descriptions of classifications in the pick list along with guidance for selecting categories (e.g., possibly instructions limiting selection to the one classification that best describes a documented contaminant concern) should reduce the number of reporting discrepancies resulting from lack of specificity

and from overestimation (through selection of multiple classifications for one documented problem) of contaminant concerns.

- One under-reporting concern identified during the review of completed CAP reports is that contaminant information compiled in reports archived in the Environmental Conservation Online System (ECOS) database is not reflected in the CAP report. Although the existing system already retrieves data from RMIS and the Contaminant Information Management and Analysis System (CIMAS), the system would be further strengthened by including links to abstracts (or the ability to download the entire report) of these and other related reports (e.g., state data) which are queried to compile the summary statistics for completed CAP reports. Providing additional information regarding existing reports archived in ECOS should ensure that all existing contaminant data is reviewed by a contaminant specialist and captured in the CAP report. This modification would also improve consistency between existing information systems.

- Additional specificity in reporting would be provided by assigning a contamination level (1-4) to each individual contaminant category rather than to a potentially contaminated area as a whole. Currently the data management system requires a contaminant level to be assigned to each potentially contaminated area. By designating a contamination level for each contaminant, the current status (e.g., known presence, suspected presence, documented contaminant problem) of each individual contaminant could be confirmed. By linking a contamination level to individual contaminant categories, reporting deficiencies associated with identifying contaminants that are listed solely based on their role as a potential spill threat can be resolved. The summary statistics query function of ECOS could then be modified such that contaminant categories selected that correspond to a contamination level 4 designation would be excluded from the "potentially impacted areas" totals.

- Modification of the data management system to include a new field, "chemicals of potential concern", would facilitate the documentation of site-specific contaminant concerns and enhance the reporting specificity. This field would be completed in all CAP reports where contamination level 1, 2, or 3 is selected to describe a given contaminant class.

2.4 Professional Perspectives

Independent assessments of the proposed SRP approach were obtained through interviews with risk assessment professionals. A total of four interviews were conducted. Discussion points focused on an assessment of the proposed SRP approach, perspectives on the existing prioritization systems with goals similar to those of the FWS, potential limitations of ranking and prioritization systems, and advantages to using prioritization tools. The following sections discuss the perspectives of each of the risk assessment professionals interviewed. Their initial feedback is being used to guide project development.

Anne Fairbrother, DVM, PhD (U.S. Environmental Protection Agency, Chief, Ecosystem Characterization Branch, Western Ecology Division)

When questioned regarding her perspective on the proposed SRP for the CAP, Dr. Fairbrother indicated that the theory of the proposed approach is sound and that further development of such a system is worthwhile; however, she noted that there are several additional considerations and potential modifications that should be accounted for in the application of the SRP in the CAP. One concern, in particular, is related to the development of relative sensitivity rankings for various species/contaminant pairings. Dr. Fairbrother indicated that this approach would be valid in many cases; however, notable exceptions would result due to species specific variability (e.g., susceptibility of smaller organisms to contaminant exposure and impacts due to greater surface area), variable susceptibility to contaminant exposure at different trophic levels (e.g., food chain exposure effects magnified in carnivore versus herbivore), and chemical-specific differences (e.g., using model chemicals might oversimplify chemical-specific exposure concerns).

To improve the overall accuracy of the proposed approach, Dr. Fairbrother suggested 1) consideration of site-specific conditions and 2) selection of representative feeding guilds. Dr. Fairbrother also noted that a clear statement of the goal of the ranking approach (e.g., ranking site-specific concerns vs. national programmatic prioritization of contaminated sites) is necessary. She suggested that, regardless of the overall goal of the model, the SRP approach should have the flexibility to include regional and/or site-specific conditions (background conditions, soil types, etc). Additionally, she noted that minimal data collection efforts (e.g., three to five samples at a site) could greatly improve the model performance.

The most notable limitation of ranking and scoring systems, according to Dr. Fairbrother, is their assumption of complete contaminant transport and absorption. In many cases, this conservative assumption, although not necessarily representative of existing conditions, results in model output that is protective of ecological endpoints. When asked about the ability of existing ranking and prioritizing approaches to meet FWS needs, Dr. Fairbrother indicated that each existing approach is designed with specific agency goals in mind and would not be applicable to FWS needs without significant modification. Therefore, Dr. Fairbrother believes that further development of the SRP pilot approach for the FWS based on risk assessment theory is appropriate.

Wayne Landis, PhD (Western Washington University, Director, Institute of Environmental Toxicology and Chemistry)

Dr. Landis noted that the proposed SRP approach shares some of the features of existing systems (including his relative risk model - see Section 2.5.4.2); however, he is critical of its reliance on surrogates to simplify the SRP matrix. Dr. Landis indicated that using representative chemicals and surrogate species pairings to develop a model for toxicity results in a tradeoff of accuracy for consistency. Ultimately, he believes that such an approach produces nonsense results that may over- or underestimate actual ecological risks. He also notes that the proposed approach lacks an

uncertainty analysis, which he deems essential to determine the accuracy and sensitivity of the model.

Dr. Landis indicated that a focus on risk assessment theory must be maintained to obtain meaningful model output. He suggests that the following elements must be considered to accurately estimate risk: 1) the spatial component of the model (e.g., distribution of the toxicants and the assessment endpoints); 2) transparency of the model (e.g., clearly stated rules and assumptions, consistent calculations, and reliance on readily available information and common software); and 3) the geographic extent of the assessment (e.g., focus on site-specific concerns).

Given these concerns when prioritizing risks, Dr. Landis suggested that a system similar to the relative risk model could meet FWS needs. He recommends tying a geographic information system (GIS) component to the relative risk evaluation approach at each refuge in order to assess potential sources and delineate subareas of concern (grouped by stressors and potential impacts). The relative risk model in its current form is likely to be too detailed for routine application by field personnel; however, Dr. Landis indicated that several options are available to tailor this approach to support the CAP (e.g., simplification of the model based on commonalities of refuges or the formation of a staff group that would conduct the process for all refuges).

Bradley E. Sample, PhD (CH2M Hill)

Given the objectives of the FWS in developing the SRP approach, Dr. Sample indicated that there is no existing ranking or prioritizing system that he is aware of that would be applicable to the needs of the Service. Dr. Sample acknowledged that the FWS has made considerable progress on developing a tailored risk prioritization system; however, he had several concerns with the proposed SRP approach in its current form. He cautioned that there are no "cookbook approaches" to assessing ecological risks; therefore, it would be inappropriate to utilize a system that does not account for site-specific concerns (and data, if available). He also expressed concern over the use of representative chemicals in the SRP approach. By using model chemical compounds, he indicated that there would be a loss of resolution and accuracy in the model due to 1) the chemical-specific variability in toxic responses and 2) the physiochemical nature of the compound. Dr. Sample suggested that the focus of the approach should be broader than toxic affects alone and should address characteristics such as persistence and bioaccumulative potential. An additional limitation of the SRP approach, according to Dr. Sample, is the semi-quantitative structure of the model. He suggests that assigning numeric values to the toxicity estimate and the exposure estimate in the SRP approach in order to develop a numeric risk value (for prioritization purposes) for each potentially contaminated area creates data that has no basis in reality. Because the SRP approach is based on qualitative information from a retrospective analysis, qualitative ranking of contaminant concerns (e.g., through tallying of marks on a checklist or assessment of high priority attributes) is a more appropriate measure of risk prioritization. Finally, Dr. Sample felt that the proposed approach would be strengthened by increasing the transparency of the model. He suggested that a clearly defined management goal for the application of the approach (site-specific ranking of contaminant concerns vs. regional or national ranking of contaminated sites) is essential to determine the ability of the system to achieve meaningful results.

Based on these concerns and his understanding of FWS objectives for developing this system (Dr. Sample focused more on site-specific applications to aid field biologists rather than regional and/or national ranking of contaminant concerns), Dr. Sample recommends a tiered approach that follows the general risk assessment paradigm. Dr. Sample suggests that the first tier of such an approach would encompass site descriptors, an evaluation of the relative resource value of the site, and a review of all potential sources and stressors. The information compiled in the data management system for CAP particularly lends itself to application to this tier of risk analysis. At this stage, qualitative ranking could be conducted for each attribute of interest (e.g., the number of contaminant threats, acute/chronic concerns, use patterns relative to spatial extent of contamination, potential magnitude of exposure, frequency of contaminant events, etc). Tier II would involve documentation of the types and quantities of chemicals present and the potential for exposure and Tier III would review what existing information is available for a site and what data remains to be collected. Dr. Sample indicated that these tiers could be developed to guide field biologists through subsequent levels of screening level risk assessments. Dr. Sample suggested that the tiered approach coupled with guidance documents to assist field investigators in developing and carrying out data collection plans should provide a consistent and meaningful understanding of site-specific risks consistent with FWS goals.

Glenn Suter, PhD (U. S. Environmental Protection Agency, National Center for Environmental Assessment)

When asked about the potential for existing ranking and scoring systems to meet the objectives of the FWS, Dr. Suter indicated that ranking and scoring systems in general are not a sound approach for screening contaminant risks. Dr. Suter noted that there are many types of these existing systems (due to their popularity in the late 1970s and 1980s); however, he believes they are largely unsuccessful in assessing risks. Prioritization of risks using ranking or scoring approaches, according to Dr. Suter, often produces nonsense output resulting from system oversimplification and arbitrary input information. Given the limitations of ranking and scoring systems, Dr. Suter recommends a screening-level risk assessment approach for prioritizing contaminant concerns. He suggests that consistency can be promoted in this approach through using screening and benchmark values, developing simplifying assumptions or defaults appropriate for FWS applications, applying existing exposure information to simple exposure models, and using common endpoint receptors (of sufficient geographic range to account for nationwide exposure considerations). Dr. Suter indicated that all of these considerations could be captured in a software-based screening risk assessment process that would guide consistent evaluation and prioritization of site-specific risks.

2.5 Review of Existing Ranking and Prioritizing Approaches

The following sections discuss several existing ranking and prioritizing systems for contaminated sites that could be applied to guide the development of the SRP approach. Ranking and prioritizing approaches were identified through an extensive literature search of biological databases and the internet. In addition, agency publication searches were conducted to identify existing ranking and prioritizing systems for contaminated sites used by U.S. Environmental Protection Agency (USEPA), the U.S. Department of Energy (USDOE), the U.S.

Department of Defense (USDOD), and other organizations and agencies. For each system identified, strengths and weaknesses and their potential to meet the goals of the SRP approach are discussed. Summary tables of the various ranking and prioritizing approaches for contaminated sites identified are provided in Appendix A.

2.5.1 United States Environmental Protection Agency Approaches

Hazard Ranking System; Final Rule

The USEPA's hazard ranking system (HRS) is one of the most widely used and recognized systems for hazard ranking of uncontrolled waste sites (USEPA, 1990). USEPA uses the HRS to develop individual site scores as a basis for adding sites to the National Priority List (NPL). The hazard ranking system uses a structured analysis approach to scoring sites based on detailed guidelines. Numeric values are assigned to risk factors associated with 1) likelihood of an existing or potential contaminant release; 2) waste characteristics; and 3) people or sensitive environments affected by the release. These factors are scored for four pathways or exposure routes (ground water, surface water, soil, and air). Individual factor scores are combined into an overall site score using a root-mean-square equation. USEPA has developed scoring software (PREscore) to facilitate scoring calculations. Pathway scores are normalized to a 100-point scale. An overall site score of 28.5 or greater qualifies a site for listing on the NPL. The data requirements for application of the HRS are fairly extensive and therefore necessitate that a detailed site evaluation be conducted. Of these data requirements, only a handful of data elements are currently available in the data management system for CAP (e.g., observed/potential release (groundwater, surface water, soil, and air exposure routes) and distance to sensitive environments). A list of critical data elements necessary to support the HRS is included in the summary description in Appendix A.

One of the primary benefits of using this approach is that the system has been widely used and has established guidelines for assigning numeric values to increase scoring uniformity. Due to its widespread use, USEPA has developed several support tools for the HRS to facilitate score derivation (e.g., PREscore and the Superfund Chemical Data Matrix (SCDM)). An additional benefit of using this approach is that is has been successfully applied to a variety of different sites with varying waste hazard concerns.

Application of this approach to the proposed ranking and prioritizing system for CAP is primarily limited by the data gap problems. Most sites for which the HRS is used have been studied more extensively than the potentially contaminated areas identified in CAP. Guidelines for the HRS prohibit scoring of factors/criteria for which there is insufficient supporting data; consequently, these data gaps can significantly affect the overall score depending on the relative weight assigned to the factor in question. A common criticism of this approach is that the extent of the data collection effort can unduly influence the scoring outcome because scoring is based on the presence or absence of **measured** contamination in a given pathway. Consequently, there is a tendency for sites with extensive data collection efforts to have higher overall scores. Additionally, the HRS has been revised from its original version in 1990, therefore, there are concerns regarding the comparability of site scores prior to and following the revision.

Hazard Ranking of Contaminated Sediments Based on Chemical Analysis, Laboratory Toxicity Test, and Benthic Community Structure: Method of Prioritizing Sites for Remedial Action

This approach was developed by the USEPA Great Lakes National Program Office–Assessment and Remediation of Contaminated Sediments (ARCS) Program to assist in the hazard ranking of contaminated sediment sites for remedial action (USEPA, 1994). In this approach, hazards associated with contaminants in sediments are assessed using toxicological, ecological, and bioavailability data. Toxic units (defined as the ratio of the bioavailable component of a compound to the USEPA chronic water quality criteria for that chemical) are summed for all chemicals measured at a site. In addition, normalized toxicity ranks based on laboratory toxicity tests and benthic community structure are figured into a final ranking score. The estimate of relative hazard of sediment contaminants to aquatic life for a site is the mean of the ranks for the sediment chemistry data (reflected in toxic units), laboratory toxicity tests, and benthic community structure.

This ranking and prioritizing approach is not likely to achieve the objectives of the proposed ranking and prioritizing system for CAP. Although a major strength of this system is its reliance on existing toxicity data for the relative comparison and ranking of sites (as proposed with the CAP ranking and prioritizing approach), it requires that laboratory sediment toxicity tests be conducted and that benthic community data be collected. Both of these data requirements are beyond the scope of the data collection objectives of the system proposed for CAP.

Classification of Hazardous Wastes

This approach uses statistical techniques to rank hazardous waste sites (and their associated mixed wastes) based on risk classifications (Klee and Flanders, 1980). In this system, statistical analysis techniques (linear discriminant analysis) are used to rank hazardous waste sites. This approach uses "training data" to classify sites into defined risk groups (very hazardous, moderately hazardous, and slightly hazardous) based on specific criteria (variables) using statistical analysis. Regions of variable space are graphically displayed using discriminant analysis. New sites are classified into risk groups categories based on the proximity of the boundaries of groups to the designated test case boundaries.

Relative to the goals of the proposed ranking and prioritizing system for CAP, there are several advantages to application of this approach. Most notably, the ranking and prioritizing criteria (and associated data elements) can be tailored to meet site-specific or program-specific goals. For example, this approach was used by USEPA to rank sanitary landfill sites based on groundwater pathways and the criteria evaluated using statistical techniques were related to factors effecting transport and exposure potential (e.g., soil permeability, groundwater distance, waste hazard potential, and yearly infiltration). The multivariate methods used are able to systematically classify sites into risk categories based on reference "training data". According to the method developer, statistic model ranking systems are easy to implement and are robust (e.g., variations in the variables considered do not affect the overall site ranking). The primary limitations to this system, however, include the requirement of considerable technical expertise

and training in statistical techniques and the inability to conduct sensitivity and uncertainty analyses with this approach.

2.5.2 United States Department of Energy Approaches

Demonstration of the Applicability of Implementing the Enhanced Remedial Action Priority System (RAPS) for Environmental Releases

The RAPS approach was developed by the USDOE to assist in multimedia assessment and ranking of waste sites managed by the agency based on human health risks (Whelan et al., 1989). The RAPS approach prioritizes hazardous and radioactive waste disposal sites using limited site-specific data. The system is used by the USDOE as a management tool for fund allocation and determination of additional investigation and remediation needs at waste sites. Environmental surveying applications of this system for both active and inactive sites are referred to as the Multimedia Environmental Pollutant Assessment System (MEPAS). The primary output from the RAPS system is the hazard potential index (HPI). HPI values are developed for each exposure route (groundwater, surface water, overland flow, and atmospheric pathways) and are the combination of the environmental contaminant concentration, the population exposed, and the toxicity. Three types of data are required by the RAPS model: source-term data (contaminant identity, quantity, concentrations, metabolic breakdown products, and release type), site-specific data (hydrology, geology, meteorology, climatology, and demographics), and constituent properties (physiochemical properties and human health toxicity). Data elements for this methodology include contaminant transport, contaminant retention, toxicity, population distribution, contaminant route, exposure type, exposure duration, and waste type. Fields available in the existing data management system for CAP that address these data needs include Section 5–Transport Pathways (entries for surface water, ground water, air, and biotic routes) and the contaminant classification field in the Area Reports sections Section 8–Potentially Contaminated Areas.

An advantage of the RAPS methodology is that the primary objective of this system is similar to the proposed ranking and prioritizing approach for CAP: to rank the relative hazard of sites nationwide and contaminant concerns based on limited available information. This methodology is one of the most widely used systems for USDOE sites and has been demonstrated on both large- and small-scale applications.

The largest limitation to application of this approach to the proposed ranking and prioritizing system for CAP is that the primary goal of the RAPS methodology is to identify and prioritize human health hazards. Ecological concerns are not readily considered; however, the system could be adapted for inclusion of various ecological receptors. Another potential disadvantage (depending on the objectives of the application) is that the process is comparative and is not designed to be predictive of actual risks resulting from the presence of environmental contaminants; therefore, there is an ultimate tradeoff between accuracy and consistency.

Use of the Multimedia Environmental Pollutant Assessment System (MEPAS) for Large- and Small-Scale Applications

The MEPAS model is a version of the RAPS system that is used by USDOE's Environment, Safety, and Health division for environmental survey applications (Buck and Aiken, 1989). As with the RAPS methodology, the output of the MEPAS model is the HPI. Similar advantages and limitations exist for both systems.

Workbook for Prioritizing Petroleum Industry Exploration and Production Sites for Remediation

This method was developed by Environmental Assessment Technologies for the Idaho National Engineering and Environmental Laboratory for ranking of human health and ecological hazards resulting from petroleum exploration and production (E&P) sites using a risk-based corrective action (RBCA) framework (White, 1998). The workbook outlines a risk-based approach for prioritizing petroleum E&P sites for remediation. A scoring system combines scores for "evaluation factors" relating to the contaminants present onsite, the potential exposure pathways, and the potential receptors. The process is an integration of several existing systems including the Canadian National Classification System for Contaminated Sites and the USFWS lands Biomonitoring Operations Manual. The workbook provides a screening-level approach that incorporates readily available information and does not require extensive site characterization for completion. Scoring guidelines are established and rankings for each "evaluation factor" are based on high, medium, or low potential risk categories. Data elements associated with this approach include the site location, contaminant/waste type, depth to water table, geologic map/survey data, annual rainfall data, surface cover information, proximity to surface and drinking water, topographic information, site flood potential, adjacent water resources uses, and land use information. Some of this information is available in the existing CAP data management system (e.g., site location, contaminant/waste type, land use information); however, the remaining data requirements typically could be fulfilled using readily available sources.

Due to the reliance on existing approaches from the USFWS biomonitoring program (the predecessor to the current CAP manual), this approach satisfies several of the objectives of the proposed ranking and prioritizing approach for CAP. The workbook relies on basic site-specific and readily available information rather than data collected from extensive site investigations. Qualitative descriptors (high, medium, and low risk) are given numeric scores for comparative site ranking. According to the workbook developer, the approach is rapid and inexpensive to perform. The accuracy of the system may be limited by its reliance on qualitative information and professional judgement to achieve screening-level evaluations. Additionally, the approach had not been field tested or evaluated at the time the method was reported.

Environmental Restoration Risk-Based Prioritization Work Package Planning and Risk Ranking Methodology

The risk-based prioritization methodology was developed to assist USDOE managers at Oak Ridge Field Office to identify, evaluate, and prioritize environmental restoration (ER) program funding decisions (Dail et al., 1995). This approach relies on qualitative data to assess program

initiatives based on their risk and their potential to achieve the goals of the Environmental Restoration Program. Initially, a work package planning form is completed by technical site experts familiar with proposed restoration projects. Completion of these forms is guided by specific rules to provide consistency. Review of information provided on the forms is conducted by an objective decision making body (ER prioritization board) to develop risk-based work package priorities based on the risk/benefit estimates developed by site technical experts. The board uses a decision support tool, the Environmental Restoration Benefit Assessment Matrix (ERBAM) to determine a risk score for each proposed work package. This tool evaluates six selection criteria (e.g., public health, environmental protection, site personnel safety, stakeholder preference, site mission, and cost effectiveness) along with information about impact severity and event likelihood. Matrix output includes numeric values to describe both existing site risks as well as the anticipated reduction in risk following completion of the work package. The overall risk score is evaluated by management to rank work packages and program activities.

Although this approach shares one of the objectives of proposed ranking and prioritizing approach for CAP (to rank sites based on potential risks using limited site-specific data), the criteria, which are the basis of work package scoring, differ from those to be considered with the CAP approach. To limit data collection requirements, this methodology relies heavily on qualitative information and professional judgement; however, uniformity is maintained through specific guidelines established to determine impact severity and event likelihood scores. Limitations of this approach include the reliance on boards of professionals to review and provide technical expertise to the scoring process. The prioritization process, therefore, is inherently labor intensive and somewhat subjective (despite the numeric output of the matrix).

Use of Risk to Resolve Conflicts in Assessing Hazards at Mixed-Waste Sites

The Site Ranking System (SRS) ranks hazards at mixed-waste USDOE sites based on scoring factors related to human health risks. The product of three factors (the potentially exposed population, the average amount of waste exposure, and the toxicity of the waste) is determined for three exposure routes (surface water, groundwater, and air) to calculate the relative risk of a release. Special consideration is given to carcinogenic, noncarcinogenic, and radioactive compounds. Several data elements are required for input into algorithms developed for the determination of the site rank: the distance from the site to nearest population, population at risk, exposure potential, chronic toxicity, quantity of hazardous material, and effectiveness of engineering barriers. This approach only considers human health risks, so additional algorithms addressing ecological risks would need to be developed to meet the objectives of the proposed ranking and prioritizing scheme for CAP. Additionally, the data collection requirements are more extensive for this system because information about waste properties (including identity, quantity, and toxicity), site features, and facility design are required.

A Multimedia Screening-Level Model for Assessing the Potential Fate of Chemicals Released to the Environment

A screening-level multimedia model (TOX-SCREEN) was developed to assess the potential for human exposure to contaminants in air, water, or soil (McDowell-Boyer and Hetrick, 1982). The

model was developed to provide an approach for rapid assessment of the potential for bioaccumulation of contaminants. To minimize the data collection requirements, model simplifications, including the assumption that water bodies are located adjacent to contaminated air and land sources, were incorporated in the model. In addition, site-specific data is not used (rather regional and nationwide information is preferred) to minimize the data collection needs. Pollutant dispersion models for each media considered (estimated by transfer rate coefficients, deposition velocities, and mass loading parameters) are used to estimate exposure potential. This approach is not designed for ranking and prioritizing applications; however, as a screening level tool it provides an example of a rapid assessment technique requiring limited site-specific information. The model is designed with many default assumptions and involves little data collection. The potential for this model to be applied as a decision support tool for CAP is limited by the emphasis of the model on human health effects only. In addition, the model relies on generic default values that reduce its utility for site-specific interpretation or comparisons between contaminated sites.

2.5.3 United States Department of Defense Approaches

User's Manual for the Defense Priority Model. Version 2.0 Revision

The Defense Priority Model (DPM) is used by the USDOD Installation Restoration Program to establish remedial action priorities on USDOD disposal sites using site-specific data. The DPM computes a numeric score (ranging from zero to 100) to reflect the potential threat to human health and the environment based on contaminant pathway, hazard, and receptors using site-specific data typically collected during the preliminary assessment/site investigation (PA/SI) and the remedial investigation/feasibility study (RI/FS) phases. For each pathway (surface water, groundwater, air/soil), hazard, receptor, and pathway subscores are calculated for both human health and environmental hazards. Hazard scores are developed by comparing contaminant levels at the site to toxicological benchmark values. If there is not an established benchmark value for a given contaminant, default values are used in the model. For the receptor and transport pathway scores, assigned weights and scores for individual factors are combined. The final site score is the combination of overall subscores for each transport pathway and potential receptor combination. A complete list of data elements required for use of the DPM model is included in Appendix A.

The DPM has been used extensively on USDOD sites and its performance has been frequently evaluated. It offers several advantages over other systems including its consideration of both ecological and human health effects. In addition, to address potential data gap concerns, both site-specific and regional data can be used, and procedures to evaluate hazards at sites without observed contamination are available. The primary limitation of this approach is the potential for toxicity data gaps. The DPM manual recommends that new benchmark values be determined when a benchmark value is not documented for a given chemical.

Development and Demonstration of a Hazard Assessment Rating Methodology for Phase II (HARM II) of the Installation Restoration Program (IRP)

The Hazard Assessment Rating Methodology (HARM) is a site-screening system developed by the U.S. Air Force with assistance from the USDOE for application in the initial phase of the Installation Restoration Program. HARM II, a modified version of its predecessor, utilizes toxicological benchmarks to evaluate the relevance of various pathway risks and hazard scores in the model. HARM II is designed for prioritizing detailed site investigation and remedial action needs while its relative, the DPM, is intended for evaluation of sites following PA/SI and RI/FS activities. HARM II computes a numeric score to reflect the potential threat to human health and the environment based on contaminant pathways, hazards, and receptors using site-specific data typically collected during phase I (background site search and identification of problem sites) of the IRP. For each pathway (surface water and groundwater), hazard, receptor, and pathway subscores are calculated for both human health and environmental hazards. Hazard scores are developed by comparing contaminant levels at the site to toxicological benchmark values. The final site score is the combination of overall subscores (on a zero to three rating scale) for each transport pathway and potential receptor combination.

As a site-screening system, the HARM II approach is inherently less data-intensive than its relative, the DPM; however, some site-specific monitoring data is still desirable. The system is intended primarily for use at sites where monitoring wells are installed and test well data are available; however, it is possible to apply this approach in the absence of these monitoring data. The advantages and limitations of this system relative to the proposed ranking and prioritizing approach for CAP are similar to those outlined for the DPM. While the data requirements for this method are reduced, they are still likely beyond the scope of the proposed approach.

Waste Site Characterization and Prioritization Using a Geographic Information System

The U.S. Army has endeavored to identify and characterize waste sites on its properties. Like the CAP approach, a characterization of each site and all potential contaminant threats is conducted. The waste site characterization and prioritization approach attempts to score waste sites based on a modified version of the USEPA HRS model (Soby et al., 1992). The waste site prioritization approach integrates existing property investigation information for U.S. Army waste sites into a comprehensive GIS database management system (DMS). Information for each site is retrievable in graphic format. Site prioritization is achieved by calculating a site score (based on a modified EPA Hazard Ranking System approach) and evaluating site-specific information maintained in the GIS data management system.

Due to this system's use of a modified HRS system for ranking and scoring waste sites, the required data elements will be similar to those previously identified in the HRS section. The primary advantage of the U.S. Army approach is that integrating existing waste site data with property maps makes the GIS DMS an attractive tool for site-specific decision-making applications. Other advantages and limitations of this approach relative to the proposed approach for CAP are similar to those discussed in section 2.5.1 due to its use of a HRS-based method for site scoring.

2.5.4 Other Organization and Agency Approaches

Development of a Contaminated Land Assessment System (CLASS) Based on Hazard to Surface Water Bodies

The CLASS approach has two components: a database for identification and characterization of contaminant sources, pathways, and targets and a hazard modeling system for determination of the future pollution potential of the sites (Kelly and Lunn, 1999). The overall objective of the CLASS approach is to assist the Newcastle City Council in prioritizing future monitoring, site investigation and potential remediation activities. The prototype system utilizes ARC/INFO to predict pollution migration from contaminated lands using information regarding pollutant sources, pathways, and targets. The hazard index is estimated based on ranks and ranges for various physiochemical and environmental factors for current and historic industrial sites. The index is designed to guide the determination of remediation and monitoring needs for historic and current industrial sites, respectively. Results of the model are displayed in hazard assessment maps containing locations of industrial sites and their corresponding hazard index value. Hazard index modeling allows for the ranking of sites based on their relative hazard potential.

This approach shares several objectives with the proposed approach for CAP. Like the CAP system, CLASS attempts to characterize all potential contaminant concerns at a specific site based on its previous and/or current uses. The approach then retrieves physiochemical information from USEPA chemical property databases for input into the model. These data, along with information about the hydrogeology, site area, and contaminant travel time, provide the basis for an ARCVIEW system able to interpret and integrate physical maps, physiochemical data, and hazard assessment results. Only basic site-specific information is used and can be retrieved from the GIS system. The prototype system to date has been successful in providing comparative assessments and rankings for contaminated sites. Primary limitations of this approach are that data gaps are not adequately addressed. Additionally, in the prototype system, only surface water bodies are considered as pollution targets (with the assumption that terms for carcinogenicity, toxicity, and bioconcentration factors adequately address potential risks to human and aquatic receptors).

Design Considerations and a Suggested Approach for Regional and Comparative Ecological Risk Assessment

This approach involves a regional assessment to evaluate various risk components at individual sites within a region, rank the relative importance of these sites, and incorporate available information for individual sites to predict the relative risk among locations in the specified region (Landis and Wiegers, 1997). The objective of this relative risk model (RRM) is to guide risk prioritization for management of ecological resources. As part of this assessment approach, a complete list of sources, habitat types, and potential impacts to assessment endpoints are identified. The relative risks to endpoints of concern are evaluated using a relative ranking process. First, each region or area of interest is divided into subareas of concern. The sources and habitats previously identified are then ranked to reflect the magnitude of the sources and

their relative impact potential between subareas. Using the ranks assigned for source, habitat, and subareas, a matrix of numeric multipliers is developed. An additional matrix of exposure and effects factors is developed through binary assignment of numeric values (1 for an effect that is likely to occur and 0 for one that is less likely). The product of these exposure/effects filters and the numeric multipliers from the previous step results in a relative ranking of risks within the subareas. The complexity of the relative risk model ranking and scaling matrices increases with the number of stressors and potential effects evaluated. The approach can be tailored to address site-specific source and impact concerns.

Each ranking matrix using the RRM approach is tailored to the unique factors of concern for a region or area of interest. Therefore, the data elements of interest include information about potential sources (including their location), habitat types, exposure potential, and impact likelihood. The CAP data management system includes information regarding each of these data elements. The primary advantage of this approach is that the matrix is simplistic and requires limited site-specific data. Ranks and scalars are assigned based on relative risks and professional judgement. Additionally, because physiochemical data is not incorporated, contaminants for which there is little available information can be considered. Like the proposed ranking and prioritizing approach for CAP, this methodology is designed to facilitate the decision making process regarding environmental risks and additional assessment/data collection needs.

Due to the simplified structure of the matrices used in this approach, the method could be limited by its relative risk approach depending on its application. The ranking and scaling is subjective and based on professional judgement; therefore, variability in results between specialists performing the ranking model is possible. Additionally, model verification is impossible without conducting field investigations to assess the validity of ranking assumptions.

A Regional Multiple-Stressor Rank-Based Ecological Risk Assessment for the Fjord of Port Valdez, Alaska

Investigators used the regional risk assessment approach outlined by Landis and Wiegers (1997) to develop a relative risk model for Port Valdez. The model was applied to rank and sum individual risks quantitatively for each designated subarea, source, and habitat effected. For each subarea within the region, the sources of stressors were evaluated to estimate exposure of receptors within the habitats included in the analysis. A list of model assumptions and rules for ranking were established. Comparison of the risk scores for each subarea identified areas of highest risk for management decision-making purposes.

National Classification System for Contaminated Sites

This approach was developed as part of the National Contaminated Sites Remediation Program initiated by the Canadian Council of Ministers of the Environment (CCME) in order to improve consistency in the evaluation of contaminated sites. The system is designed to be applicable to all types of contaminated sites using readily available information (including site characteristics, contaminant presence and location). The National Classification System is also available in electronic database format to facilitate data input and retrieval of scores. The system is designed

as a screening tool for identifying sites based on qualitative risk (high, medium, low) for prioritization of funding needs for additional action (e.g. site characterization, risk assessment, remediation). In this approach, site characteristics are assigned numeric scores which are then prioritized based on a additive factorial method where various characteristics are weighted according to their relevance to the overall hazard associated with a given site. The evaluation factors used to prioritize site need encompass the contaminant characteristics, exposure pathways, and receptors associated with a contaminated site. The National Classification System includes procedures intended to address information gaps that may result when sufficient site information is not readily available. If there is insufficient data to score a given evaluation factor, a score equal to half the maximum allowable score for that parameter is assigned and is denoted as an estimated value. When totaling scores for a contaminated site, estimated scores are both incorporated in the final calculation and tallied separately to determine a margin of error and are reported as the final score "$\pm$" the separately summed estimates. The approach also provides guidance for incorporating site-specific considerations and has separate procedures for sites with known contamination versus potential contamination. Unlike several approaches previously discussed, the National Classification System was not designed for detailed relative ranking of contaminated sites. Rather, sites are classified based on their scores evaluation factors into four separate classes based on their overall estimated score.

Demonstration of a Toxicological Risk Ranking Method to Correlate Measures of Ambient Toxicity and Fish Community Diversity

This approach was developed by the Maryland Department of Natural Resources to integrate an environmental ambient toxicity testing risk ranking method with a biological community assessment approach (Hartwell, 1997). The ranking scheme used was designed to evaluate the ambient toxicological data in a site-specific metric appropriate for comparison to other metrics (e.g., index of biotic integrity or community diversity indices). The scoring approach allows for comparison of individual sites and evaluation of sample trends. Data elements used in scoring ambient toxicity data included severity of effects, degree of response, test variability, site consistency, and the number of measured endpoints. These data elements are not compatible with those available in the CAP data management system and are based on laboratory testing results.

Investigators found that this approach correlated well with fish community metrics and was effective for comparison of individual sites. Application of this methodology to the proposed CAP ranking and prioritizing approach; however, is limited by the requirement for site-specific toxicity testing and water, sediment, and fish community sampling.

Hazard Ranking of Landfills Using Fuzzy Composite Programming

A multicriteria assessment system is demonstrated in a case study as a tool for screening and prioritizing unregulated disposal sites according to their level of environmental and health hazard (Hagemeister et al., 1996). The assessment procedure utilizes fuzzy composite programming (FCP) to aggregate individual hazard scores (determined through available data and best professional judgement) into a final overall hazard level for a site. The aggregate hazard is a

fuzzy number that reflects the most likely range and the largest range of hazards relative to the best and worst case scenarios. FCP is not as labor- and data-intensive as other approaches and provided a means of incorporating uncertainties into the final score. The method is also flexible enough to incorporate numerous environmentally relevant parameters in the hazard assessment. A complete list of data elements considered in the case study is included in Appendix A. Limitations to the approach include reliance on professional judgement to assign hazard levels in the absence of data for a given parameter. This subjectivity adds variability between hazard ranking scores when various individuals conduct the FCP method.

A Method for Assessing Environmental Risk: a Case Study of Green Bay, Lake Michigan, USA

This approach was developed jointly by the University of Wisconsin, the Wisconsin Department of Natural Resources, and USEPA to develop risk reduction strategies using a relative ranking system for ecosystem stressors (Harris et al., 1994). In this approach, risk values are assigned to each ecosystem stressor-impaired use pair based on the degree of effect that the stressor contributes to ecosystem risk (measured by impaired use criteria). A predefined scale of zero (no impact) to 3 (major impact) was applied to an impact matrix to determine numeric risk values. Risk values for ecosystem stressors are then ranked using fuzzy set theory calculations. In this application of the method, data elements included stressor severity, time/duration of contaminant event, prevention management activities, and remediation management activities. Fuzzy set decision matrices allow for differentiation between the risk and importance associated with multiple environmental stressors. According to the investigators, the system function is retained even when data are lacking. As with many approaches previously discussed, investigators must have a comprehensive understanding of the ecosystem functions and potential stressor impacts. There is potential for variability in model results based on professional judgement input from individual investigators.

A Decision Analysis Technique for Ranking Sources of Groundwater Pollution

In order to prioritize potential groundwater pollution sources in Idaho, a decision analysis technique was developed by the State of Idaho and California State University (Shook and Grantham, 1993). In this approach, potential sources (defined as a type of land use) of groundwater contamination are identified through an inventory of historic data. Sources were ranked based on their regional and/or statewide effects rather than site-specific impacts. For each potential source, a total rating score was developed based on the regulatory adequacy factor, the public health risk factor, and the aquifer vulnerability factor scores. Each factor was developed using criteria for assigning high, medium, or low risk numeric values. Specific data elements evaluated in the model include 1) the potential for existing programs to prevent or remedy groundwater contamination (regulatory adequacy factor), 2) the severity of the potential impact on public health (public health risk factor), and 3) the vulnerability of the groundwater system to pollution (aquifer vulnerability factor). Although this application of the ranking approach does not meet the objectives of the proposed ranking and prioritizing system for CAP, it could be modified based on desired CAP applications. One benefit of the decision tool is that ranking scores can be developed rapidly with limited information based on criteria for assigning high, medium, and low risk numeric values for each factor included in the final score. This

approach evaluates the relative risk of potential sources but is not developed for site-specific comparisons and prioritization. In addition, only human health impacts are considered.

Assessment of Waste Disposal Sites Using Expert Systems

The method was designed by Lehigh University investigators to provide a framework for hazard assessment of waste sites and remedial decision support. The system, known as GEOTOX, is designed to score a variety of factors related to hazards at waste sites based on readily available information. When data are lacking, the model can calculate a score with incomplete information. For each criterion evaluated, there is a set of rules that determine a score for that parameter based on set input conditions. The scoring process is similar to that used by USEPA's HRS. The goal of the system is to derive an estimate of the degree of potential hazard associated with a site. The overall site hazard score is the weighted sum of three site hazard components: the permanent hazard (related to soil and hydrogeologic factors), the local hazard (related to contamination severity), and the global hazard (related to environmental sensitivity). Data elements incorporated into each of the three hazard components include the contaminant quantity, toxicity, persistence, treatment, transport route, distance, depth, slope, permeability/sorption of the unsaturated zone, aquifer sorption and permeability, depth to aquifer, extent of contamination, importance, targets, and containment. To a large extent, the existing CAP data management system does not contain sufficient data to satisfy the critical data needs of the GEOTOX approach.

One of the benefits of the GEOTOX approach is that the data requirements are not as extensive as with some of the systems previously described. The approach focuses on preliminary site data and can be modified as additional data become available. In addition, specific rules are established for assigning scores for various criteria. The primary limitation of the approach is that data gaps in the model are addressed through use of default values. This design attempts to minimize data collection requirements; however, depending on the relative weights of the missing data in the model, these defaults could skew the output results when compared to other sites.

2.6 Summary of Existing Ranking and Prioritizing Systems

The SRP approach is intended both to facilitate the assessment and prioritization of environmental concerns by contaminant specialists for further investigation (often with limited data) and to allow consistent prioritization of resources at the management level for the assessment of environmental risks on DOI lands nationwide. The systems we reviewed were developed for a variety of applications with essentially the same underlying goals: 1) to conduct screening-level assessments of site-specific contaminant hazards and 2) to consistently rank investigation and/or management needs between sites based on relative risks. A review of these existing approaches and discussions with risk assessment professionals suggest that a common limitation of ranking and prioritizing systems is a tradeoff between consistency and accuracy. Because these approaches attempt to assess site-specific needs (e.g., monitoring, investigations, remediation) while promoting consistency in programmatic allocation of resources, they must be transparent enough to address a variety of potential habitats and receptors while still considering

sufficient site-specific information to characterize hazards in the area of interest. Based on the evaluation of existing approaches, it appears that achieving balance between these goals is difficult (e.g., as the data requirements for more accurate site-specific assessments increase, the potential for data gaps and inconsistencies in relative-risk comparisons between sites also rises). Consequently, clear definition and prioritization of the system goals (e.g., programmatic priority-setting vs. field-level investigation planning) is necessary.

Enhanced accuracy and consistency with site-specific exposure date (i.e., measured concentrations rather than estimated) was a common theme. While obtaining baseline chemistry data has a cost, the systems that use such data are inherently more accurate. Use of default values or surrogate chemical data when specific toxicological effects data were lacking was another common element of the reviewed systems.

The number and diversity of existing ranking systems makes it likely that one or more could be modified to meet FWS and USGS needs regarding the CAP. The agencies should consider optimizing / modifying one or more of these approaches as an option, again following more refinement of ranking and prioritization system goals.

2.7 References for Section 2

Barnthouse, L.W., Breck, J.E., Jones, T.D., Kraemer, S.R., Smith, E.D., and Suter II, G.W. 1986. Development and demonstration of a hazard assessment rating methodology for Phase II of the Installation Restoration Program. DE86007065. U.S. Department of Energy, Environmental Sciences Division. Oak Ridge National Laboratories, Oak Ridge, TN.

Buck, J.W. and Aiken, R.J. 1989. Use of the Multimedia Environmental Pollutant Assessment System (MEPAS) for Large- and Small-Scale Applications. DE90001898/PNL-SA–16844. U.S. Department of Energy, Pacific Northwest Laboratory, Richland, WA.

Canadian Council of Ministers of the Environment. 1992. National classification system for contaminated sites. Canadian Council of Ministers of the Environment, CCME Contaminated Sites Task Group. Winnipeg, Manitoba.

Dail, J.L., Nanstad, L.D., and White, R.K. 1995. Environmental restoration risk-based prioritization work package planning and risk ranking methodology. ES/EM/TM-112/R2. U.S. Department of Energy, Office of Environmental Management, Oak Ridge National Laboratories, Oak Ridge, TN.

Hagemeister, M.E., Jones, D.D., and Woldt, W.E. 1996. Hazard ranking of landfills using fuzzy composite programming. Journal of Environmental Engineering. 122(4): 248-58.

Harris, H.J., Wenger, R.B., Harris, V.A., and Devault, D.S. 1994. A method for assessing environmental risk: A case study of Green Bay, Lake Michigan, USA. Environmental Management. 18(2): 295-306.

Hartwell, S.I. 1997. Demonstration of a toxicological risk ranking method to correlate measures of ambient toxicity and fish community diversity. Environmental Toxicology and Chemistry. 16(2): 361-371.

Kelly, C. and Lunn, R.J. 1999. Development of a contaminated land assessment system based on hazard to surface water bodies. Water Research. 33(6): 1377-86.

Klee, A.J. and Flanders, M.U. 1980. Classification of hazardous wastes. Journal of the Environmental Engineering Division, Proc. of the Amer. Soc. Of Civil Eng., 106(EE1): 163-175.

Landis, W.G. and Wiegers, J.A. 1997. Design considerations and a suggested approach for regional and comparative ecological risk assessment. Human and Ecological Risk Assessment. 3(3): 287-297.

McDowell-Boyer, L.M. and Hetrick, D.M. 1982. A multimedia screening-level model for assessing the potential fate of chemicals released to the environment. DE82018185, ORNL/TM-8334. U.S. Department of Energy, Health and Safety Research Division. Oak Ridge National Laboratories, Oak Ridge, TN.

Mikroudis, G.L., Wilson, J.L., and Fang, H.Y. 1985. Assessment of waste disposal sites: Utilizing expert systems. In Toxic and Hazardous Wastes: Proceedings of the 17th Mid-Atlantic Industrial Waste Conference. June 23-25, 1985. Technomic Publishing Co., Lancaster, PA. pp.374-386.

Rechard, R.P. and Chu, M.S.Y. 1991. Use of risk to resolve conflicts in assessing hazards at mixed-waste sites. DE91 017314, SAND–91-0587C. U.S. Department of Energy, Sandia National Laboratories, Albuquerque, NM.

Shook, G. and Grantham, C. 1993. A decision analysis technique for ranking sources of groundwater pollution. Journal of Environmental Management. 37: 201-206.

Soby, M.T., Connolly, K.J., and Folsom, R. 1992. "Waste site characterization and prioritization using a geographic information system." In Geographic Information Systems (GIS) and Mapping–Practices and Standards, ASTM STP 1126, A.I. Johnson, C.B. Pettersson, and J.L. Fulton, eds., American Society for Testing and Materials, Philadelphia, pp. 280-294.

U.S. Department of Defense. 1989. User's manual for the Defense Priority Model. Version 2.0. Revision 1. USDOD, Office of the Deputy Assistant Secretary of the Defense (Environment). The Pentagon, Washington, D.C. January.

U.S. Environmental Protection Agency. 1990. Hazard ranking system–Final rule. 40 CFR 300 Appendix A, December 14.

U.S. Environmental Protection Agency. 1994. Assessment and Remediation of Contaminated Sediments (ARCS) Program. Hazard ranking of contaminated sediments based on chemical analysis, laboratory toxicity tests, and benthic community structure: Method of prioritizing sites for remedial action. USEPA, Great Lakes National Program Office, Chicago, IL. EPA 905-R94-024.

Whelan, G., Droppo, J.G., Jr., Strenge, D.L., Walter, M.B., and Buck, J.W. 1989. A demonstration of the applicability of implementing the enhanced remedial action priority system (RAPS) for environmental releases. DE90007613, PNL–7102. U.S. Department of Energy, Office of Environment, Safety, and Health. Pacific Northwest Laboratory, Richland, WA.

White, G.J. 1998. Workbook for prioritizing petroleum industry exploration and production sites for remediation. Lockheed Martin Idaho Technologies Company, Inc. for U.S. Department of Energy, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID. INEEL/EXT-98-00609, DE98058437.

Wiegers, J.K., Feder, H.M., Mortensen, L.S., Shaw, D.G., Wilson, V.J., and Landis, W.G. 1998. A regional multiple-stressor rank-based ecological risk assessment for the fjord of Port Valdez, Alaska. Human and Ecological Risk Assessment. 4(5): 1125-1173.

3.0 FUNCTIONAL GROUPING SYSTEMS FOR BIOLOGICAL ORGANISMS (TASK 2A)

Task 2A of the project proposal calls for the development of a system for classifying organisms into functional groups with corresponding representative species (identified through selection criteria). Development of a functional grouping system for biological organisms is just one facet of the proposed standardized process for estimating risk posed by contaminants to resources managed by the U.S. Department of the Interior (DOI). Prior to selecting an ecological classification system, a literature review of existing classification systems was conducted with a focus on potential exposure routes and refuge resources at risk from exposure. The following sections provide a summary for each classification system identified, evaluates these approaches based on their ability to meet the objectives of the proposed contaminant ranking and prioritizing system, recommends a candidate functional grouping system that meets the needs of the proposed ranking and prioritizing approach, and identifies selection criteria for surrogate species from each functional group.

3.1 Grouping receptors into functional systems

The most common means of grouping living organisms is through a hierarchal biological classification system based on phylogenetic relationships. In this system, a hierarchy of categories (Kingdom, Phylum, Class, Order, Family, Genus, and Species) where each category is a collection of related groups from the next-lower category is used to describe organisms. In this manner, a Class is a closely-related group of Orders. Examples of Classes in this system include fish (Agnatha, Chondrichthyes, Osteichthyes), amphibians (Amphibia), reptiles (Reptilia), birds (Aves), and mammals (Mammalia). Functional grouping systems are based on the classification structure of the hierarchal system described above; however, species are further classified based on a similar characteristic function (e.g., trophic function). For example, in a trophic-based functional classification system, species can be grouped according to similar method or location of foraging. These groups of species that occupy a particular trophic level and share similar feeding strategies are known as guilds. Therefore, a functional grouping system based on trophic function might include major feeding guilds (e.g., herbivore, omnivore, detritivore, carnivore, insectivore) grouped by class (e.g., fish, amphibians, reptiles, birds, and mammals).

3.2 Existing functional grouping systems for biological organisms

The following sections discuss several existing functional grouping systems for biological organisms that could be applied to the proposed ranking and prioritizing approach. Functional grouping systems were identified through an extensive literature search of biological databases and the internet. In addition, agency publication searches were conducted to identify existing classification approaches used by U.S. Environmental Protection Agency (USEPA), the U.S. Department of Energy (USDOE), and the DOI. For each system identified, strengths and weaknesses and their potential to meet the needs of the proposed ranking and prioritizing approach are discussed. Summary tables of the various ecological classification approaches identified are provided in Appendix B.

3.2.1 United States Environmental Protection Agency Approaches

Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities: Volume One

The USEPA has applied various approaches to grouping receptors by function. Most of these systems rely on a community or feeding guild approach whereby receptors potentially exposed to contaminants are grouped based on trophic relationships and habitat types. The Office of Solid Waste describes a method to group receptors in this manner in *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities: Volume One* (USEPA, 1999a). In the Problem Formulation chapter of this protocol, habitat-specific food webs are developed by identifying the major feeding guilds for birds, mammals, reptiles, amphibians, and fish based on the dietary habits and feeding strategies of receptors. Invertebrates and plants were not grouped into guilds, but were instead categorized based on the communities and various environmental media they inhabit. Within each major feeding guild (e.g., herbivore, omnivore, carnivore, insectivore), species are grouped into individual classes (e.g., mammals, birds, reptiles, amphibians, fish) and the overall food web structure is organized by trophic level. For each class-specific guild, several representative receptors were identified. In addition one surrogate, or measurement receptor, was selected for example habitat-specific food webs (e.g., forest, tallgrass prairie, shrub/scrub, freshwater wetland, etc.) based on five selection criteria: ecological relevance, exposure potential, sensitivity, social or economic importance, and availability of natural history information.

One of the benefits of applying the functional groupings assigned in this protocol to the proposed ranking and prioritizing system for CAP is that the representative receptors identified are grouped both by class-specific guilds and by media type (e.g., aquatic, sediment, soil, and terrestrial receptors). Consequently, exposure can be addressed in terms of media and trophic effects. The main drawback of this approach is that measurement receptors or surrogates must be assigned for each habitat-specific food web. To support the proposed ranking and prioritizing system, a more generalized approach that does not rely on the development of habitat-specific food webs would be preferred to allow for consistency in the selection of surrogate species.

Technical Support Document for the Hazardous Waste Identification Program: Risk Assessment for Human and Ecological Receptors, Volumes 1 and 2

In support of the Hazardous Waste Identification Rule (HWIR), threshold levels for contaminants have been established using an innovative risk assessment tool known as the Multipathway Analysis (MPA), which examines potential exposure pathways, direct and indirect, from various sources (USEPA, 1995). In this approach, ecological receptors were selected to represent major trophic elements of generalized aquatic and terrestrial food webs. Receptors identified in this system were selected based on their ecological significance, their trophic interactions with other species, and their relation to likely exposure pathways. In addition, consistency was maintained by selecting surrogate species with nationwide distribution.

The generic freshwater ecosystem was divided into two compartments representing potential exposure media: water-based (limnetic) and sediment-based (littoral). The major limnetic and littoral trophic levels were identified and surrogates were selected for mammal and bird groups; however, rather than identifying specific surrogates from aquatic limnetic and sediment communities, rules for selecting representative species were provided consistent with the selection criteria outlined in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (Stephan et al., 1985). The generic terrestrial ecosystem was divided into three main receptor groups: plants, species not associated with soil (nonsoil), and soil-associated species. Surrogates from major trophic levels in the nonsoil system were identified; however, representative species from four major soil-associated receptor groups were not selected (rather, rules for choosing appropriate surrogates were provided).

Several aspects of this system would be beneficial if applied to the proposed ranking and prioritizing approach for CAP. A major strength of this classification system is the consistency provided by selecting receptors with nationwide distribution. For functional groups where surrogate species were identified, receptors for which sufficient toxicological data exist were chosen (e.g., nonsoil insectivore such as short-tailed shrew). The focus on only two generic ecosystems (rather than several site-specific food webs) provided additional consistency in this approach. A major drawback to this approach, however, is the potential for inconsistencies due to reliance on rules to select representative species for functional groups where a surrogate has not been identified.

Wildlife Exposure Factors Handbook, Volumes I and II

The Wildlife Exposure Factors Handbook (hereafter referred to as the Handbook) is a valuable source of data, references, and guidance for conducting screening-level risk assessment for common wildlife species exposed to environmental contaminants (USEPA, 1993). In the Handbook, species selected from several classes (mammals, birds, amphibians, and reptiles) are divided into guilds based on diet and habitat (e.g., insectivore, carnivore, aquatic herbivore/insectivore). From each guild, surrogate species are selected as representative of the entire guild. Species were selected to represent major taxonomic groups (major vertebrate groups, orders, and families), a range of diets likely to be associated with contaminated media, various habitat types, a range in body sizes, and a widespread geographic distribution. In addition, species of societal and regulatory significance were considered.

One benefit of using the functional grouping of species provided in the Handbook is that it is a widely accepted and applied tool used in screening-level risk assessments. In addition, toxicological data are available for many of the representative species identified in the Handbook (this is particularly true of mammalian and avian species; however, profiles on amphibians and reptiles are less developed). Due to the selection of species representative of various sizes, taxonomic groups, diets, and habitats, the grouping system in the Handbook is generic and widely applicable allowing for consistent results. Due to the breadth of the species selection process; however, one of the limitations of this system is that it is not always appropriate for site-

specific risk assessments. Another drawback to this system is that fish and aquatic and terrestrial invertebrates have not been included in the Handbook.

Data Collection for the Hazardous Waste Identification Rule. Section 14.0 Ecological Benchmarks

This document outlines the data sources and methodology used in an ecological risk module applied to the HWIR to generate risk estimates for receptor taxa of concern (USEPA, 1999c). Protective chemical stressor concentration limits were derived for specific communities and populations in direct contact with contaminated media. A total of eight communities were addressed in this approach (mammalian, avian, terrestrial plants, aquatic plants and algae, herpetofauna, soil community, aquatic community and the benthic community). Data were provided for a total of 57 ecological receptors of concern; however, the surrogate approach was not used in this system. The benefit of applying this system to the proposed ranking and prioritizing system for CAP is that the functional groupings described have been successfully applied to a risk estimation approach. This system is more complex, however, and application of the surrogate concept has not been considered.

Aquatic Food Web Module: Background and Implementation for the Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) for HWIR99

The Aquatic Food Web (AqFW) module document, like the preceding Data Collection and Technical Support documents, was developed to support the HWIR (USEPA, 1999b). This module is designed to predict contaminant concentrations is aquatic species in coldwater and warmwater freshwater habitats. The module framework includes four representative habitats (streams/rivers, permanently flooded wetlands, ponds, and lakes). To determine contaminant levels, four major classifications of taxa are used for the eight representative habitats: (1) algae/phytoplankton/plants, (2) zooplankton, (3) benthos, and (4) fish. Further subclassification of species for each major taxa based on feeding guilds was included (e.g., benthic species were divided into detritivore and filter feeder subgroups). Using these functional classifications, a general food web structure was created for each representative aquatic habitat and tissue concentrations were predicted for all compartments in the system. While the classification systems from this approach could be readily applied to the proposed ranking and prioritizing system for CAP, the application of the functional species grouping to a predictive model is beyond the scope of the proposed system. In addition, this approach is very habitat-specific and requires that surrogates be selected on a case-by-case basis.

3.2.2 U.S. Department of Energy Approaches

Toxicological Benchmarks for Wildlife

This report (Opresko et al., 1995) provides no observed adverse effects levels (NOAELs) and lowest observed effects levels (LOAELs) as toxicological benchmarks for assessing effects of 85 chemicals on 8 representative mammalian wildlife species (short-tailed shrew, little brown bat, meadow vole, white-footed mouse, cottontail rabbit, mink, red fox, and whitetail deer) and 11

avian wildlife species (American robin, rough-winged swallow, American woodcock, wild turkey, belted kingfisher, great blue heron, barred owl, barn owl, Cooper's hawk, osprey, and red-tailed hawk). These wildlife species were selected because they are widely distributed and are representative of a range of body sizes and dietary preferences. Due to the widespread use of these benchmarks by risk assessors for both screening-level and baseline ecological risk assessments and the availability of toxicological information for these wildlife species, application of the surrogate species identified in this approach could be useful to the proposed ranking and prioritizing system. The main limitation of the species list provided in this report is that only mammalian and avian species are considered, so expansion of the species list provided in the report to include amphibians, reptiles, fish, and other aquatic species would be necessary to meet the goals of the proposed ranking and prioritizing system for CAP.

Development and Validation of Bioaccumulation Models for Small Mammals

In this report (Sample et al., 1998), whole-body contaminant concentrations for 16 chemicals in small mammals are estimated to evaluate exposure risks to predatory wildlife. Small mammals were segregated into various trophic guilds (insectivore, herbivore, and omnivore) based on diet. Using this system, uptake factors were estimated in order to determine body burdens for both individual species and trophic groups. Small mammal species used were selected based on the availability of data from studies where chemical concentrations in co-located small mammal and soil samples were determined. Unlike some of the other approaches previously discussed, the data set available in this report is small and would only apply to small mammal receptors in the proposed ranking and prioritizing system for CAP. The selection criteria for the species included in this bioaccumulation database was limited to the data availability for each given species on a site specific basis. Widespread species distribution was not considered, therefore, the applicability of this system on a nationwide basis would have to be further evaluated.

Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants

This report provides general methods for estimating exposure of terrestrial wildlife to contaminants of concern (Sample et al., 1997). Life history parameters are provided for selected mammalian and avian species; however, reptiles and amphibians are not considered in this approach due to limited data. Information regarding the distribution, body size and weight, diet, metabolism, habitat requirements, and food/water/soil ingestion rates for each selected species is provided. Species for which life history information is available were selected because they are likely to occur at DOE facilities and are considered potential endpoints. In addition, the representative species in this report were chosen to avoid repetition with species reported in other approaches such as the *Wildlife Exposure Factors Handbook* (USEPA, 1993). Due to the availability of toxicological data for these wildlife species, application of the surrogate species identified in this approach could be useful to the proposed ranking and prioritizing system. The main limitation of the species list provided in this report is that only mammalian and avian species are considered, so expansion of the species list provided in the report to include amphibian, reptile, fish, and other aquatic species would be necessary to meet the goals of the proposed ranking and prioritizing system for CAP.

3.2.3 Other Approaches

Wildlife Contaminant Exposure Model

The Wildlife Contaminant Exposure Model (WCEM) was developed by the Canadian Wildlife Service (Environment Canada, 1999) through a cooperative agreement with the USEPA as a tool to improve the quality of wildlife risk assessments. This approach can be applied to both screening level and more detailed risk characterizations and allows for more consistent and efficient estimates of exposure. Users of this tool can create site-specific wildlife and contaminant scenarios. The Canadian verison of this tool provides wildlife history parameters for 49 mammalian, avian, reptilian, and amphibian species, 32 of which are contained in the *Wildlife Exposure Factors Handbook* (USEPA, 1993). Species were selected with emphasis on data suitable for the Canadian environment. Although the modeling tool itself is highly site-specific and requires the development of contaminant and wildlife profiles by the user, the profiles for the representative species are applicable to the ranking and prioritizing system proposed.

Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas

In this report, the Texas Natural Resources Conservation Commission (Commission, 2000) adapts the approach described in *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities: Volume One* (USEPA, 1999a). In this approach, communities, feeding guilds, and representative species that could potentially be exposed at a given site are identified as part of the screening-level ecological risk assessment. While the Commission adheres to the protocol outlined by USEPA, they have modified the surrogate species list to be representative of specific ecological receptors that the Commission is trying to protect in the state of Texas. Nineteen community/feeding guild groups were identified representing various trophic levels (e.g. omnivore, carnivore, herbivore) and classes (e.g., mammal, bird, amphibian). This approach exemplifies how the generic system developed by USEPA can be applied to produce a more detailed and habitat-specific system. The advantages of applying this system to the proposed ranking and prioritizing system for CAP is that more meaningful information about site specific contaminant problems could be elucidated; however, it limits the ability for the ranking system to be consistently interpreted on a national scale.

Pesticide Bulletin for T&E Species and Migratory Birds in USFWS Region 2 - DRAFT

This regional pesticide bulletin contains information on protecting Federally-listed threatened and endangered species (T&E) and migratory birds from adverse effects associated with pesticide applications (USFWS, 2001). Specific protection measures for applications can be determined by examining the toxicity category of the pesticide (ranging from Class 0, practically nontoxic, to Class 3, very highly toxic, compounds) and the ecotoxicity (ecotox) category of the receptor of concern. A total of sixteen ecotox categories were identified as representative of the potential receptors of concern for pesticide application; however, no surrogates were assigned for each category. The species are grouped into ecotox categories based on their similarity of toxicological responses to pesticides. The primary advantage of the classification system used in

this report is that it was designed to be representative of USFWS trust resources (e.g. T&E species and migratory birds). The ecotox categories presented are ideal for application in Region 2; however, additional classes would likely be necessary for use on a national scale. In addition, to apply this system to the proposed ranking and prioritizing approach for CAP, individual surrogate species should be identified for each species toxicity category.

3.3 Candidate Functional Grouping System Recommendation

Based on a review of the strengths and weaknesses of existing functional grouping systems for biological organisms that could potentially be used in the proposed ranking and prioritizing approach, it appears that the needs of the proposed system would be achieved through a system that combines some of the features of the previously discussed approaches while assigning rules for selecting surrogate species that are unique to the goals of the CAP system. The most basic system that could be applied to the proposed ranking and prioritizing approach would be based on the major species classes (e.g., mammal, bird, reptile, amphibian, fish) with one surrogate selected for each class based on the national ecological significance of the species and the availability of toxicity information. While it is almost certain that a database could be populated with toxicity information for most chemicals using this system, the ability of a system using one species surrogate for a large group of organisms to accurately predict the potential for effects to a given species is uncertain. As a result, it may be preferable to further divide the basic system into subgroups based on habitat and trophic characteristics of the species in each class. For example, the system used in *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Volume 1* divided species classes based on habitat (terrestrial, aquatic, soil, sediment) and trophic guilds (omnivore, herbivore, carnivore, etc.) (USEPA, 1999). Such a classification system could be further divided into more specific habitat-level groups (e.g. freshwater, saltwater, coldwater, warmwater, etc.). For the purposes of a test run of the proposed ecological classification system, it would be beneficial to test both a more detailed system containing habitat-type and trophic-level groups along with a coarse system identifying only the major species categories and corresponding surrogates. By testing both approaches, the potential for data gaps using each system can be assessed.

For the basic system, it is proposed that five vertebrate species classes be used (bird, mammal, fish, reptile, amphibian) in addition to a representative plant and invertebrate. The surrogate organism for each category was selected based on availability of toxicity information and nationwide distribution of the species. A list of the surrogate organisms selected for each species category is provided in Table 3-1.

Table 3-1. Species categories and selected surrogates for coarse system of species categorization to support a contaminant ranking and prioritization system

Species Category	Selected Surrogate
Bird	northern bobwhite (*Colinus virginianus*)
Mammal	Norway rat (*Rattus norvegicus*)
Freshwater Fish	rainbow trout (*Oncorhynchus mykiss*)
Saltwater Fish	sheepshead minnow (*Cypinodon variegatus*)
Reptile	racer (*Coluber constrictor*)
Amphibian	bullfrog (*Rana catesbeiana*)
Plant	corn (Zea mays)
Freshwater Invertebrate	water flea (*Daphnia magna*)
Saltwater Invertebrate	mysid shrimp (*Mysidopsis bahia*)

The species categories identified in the basic system can be further divided into subgroups reflecting trophic interactions and potential routes of exposure. An example of a more detailed functional grouping system is shown in Table 3-2. When assigning subgroups and surrogate species for this expanded classification system, it was desirable to cover major taxonomic groups, trophic levels (herbivore, omnivore, carnivore), habitat types (freshwater and marine), various body sizes, and potential exposure routes (aquatic, sediment, soil, and terrestrial exposure). Additional criteria for surrogate selection included the availability of toxicity information for a species and the national distribution of each surrogate. Many of the surrogates identified in Table 3-2 are species recommended by USEPA for ecological effects testing; consequently, a larger database of toxicity data is accessible for the development of the proposed ranking and prioritizing system. These species are recommended by USEPA in part because they are ecologically relevant, have high exposure potential in the environment, and are relatively sensitive to the effects of contaminant stressors in the environment.

3.3 Proposed Rules for Development of the Toxicity Database

One of the obvious drawbacks of using a surrogate species approach for the development of a standardized ranking and prioritizing database for contaminants is that data gaps are unavoidable, particularly for species classes where toxicological data are not readily available (e.g. amphibians and reptiles). The goal of a ranking and prioritizing database is to achieve the most representative toxicity estimate for each chemical/ecological surrogate combination. To avoid data gaps while maintaining representative surrogate selections for each chemical or ecological group, it is necessary to develop a set of rules guiding the process of populating the toxicity estimate database. The following set of rules should be applied when developing toxicity databases for both the basic and detailed systems outlined above.

Table 3-2. Species categories and selected surrogates for detailed system of species categorization to support a contaminant ranking and prioritization system

Species Categories	Surrogate Species
AQUATIC RECEPTORS – Freshwater	
Fish	
Carnivorous	rainbow trout (*Oncorhynchus mykiss*)
Omnivorous	bluegill sunfish (*Lepomis macrochirus*), fathead minnow (*Pimephales promelas*)
Invertebrates	
Crustacean	water flea (*Daphnia magna*)
Mollusc	zebra mussel (*Dreissena polymorpha*)
Aquatic Plants	
Vascular	duckweed (*Lemna gibba*)
Nonvascular	freshwater diatom (*Navicula pelliculosa*)
AQUATIC RECEPTORS – Marine	
Fish	
Carnivorous	mummichog (*Fundulus heteroclitus*)
Omnivorous	sheepshead minnow (*Cyprinodon variegatus*)
Invertebrates	
Crustacean	mysid shrimp (*Mysidopsis bahia*) or marine copepod (*Acartia tonsa*)
Mollusc	eastern oyster (*Crassostrea virginica*)
Aquatic Plants	
Vascular	eelgrass (*Zostera marina*)
Nonvascular	marine diatom (*Skeletonema costatum*)
SEDIMENT RECEPTORS – Freshwater	
Sediment Invertebrates	freshwater midge (*Chironomus tentans*), freshwater amphipod (*Hyalella riparius* or *Hyella azteca*), or freshwater oligochaete (*Lumbriculus variegatus*)
SEDIMENT RECEPTORS – Marine	
Sediment Invertebrates	marine amphipod (*Ampelisca abdita*), estuarine amphipod (*Leptocheirus variegatus*), or marine polychaete (*Neanthes arenaceodentata*)
TERRESTRIAL RECEPTORS	
Soil Receptors	
Terrestrial plants	corn (*Zea mays*) – monocot soybean (*Glycine max*) – dicot
Soil invertebrates	common brandling worm (*Eisenia foetida*) or earthworm (*Lumbricus terrestris*)

Table 3-2 (Continued). Species categories and selected surrogates for detailed system of species categorization to support a contaminant ranking and prioritization system

Species Categories	Surrogate Species
TERRESTRIAL RECEPTORS (cont)	
Mammals	
Carnivorous	deer mouse (*Peromyscus maniculatus*)
Omnivorous	raccoon (*Procyon lotor*)
Herbivorous	mink (*Mustela vison*)
Birds	
Carnivorous	red-tailed hawk (*Buteo jamaicensis*)
Omnivorous	northern bobwhite (*Colinus virginianus*) or mallard duck (*Anas platyrhynchos*)
Herbivorous	Canada goose (*Branta canadensis*)
Reptiles	
	water snake (*Nerodia sipedon*)
Amphibians	
	bullfrog (*Rana catesbeiana*)

3.3.1 Basic (Coarse) System

- If toxicity data exist for the surrogate species identified in Table 3-1, it should be used as a default for generating the risk estimation database.

- In the absence of toxicity data for one of the surrogate species for a given contaminant in the matrix, toxicity data for any other species within the same class of organisms should be sought out. This species within the same biological class for which data are available would replace the previously identified surrogate only for the specific chemical/species combination for which data were lacking.

- When selecting a substitute surrogate, best professional judgement should be used to identify a species that is both sensitive to the compound of concern and relevant to the habitat being assessed whenever possible.

3.3.2 Detailed System

- If toxicity data exist for the surrogate species identified in Table 3-2, it should be used as a default for generating the risk estimation database.

- In the absence of toxicity data for one of the surrogate species for a given contaminant in the matrix, toxicity data for another species within the genus should be identified. If data for other species within the same genus are unavailable, a toxicity value for another

representative within the same family should be selected. This process of searching for toxicity data for a species in the next-higher category (e.g., genus followed by family, order, class, phylum) of the hierarchal biological classification system should be pursued until a suitable surrogate is identified. This species for which data are available would replace the previously identified surrogate only for the specific chemical/species combination for which data were lacking.

For example, if tributyltin (TBT) toxicity data were unavailable for the eastern oyster (*Crassostrea virginica*), the surrogate identified for the aquatic saltwater invertebrate–mollusc species class, toxicity data for other another oyster in the same genus (e.g. *Crassostrea gigas*) would be used if available. Potential surrogates for each biological category of information are shown for this example in Table 3-3. To assist in the process of selecting surrogate organisms, phylogenetic information for each surrogate identified in Tables 3-1 and 3-2 is provided in Appendix C. A complete list of organisms in each species category can be accessed using the National Center for Biotechnology Information (NCBI) browser at http://www.ncbi.nlm.nih.gov/Taxonomy/tax.html/.

- When dealing with contaminants that have been extensively studied, it is probable that toxicity data exist for many species including the selected surrogate. In cases where there is an extensive database for a given contaminant, every effort should be made to select toxicity data for the species that is most sensitive to the contaminant of concern.

Table 3-3. Example of surrogate selection options for progressively higher phylogenetic groups to replace the eastern oyster (*Crassostrea virginica*) in the absence of sufficient data

Genus	Crassostrea	Pacific oyster (*Crassostrea gigas*)
Family	Ostreidae	edible oyster (*Ostrea edulis*)
Order	Ostreoida	deep sea oyster (*Neopycnodonte cochlear*)
Class	Bivalvia	blue mussel (*Mytilus edulis*)

3.4 References for Section 3

Environment Canada. 1999. Wildlife Contaminant Exposure Model. http://cws-scf.ec.gc.ca/nwrc/wcem/species_e.html

Opresko, D.M. et al. 1995. Toxicological Benchmarks for Wildlife: 1995 Revision. ES/ER/TM-86/R2. U.S. Department of Energy, Oak Ridge National Laboratory, Office of Environmental Management, Oak Ridge, TN.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman, and Brungs, W.A. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. Environmental Research Laboratory, Office of Research and Development, USEPA, Duluth, MN.

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter II, and Welsh, C.J.E. 1997. Methods and tools for estimation of the exposure of terrestrial wildlife to contaminants. USDOE, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, and Suter, II, G.W. 1998. Development and validation of bioaccumulation models for small mammals. USDOE, Office of Environmental Management, Oak Ridge National Laboratory, Oak Ridge, TN.

Texas Natural Resource Conservation Commission. 2000. Guidance for conducting ecological risk assessments at remediation sites in Texas. Website at http:/www.tnrcc.state.tx.us/permitting/remed/techsupp/erag8_00.pdf

USEPA. 1993. Wildlife exposure factors handbook. EPA/600/R-93/187a. USEPA, Office of Health and Environmental Assessment, Office of Research and Development, Washington, DC.

USEPA. 1994. Technical support document for the Hazardous Waste Identification Program: Risk assessment for human and ecological receptors, Volumes 1 and 2. USEPA, Office of Solid Waste, Washington, DC.

USEPA. 1999a. Screening level ecological risk assessment protocol for hazardous waste combustion facilities, Volume One. USEPA, Office of Solid Waste, Washington, DC. Website at http://www.epa.gov/epaoswer/hazwaste/combust/eco-risk/volume1/

USEPA. 1999b. Aquatic food web module: Background and implementation for the multimedia, multipathway, and multireceptor risk assessment (3MRA) for HWIR99. USEPA, Office of Solid Waste, Washington, DC. Website at http://www.epa.gov/OSWRCRA/hazwaste/id/hwirwste/pdf/risk/modules/s0049.pdf

USEPA. 1999c. Data collection for the hazardous waste identification rule, Section 14.0 Ecological Benchmarks. USEPA, Office of Solid Waste, Washington, DC. Website at http://www.epa.gov/OSWRCRA/hazwaste/id/hwirwste/pdf/risk/data/s0044.pdf

White, J.A. 2001. Draft pesticide bulletin for threatened and endangered (T&E) species and migratory birds in USFWS Region 2. USFWS, Region 2, Environmental Contaminants Program. Austin, TX.

4.0 CHEMICAL CLASSIFICATION AND CHEMICAL RANKING AND SCORING PROCEDURES (TASK 2B)

Task 2B of the project proposal intended to develop a preliminary chemical classification system then select a single model chemical to represent each class of chemicals. The model chemicals would then be used in an SRP system for site specific chemical prioritization or in a more generic chemical ranking and scoring (CRS) system to evaluate the (generic) relative hazards of chemicals. We distinguish chemical-based CRS systems from site-based ranking systems (e.g., potential sites for listing on the National Priority List) or issue-based ranking systems (e.g., risk from occupational exposure versus contaminated food) by defining CRS systems as having the following attributes:

- ranks or scores a list of chemicals
- results in relative ranking, not quantitative measure of risk
- includes measures either of toxicity alone or preferably toxicity and exposure

There are many site-based or issue-based SRP systems that include a CRS system as the initial basis for ranking; some of these have been reviewed in Section 2.0 of this report and are not considered further here.

This section presents the results of our review and assessment of possible existing chemical classification systems, a report on the use of what we believe are the two most suitable CRS systems currently available, and a discussion of the utility and limitations of chemical classification and CRS systems compared to more rigorous screening level risk assessments of individual chemicals.

4.1 Chemical Classification

Approximately 75,000 chemicals have been produced and used in the United States in the past 25 years, with over 15,000 estimated to have been produced in significant amounts (Swanson et al. 1997). A primary objective of Task 2B included identifying five chemical classes from the proposed functional chemical classification system to be evaluated as a test case along with five of the species categories identified in the coarse functional ecological grouping system discussed in Section 3.0. Specifically, this task initially involves classifying this enormous number of chemicals into a much smaller number of groups and to find a model chemical that represents that group. This undertaking is fraught with much uncertainty and arbitrary decision making. The problem lies in deciding on a systematic means of evaluating the important characteristics of these chemicals and using some form of structure-activity model to group the chemicals and then to assign one or more chemicals to be representative of that group. By taking a systematic approach to chemical structure alone, we have identified the classes of chemicals listed in Table 4-1. This list is not all inclusive, there is overlap among classes, and it is inconsistent in the breadth and resolution of each class. One could make equally logical arguments for different classifications. For example, one might include all transition metals or all alkaline earth metals in separate aggregate classes. Another option involves development of a higher resolution classification system, using subclasses as shown in Table 4-2 for pesticides that is based on the

Pesticide Action Network (PAN) Classification (http://www.panna.org/). One might also create a system comprised of simpler and smaller number of chemical classes such as that used by Mackay et al. (2000) for organizing physical-chemical properties into a database (Table 4-3). The latter classification is useful as it retains consistency with a widely-used database of chemical properties. Although it does not include some chemicals that would be of potential concern at DOI lands, additional classes could be added to this list to capture refuge-specific contamination concerns.

All of these classifications, though based on best professional judgment, are subjective and widely different classes can be developed depending on how the classes are to be used and what chemical characteristics are considered. Rather than developing a new chemical classification system, the chemical classes listed in Table 4-3 were selected as the recommended classification system given its 1) utility for practical implementation, 2) availability of information for individual chemicals within a class, and 3) flexibility to incorporate additional subcategories to address chemicals of concern to DOI resources. This classification retains consistency with most physical-chemical databases, includes much of the breadth of chemicals identified by CAP, and maintains a logical ordering based on chemical structure. As we noted when classifying organisms into functional grouping classifications in Section 3.3, the coarse ecological grouping system (see Table 3-1) is sufficiently broad that sufficient toxicity information would likely be available for each surrogate identified in the classification. Similarly, the categories in Table 4-3 are broad and contain many chemicals for which adequate physiochemical and toxicity data exist. Although the proposed chemical classification system is a coarse approach, it allows for the inclusion of subclasses as needed. For example, one could break the herbicide class into sulfonyl ureas, phenoxy acids, etc. or insecticides into organophosphates, pyrethroids, etc. We investigate the utility of these sub-classifications below.

We have specifically chosen not to classify according to toxic mode or mechanism of action because nearly all of these chemicals have multiple modes and/or mechanisms of action and such a classification would have created a very complex mix of chemical structures and properties within each toxicological class. For the purposes of this task, we then selected a small subset of five chemical classes or subclasses to investigate further. The intent was to gain insight into the potential limits of chemical classification and test the sensitivity of the classification to the choice of a representative model chemical. In the chemical classification system we selected, the subset of chemical classes was selected to include 1) both well recognized classes for which ample information exists as well as classes for which data are more scarce, and 2) chemicals of importance on DOI lands (based on the contaminant pick list included in the CAP data management system and our review of 113 CAPs completed as of August 2001, see Section 2.3):

(1) sulfonyl urea herbicides (SUHs)
(2) organophosphate insecticides (OPs)
(3) organochlorine pesticides (OCPs)
(4) polychlorinated biphenyls (PCBs)
(5) polycyclic aromatic hydrocarbons (PAHs)

Table 4-1. Chemical classification based on chemical structure.

Acrylamides	Cyclopentadienes	Nicotine and Salts
Acrylic Acids and Its Esters	Dinitrophenols	Nitrobenzenes
Aldehydes	Dinitrotoluenes	Nitroparaffins
Aliphatic Amines	Dinitrocresols	Nitrophenols
Alkanolamines	Epoxides (ethylene oxide,	Nitrotoluenes
Alkenes	propylene oxide,	Organic Acids
Alkylbenzenes	and butylene oxide)	Organic Anhydrides
Aluminum and Its Compounds	Ethyl Fluorocarbons	Organic Peroxides
Aminoazobenzenes	Fluorides	Organic Silicon Compounds
Azobenzenes	Fluorocarbons	Organoarsenicals
Antimony and Its Compounds	Glycols	Organoisocyanates
Arsenic and Its Compounds	Glycol Ethers	Organolead Compounds
Aryl Sulfonic Acids and Salts	Glycidyl Ethers	Organomercurials
Aryl Phosphates	Haloalcohols	Organophosphate Compounds
Azides, Inorganic	Haloethanes	Palladium and Its Compounds
Benzenepolycarboxylates	Haloethers	Pesticides
Benzotriazoles	Halomethanes	PFCs
Beryllium and Its Compounds	Halons	Phthalates Esters
Biphenyl Oxides	Haloethylenes	Platinum and Its Compounds
Boron and Its Compounds	Halounsaturated Ethanes	Polychlorinated Biphenols
Brominated Dibenzo-p-dioxins	HCFCs	Polychlorinated Biphenyls
Brominated Diphenyl Ethers	Iron and Its Compounds	Polycyclic Organic Matter
Brominated Aromatic Compounds	Indium and Its Compounds	Polyethylene Glycols
Bromobenzenes	Inorganic Chlorines	Polycyclic Aromatic
Bromochloromethanes	Inorganic Sulfur	Hydrocarbons
Cadmium and Its Compounds	Ketonic Solvents	Polypropylene Glycols
CFCs	Lead and Its Compounds	Selenium and Its Compounds
CFEs	Lithium and Its Compounds	Silicones
Chlorinated Dibenzofurans	Manganese and Its Compounds	Siloxanes
Chlorinated Paraffins	Metallocenes	Silver and Its Compounds
Chlorinated Naphthalenes	Inorganic Mercury and Its	Tellurium and Its Compounds
Chlorinated Dibenzo-p-dioxins	Compounds	Tetramethylbenzenes
Chlorinated Benzenes	Mercaptobenzothiazoles	Thallium and Its Compounds
Chloropentadienes	Methacrylic Acid and Its Esters	Thioureas
Chlorophenols	Molybdenum and Its Compounds	Titanium and Its Compounds
Chloropropenes	Methyl Fluorocarbons	Trichlorobenzenes
Chlorotoluene	Methyl Ethyl Benzenes	Trimethylbenzenes
Chromium and Its Compounds	Nickel and Its Compounds	Trinitrophenols
Cobalt and Its Compounds	Nitroparaffins	Uranium and Its Compounds
Copper and Its Compounds	Nitroaromatic Compounds	Ureas
Creosote	Nitriles	Xylenols
Cyclic Alkenes		Zinc and Its Compounds

Table 4-2. Chemical Classification of Pesticides (based on Pesticide Action Network Classification)

Chemical Class	Description
1,3-Indandione	Rodenticides that act as anticoagulants. Indandione structure, with substituents.
2,6-Dinitroaniline	Herbicidal compounds containing a dinitroaniline functional group.
Alkyl phthalate	Compounds derived from phthalic acid. Used as insecticides and insect repellents, as well as softeners in plastics manufacturing.
Anilide	Herbicidal compounds with an anilide functional group. Examples are propanil and flufenacet.
Azole	Fungicidal compounds.
Benzimidazole	Fungicidal compounds with a benzimidazole group. Benomyl and thiabendazole are examples.
Benzoic acid	Compounds with a benzoic acid functional group. Many of these are herbicides. Examples are chloramben and dicamba.
Benzoyl urea	Herbicidal compounds with a urea functional group having a benzoyl substituent. Diflubenzuron and Triflumuron are examples.
Bipyridilium	Herbicides containing two pyridine rings, joined through a C-C bond. Paraquat is a bipyridilium compound.
Bis-Carbamate	Compounds containing two carbamate moieties. Typically herbicides.
Botanical	Pesticides derived from plants. These pesticides are typically a plant's natural defense against insects or fungi. Examples are nicotine and pyrethrins.
Carboxamide	Fungicidal compounds. Carboxin and flutolanil are examples.
Chlorinated phenol	Chlorinated aromatic alcohols typically used as microbiocides, fungicides, algaecides, or wood preservatives.
Chloroacetanilide	Herbicidal compounds with a chloroacetanilide functional group. These compounds are frequently found with their breakdown products as contaminants in groundwater. Examples are alachlor and metolachlor.
Chlorophenoxy acid/ ester	Herbicidal compounds such as 2,4-D and 2,4,5-T.
Chloropyridinyl	Triclopyr and its salts are members of this chemical class of herbicidal compounds.
Coumarin	Rodenticides that act as anticoagulants. Cinnamic acid lactone structure.
Cyclohexenone	A relatively new class of herbicidal compounds.
Diacylhydrazine	A relatively new class of insecticide that is persistent in the environment and may pose substantial ecological risks. Methoxyfenozide and tebufenozide are examples.
Dicarboximide	Fungicidal compounds. Vinclozolin and iprodione are examples.
Dinitrophenol	Herbicidal and fungicidal compounds.
Dithiocarbamate	Typically fungicides with a carbamate structure where sulfurs replace both oxygens in the amide functional group. Examples are maneb, metam sodium, and ziram.
Halogenated organic	A diverse array of compounds composed mainly of carbon, hydrogen, and fluorine, chlorine, and/or bromine. Used as fumigants, fungicides, solvents and propellants.
Imidazolinone	A relatively new class of herbicidal compounds.
Inorganic-Arsenic	Arsenic-containing compounds that do not have arsenic-carbon bonds.
Inorganic-Cadmium	Cadmium-containing compounds that do not have cadmium-carbon bonds.
Inorganic-Chromium (VI)	Chromium-containing compounds that do not have chromium-carbon bonds, where the chromium atom is hexavalent (Cr^{+6}).
Inorganic-Lead	Lead-containing compounds that do not have lead-carbon bonds.

Table 4-2 (Continued). Chemical Classification of Pesticides (based on Pesticide Action Network Classification)

Chemical Class	Description
Inorganic-Mercury	Mercury-containing compounds that do not have mercury-carbon bonds.
Inorganic-Silver	Silver-containing compounds that do not have silver-carbon bonds. Most are used as microbiocides.
Inorganic-Zinc	Zinc-containing compounds that do not have zinc-carbon bonds. Most are used as microbiocides or fungicides.
Microbial	Pesticides composed of a particular species of microbe, e.g. *Bacillus thuringiensis.* Generally, these microbes produce a toxin that is the "active ingredient" that kills a pest. Microbial pesticides are typically very selective, affecting only the target pest.
N-Methyl carbamate	Compounds (mostly insecticides) with an N-methyl amide functional group.
Naphthalene acetic acid	Plant growth regulators with low acute toxicity.
Oil - essential	Oils with pesticidal properties extracted from plants. Examples are cinnamon, peppermint, jasmine, and lavender oils.
Oil - vegetable	Oils extracted from plants such as soybeans and corn and used as insecticides. They work by smothering the insects.
Organoarsenic	Arsenic-containing compounds with an organic moiety bound directly to arsenic.
Organochlorine	Compounds, mostly insecticides, composed primarily of carbon, hydrogen, and chlorine.
Organomercury	Mercury-containing compounds with an organic moiety bound directly to mercury.
Organophosphorus	Compounds, mostly insecticides, that contain a phosphorus atom bound to organic substituents, either alkyl or alkoxy groups. Most organophosphorus pesticides are cholinesterase inhibitors which cause neurotoxicity.
Organotin	Tin-containing compounds with an organic moiety bound directly to tin. Examples are tributyltin or triphenyltin salts.
Other carbamate	Compounds (mostly insecticides) with an amide functional group with substituents besides methyl groups. Many of these carbamates are mild cholinesterase inhibitors which cause neurotoxicity.
Petroleum derivative	Compounds derived from crude oil through a distillation process. Frequently used as solvents, adjuvants, and insecticides.
Pheromone	Insect sex-attractant hormones used to disrupt mating. These compounds are used in very small quantities and are very selective for a particular insect species. Their chemical structure is typically a long-chain alcohol, aldehyde or ester with at least one double bond.
Phosphonoglycine	Herbicidal organophosphorus compound. Glyphosate and its salts and esters (active ingredients in Roundup products) belong to this class of compounds.
Pyrazole	A relatively new class of insecticides, Chlorfenapyr (Pirate) is an example.
Pyrethroid	Synthetic insecticides (typically cyclopropane carboxylates) structurally similar to pyrethrins, which are naturally occurring insecticidal compounds.
Pyridinecarboxylic acid	Herbicidal compounds with low acute toxicity.
Quaternary ammonium	Ammonium salts with four alkyl or aryl groups, typically used as microbiocides or algaecides.
Silicone	Synthetic oils with a silicon-oxygen backbone. Used as antifoaming agents and emulsifiers.
Soap	Compounds with surfactant or detergent properties. Used as insecticides and adjuvants.

Table 4-2 (Continued). Chemical Classification of Pesticides (based on Pesticide Action Network Classification)

Chemical Class	Description
Substituted benzene	Fungicidal compounds with a benzene ring substituted with various substituents. Some of these compounds are very toxic wood preservatives such as pentachloro-nitrobenzene (PCNB) and hexachlorobenzene.
Sulfonyl urea	Herbicidal compounds with a urea functional group having a sulfonyl substituent. Bensulfuron-methyl and primisulfuron-methyl are examples.
Thiocarbamate	Typically herbicides with a carbamate structure where sulfur replaces one of the oxygens in the amide functional group. Examples are cycloate, butylate, and molinate. These compounds are weak cholinesterase inhibitors.
Triazine	Typically herbicides or microbiocides containing a triazine ring.
Uracil	Herbicidal compounds derived from uracil. Bromacil and terbacil are examples.
Urea	Herbicidal compounds with a urea functional group. Diuron and linuron are examples.

Table 4-3. Chemical classification used by Mackay et al. (2000) for physical-chemical property database, modified to include metals.

monoaromatics	hydrocarbons	aldehydes and ketones
chlorobenzenes	halogenated hydrocarbons	phenolic compounds
PCBs	ethers	carboxilic acids
PAHs	alcohols	esters
PCDDs	fungicides	nitrogen and sulfur compounds
PCDFs	metals	herbicides
		insecticides

4.1.1 Required Chemical Property Data

The criteria used to select model chemicals to represent a chemical class are arbitrary in some cases; however, a framework for identifying surrogate chemicals can be developed such that rules for model chemical selection are based on chemical properties, toxicity profiles, availability of ecotoxicological information, and professional judgement. For example, risk is going to be a function of chemical exposure and endpoint-specific or site-specific toxicity. Chemical exposure is a function of the physical-chemical properties of the chemical (that determine the generic fate of the chemical), site-specific properties of the environment (that determine the site-specific fate of the chemical), and the release or loading of the chemical to the environment. The latter two sets of parameters cannot be incorporated into a generic CRS system (they are within the domain of an SRP system or a risk assessment). Given the nature of the chemical classes listed above (all are organic chemicals) and the need for information on expected (generic) fate of the chemical, we can easily determine the parameters necessary for any chemical profile. These are the same parameters that are required to perform an evaluative Level II or Level III multimedia fate model of a chemical (Mackay et al., 2000):

(1) water solubility
(2) vapor pressure
(3) octanol-water partition coefficient (K_{ow})

(4) melting point
(5) molar mass
(6) reaction half-life in air, water, soil, bedded sediment, suspended sediment, aerosol, biota
In addition to the physical-chemical properties, toxicity information is needed for each biological indicator to be used in the CRS, SRP, or risk assessment process. This information is dependent upon the type of assessment system that is being used and on rules established for missing data values for an indicator (i.e., selection of surrogate species if data on primary species is not available). Defining the toxicity assessment is beyond the scope of this task, so we will simply use common threshold values (e.g., LC50s and EC50s) for our analysis here. Below we use a much more detailed toxicity assessment when we perform a test of a CRS system (Section 4.3).

4.1.2 Selection and Appropriateness of Representative Chemicals

For most hazard or risk assessment screening applications, uncertainty of an order of magnitude is considered acceptable. Uncertainty that is much greater than this makes the assessment of little value; uncertainty much less than this usually requires resources that exceed the worth of the (screening) assessment. Thus, an appropriate criterion for a chemical to be representative of a broader chemical class might be a chemical that is at the mid-point within a factor of ten range of physical-chemical and toxicological properties. A preliminary review of both the chemical and toxicological properties of chemicals within each of the five test classes listed above (page 51) reveal that chemical property values can vary many orders of magnitude within each class. One also must consider how the aggregate properties influence exposure and toxicity. Two chemicals within a class may have very similar degradation half-lives, but their water solubilities could be several orders of magnitude different. For example, more water-soluble chemicals could be transported (and diluted) much more rapidly than their less water-soluble counterparts, resulting in a much lower risk estimate. If the chemical is not readily metabolized, then less water-soluble chemicals could accumulate in the food chain and would be much more likely to yield higher exposure to soil or sediment dwelling organisms. Thus, the complexity of the transport-fate-toxicity progression makes it very difficult to decide which properties determine the representativeness of individual chemicals.

An example of this is presented for PAHs. We performed a Level III multimedia fate model for seven PAHs to illustrate the fate of these chemicals and to estimate an overall reaction half-life for each PAH (Figure 4-1a-g). The relevant physical-chemical properties used for the fate modeling are listed in Table 4-4 and were obtained from Mackay et al. (2000). The aqueous solubilities of these seven PAHs range over five orders of magnitude, vapor pressures range over ten orders of magnitude, K_{ow} values range almost five orders of magnitude, and overall reaction half-lives range over three orders of magnitude. Clearly, one cannot represent the physical-chemical properties of the entire class of PAHs with a single PAH. One might next consider using a single PAH to represent all PAHs with the same number of rings. This decreases the range of values, but one still exceeds an order of magnitude for many parameters. For example, both Naphthalene and C4-Naphthalene have two aromatic rings, but C4-Naphthalene has four substituted methyl groups. The aqueous solubility and K_{ow} values differ by over 100, the vapor pressures differ by over 25,000, and the overall half-lives differ by more than a factor of ten. Similar, though slightly smaller differences, exist between non-substituted PAHs of same ring

number but different configurations. For example, the highly condensed benzo[a]pyrene and the linear dibenz[ah]anthracene both have five aromatic rings, but their aqueous solubilities differ by more than a factor of ten and their vapor pressures differ by three orders of magnitude (data not shown). One introduces a substantial amount of error even when using a single PAH to represent other PAHs of the same ring number.

Table 4-4. Example of physical-chemical properties of some PAHs

Property	Nap	C4-Nap	Phe	Pyr	BaP	BPr	Cor
# aromatic rings	2	2	3	4	5	6	7
solubility (g/m^3)	32	$9.8x10^{-2}$	1.18	$1.3x10^{-1}$	$3.8x10^{-3}$	$2.6x10^{-4}$	$1.4x10^{-4}$
vapor pressure (Pa)	11	$4.0x10^{-4}$	$2.0x10^{-2}$	$6.0x10^{-4}$	$7.0x10^{-7}$	$2.2x10^{-8}$	$2.0x10^{-10}$
log K_{ow}	3.3	5.3	4.5	5.18	6.04	7.1	8.2
Melting point (ºC)	81	122	101	156	175	275	440
overall half-life (h)	57	8588	4758	20369	26536	30143	83501

Nap: naphthalene, C4-Nap: tetramethyl naphthalene, Phe: phenanthrene, Pyr: pyrene, BaP: benzo[a]pyrene, BPr: benzo[ghi]perylene, Cor: coronene

A similar analysis can be performed for the other classes of chemicals; a summary is given in Table 4-5 and includes a range of toxicity values. Given the immense range in values that control both the exposure and toxicity of chemicals within a chemical class, the use of a representative chemical for these classes is not advisable or particularly useful for CAP. The example for PAHs in Table 4-4 indicates that the use of sub-classifications (e.g., ring number) reduces the range of physical-chemical values, but not enough to limit the utility of using model chemicals to represent a class (assuming uncertainty is to be kept below about an order of magnitude). Similarly, making sub-classes of the organophosphate insecticides (e.g, phosphates, phosphorothionates, phosphorodithionates) reduces the range of physical-chemical values, but not below 1-2 orders of magnitude. Assigning sub-classes of PCB compounds based on the number of chlorine substituents is the only sub-classification that reduces the range of physical-chemical values to less than an order of magnitude. However, the range of toxicity values still remains greater than an order of magnitude for several of the PCB sub-classes due to the specific Ah-receptor mediated toxicity of the non-ortho and mono-ortho PCBs congeners (i.e., the position of the chlorine group on the biphenyl ring determines toxicity but does not have an effect on physical-chemical properties).

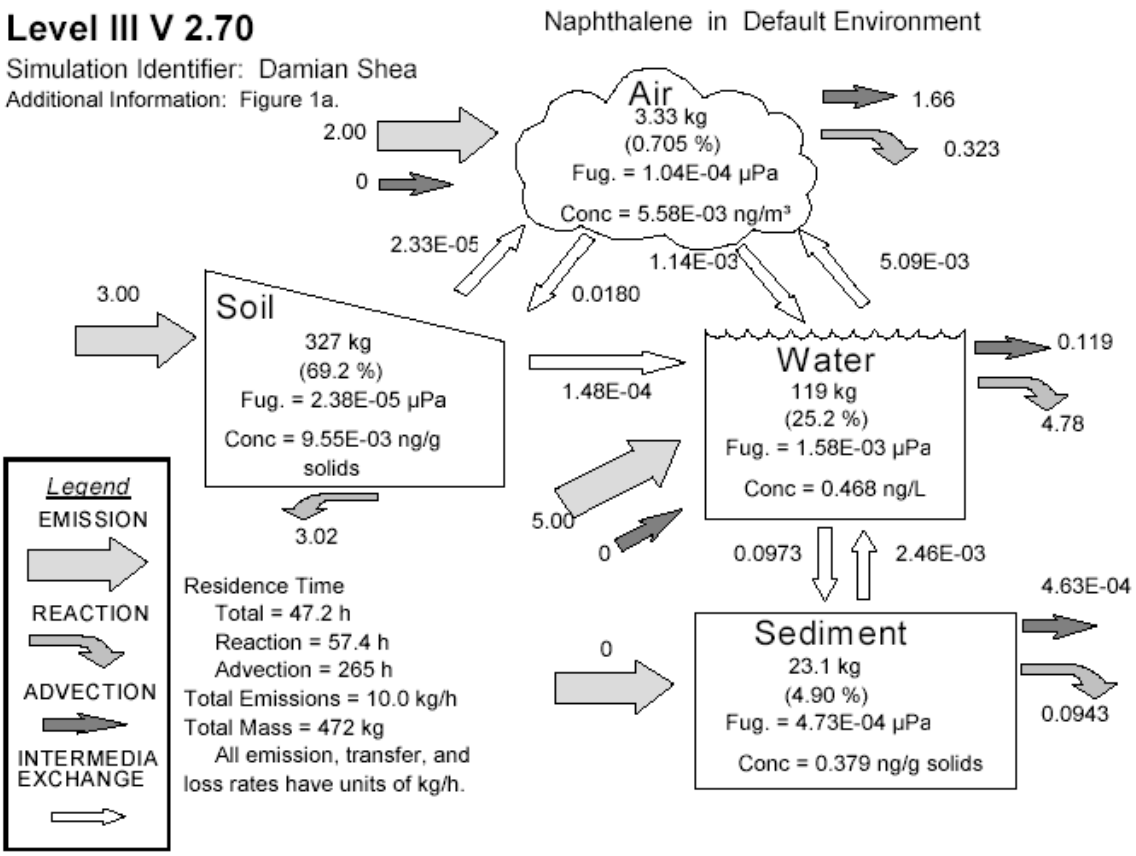


Figure 4-1a. Generic multimedia fate model of naphthalene.

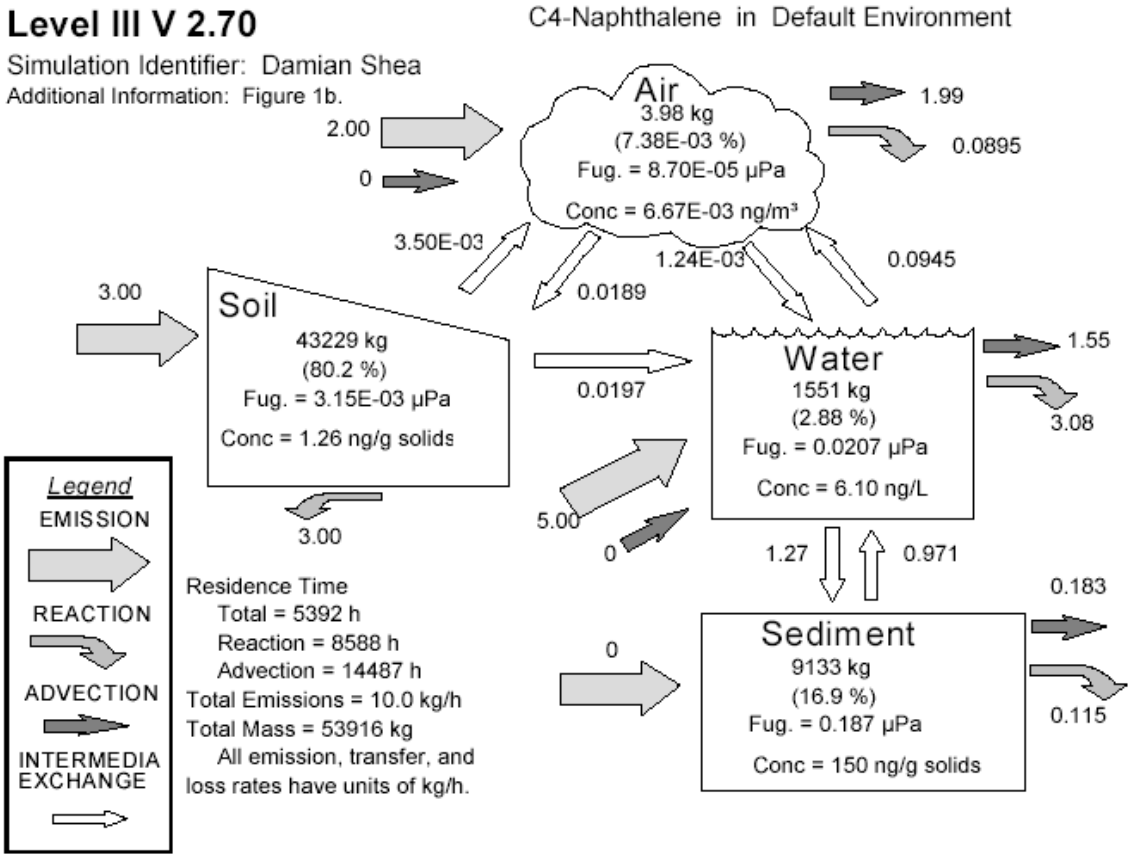


Figure 4-1b. Generic multimedia fate model of C4-naphthalene.

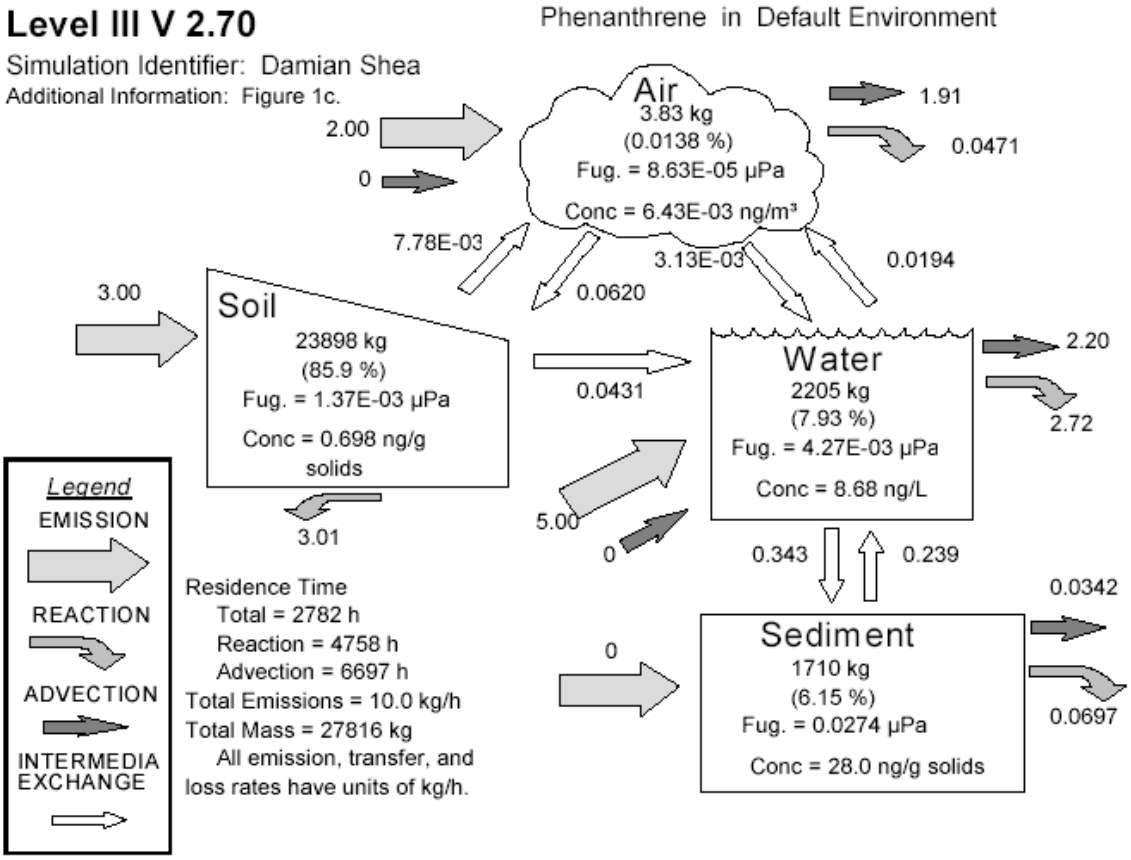


Figure 4-1c. Generic multimedia fate model of phenanthrene.

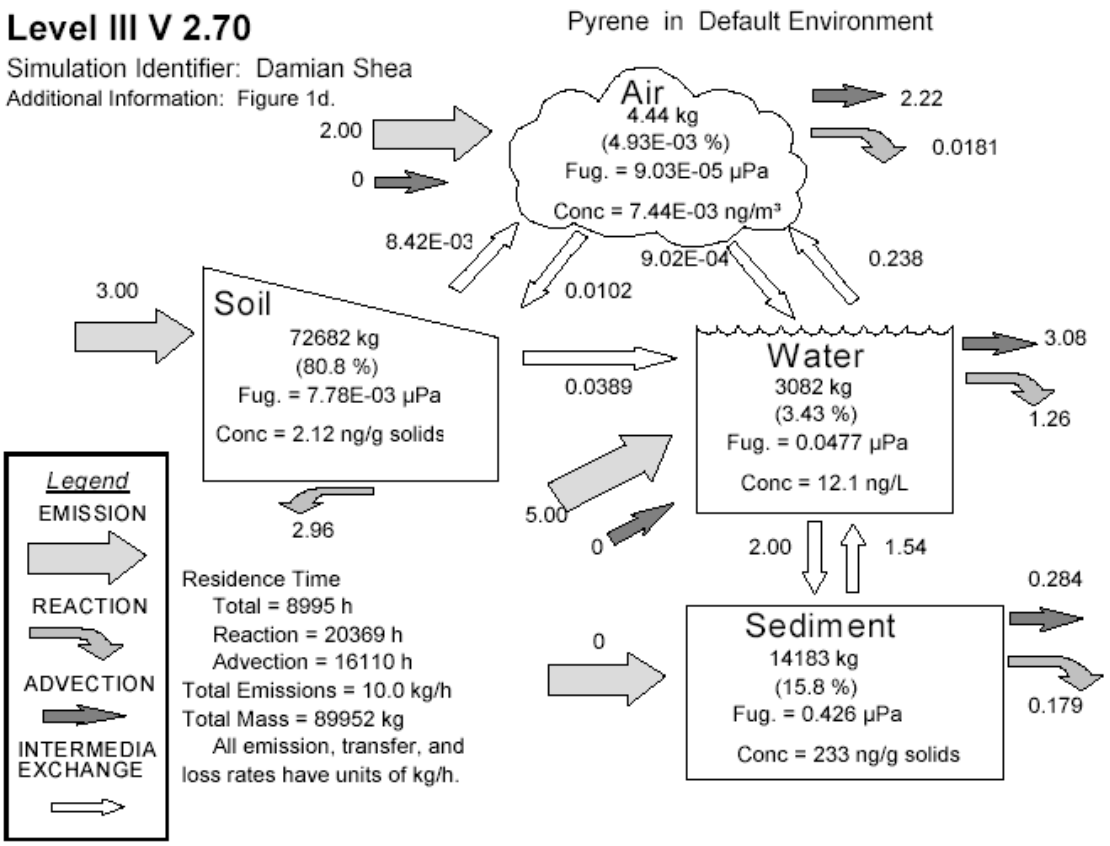


Figure 4-1d. Generic multimedia fate model of pyrene.

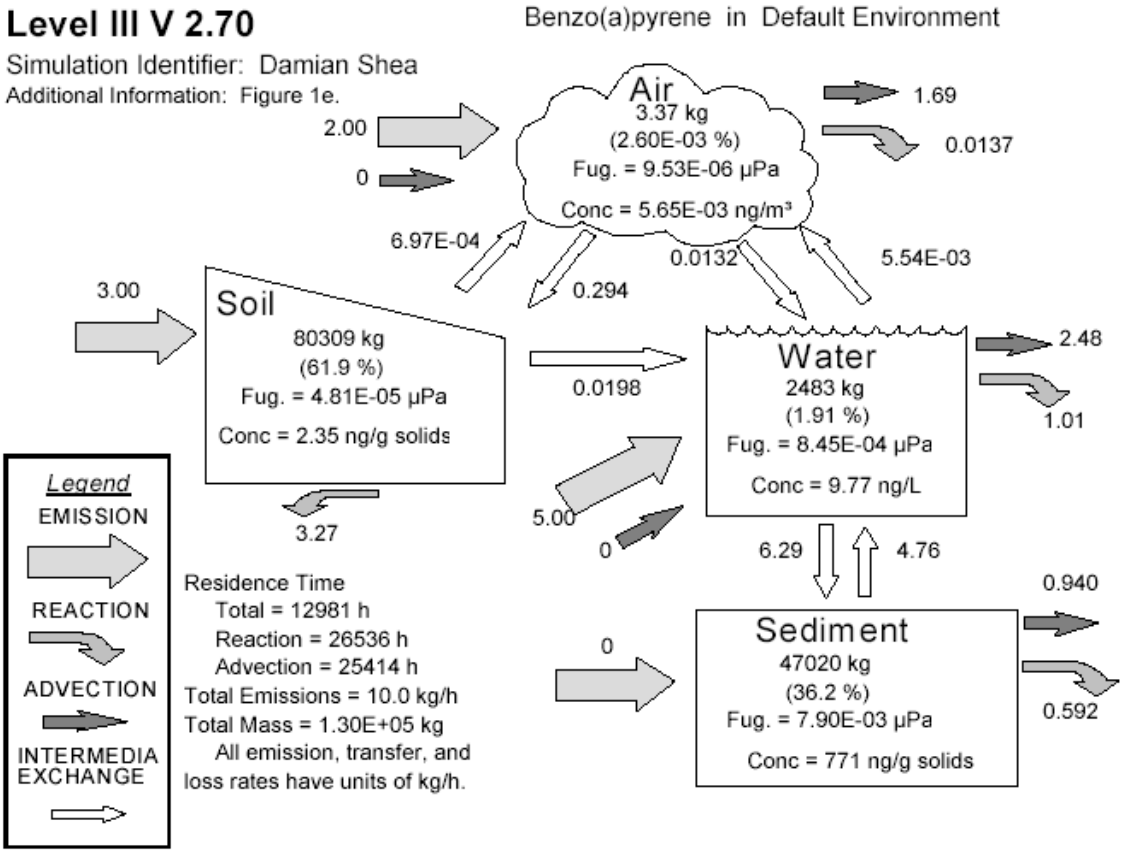


Figure 4-1e. Generic multimedia fate model of benzo[a]pyrene.

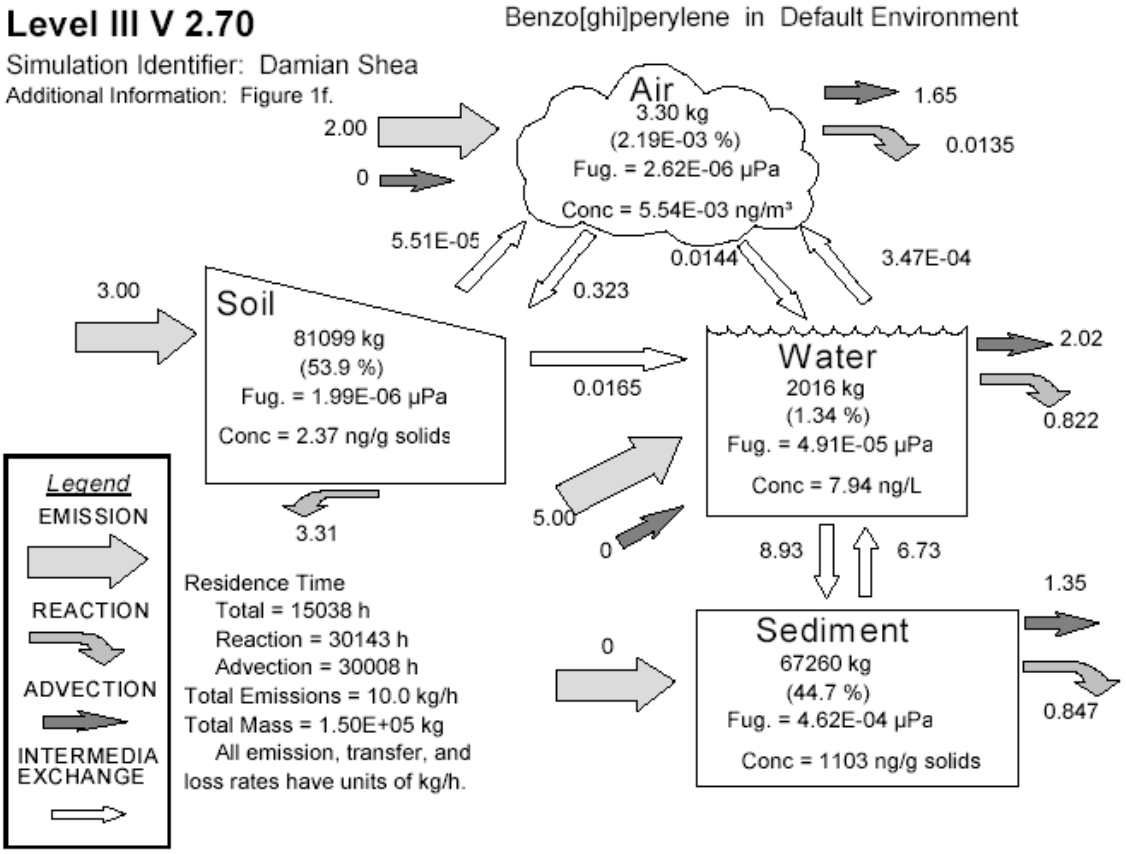


Figure 4-1f. Generic multimedia fate model of benzo[ghi]perylene.

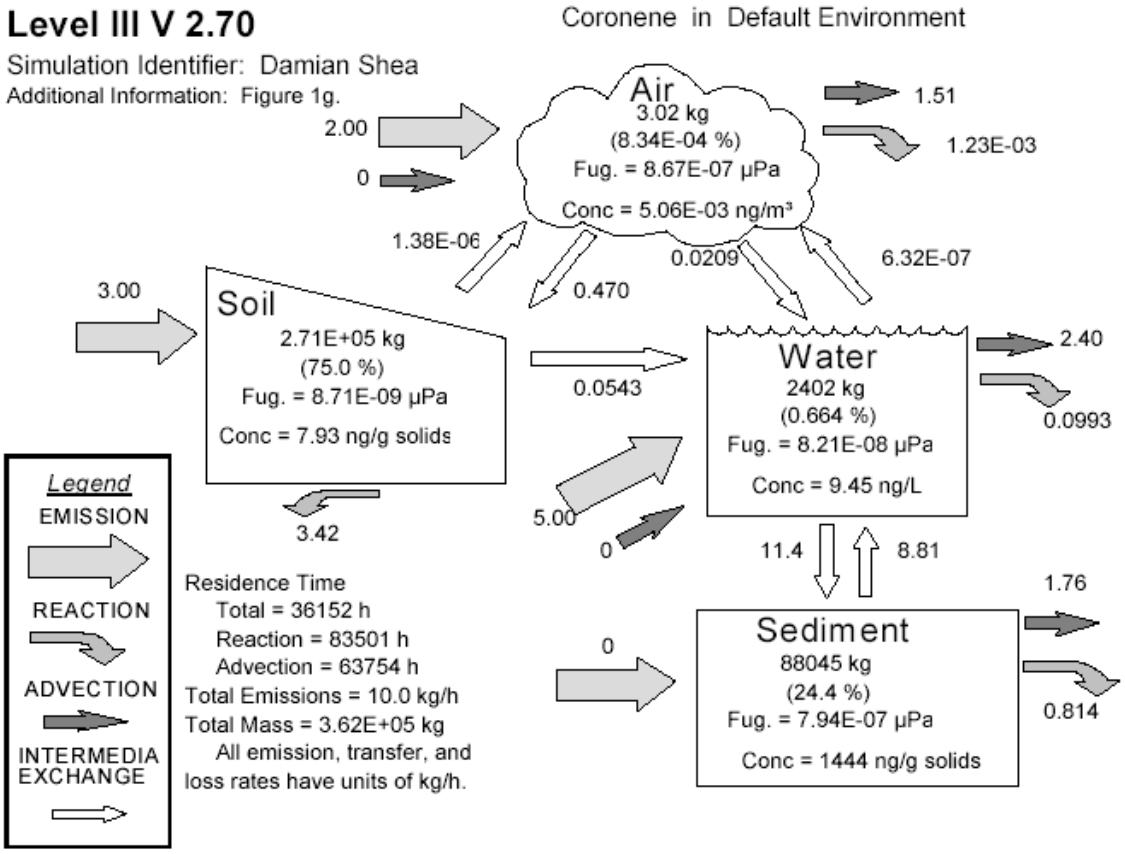


Figure 4-1g. Generic multimedia fate model of coronene.

Given the discussion and examples above, we have concluded that it is a very serious mistake to select individual model chemicals to represent broad classes of contaminants for ranking and scoring, or for more rigorous risk assessment. Instead, we recommend that any CRS (or SRP or risk assessment) process include individual chemicals that can be readily measured using standard methods of analysis, that have relevant physical-chemical and toxicological properties available, and that are produced or used in quantities that might yield or have been demonstrated to yield (through monitoring data) meaningful exposure in the environment.

Table 4-5. Range of values for physical-chemical and toxicological properties for five chemical classes.

Property	SUHs	OPs	OCPs	PCBs	PAHs
solubility (g/m^3)	$10^{3.5}$	$10^{3.4}$	$10^{4.3}$	$10^{5.3}$	10^{5}
vapor pressure (Pa)	10^{9}	$10^{4.8}$	$10^{3.6}$	$10^{7.6}$	10^{10}
K_{ow}	$10^{2.5}$	$10^{2.7}$	$10^{3.3}$	10^{4}	10^{5}
overall half-life (h)	$10^{1.5}$	$10^{1.6}$	10^{2}	$10^{2.1}$	10^{3}
EC50 (µg/L)	$10^{1.3}$	10^{4}	10^{3}	$10^{4.7}$	10^{2}

SUHs: sulfonyl urea herbicides, OPs: organophosphate insecticides, OCPs: organochlorine pesticides, PCBs: polychlorinated biphenyls, PAHs: polycyclic aromatic hydrocarbons

4.2 Chemical Ranking and Scoring

The USGS and FWS have expressed interest in developing a standardized, systematic process of performing a screening-level estimation of risk posed by contaminants to resources that they manage. They desired a standardized ranking and prioritizing system that would use a standard set of toxicity and exposure values for potential contaminant-species interactions as the basis for a uniform process for ranking and prioritizing contaminants. More detailed background information and a thorough review of both existing SRP approaches and the proposed SRP for CAP is provided in Section 2.0 of this report. This section focuses on chemical ranking and scoring (CRS) procedures which could be incorporated into the SRP system for CAP. These procedures are independent of location, though they could be used as the basis of site-specific or issue-specific assessments.

Despite the immense concern over this issue and the effort devoted to understand the fate and effects of chemicals in the environment, there is no agreement on how to rank or categorize chemicals according to their persistence, bioaccumulation, and toxicity. Numerous CRS screening tools have been developed for priority-setting in risk assessment that involve ordering chemicals either by scoring and ranking them individually or placing them in groups based on degree of concern (e.g., high, medium, low). The vast majority of these CRS systems were developed prior to 1990, reflecting the popularity they enjoyed in the late 1970's and 1980's. We have identified over 140 chemical ranking systems developed prior to 1994. Since the mid-1990s only a few peer-reviewed CRS systems have been proposed, as more quantitative risk assessment procedures have matured and gained wide acceptance. Davis et al. (1994) reviewed 51 CRS methodologies that existed at the time of that review. This review was somewhat critical of the lack of consistency and agreement of the CRS methods and offered recommendations for improvement and how to reach consensus on a general framework for CRS systems. This review was followed by a Pellston Workshop in 1995 (Swanson and Socha, 1997) that reviewed the underlying management goals and scientific basis for CRS systems, and outlined future research needs and recommendations. Neither of these reviews provided revised or improved CRS systems, but since that time four new peer-reviewed CRS systems have been proposed and one existing CRS system has undergone a major modification. These five CRS systems are summarized in Appendix D. We reviewed many of the CRS systems evaluated by Davis et al. (1994) and found them to be inferior in many ways to those more recently developed (Appendix D). The summary provided by Davis et al. (1994) provides adequate explanation of older systems, including limitations that have since been improved upon.

4.2.1 Existing Chemical Ranking and Scoring Approaches

The following sections discuss several existing CRS systems for contaminants that could be applied to the proposed ranking and prioritizing approach. Functional CRS systems were identified through an extensive search of literature databases and the internet. In addition, agency publication searches were conducted to identify existing classification approaches. For each system identified (that has not been previously summarized either in Davis et al. (1994) or Swanson and Socha (1997)), strengths and weaknesses and their potential to meet the needs of

the proposed ranking and prioritizing approach are discussed. Summary tables of the CRS approaches reviewed are provided in Appendix D.

University of Tennessee Chemical Hazard Evaluation for Management Strategies (CHEMS-1)

CHEMS-1 was developed as a screening tool for the evaluation of chemical hazards to human health and the environment. The system includes measures of human health and environmental toxicity data, release amounts, and physiochemical data. The system is designed to address several tasks including selecting estimation methods for data gaps, establishing rules to assign scores for toxicity and exposure potential, and developing a weighted algorithm to combine individual scores into a rank for each chemical. An advantage of the CHEMS-1 ranking and scoring approach is that it allows for interpretation of chemical release data with information on the environmental persistence and bioaccumulation potential of individual compounds. CHEMS-1 is a first tier approach that relies on fish toxicity data only for evaluation of environmental effects. Proposed future work includes expansion of the system to include toxicity data for various trophic levels and expanding the scoring capabilities for exposure assessment to include fate and transport modeling; however, at this time, the utility of this system when assessing diverse environmental hazards is limited. CHEMS-1 attempts to incorporate physiochemical data for all TRI compounds in the algorithm; therefore, data gaps are likely.

Hazard Ranking of Organic Contaminants in Refinery Effluents

This approach was developed by the University of Oslo and the Center for International Studies at the Massachusetts Institute of Technology for hazard ranking of constituents in petroleum effluents based on physiochemical properties (Siljehom, 1997). The hazard level for this model is a function of the product of physiochemical variables for individual compounds. The final score for each chemical is obtained by normalizing the hazard level calculation. This system adequately ranks and prioritizes the environmental hazards associated with various chemicals at a site; however, it will not allow for comparison of risk between sites without modification of the existing model. In addition, the model does not address data gaps (e.g., the only species for which toxicity data was available for all compounds considered in the trial run was *Daphnia magna*).

U.S. EPA Use Cluster Scoring System (UCSS)

U.S. EPA developed the UCSS to prioritize chemicals and chemical groups, or clusters, for risk reduction purposes, targeting specific industries and chemical users (USEPA, 2000). The system is a computer program that contains hazard and exposure data compiled from various sources and databases for chemicals and chemical clusters. A use cluster is a set of chemicals that are used (and can be substituted) for a particular use. Scoring of individual chemicals within clusters allows the user to rank high, medium, and low concern compounds and subsequently substitute lower risk chemicals for risk reduction initiatives. Scores are assigned for six components that are combined to produce an overall UCSS score for individual compounds. The system currently contains data for 400 different use clusters and approximately 5,000 individual

chemicals. The advantages of the UCSS when applied to the conceptual CAP SRP system include the extensive and well established database of toxicity information, relatively low complexity, and a chemical grouping approach analogous to the one proposed for CAP that could serve as a template or allow determination of the relative representativeness of surrogates based on hazard potential. We found the UCSS is limited by difficulties experienced when attempting to isolate the ecological hazard scores from the human health scores. This approach is also limited because the UCSS does not provide raw scoring data or allow for uncertainty analysis.

U.S. EPA Waste Minimization Prioritization Tool (WMPT)

The Waste Minimization Prioritization Tool (WMPT) is a CRS system that provides relative rankings of chemicals intended for making waste management and waste minimization decisions (USEPA, 1997a). The WMPT generates an overall chemical score from data on toxicity and the potential for exposure, the latter based on the chemical's persistence and bioaccumulation potential. The WMPT can be used for both humans and ecosystem assessments. The WMPT incorporates the amount of a chemical generated and its potential for release into the environment (termed a "subfactor mass"), but it only considers loading and not transport. The loading information could be regional or national in scale. The WMPT retains the numerical score so that arbitrary classifications are more transparent. Modification of this system would be necessary in order to use the subfactor mass approach for CAP SRP applications. In addition, the WMPT incorporates several assumptions (particularly related to persistence and toxicity algorithms) but an analysis of uncertainty is not included in this approach.

Michigan Department of Environmental Quality Chemical Scoring and Ranking Assessment Model (SCRAM)

The Scoring and Ranking Assessment Model (SCRAM) was developed to be used as an analytical tool for chemical scoring and ranking by the Michigan Department of Environmental Quality, Surface Water Quality Division (SWQD), and Michigan State University, National Food Safety and Toxicology Center (Snyder et al., 2000a-d). Specifically, this model is intended to be used as a decision support tool for managing and prioritizing chemicals for risk assessment or further research. The system is designed to evaluate the relative risk associated with individual chemicals and is inappropriate for evaluating mixtures. SCRAM contains standardized guidelines for selecting and scoring appropriate data in the three categories for each chemical assessed. Further details regarding scoring and relative risk ranking using this model are presented in Section 4.3.

Like many other approaches described above, the SCRAM approach emphasizes persistence, bioaccumulation, and toxicity when modeling relative risk; however, it also is unique in its approach to handling uncertainty. Unlike many models available, SCRAM assigns uncertainty scores for each category of information incorporated in the model (persistence, bioaccumulation, and toxicity) allowing for interpretation of potential risks associated with chemicals for which little data are available. In fact, bias in the model whereby higher scores (indicative of greater environmental concern) are assigned in cases where chemical specific data are scarce is intended

to provide the impetus for additional research efforts. If a user believes this bias is not warranted, they can manually adjust or eliminate the uncertainty scores. SCRAM provides separate chemical and uncertainty scores, along with a combined uncertainty score. Again, this provides transparency and flexibility so that prioritization can be performed in different ways and it is clear what type of scores are driving the ranking (i.e., the relative importance of the uncertainty score to the overall ranking is clear).

The environmental fate properties of a chemical are emphasized in SCRAM by applying a weighting factor to the scores for persistence and bioaccumulation. This weighting factor is applied to the chemical and uncertainty scores for bioaccumulation and persistence to intentionally increase the influence of these two exposure-related properties on the final score. The developers of SCRAM bias the environmental fate in the model because of their concern that a chemical may have a toxicity that has yet to be identified. The authors of SCRAM claim that the aggregation of chemical properties into a single score, the evaluation of chemicals with limited data, and the additional bias given to the environmental fate category allow the identification of chemicals with limited data that could potentially cause adverse effects in the environment. This bias is not universally accepted; however, the advantage of SCRAM is that the derivation of the scores and the biases are transparent and can be modified by the user.

Based on the reviews of the systems summarized in Appendix D and preliminary testing of reviewed systems that were available in the public domain, we choose to run a more detailed test using a modified version of the Chemical Scoring and Ranking Assessment Model (SCRAM) that was developed to score and rank the relative risk of chemicals in the Great Lakes region (Mitchell et al. 2002; Snyder et al. 2000a,b,c,d). This test application built upon the example that the model developers used for chemical data from the Great Lakes region; however, for our purposes, the model was modified to evaluate terrestrial and aquatic ecological risks only (e.g., the human health component of the model was eliminated). A more detailed discussion of the relative risk scoring and modeling results are presented in Section 4.3.We found the SCRAM system to be flexible and generic enough to be used for national or other regional scale applications, with some advantages over other CRS systems evaluated. The SCRAM model is available at no charge and can be downloaded via the internet. However, the database used in SCRAM is proprietary and is not available to the public.

ChemSCORER

ChemSCORER is a chemical ranking and scoring model developed by Don Mackay and co-workers at Trent University in Peterborough, Ontario, Canada (Mackay et al., 2000) who are also the developers of the multimedia fugacity models used to generate data for Figure 4-1. The system is only in a beta test version and has not been published yet, but it is available for testing. ChemSCORER is a Microsoft Excel spreadsheet based tool that provides a rapid assessment of environmental hazard associated with organic chemicals. Much like SCRAM, it assesses individual chemicals for persistence (P), potential for bioaccumulation (B), and toxicity (T). In addition, ChemSCORER includes an assessment of the potential for long-range transport (LRT). The model ranks individual chemicals against a set of reference chemicals. Data from over 160

chemicals are provided in the default database of the beta version. The database is easily modified by the user. Model output includes:

1. a summary plot of P, LRT, B, and T
2. Level I, II, and III multimedia fate summaries
3. Level I, II, and III characteristic travel distance summaries
4. summary of chemical fate in an evaluative foodweb

ChemSCORER provides a capability to graphically illustrate the chemical fate and bioaccumulation, in addition to plotting the scoring and ranking of chemicals. ChemSCORER is not nearly as robust as SCRAM, with regard to toxicity endpoints and inclusion of surrogate species. However, there is no reason that additional toxicity data could not be added to this model. ChemSCORER also uses a non-proprietary database that is integrated into the model (no manual entry of data is required), whereas SCRAM uses a proprietary database that is not integrated into the model (data must be manually transferred from the SCRAM or user database and entered into SCRAM). Unlike SCRAM, ChemSCORER does not include uncertainty in the scoring of chemicals, though it would be easy to modify the algorithm to include uncertainty. The ChemSCORER model and database are available at no charge and can be downloaded via the internet. To our knowledge, the model has not yet undergone peer review and is still considered a beta test version. We provide an illustration of this system with a single chemical as a comparison to SCRAM in Section 4.4.

4.3 Initial Testing of SCRAM as a Chemical Ranking and Scoring System

The sections below presents a summary of the standardized guidelines in SCRAM for selecting and scoring appropriate data in the three categories for each chemical assessed. Our intent here is to provide a description and initial assessment of SCRAM as a tool for scoring and ranking chemicals on DOI lands. We first tested SCRAM in its original form and then modified SCRAM to exclude human health endpoints.

4.3.1 Selection of Chemicals

Given the preliminary nature of this exercise and the desire to develop a system that could include chemicals for which data are lacking, we screened a large number of chemicals to obtain a manageable list to be tested. We followed the general approach used by the developers of SCRAM and obtained a nearly identical list of chemicals. First, a literature review was conducted to determine which chemicals had at least one data point for persistence, bioaccumulation, and toxicity. We then chose chemicals from chemical classes that were commonly reported on CAP reports and that spanned a broad range of chemical and toxicological properties. The selected chemicals were scored using the SCRAM model described by Snyder et al. (2000a), and then separately using SCRAM modified to exclude human toxicity and to include only the surrogate species identified in Section 3.3 of this report. Table 4-6 presents example toxicity values of selected chemicals for primary surrogate species identified in the coarse functional grouping system previously described in Section 3.3.

4.3.2 Data Sources

Numerous books, reports, peer-reviewed papers, and online databases were searched to find data describing the persistence, bioaccumulation and toxicity of the chemicals. A listing of most of the sources is provided in Table 4-6. We also searched Mackay et al. (2000) and several proprietary databases (available to authors from North Carolina State University). In the end, we used the proprietary database incorporated in SCRAM because it contained similar values to the others, provided consistency with the previous applications of SCRAM, and required over 2000 hours of effort to obtain (E. Snyder, pers. comm.). The data selection procedure used in SCRAM is discussed in Mitchell et al. (2002) and Snyder et al. (2000a,b,c) and summarized below.

Table 4-6. Example Toxicity Values for Surrogate Species Identified for the Coarse Functional Grouping System.

Species Category	Primary Surrogate	Units	Sulfonyl Urea Herbicides		Organophosphate Pesticides		Polycyclic Aromatic Hydrocarbons		Organochlorine Pesticides		Polychlorinated Biphenyls	
			Primisulfuron-methyl		Chlorpyrifos				DDT			
			Acute LD50	Chronic (NOEL or NOEC)	Acute LD50	Chronic (NOEL or NOEC)	Acute LD50	Chronic (Lowest NOEL or NOEC used)	Acute LD50	Chronic	Acute LD50	Chronic (Lowest NOEL or NOEC used)
bird	northern bobwhite	mg/kg or mg/kg/d	>2150 [1-3]	500 [3][a]	13.3-32.0 [4]	---	---	---	---	---	604 [5][m]	---
mammal	Rat (oral)	mg/kg or mg/kg/d	>5050 [1, 2]	12.4 [3]	69-276 [6]	0.0132 [7]	490 [8][f]	41 [9][f]	87.0 [10]	1[11]	794-1269 [5][m]	10 [12][n]
freshwater fish	rainbow trout	mg/l	13[2, 10]	---	0.003 [1]	---	0.03 [13][h]	0.011[14][f]	0.007 [15]	---	0.012-0.067 [16][m]	---
saltwater fish	sheepshead minnow	mg/l	100[10]	---	0.076 [10]	---	2.4 [17][d]	---	0.0050 [10]	---	0.0001-0.00032 [18][m]	---
reptile	racer	mg/kg or mg/kg/d	---	---	---	---	---	---	---	---	---	---
amphibian	bullfrog	mg/kg or mg/kg/d	---	---	>400 [19]	---	>6.7 mg/l[16][dg]	---	7.6 [10][l]	---	---	---
plant	corn	kg/ha or lb/acre	0.00185 [3][k]	---	---	---	10-1000[20][j]	---	---	---	---	---
freshwater invertebrate	water flea	mg/l	260 [1][e]	0.41[21]	0.00008 - 0.00013 [22]	0.00004 [23]	0.005[24][g]	0.11[25][h]	0.00036 [16][e]	---	0.0026 [26][p]	---
saltwater invertebrate	mysid shrimp	mg/l	16[21]	---	0.000035 [23]	<0.0000046[23]	0.97[14][i]	100,000 þ	0.00086-0.0016 [16][c]	---	0.003 [5][mo]	---

Secondary species used when data for primary surrogates were not available as indicated in footnote.

a: Mallard duck, dietary; b:*Rana pipiens*; c:*Palaemon macrodactylus* (Korean shrimp); d:24h; e:48h; f:naphthalene; g:benzo(a)pyrene; h:phenanthrene; i:acenaphthene; j:mix of naphthalene, phenanthrene and pyrene; k:NOEC, nontarget phytotoxicity; l:frog; m:aroclor; n:diertary; o:glass shrimp; p:PCB1248; q:fluorene;

Sources of Data for Table 4-6.

1. Tomlin, C. 1994. The pesticide manual. A world compendium. Incorporating the agrochemicals handbook. The British Crop Protection Council, Surrey, UK.
2. Extension Toxicology Network. 1996. Pesticide information profile on primisulfuron-methyl. http://extoxnet.orst.edu/pips/primisul.htm 12/1/04.
3. Pest Management Regulatory Agency, Health Canada. 2001. Proposed regulatory decision document. PRDD2001-02. www.hc-sc.gc.ca/pmra-arla/ 12/1/04.
4. Booth, G.M., Mortensen, S.R., Carter, M.W., and Schaalje, B.G. 2005. Hazard evaluation for northern bobwhite quail (*Colinus Virginianus*) exposed to chlorpyrifos-treated turf and seed. Ecotoxicology and Enviromental Safety. 60: 176-187.
5. Prager, J. 1996. Environmental contaminant reference databook. Van Nostrand Reinhold, New York, NY.
6. Gaines, T.R. 1969. Acute toxicity of pesticides. Acute Toxicity of Pesticides. 14: 515-534.
7. U.S. EPA, Office of Prevention, Pesticides and Toxic Substances. 2000. Toxicology Chapter for Chlorpyrifos. DP Barcode D263892, Case 818975, Submission S576466, PC Code 059101. http://www.epa.gov/pesticides/op/chlorpyrifos/rev_tox.pdf 12/04.
8. Bingham, E., Cohrssen, B., Powell, C. 2001. Patty's toxicology. John Wiley and Sons, New York, NY.
9. Hazardous Substances Data Bank-TOXNET. 2004. Naphthalene. http://toxnet.nlm.nih.gov/ 12/04.
10. Pesticide Action Network. Pan Pesticide Database. http://www.pesticideinfo.org/Index.html 11/04.
11. Extension Toxicology Network. 1996. Pesticide information profile on DDT. http://extoxnet.orst.edu/pips/ddt.htm 12/04.
12. Nishida, N., Farmer, J., Kodavanti, P., Tilson, H., MacPhail, R. 1997. Effects of acute and repeated exposures to Aroclor 1254 in adult rats: Motor activity and flavor aversion conditioning. Fundamentals of Applied Toxicology. 40: 68-74.
13. Eisler, R. 2000. Handbook of chemical risk assessment. Health hazards to humans, plants and animals. Lewis Publishers, New York, NY.
14. Nagpal, N. 1993. Ambient water quality criteria for polycyclic aromatic hydrocarbons (PAHs). Ministry of Environment, Lands and Parks. British Columbia, Canada. http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/pahs/pahs-05.htm.
15. Montgomery, J. 1997. Agrochemicals desk reference. Lewis Publishers, New York, NY.
16. Verschueren, K. 2001. Handbook of environmental data of organic chemicals. John Wiley and Sons, Inc, New York, NY.
17. Anderson, J., Neff, J., Cos, B., Tatem, H., Hightower, G. 1974. The effects of oil on estuarine animals: Toxicity, uptake and depuration, respiration. In Vernberg, F,, Vernberg, W., eds. Pollution and physiology of marine organisms. Academic Press, New York, NY., 285-310.
18. HSDB Database-TOXNET. 2004. PCBs. http://toxnet.nlm.nih.gov 12/04.
19. U.S. Department of Interior, Fish and Wildlife Service. 1984. Handbook of toxicity of pesticides to wildlife. 12/04.
20. Kim, H., Oh, H., Yoon, B., Kim, .J, Lee, I. 2004. Effects of crude oil, oil components, and bioremediation on plant growth. 39: 2465-2472.
21. USEPA. 1990. Primisulfuron-methyl (Beacon) herbicide profile 6/90. EPA Fact Sheet. http://pmep.cce.cornell.edu/profiles/herb-growthreg/naa-rimsulfuron/primisulfuron-methyl/herb-prof-primisulf-meth.html 11/04.
22. Foe, C., and Sheipline, R. 1993. Pesticides in surface water from applications on orchards and alfalfa during the winter and spring of 1991-92. Central Valley Regional Water Quality Control Board. Sacramento, CA.
23. USEPA, Office of Prevention, Pesticides and Toxic Substances. 2002. Interim reregistration eligibility decision for chlorpyrifos. 738-R-01-007. http://www.epa.gov/oppsrrd1/REDs/chlorpyrifos_ired.pdf 12/04.
24. HSDB Database-TOXNET. 2004. Benzo(a)pyrene. http://toxnet.nlm.nih.gov/ 12/04.
25. Verschueren, K. 2001. Handbook of environmental data of organic chemicals. John Wiley and Sons, Inc, New York, NY.
26. Spero, J., Devito, B., and Theodore, L. 2000. Regulatory chemicals handbook. Dekker, Inc, New York, NY.

4.3.3 SCRAM Scoring Approach

For the bioaccumulation category, scores are assigned based on available bioaccumulation factors (BAF), bioconcentration factors (BCF), or octanol water partition coefficients (K_{ow}). The types of bioaccumulation data available (e.g., measured vs. estimated) determine what uncertainty score will be assigned for this category. Scoring for the persistence category is determined by the ranges of half lives reported in five separate environmental categories: biota, soil, air, sediment, and water. Again, uncertainty scores are assigned for this category based on the availability of data for each compartment. Given that the exposure potential for a chemical is largely dependent on bioavailability and environmental persistence, the bioaccumulation chemical score (B_{chem}) and persistence chemical score (P_{chem}) are multiplied (to increase the percentage of the final chemical score that is determined by these two factors). Further emphasis is placed on exposure in SCRAM by applying a weighting factor (of 1.5) to the bioaccumulation and persistence scores. The same weighing factor is used for the product of the bioaccumulation and persistence uncertainty scores (B_{unc} and P_{unc}, respectively).

Significant to possible application to DOI lands, the toxicological effects used for scoring reflected population-level endpoints for mammalian and avian wildlife (terrestrial toxicity category). For example, changes in enzyme function or hematology were deemed not to be adequate endpoints for scoring wildlife. Population-level endpoints included significant effects on growth, survival, reproduction or development, or factors affecting viability such as, severe histopathological effects or severe clinical signs, or other endpoints that could affect population dynamics.

The scoring approach for the toxicity category is determined based on the persistence chemical score. Acute toxicity data (LC50 or EC50 values for both acute aquatic [AA] and acute terrestrial [AT]) is considered when the P_{chem} value is low (e.g., less than 2) and subchronic/chronic toxicity data (subchronic/chronic terrestrial [CT], subchronic/chronic aquatic [CA], and subchronic/chronic human [CH]) is used when the P_{chem} value is high (e.g. 3 or above). When acute toxicity data are considered, terrestrial toxicity scores are determined based on toxicity data for organisms in five categories: plants, mammals, birds, invertebrates, and amphibians/reptiles. Similarly, acute aquatic toxicity data is interpreted for organisms in the following categories: plants, amphibians, warm water fish, cold water fish, and invertebrates. Uncertainty scores are determined for both terrestrial and aquatic toxicity categories based on the availability of toxicity information. When acute toxicity information is assessed, the final chemical (F_{chem}) and final uncertainty (F_{unc}) scores for a chemical assessed using SCRAM are determined using equations 1 and 2, respectively:

(1) $F_{chem} = (B_{chem} \times P_{chem})(1.5) + AA_{chem} + AT_{chem}$

(2) $F_{unc} = (B_{unc} \times P_{unc})(1.5) + AA_{unc} + AT_{unc}$

When persistence of a chemical is of greater concern, subchronic/chronic toxicity scores are assigned for the same groups of organisms identified above for aquatic and terrestrial categories using appropriate toxicity data (e.g., no observed effect level [NOEL], no observed adverse effect level [NOAEL], lowest observed effect level [LOEL], lowest observed adverse effect level

[LOAEL], etc.). Uncertainty scores for subchronic/chronic terrestrial and aquatic toxicity are assigned analogous to the approach used for acute toxicity. In addition, the subchronic/chronic human toxicity data is considered in the SCRAM approach; however, for the evaluation of the SCRAM approach for DOI applications, SCRAM was modified to exclude the human toxicity scoring. When subchronic/chronic toxicity information is evaluated, the final chemical and final uncertainty scores for an individual chemical are determined using equations 3 and 4, respectively:

(3) $F_{chem} = (B_{chem} \times P_{chem})(1.5) + CA_{chem} + CT_{chem}$

(4) $F_{unc} = (B_{unc} \times P_{unc})(1.5) + CA_{unc} + CT_{unc}$

Finally, a composite score is calculated for each chemical to provide additional insight into the overall significance of uncertainty in the ranking and scoring process:

(5) $F_{comp} = F_{chem} + F_{unc}$

SCRAM preserves the final chemical and uncertainty scores as separate values. A rank order is then reported for both the chemical score and the composite score.

SCRAM is biased toward deriving maximum chemical and uncertainty scores for each scoring category. For example, when SCRAM reports scores it rounds to the next greater integer. When SCRAM finds the uncertainty score is zero for persistence or bioaccumulation, but not both, it coverts the zero to a one so that the uncertainty points for the other category are not canceled out.

The final chemical score (incorporating bioaccumulation, persistence and toxicity) and the uncertainty score are summed in Equation 5 to arrive at the final composite score. The maximum scores possible with this system are listed in table 4-7.

Table 4-7. Maximum chemical and uncertainty scores for SCRAM model (from Snyder et al., 2002a)

Scoring Category	Maximum Chemical Score	Maximum Uncertainty Score
Bioaccumulation	5	5
Persistence	5	10
Acute Terrestrial Toxicity	5	5
Acute Aquatic Toxicity	5	5
Subchronic/Chronic Terrestrial Toxicity	5	5
Subchronic/Chronic Aquatic Toxicity	5	5
Subchronic/Chronic Human Toxicity	5	5

4.3.4 Results using the SCRAM Model

4.3.4.1 Composite Scores and Relative Rankings

A test run of the SCRAM model was performed and the resulting chemical, uncertainty, and final composite scores are listed in Table 4-8 for all chemicals scored using the modified SCRAM model. The chemical scores listed under the "SCRAM" column (third column in Table 4-8) match those in Mitchell et al. (2002) because all data input and modeling was identical to theirs. Note that the SCRAM database provided to us did not link any values to their source; there was no literature or data-source citation. Therefore, we could not independently verify the accuracy of the database or review the "best professional judgment" used to create the database. The composite score was the sum of the final modified-SCRAM chemical score and the final uncertainty score. Our modification of the SCRAM model (to exclude human health effects) had no effect on the uncertainty score. The modification did influence most of the chemical scores, but the effect was usually quite small and almost always yielded a lower score than the original SCRAM model (due to the absence of some more sensitive species and the removal of human toxicity from the modified SCRAM model). Given these changes, the agreement between the two scoring methods is quite good and leads us to question the utility of creating a separate toxicity database based solely on the ecological matrix given in Section 3.3.

With the preservation of both final chemical and uncertainty scores as separate values, users could assign different weight to the uncertainty score. Using the original weighting of SCRAM, the contribution of the uncertainty score to the relative ranking of chemicals is illustrated in Table 4-9 as was done by Mitchell et al. (2002) with their original SCRAM model. The composite and chemical score rankings were derived by sorting the chemicals in descending order and then assigning the appropriate relative rank. When chemicals had the same composite or chemical score, the same relative ranking was assigned to the same scores.

Mitchell et al. (2002) showed that comparison of the ranking by composite score to the ranking by chemical score provided insight into how uncertainty influences the ranking of chemicals (Table 4-9). Each chemical was ranked according to its composite score (Column A) and its chemical score (Column B). The greater the number in Table 4-9 column C, the greater the uncertainty was with that chemical. For example, PCBs and most chlorinated pesticides had low and often negative values in column C (Table 4-9) indicating low uncertainty. These chemicals typically have been well studied; more data using better methods (e.g., measurements versus estimation) would lead to lower uncertainty scores using the algorithms in SCRAM. Conversely, chemicals such as indeno(1,2,3-cd)pyrene and dibromochloromethane had values in column C (Table 4-9) above 50 indicating a high degree of uncertainty. These chemicals typically have little or no toxicity data for many of the surrogate species so they rank higher on the composite score than on the chemical score. The rational for this is clear, but it could easily lead to equally erroneous ranking due to insufficient data. It may be more appropriate to rank chemicals based on what is known and to simply identify those chemicals for which little is known. The SCRAM model would allow you to do this, but it is not the default method.

Mitchell et al. (2002) make some cautionary statements about the application of SCRAM to real data: the numerical ranking of chemicals does not represent any quantitative measure of hazard or risk, and becomes most useful when combined with chemical use rates and/or source loading to the environment. They further state that "SCRAM should not be substituted for a risk assessment, the model is set up as a ranking tool for hazard identification and the determination of research needs." This is not a fault of SCRAM, rather it is simply a (major) difference in the purpose of a chemical ranking and scoring model versus a risk assessment.

Table 4-8. Chemical, uncertainty and composite scores calculated by SCRAM.

CAS. No.	CHEMICAL NAME	Chemical Score		Uncertainty Score	Composite Score
		SCRAM	Modified SCRAM		Modified SCRAM
83329	Acenaphthene	21	19	16	35
208968	Acenaphthylene	8	7	40	47
107131	Acrylonitrile	11	11	12	23
15972608	Alachlor	19	17	8	25
309002	Aldrin	37	37	13	50
120127	Anthracene	36	33	18	51
7440360	Antimony	16	15	11	26
7440382	Arsenic	22	16	6	22
1912249	Atrazine	22	14	5	19
7440393	Barium	16	14	10	24
56533	Benz (a) anthracene	41	38	30	68
50328	Benz(a)pyrene	19	22	14	36
71432	Benzene	19	17	17	34
92875	Benzidine	22	22	15	37
7440417	Beryllium	23	23	12	35
128370	BHT	20	20	17	37
92524	Biphenyl	17	17	15	32
74975	Bromochloromethane	7	6	31	37
75274	Bromodichloromethane	20	13	28	41
75252	Bromoform	18	18	27	45
2008415	Butylate	30	26	32	58
85687	Butylbenzylphthalate	18	16	14	30
7440439	Cadmium	23	21	3	24
1563662	Carbofuran	20	19	10	29
75150	Carbon disulfide	9	8	29	37
56235	Carbon tetrachloride	18	18	12	30
57749	Chlordane	52	52	8	60
108907	Chlorobenzene	26	25	26	51
67663	Chloroform	17	16	10	26
106434	4-Chlorotoluene	12	11	26	37
2921882	Chlorpyrifos	30	27	12	39
7440473	Chromium	23	23	5	28
7440484	Cobalt	15	14	10	24
7440508	Copper	21	21	6	27
21725462	Cyanazine	20	20	24	44
57125	Cyanide	12	12	16	28
94757	2,4-D	22	17	7	24

Table 4-8 (Continued). Chemical, uncertainty and composite scores calculated by SCRAM.

CAS. No.	CHEMICAL NAME	Chemical Score		Uncertainty Score	Composite Score
		SCRAM	Modified SCRAM		Modified SCRAM
72548	p,p'-DDD	48	48	19	67
72559	p,p'-DDE	53	53	10	63
50293	p,p'-DDT	53	53	7	60
117817	DEHP	26	24	8	32
1740198	Dehydroabietic acid	18	16	18	34
333415	Diazinon	30	29	10	39
53703	Dibenzo(a,h)anthracene	42	40	28	68
124481	Dibromochloromethane	18	14	34	48
1918009	Dicamba	21	19	20	39
95501	1,2-Dichlorobenzene	22	22	16	38
541731	1,3-Dichlorobenzene	30	28	16	44
106467	1,4-Dichlorobenzene	15	16	11	27
75343	1,1-Dichloroethane	8	9	21	30
107062	1,2-Dichloroethane	19	17	9	26
75718	Dichlorofluoromethane	21	20	30	50
75092	Dichloromethane	17	15	12	27
120365	Dichlorprop	17	16	28	44
78875	1,2-Dichloropropane	15	12	13	25
542756	1,3-Dichloropropene	11	10	14	24
60571	Dieldrin	38	38	5	43
84662	Diethylphthalate	11	8	10	18
121697	N,N-Dimethylaniline	8	6	31	37
84742	Di-n-butylphthalate	21	17	13	30
117840	Di-n-octyl phthalate	30	22	16	38
115297	Endosulfan	30	30	11	41
72208	Endrin	37	37	9	46
759944	EPTC	23	21	24	45
563122	Ethion	45	40	22	62
100414	Ethylbenzene	10	9	20	29
206440	Fluoranthene	32	28	16	44
86731	Fluorene	24	22	20	42
944229	Fonophos	29	27	30	57
110009	Furan	13	13	23	36
76448	Heptachlor	38	38	6	44
1024573	Heptachlor epoxide	40	36	13	49
118741	Hexachlorobenzene	53	50	9	59
67721	Hexachloroethane	33	30	11	41
110543	Hexane	25	20	28	48
193395	Indeno(1,2,3-cd)pyrene	11	18	43	61
78591	Isophorone	7	na	11	na
143500	Kepone	38	38	17	55
7439921	Lead	23	16	1	17
58899	Lindane	38	35	3	38
330552	Linuron	33	32	19	51
121755	Malathion	20	20	14	34
7439965	Manganese	19	11	9	20
94746	MCPA	22	16	24	40

Table 4-8 (Continued). Chemical, uncertainty and composite scores calculated by SCRAM.

CAS. No.	CHEMICAL NAME	Chemical Score		Uncertainty Score	Composite Score
		SCRAM	Modified SCRAM		Modified SCRAM
7085190	Mecoprop	33	28	26	54
7439976	Mercury	45	39	7	46
72435	p,p'-Methoxychlor	36	34	11	45
90120	1-Methylnaphthalene	29	26	23	49
91576	2-Methylnaphthalene	27	25	30	55
51218452	Metolachlor	16	14	13	27
21087649	Metribuzin	20	18	25	43
2385855	Mirex	53	49	9	58
7439987	Molybdenum	21	14	9	23
91203	Naphthalene	13	12	12	24
7440020	Nickel	21	14	6	20
Class 07-8	PBBs	40	36	10	46
1336363	PCBs	53	49	8	57
40487421	Pendimethalin	37	38	30	68
608935	Pentachlorobenzene	39	33	14	47
87865	Pentachlorophenol	29	30	7	37
85018	Phenanthrene	30	26	12	38
108952	Phenol	21	17	9	26
298022	Phorate	19	17	26	43
39801144	Photomirex	43	40	22	62
1610180	Prometon	20	16	31	47
129000	Pyrene	26	22	15	37
110861	Pyridine	10	9	31	40
7782492	Selenium	23	22	7	29
7440224	Silver	18	16	11	27
93721	Silvex	19	17	14	31
122349	Simazine	29	22	16	38
7440246	Strontium	11	6	14	20
100425	Styrene	18	na	23	na
1746016	2,3,7,8-TCDD	45	36	4	40
13071799	Terbufos	16	15	10	25
634662	1,2,3,4-Tetrachlorobenzene	38	33	13	46
634902	1,2,3,5-Tetrachlorobenzene	34	32	17	49
95943	1,2,4,5-Tetrachlorobenzene	40	34	15	49
79345	1,1,2,2-Tetrachloroethane	12	na	10	na
127184	Tetrachloroethylene	16	14	10	24
116290	Tetradifon	21	na	33	na
109999	Tetrahydrofuran	7	6	22	28
7440315	Tin	13	19	13	32
7440326	Titanium	15	na	9	na
108883	Toluene	31	26	10	36
8001352	Toxaphene	53	50	9	59
87616	1,2,3-Trichlorobenzene	30	26	16	42
120821	1,2,4-Trichlorobenzene	30	26	11	37
108703	1,3,5-Trichlorobenzene	27	26	15	41
71556	1,1,1-Trichloroethane	12	12	12	24
79005	1,1,2-Trichloroethane	21	12	25	37

Table 4-8 (Continued). Chemical, uncertainty and composite scores calculated by SCRAM.

CAS. No.	CHEMICAL NAME	Chemical Score		Uncertainty Score	Composite Score
		SCRAM	Modified SCRAM		Modified SCRAM
79016	Trichloroethylene	22	12	16	28
95954	2,4,5-Trichlorophenol	30	19	18	37
88062	2,4,6-Trichlorophenol	20	17	7	24
1582098	Trifluralin	36	34	12	46
7440622	Vanadium	18	12	9	21
1330207	Xylene (o,m,p included)	9	8	16	24

Table 4-9. Relative rankings of the chemical score ranking versus the composite score ranking.

CAS. No.	CHEMICAL NAME	A. Ranking by Chemical Score	B. Ranking by Composite Score	C. A-B[1]
53703	Dibenzo(a,h)anthracene	9	1	8
56533	Benz (a) anthracene	13	1	12
40487421	Pendimethalin	13	1	12
72548	p,p'-DDD	8	4	4
72559	p,p'-DDE	1	5	-4
563122	Ethion	9	6	3
39801144	Photomirex	9	6	3
193395	Indeno(1,2,3-cd)pyrene	74	8	66
50293	p,p'-DDT	1	9	-8
57749	Chlordane	3	9	-6
118741	Hexachlorobenzene	4	11	-7
8001352	Toxaphene	4	11	-7
2385855	Mirex	6	13	-7
2008415	Butylate	41	13	28
1336363	PCBs	6	15	-9
944229	Fonophos	39	15	24
143500	Kepone	13	17	-4
91576	2-Methylnaphthalene	48	17	31
7085190	Mecoprop	36	19	17
120127	Anthracene	27	20	7
330552	Linuron	30	20	10
108907	Chlorobenzene	48	20	28
309002	Aldrin	18	23	-5
75718	Dichlorofluoromethane	64	23	41
1024573	Heptachlor epoxide	20	25	-5
95943	1,2,4,5-Tetrachlorobenzene	24	25	-1
634902	1,2,3,5-Tetrachlorobenzene	30	25	5
90120	1-Methylnaphthalene	41	25	16
110543	Hexane	64	29	35
124481	Dibromochloromethane	101	29	72
608935	Pentachlorobenzene	27	31	-4
1610180	Prometon	88	31	57
208968	Acenaphthylene	128	31	97
7439976	Mercury	12	34	-22
72208	Endrin	18	34	-16
Class 07-8	PBBs	20	34	-14
1582098	Trifluralin	24	34	-10
634662	1,2,3,4-Tetrachlorobenzene	27	34	-7
72435	p,p'-Methoxychlor	24	39	-15
759944	EPTC	61	39	22
75252	Bromoform	74	39	35
76448	Heptachlor	13	42	-29
541731	1,3-Dichlorobenzene	36	42	-6
206440	Fluoranthene	36	42	-6
21725462	Cyanazine	64	42	22

Table 4-9 (Continued). Relative rankings of the chemical score ranking versus the composite score ranking.

CAS. No.	CHEMICAL NAME	A. Ranking by Chemical Score	B. Ranking by Composite Score	C. A-B[1]
120365	Dichlorprop	88	42	46
60571	Dieldrin	13	47	-34
21087649	Metribuzin	74	47	27
298022	Phorate	78	47	31
87616	1,2,3-Trichlorobenzene	41	50	-9
86731	Fluorene	53	50	3
115297	Endosulfan	32	52	-20
67721	Hexachloroethane	32	52	-20
108703	1,3,5-Trichlorobenzene	41	52	-11
75274	Bromodichloromethane	109	52	57
1746016	2,3,7,8-TCDD	20	56	-36
94746	MCPA	88	56	32
110861	Pyridine	122	56	66
333415	Diazinon	35	59	-24
2921882	Chlorpyrifos	39	59	-20
1918009	Dicamba	69	59	10
58899	Lindane	23	62	-39
85018	Phenanthrene	41	62	-21
95501	1,2-Dichlorobenzene	53	62	-9
117840	Di-n-octyl phthalate	53	62	-9
122349	Simazine	53	62	-9
87865	Pentachlorophenol	32	67	-35
120821	1,2,4-Trichlorobenzene	41	67	-26
92875	Benzidine	53	67	-14
129000	Pyrene	53	67	-14
128370	BHT	64	67	-3
95954	2,4,5-Trichlorophenol	69	67	2
79005	1,1,2-Trichloroethane	111	67	44
106434	4-Chlorotoluene	118	67	51
75150	Carbon Disulfide	125	67	58
74975	Bromochloromethane	129	67	62
121697	N,N-Dimethylaniline	129	67	62
108883	Toluene	41	78	-37
50328	Benz(a)pyrene	53	78	-25
110009	Furan	109	78	31
7440417	Beryllium	51	81	-30
83329	Acenaphthene	69	81	-12
121755	Malathion	64	83	-19
71432	Benzene	78	83	-5
1740198	Dehydroabietic acid	88	83	5
117817	DEHP	50	86	-36
7440315	Tin	69	86	-17
92524	Biphenyl	78	86	-8
93721	Silvex	78	89	-11
56235	Carbon tetrachloride	74	90	-16

Table 4-9 (Continued). Relative rankings of the chemical score ranking versus the composite score ranking.

CAS. No.	CHEMICAL NAME	A. Ranking by Chemical Score	B. Ranking by Composite Score	C. A-B[1]
84742	Di-n-butylphthalate	78	90	-12
85687	Butylbenzylphthalate	88	90	-2
75343	1,1-Dichloroethane	122	90	32
7782492	Selenium	53	94	-41
1563662	Carbofuran	69	94	-25
100414	Ethylbenzene	122	94	28
7440473	Chromium	51	97	-46
57125	Cyanide	111	97	14
79016	Trichloroethylene	111	97	14
109999	Tetrahydrofuran	129	97	32
7440508	Copper	61	101	-40
106467	1,4-Dichlorobenzene	88	101	-13
7440224	Silver	88	101	-13
75092	Dichloromethane	98	101	-3
51218452	Metolachlor	101	101	0
107062	1,2-Dichloroethane	78	106	-28
108952	Phenol	78	106	-28
67663	Chloroform	88	106	-18
7440360	Antimony	98	106	-8
15972608	Alachlor	78	110	-32
13071799	Terbufos	98	110	-12
78875	1,2-Dichloropropane	111	110	1
7440439	Cadmium	61	113	-52
94757	2,4-D	78	113	-35
88062	2,4,6-Trichlorophenol	78	113	-35
7440393	Barium	101	113	-12
7440484	Cobalt	101	113	-12
127184	Tetrachloroethylene	101	113	-12
91203	Naphthalene	111	113	-2
71556	1,1,1-Trichloroethane	111	113	-2
542756	1,3-Dichloropropene	121	113	8
1330207	Xylene (o,m,p included)	125	113	12
7439987	Molybdenum	101	123	-22
107131	Acrylonitrile	118	123	-5
7440382	Arsenic	88	125	-37
7440622	Vanadium	111	126	-15
7440020	Nickel	101	127	-26
7439965	Manganese	118	127	-9
7440246	Strontium	129	127	2
1912249	Atrazine	101	130	-29
84662	Diethylphthalate	125	131	-6
7439921	Lead	88	132	-44

4.3.4.2 Scoring and Ranking Using Model Representative Chemicals

To illustrate how the SCRAM system (or any other CRS system) would work when using a single model chemical to represent a broader chemical class, we ran SCRAM with candidate model chemicals (for the five test chemical classes) and using the toxicity data for five ecological groupings from the coarse functional grouping system. The results are summarized in Table 4-10. Different model PAHs yield composite score ranking as high as number 2 (dibenzo[a,h]anthracene) and as low as number 117 (naphthalene), out of the approximately 150 chemicals tested. Clearly, one cannot choose a single PAH to represent the class of PAHs with the SCRAM model. As was shown above for the physical-chemical and toxicity data (Tables 4-4 and 4-5), this is a function of the breadth of chemical properties and will be semi-independent of the type of CRS or risk assessment model that is used (model dependence would exist if there are differences in how the models weight various factors). For organochlorine pesticides, composite scores range from 7 to 65, and once again no single chemical can be representative of this class of chemicals. Composite scores range from 3 to 48 for PCBs, 113-128 for sulfonyl urea herbicides, and 49-112 for organophosphate insecticides. Only the sulfonyl urea herbicides have a small enough range to have one chemical serve as a model for the others. However, given the wide range of values reported above, one would need to confirm this by running the modified SCRAM model on all other sulfonyl urea herbicides (which negates the reason for using a model chemical). The data presented in Table 4-5 indicate that problems would arise with representativeness should the other sulfonyl urea herbicides be considered. In aggregate, the SCRAM ranking in Table 4-10 confirms our initial concerns about the use of model chemicals to represent a class of chemicals - it is not advised for CAP applications.

4.3.4.3 Prioritizing Chemicals

After the aggregation of the final composite scores and the relative ranking of chemicals are completed, estimates (or classification scores) of chemical loading (perhaps modified to account for transport to site of interest) can be used to obtain final ranking and priority of chemicals. Loading and transport are highly influenced by site-specific characteristics and are therefore beyond the scope of SCRAM. To provide a consistent and standardized procedure for national or regional ranking of chemicals, a generic environment can be used with the assumptions of a constant chemical loading and homogeneous spatial distribution throughout environmental compartments as was done for the Level III fugacity models (Figure 4-1). There is no alternative if regional or national scale rankings are desired. National chemical production or use estimates for a particular chemical can be used to estimate loading and then combined with a generic national spatial scale. Or a smaller, representative generic environment can be used with an arbitrary chemical loading (e.g., 1 kg/d). This obviously introduces the problem of how well the generic environment represents specific areas of concern. In addition, even if everything else is equal, differential transport at different sites can alter chemical exposure by many orders of magnitude. Thus, a decision must be made as to what spatial scale will be represented and what range of conditions (chemical loading and attenuation) will be used. It is at this point, that simple classification of chemicals could be made (e.g., high, medium, low priority) and a simple 2 x 3 matrix of these three classes could be prepared from the SCRAM results and the exposure estimate (based on sales/production, use rate, modeling, etc.). However, it is premature to offer

such a classification scheme given the previously outlined concerns with oversimplifications. Obviously, measuring contaminant concentrations / loadings at a local scale helps minimize uncertainty and enhances accuracy of exposure estimates for risk assessment.

As mentioned above and stressed by Mitchell et al. (2002), "the numerical ranking of chemicals does not provide a measure of hazard or risk." SCRAM or any other CRS or SRP process is only intended to help determine the potential for a chemical to cause environmental effects based on what we know about its persistence, bioaccumulation, and toxicity. Given the potential for gross inaccuracies at any given site, we recommend that the CRS or SRP process be tested with data from FWS areas of concern and compared to an actual screening-level ecological risk assessment. This would provide FWS with some perspective on the magnitude of errors and omissions that a CRS or SRP process could have relative to a risk assessment, and thus provide information on the appropriateness and utility of using an SRP process rather than, or as a prelude to, a screening level risk assessment. Our initial attempt at this comparison, summarized in Table 4-10, indicates that a screening risk assessment can yield very different results compared to the CRS system.

We looked at exposure data from two sites studied by Shea et al. (2001) in the Lower Mississippi River Ecosystem and calculated hazard quotients (measured exposure divided by benchmark values) for most of the model chemicals evaluated using the modified SCRAM system (Table 4-10). We then ranked these values (columns 4 and 5) and also list the raw quotient value (columns 6 and 7). Although we are comparing just aquatic data for the most sensitive species (hazard quotient ranking) to a much more robust data set (SCRAM ranking), one can see great discrepancies between the ranking based on SCRAM (with no site-specific exposure estimate) and the rankings based on measured hazard quotients (compare rankings in columns 2 and 3 with those in columns 4 and 5). At Site 1, the rankings of petroleum-related low molecular weight PAH (naphthalene) and combustion-related high molecular weight PAH (dibenzo[a,h]anthracene and indeno[1,2,3-cd]pyrene) are completely reversed relative to the SCRAM rankings. This is a result of high petroleum input at this site (an oil production area). Looking at the actual hazard quotient values, the high molecular weight PAH also have very low potential for risk (quotients are <0.01) while the naphthalene quotient exceeds 10. At Site 2, all of the PAH are ranked low and have low hazard quotients, again in contrast to the SCRAM rankings.

Table 4-10. Relative rankings for potential model chemicals that represent a class of chemicals and comparison to rankings derived from measurements and a hazard quotient at National Wildlife Refuges in the Mississippi River Ecosystem.

CHEMICAL NAME	SCRAM Ranking[1]		Hazard Quotient[2]			
	Ranking by Chemical Score	Ranking by Composite Score	Ranking		Value	
			Site 1	Site 2	Site 1	Site 2
PAHs						
Dibenzo(a,h)anthracene	10	2	103	138	<0.01	<0.01
Indeno(1,2,3-cd)pyrene	76	9	107	145	<0.01	<0.01
Acenaphthylene	131	32	92	143	<0.01	<0.01
Phenanthrene	43	64	4	76	>10	<0.01
Pyrene	55	69	13	102	0.68	<0.01
Benzo(a)pyrene	55	79	47	122	0.03	<0.01
Naphthalene	114	117	6	89	>10	<0.01
OC Pesticides						
p,p'-DDE	1	7	16	4	0.05	0.04
Dieldrin	15	49	32	17	<0.01	<0.01
Lindane	25	65	79	31	<0.01	<0.01
PCBs						
PCBs	7	16	94	107	<0.01	<0.01
PCB 77	3	5	68	62	<0.01	<0.01
PCB 153	48	57	77	79	<0.01	<0.01
SU Herbicides						
Chlorsulfuron	126	128	na	na	na	na
Primisulfuron-methyl	108	113	na	na	na	na
Sulfometurn-methyl	108	113	na	na	na	na
OP Insecticides						
Phorate	80	49	na	na	na	na
Diazinon	37	61	na	na	na	na
Malathion	66	85	145	145	<0.01	<0.01
Terbufos	100	112	120	71	<0.01	<0.01

[1]The SCRAM rankings are listed for the chemical score alone and the composite score that includes both chemical and uncertainty scores. The number reflects the relative rank of that chemical out of ~140 chemicals. The lower the number, the higher the rank, and the greater the relative risk. However, there is no discriminating power among the rank values – there is no means to quantify the ecological significance of a difference in rank. The SCRAM rankings are based on all species and toxicological endpoints as described in the text.

[2]For the hazard quotient value, the numerator is the highest concentration of the chemical measured in water at the site and the denominator is the lowest aquatic life benchmark value we could find for that chemical. The hazard quotient ranking is the rank of that chemical based on the hazard quotients of ~150 chemicals measured at the site.

Similar discrepancies are seen for the other chemicals, though the differences are not as extreme as with the PAHs. Similar discrepancies would be seen for other CRS systems. The problem lies in the use of generic scoring and ranking versus actual screening risk assessment. The data presented here support the use of a screening risk assessment approach to prioritize chemical risks rather than an SRP approach.

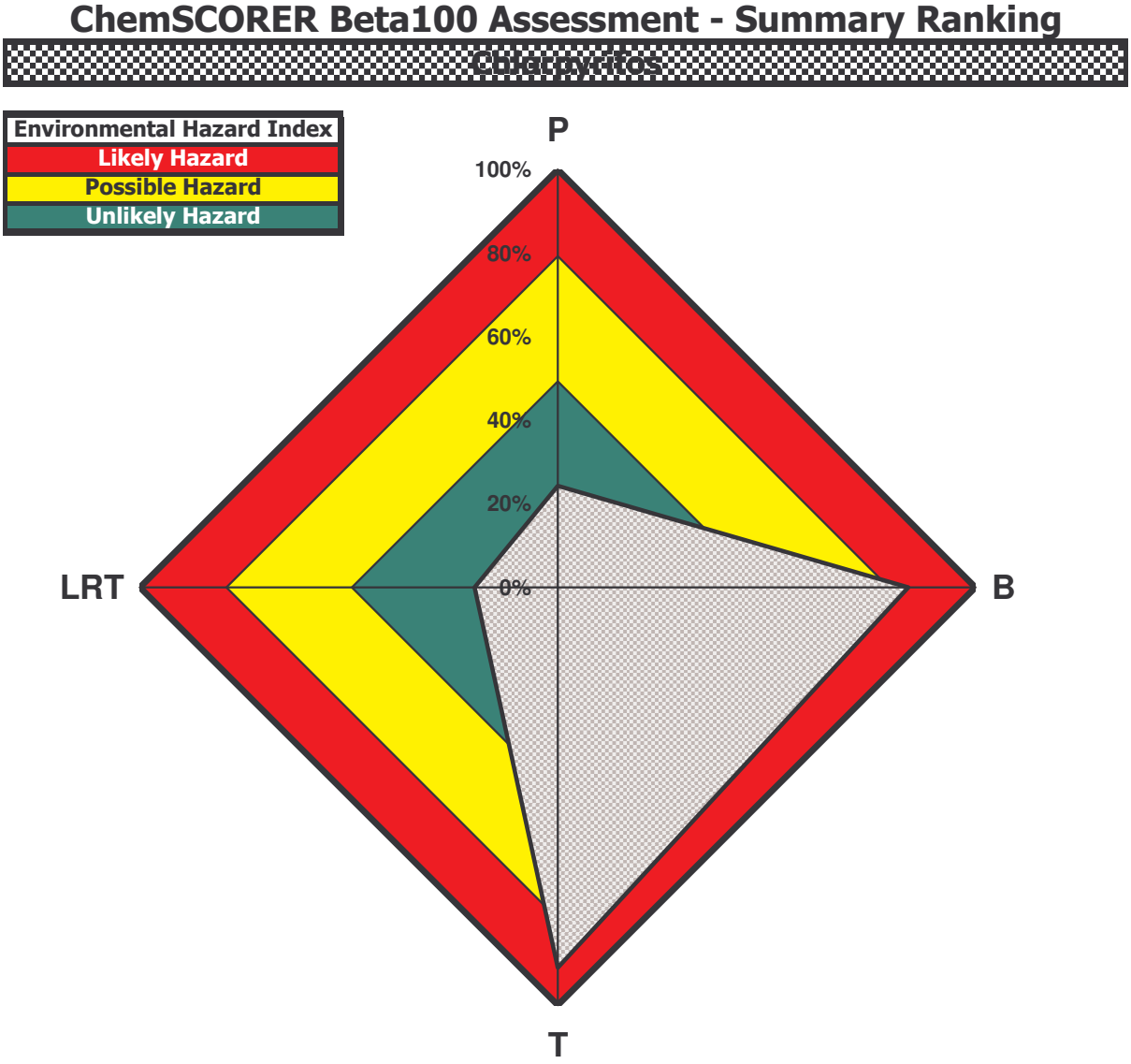
Snyder et al. (2000d) also pointed out that SCRAM lacks the quantitative nature and selectivity among chemicals that is typically found with a risk assessment approach. Snyder et al. (2002d) referred to this as "discriminating power" and states: "The power of this system to discriminate among individual chemicals based on their bioaccumulation potential, persistence, and toxicity is not great. Rather, the function of SCRAM is to rank chemicals for prioritization activities, e.g., to determine which should receive the most immediate attention for risk assessment and/or research. Absolute scores have little meaning; it is the relative scores that are important. The user must also remember that a score two times greater than another does not indicate twice the level of concern." Again, this is an attribute of any CRS system. Even if there is no error in the CRS analysis, the absolute score value has no meaning and the ranking tells you nothing about "how different" two chemicals are.

Snyder et al. (2000d) also performed a sensitivity analysis to determine what scores SCRAM would generate if only some of the data used in their published model were used for scoring. For example, if a different user found only some of the data used by Snyder et al. (2000d) and Mitchell et al. (2002), would they get different score values? The sensitivity analysis indicated that the selection of values can have a substantial effect on the resulting score values. Using the PAH phenanthrene as an example, the sensitivity analysis indicated that scores could vary by more than an order of magnitude depending on what values were selected from the literature to score the chemical. Snyder et al. (2000d) concludes by stating "Because SCRAM can be very sensitive to incomplete data sets, it is extremely important that thorough literature searches be conducted to locate as many suitable data points as possible for scoring. The user's confidence in the score should be tempered by professional judgment of the level of effort given to the literature search and review process."

4.4 Initial Evaluation of ChemSCORER

ChemSCORER is a Microsoft Excel spreadsheet based tool that provides a rapid assessment of environmental hazard associated with organic chemicals. Like SCRAM, it assesses individual chemicals for persistence (P), potential for bioaccumulation (B), and toxicity (T). In addition, ChemSCORER includes an assessment of the potential for long-range transport (LRT). The model ranks individual chemicals against a set of reference chemicals. Data from over 160 chemicals are provided in the default database of the beta version. The required input data are: chemical name, molar mass, vapor pressure, aqueous solubility, log K_{ow}, melting point, overall reaction rate half-lives in air, water, soil, and sediment, mammalian oral LD50 (rat or mouse), and 96 hour aquatic LC50 (minnow). Model output includes 1) a summary plot of P, LRT, B, and T; 2) Level I, II, and III multimedia fate summaries; 3) Level I, II, and III characteristic travel distance summaries; 4) summary of chemical fate in an evaluative foodweb.

We found the model to be very easy to use and it is the only CRS model that we reviewed that provided useful graphical output. ChemSCORER provides a capability to graphically illustrate the chemical fate and bioaccumulation, in addition to plotting the scoring and ranking of chemicals. ChemSCORER is not nearly as robust as SCRAM, with regard to toxicity endpoints and inclusion of surrogate species. However, there is no reason that additional toxicity data could not be added to this model. The main advantages of ChemSCORER is that the user interface and output of the model appear to be a better platform for use by DOI personnel than any other we have reviewed. The model and database are easily modified, the database is integrated into the model so that manual entry of data is not required, and both the model and database are non-proprietary and available at no charge. An illustration of ChemSCORER is given below.



Summary Rankings for: Chlorpyrifos

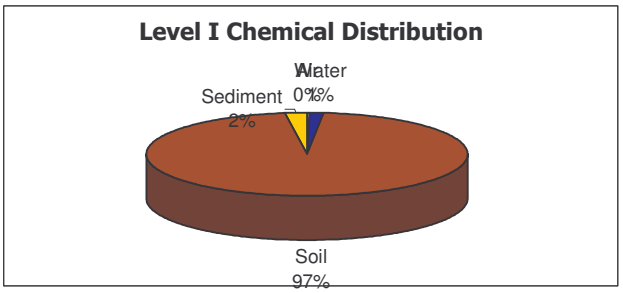
This chemical ...

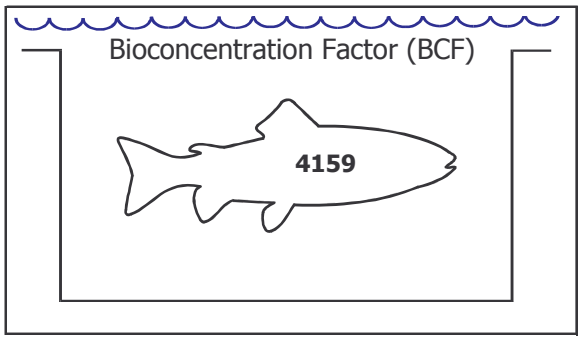
is more PERSISTENT (P) than	24 %	of chemicals in the reference set.
is more BIOACCUMMULATIVE (B) than	84 %	of chemicals in the reference set.
is more TOXIC (T) than	91 %	of chemicals in the reference set.
has greater LONG RANGE TRANSPORT (LRT) than	20 %	of chemicals in the reference set.

Figure 4-2. Summary ranking of the test chemical chlorpyrifos. The attributes of chlorpyrifos relative to all other chemicals in the database (~160) are illustrated by the grey shaded area, with percent values listed below the graph. Arbitrary classifications are given for likely hazard (red), possible hazard (yellow), and unlikely hazard (green).

ChemSCORER Beta100 Assessment - Level I Model Results
Chlorpyrifos

The Level I chemical distibution represents long term equilibrium partitioning of the chemical. Many persistent chemicals partition predominantly to soils. Long range transport usually requires partitioning (at least 1%) to one of the mobile media (air





The calculated BCF is very near the generally accepted cut-off between bioaccumulative and non-bioaccumulative substances of 5000. In the absence of rapid metabolism by organisms, this substance may be moderately bioaccumulative.

Details of Level I calculation for: Chlorpyrifos

Equilibrium Chemical Distribution

Compartment	Z	Concentration			Amount	
	(mol/m^3Pa)	(mol/m^3)	(mg/L)	(ug/g)	kg	%
Air	4.03E-04	8.19E-12	2.87E-09	2.42E-06	287	0.287
Water	9.17E-01	1.86E-08	6.53E-06	6.53E-06	1306	1.306
Soil	1.50E+03	3.05E-05	1.07E-02	4.45E-03	96197	96.197
Sediment	3.00E+03	6.10E-05	2.14E-02	8.91E-03	2138	2.138
Suspended Sediment	9.38E+03	1.91E-04	6.68E-02	4.45E-02	67	0.067
Biota (Fish)	3.81E+03	7.75E-05	2.72E-02	2.72E-02	5	0.005
Total					100000	100.000

Physical Chemical Data and Partition Coefficients

Input Parameters			Partition Coefficients		Three Solubilities	
					(g/m^3)	
Molar Mass	350.6	g/mol				
Vapor Pressure	0.00227	Pa	Log Kow	4.92	Air	3.21E-04
Aqueous Solubility	0.73	g/m^3	Log Kaw	-3.36	Water	7.30E-01
Log Kow	4.92		Log Koa	8.28	Octanol	6.07E+04
Melting Point	41	deg C				

Figure 4-3. Results from a Level I multimedia fugacity model of chlorpyrifos illustrating the relative distribution among compartments in a generic environment, the BCF, and the concentration within each compartment (given a default values of total chemical mass in the system, default compartment volumes, and the physical chemical data used in the model). Level I model assumes: equilibrium amongst all phases, conservative chemical behavior (no degradation), steady state (concentration does not change with time), and a closed system (no inputs or outputs).

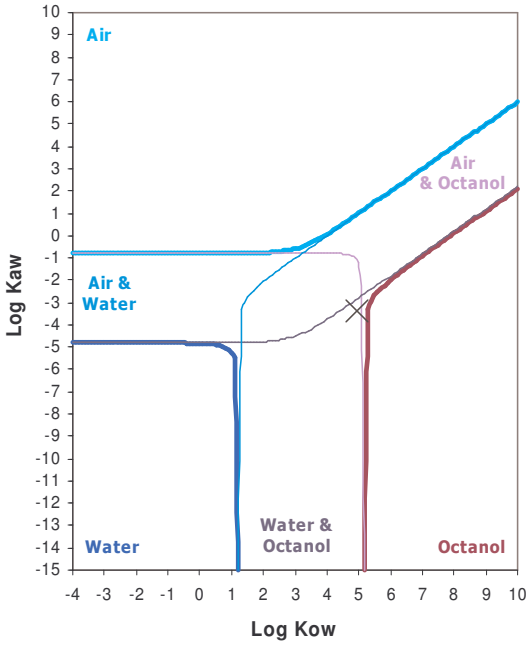
ChemSCORER Beta100 Assessment - Level II Model Results

Chlorpyrifos

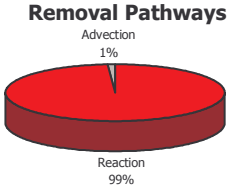
Equilibrium Partitioning Persistence Information

The figure at right identifies environmental media that have a controlling influence on the overall rate of reactive degradation of this substance. Substances that fall near the center of the diagram are expected to accumulate in all media, and overall p

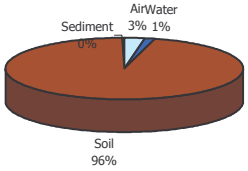
The equilibrium distribution reaction residence time calculated for this substance is several days, and is comparable to that of chlorobenzene (10 days). Reactive residence time is more than 10 times shorter than advective residence time, indicating pote



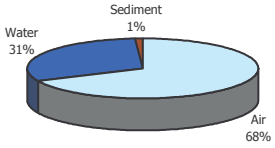
Removal Pathways



Media of Reaction



Media of Advection



Overall Residence Time:	241	hours	10.06 days
Reaction Residence Time:	244	hours	10.16 days
Advection Residence Time:	23694	hours	987.23 days

Details of Level II calculation for: Chlorpyrifos

Removal Processes - Equilibrium Distribution

Compartment	Half-life (hours)	D Values		Loss Rates		Removal %
		Reaction (mol/Pa h)	**Advection** (mol/Pa h)	**Reaction** (kg/h)	**Advection** (kg/h)	
Air	17	1.64E+09	4.03E+08	2.83E+01	6.93E+00	3.519
Water	170	7.48E+08	1.83E+08	1.29E+01	3.15E+00	1.600
Soil	170	5.51E+10	0	9.47E+02	0	94.660
Sediment	1700	1.22E+08	6.01E+06	2.10E+00	1.03E-01	0.221
Total		5.76E+10	5.93E+08	9.90E+02	1.02E+01	100.000
Reaction + Advection		5.82E+10		1000		

Figure 4-4. Results from a Level II multimedia fugacity model of chlorpyrifos illustrating the relative distribution among compartments and the relative importance of removal pathways (both degradation reactions and advection or transport) in each of the environmental media. Level II model assumes: equilibrium, non-conservative behavior (degradation is allowed), steady state, and an open system (inputs and outputs are allowed).

ChemSCORER Beta100 Assessment - Transport Model Results
Chlorpyrifos

TaPL II - Equilibrium distribution Characteristic Travel Distance

Under equilibrium partitioning conditions, this chemical is likely to be transported by both air and water.

TaPL III - Mode of entry assessments

Emission to air - Characteristic Travel Distance in Air

Characteristic Travel Distance in air is low. This chemical is not likely to be transported a significant distance in the atmosphere.

Emission to water - Characteristic Travel Distance in Water

Characteristic Travel Distance in water is moderate, and is comparable to that of chlorobenzene (1300 km). This chemical may be subject to transport in surface and near-shore marine waters.

Emission to soil - Effective Travel Distance

Emissions directly to soil are not expected to partition significantly to air or water, and are not likely to be subject to transport.

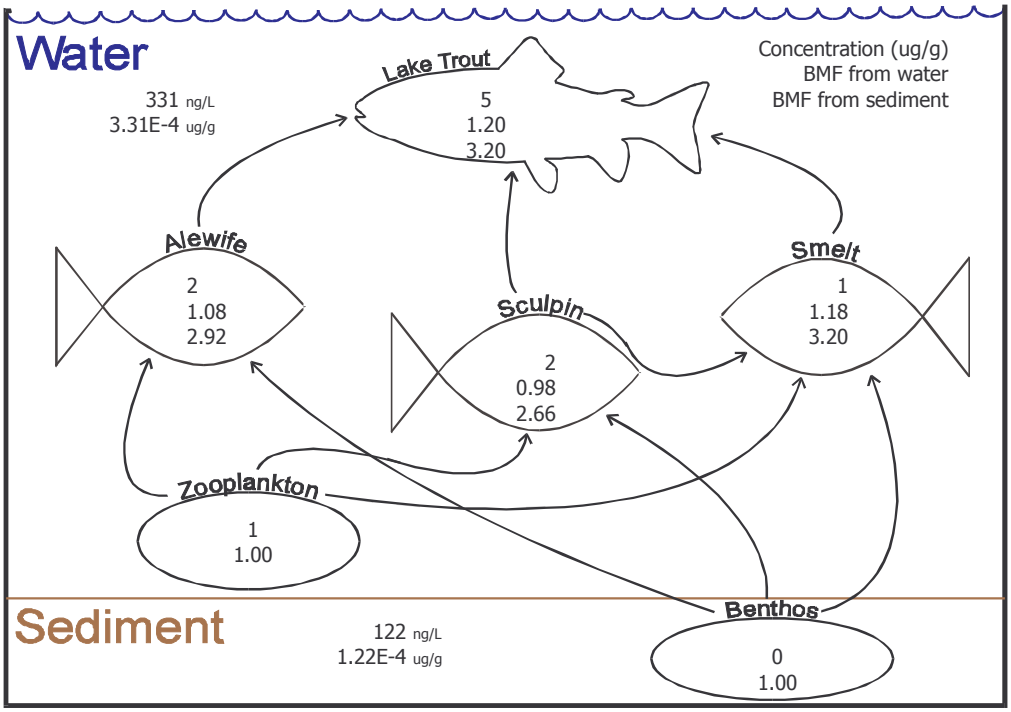
Figure 4-5. A summary of the expected "travel distance" of chlorpyrifos based on a Level II model (TaPL II) and a Level III model (TaPL III). Level III models were illustrated above in Figure 4-1 for several PAHs and assume: non-equilibrium conditions between compartments, non-conservative behavior, steady state, and an open system. Level III models are the most realistic of the three considered here. This analysis provides information on how and where a chemical is likely to be transported. The Level III results add the complexity of having the chemical emitted to air, water, or soil – the model can be adjusted to have any fraction of the total emissions split among the three compartments.

ChemSCORER Beta100 Assessment - Toxicity and Bioaccumulation
Chlorpyrifos

Toxicity Information

Mammalian oral LD50:	82 mg/kg 0.23 mmol/kg	No aquatic toxicity data was supplied.
Extrapolated LD50 - 70 kg human:	6 grams	

Evaluative Aquatic Foodweb



Overall Bioaccumulation Factor, Lake Trout / Water : 15904

Notes on Terminology:

Bioconcentration (BCF) - Increase in contaminant concentration from water to fish.
Biomagnification (BMF) - Increase in contaminant concentration from food to fish.
Bioaccumulation (BAF) - Total contaminant concentration increase due to BCF and BMF.

Figure 4-6. Illustration of the bioaccumulation of chlorpyrifos in a model aquatic food web. Within each sketched organism is listed the concentration, the BMF from water and the BMF from sediment based on the concentration in water as estimated by the Level III model. The actual concentrations listed here are dependent on the input data to the Level III model. Therefore, the model can be used in an evaluative or relative manner to compare across chemicals (using default chemical inputs and generic compartment volumes) or it can be used quantitatively for prospective or retrospective risk assessment if site-specific data are known.

4.5 References for Section 4

ASTM (American Society for Testing Materials). 1993. Annual book of standards. Section 11. Water and environmental technology. Volume 11.04. Pesticides; resource recovery; hazardous substances and oil spill responses; Waste management; Biological effects. Publication Code Number: 01-110493-48. Philadelphia, PA, USA

Davis, G.A., Swanson, M., and Jones, S. 1994. Comparative evaluation of chemical ranking and scoring methodologies. University of Tennessee Center of Clean Products and Clean Technologies. EPA Order No. 3N-3545-NAEX.

Howard, P.H. 1989a. Handbook of environmental fate and exposure data for organic chemicals, Vol I. Lewis Publishers, Chelsea, MI.

Howard, P.H. 1989b. Handbook of environmental fate and exposure data for organic chemicals, Vol II. Lewis Publishers, Chelsea, MI.

Howard, P.H. 1989c. Handbook of environmental fate and exposure data for organic chemicals, Vol III. Lewis Publishers. Lewis Publishers, Chelsea, MI.

Howard P.H. 1991. Handbook of environmental fate and exposure data for organic chemicals, Vol IV. Lewis Publishers, Chelsea, MI.

Mackay, D., Shiu, W.Y, and Ma, K.C. 2000. Illustrated handbook of physical-chemical properties and environmental fate for organic compounds, Lewis Publishers, Chelsea, MI.

Mitchell, R.R., Summer, C.L., Blonde, S.A., Bush, D.M., Hurlburt, G.K., Snyder, E.N., Giesy, J.P. 2002. SCRAM: A scoring and ranking system for persistent, bioaccumulative, and toxic substances for the North American Great Lakes - resulting chemical scores and rankings. Human and Ecological Risk Assessment. 8 (3): 537-557.

Shea, D., Hofelt, C.S., Luellen, D.R., Huysman, A., Lazaro, P.R., Zarzecki, R., Kelly, J.R.. 2001. Chemical contamination at national wildlife refuges in the Lower Mississippi River Ecosystem. NC State University Report to the U.S. Fish and Wildlife Service, Atlanta, GA. 40 pp.

Siljehom, J. 1997. A hazard ranking of organic contaminants in refinery effluents. Toxicology and Industrial Health. 13(4): 527-551.

Snyder, E.M., Snyder, S.A., Giesy, J., Blonde, S.A., Hurlburt, G.K., Summer, C.L., Mitchell, R.R., and Bush, D.M. 2000a. SCRAM: A scoring and ranking system for persistent, bioaccumulative, and toxic substances for the North American Great Lakes. Part I Structure of the scoring and ranking system. Environmental Science and Pollution Research. 7: 1-11.

Snyder, E.M., Snyder, S.A., Giesy, J., Blonde, S.A., Hurlburt, G.K., Summer, C.L., Mitchell, R.R., and Bush, D.M.. 2000b. SCRAM: A scoring and ranking system for persistent,

bioaccumulative, and toxic substances for the North American Great Lakes. Part II Bioaccumulation potential and persistence. Environmental Science and Pollution Research. 7: 115-121.

Snyder, E.M., Snyder, S.A., Giesy, J., Blonde, S.A., Hurlburt, G.K., Summer, C.L., Mitchell, R.R., and Bush, D.M. 2000c. SCRAM: A scoring and ranking system for persistent, bioaccumulative, and toxic substances for the North American Great Lakes. Part III. Acute and subchronic or chronic toxicity. Environmental Science and Pollution Research. 7: 175-184.

Snyder, E.M., Snyder, S.A., Giesy, J., Blonde, S.A., Hurlburt, G.K., Summer, C.L., Mitchell, R.R., and Bush, D.M. 2000d. SCRAM: A scoring and ranking system for persistent, bioaccumulative, and toxic substances for the North American Great Lakes. Part IV Results from representative chemicals, sensitivity analysis, and discriminatory power. Environmental Science and Pollution Research. 7: 220-224.

Stephan, C.E. 1993. Derivation of proposed human health and wildlife bioaccumulation factors for the Great Lakes Initiative. U.S. Environmental Protection Agency, Duluth, MN.

Stephan, C.E. 1995. Great Lakes water quality initiative technical support document for the procedure to determine bioaccumulation factors. EPA-820-B-95-005. U.S. Environmental Protection Agency, Office of Water, Duluth, MN.

Swanson, M.B., Davis, G.A., Kincaid, L.E., Schultz, T.W., Bartmess, J.E., Jones, S.L. and George, E.L. 1997. A screening method for ranking and scoring chemicals by potential human health and environmental impacts. Environmental Toxicology and Chemistry. 16: 372-383.

Swanson, M.B. and Socha, A.C. 1997. Chemical ranking and scoring: Guidelines for relative assessments of chemicals. SETAC Press. 154 pp.

U.S. EPA. 1995. Water quality guidance for the Great Lakes System; Final rules. Federal Register 60(56) (March 23, 1995): 15366-15425.

U.S. EPA. 1997a. Waste minimization prioritization tool. EPA530-R-97-019. Beta Test Version 1.0 User's Guide and System Documentation. Office of Solid Waste, Washington, DC.

U.S. EPA. 1997b. Proposed guidelines for carcinogen risk assessment. EPA/600/P-92/003C. Office of Research and Development, Washington, DC.

U.S. EPA. 2000. Use cluster scoring system. http://www.epa.gov/opptintr/cbep/actlocal/39-use.htm

5.0 SUMMARY AND CONCLUSIONS

As part of a complete and thorough evaluation of the processes for ranking and prioritizing contaminants as part of the CAP, we have reviewed the existing CAP framework and critical data elements, the most commonly reported contaminants on DOI lands, existing ranking and prioritizing approaches for contaminated lands, functional grouping systems for surrogate species, and existing chemical ranking and scoring systems. Additionally, a pilot test of the proposed SRP approach was conducted using toxicity information for surrogate species identified in a coarse functional ecological grouping construct.

The SRP approach is intended both to facilitate the assessment and prioritization of environmental concerns by contaminant specialists for further investigation (often with limited data) and to allow consistent prioritization by management for the assessment of environmental risks on DOI lands nationwide. The existing ranking and prioritization systems for contaminated lands described in Section 2.5 of this report were developed for a variety of applications with essentially the same underlying goals: 1) to conduct screening-level assessments of site-specific contaminant hazards and 2) to consistently rank investigation and/or management needs between sites based on relative risks. A review of these existing approaches and discussions with risk assessment professionals suggest that there is not any one existing system that fully addresses the needs of the proposed approach for CAP applications.

The foundation of the SRP approach is sound information regarding contaminant concerns on refuge lands. To ensure that consistent contaminant information is available for ranking and prioritizing contaminant concerns, refinement of the existing data management system for CAP is recommended. The data management system for CAP would be strengthened by 1) increasing the specificity of the contaminant classifications available for selection in the pick list (e.g., limit the number of broad categories) and 2) providing a detailed description of the contaminant categories in the pick list field including common contaminants and species of concern related to each given category. This refinement should reduce the number of reporting discrepancies resulting from lack of specificity and from overestimation (through selection of multiple classifications for one documented problem) of contaminant concerns. Guidance regarding retrieval of existing contaminant information (archived in separate reports within the ECOS database) should ensure that all existing contaminant data is reviewed by a contaminant specialist and captured in the CAP report. Additional specificity in reporting would be provided by assigning a contamination level (1-4) to each individual contaminant category. Finally, modification of the data management system to include a new field, “chemicals of potential concern”, would facilitate the documentation of site-specific contaminant concerns and enhance the reporting specificity.

Should management decide that further development of the proposed SRP approach is desired, our review highlights the need to address a common limitation of ranking and prioritizing systems: the tradeoff between consistency and accuracy. Because many approaches attempt to assess site-specific needs (e.g., monitoring, investigations, remediation) while promoting consistency in programmatic allocation of resources, they must be transparent enough to address a variety of potential habitats and receptors while still considering sufficient site-specific

information to characterize hazards in the area of interest. Our evaluation of these existing approaches indicates that achieving balance between these goals is difficult and that data gaps are likely as more site-specific criteria are evaluated. Work toward obtaining site specific exposure data and individual chemical toxicity data will pay off in enhanced accuracy, albeit at a cost.

To develop a database of toxicity and persistence information for specific surrogate chemical/surrogate species pairings (as outlined in the proposed SRP), we evaluated grouping systems for species such that appropriate surrogate species could be identified. In our review of the strengths and weaknesses of existing functional grouping systems for biological organisms (Section 3.2) we found that the needs of the proposed system would be achieved through a system that combines some of the features of the previously discussed approaches while assigning rules for selecting surrogate species that are unique to the goals of the CAP system. We suggest use of a coarse system for application to the proposed ranking and prioritizing approach based on the major species classes (e.g., mammal, bird, reptile, amphibian, fish) with one surrogate selected for each class based on the national ecological significance of the species and the availability of toxicity information. Given the uncertainty of a system using one species surrogate to represent a large group of organisms, we recommend further division of the coarse system into subgroups based on habitat (terrestrial, aquatic, soil, sediment) and trophic characteristics (omnivore, herbivore, carnivore, etc.) of the species in each class whenever sufficient data are available. Depending on the need for site-specificity, such a classification system could be further divided into more specific habitat-level groups (e.g. freshwater, saltwater, coldwater, warmwater, etc.). In the test run of the proposed SRP; however, data gaps arose using the basic grouping system (Table 4-6), therefore, population of a more detailed database containing habitat-type and trophic-level groups was not conducted.

In our evaluation of chemical classification systems to support the SRP (Sections 4.1 and 4.2), we found that, like the ecological group surrogates, selection of a surrogate chemical to be representative of a larger class of chemicals introduces considerable uncertainty that may ultimately compromise the validity of the proposed SRP for DOI applications. For most hazard or risk assessment screening applications, uncertainty that is much greater than an order of magnitude makes the assessment appear to have little value (although the needed accuracy should be discussed with DOI managers) and uncertainty much less than this usually requires resources that exceed the worth of the (screening) assessment. A preliminary review of both the chemical and toxicological properties of chemicals within each of the five test chemical classes revealed that chemical property values varied by many orders of magnitude within each class.

It is difficult to decide which properties determine the representativeness of individual chemicals given the complexity of the transport-fate-toxicity progression; therefore, we have concluded that it is not prudent to select individual model chemicals to represent broad classes of contaminants for ranking and scoring, or for more rigorous risk assessment. Instead, we recommend that any ranking system for CAP include individual chemicals that can be readily measured using standard methods of analysis, that have relevant physical-chemical and toxicological properties available, and that are produced or used in quantities that might yield or have been demonstrated to yield (through monitoring data) meaningful exposure in nature.

In our test of various model chemicals using the coarse ecological grouping system and SCRAM, numerical ranking of chemicals did not provide accurate measures of hazard or risk. When the final composite scores are aggregated and the relative ranking of chemicals are completed, chemical loading and transport should be used to obtain the final ranking and priority of chemicals. To provide a consistent and standardized procedure for national or regional ranking of chemicals, a generic environment can be used with the assumptions of a constant chemical loading and homogeneous spatial distribution throughout that environment; however, a decision by management must be made as to what spatial scale will be represented and what range of conditions (chemical loading and attenuation) will be used.

Options for Management Consideration

Based on the lessons learned from our review of the existing CAP data management system, the proposed SRP approach, and several existing ranking and prioritization tools, it appears that there are several options for consideration if development of a ranking and prioritization tool for CAP is pursued.

In particular, refinement of the existing CAP data management system appears to be an essential first step in enhancing the utility of CAP in achieving existing goals and the functional foundation for potential future applications (such as SRP). It is likely that this refinement process could be achieved by addressing the recommendations discussed in detail in section 2.3.2.3 (*Potential Refinement of the Existing Data Management System*). Additionally, it is important to consider the data management needs of all potential users (including management, field, and refuge users) when restructuring the CAP system. To achieve this goal, we recommend convening a workshop of representative users to discuss potential modifications necessary to better achieve user needs.

When optimization of the data retrieval capabilities in CAP (e.g., Section 2.3.2.3, *Potential Refinement of the Existing Data Management System*) is complete, further development of a ranking and prioritization approach (whether it be through selecting and modifying an existing ranking and prioritization approach to meet FWS needs or developing a new approach like SRP) remains an option. If development and/or refinement of a prioritization tool is pursued, we recommend convening a workshop with representation from FWS management and field users of CAP as well as professional risk assessors to discuss system selection (if an existing approach is desired) or development (if the SRP is pursued).

As an alternative to modification of an existing ranking and prioritization approach or development of the SRP, management should consider the potential to draw from existing screening-level risk assessment approaches to better understand risks to resources on DOI lands. As highlighted during the interview process (Section 2.4, *Professional Perspectives*), development of a software-based screening risk assessment process to guide consistent evaluation and prioritization of site-specific risks (by developing simplifying assumptions or defaults for FWS, using appropriate screening and benchmark values, applying existing exposure information into simplified models, and using common endpoint receptors) is a promising means

of achieving both consistent and accurate site-specific risk estimates. This screening-level assessment approach could be achieved with minimal preliminary data collection efforts.

Regardless of which prioritization approach (e.g., developing the SRP, optimizing an existing system, or adoption of a screening-level risk assessment approach) is preferred, it is clear that toxicity data gaps are likely to arise in any assessment. An option available to managers is to invest in development of toxicity profiles for species and chemicals frequently identified in CAP to promote consistent interpretation of contaminant risks to these resources. Specifically, guidance should be provided recommending standard sources for obtaining toxicity data and information. When data gaps are evident, significant benefits may be realized through generating 1) toxicity summaries for frequently encountered chemicals (to improve consistency and assist the CAP user) and, 2) toxicity data for frequently encountered species or those of significant resource value (to improve the accuracy and consistency).

Recommendations

Based on the lessons learned during this CAP and SRP assessment process and feedback from managers, refinement of the existing CAP data management system to increase specificity in data reporting and retrieval functions and to incorporate a peer review of completed CAP reports should be the first priority. These improvements would 1) promote more consistent and accurate data input and 2) allow users to query the system with greater confidence in the database output. This process should be guided by input from various CAP users (management, refuge, and field) to assure optimal functionality. When system improvements are complete, we recommend investment in analytical chemistry (to get exposure data) and toxicity profiles or benchmarks (to obtain consistent interpretations of the exposure data) as priorities over full-scale SRP development. Depending on the programmatic needs for the system (and the associated costs/benefits of developing a new system or modifying an existing approach), allocating resources for the purpose of preliminary data collection on DOI lands may prove to be a favorable alternative to implementing a full-scale SRP approach. In addition, optimizing / modifying one or more of the existing ranking and prioritizing approaches highlighted in this review should be considered given that the number and diversity of existing ranking systems makes it likely that one or more could be modified to meet FWS and USGS needs for the CAP. DOI management should consider the costs and benefits of developing a new screening tool against the costs and benefits of collecting data (exposure data for accuracy) and summarizing available information (recommending specific toxicological profiles, benchmarks, and models for consistency) to improve current CAP data collection and work within established risk assessment frameworks.

APPENDIX A - REVIEW OF EXISTING RANKING AND PRIORITIZING SYSTEMS

Appendix A – Existing Ranking and Prioritizing Systems Evaluated as Foundation for the Development of the Proposed Ranking and Prioritizing System for CAP

Agency/Developer	U.S. Army/Roy F. Weston, Inc.
Technical Document	Waste Site Characterization and Prioritization Using a Geographic Information System
Date	1992
Application	characterization and prioritization of waste sites on U.S. Army properties
Approach	Integrate existing property investigation information for US Army waste sites into a comprehensive GIS database management system (DMS). Information for each site is retrievable in graphic format. Site prioritization is achieved by calculating a site score (based on the EPA Hazard Ranking System approach) and evaluating site-specific information maintained in the GIS data management system.
Ranking/Prioritizing Criteria	• waste site identification info (sites itemized, operation dates, permits, waste types, etc.) • map identification • observed releases (ground water, surface water, air) • population (base and surrounding areas) • migration (ground water categorization, well data, soil and topography) • fire and explosion direct contact hazards
Strengths	Integration of existing waste site data with property maps makes the GIS DMS an attractive tool for site specific decision-making applications. Prioritization is based on a modified HRS system, so many of the advantages of the EPA HRS approach are reflected in this system.
Weaknesses	Limitations associated with the EPA HRS are reflected in this prioritization approach due to its reliance on a modified HRS score.

Agency/Developer	Terracon Environmental, University of Nebraska
Technical Document	Hazard Ranking of Landfills Using Fuzzy Composite Programming
Date	April 1996
Application	landfill hazard assessment
Approach	A multicriteria assessment system is demonstrated in a case study as a tool for screening and prioritizing unregulated disposal sites according to their level of environmental and health hazard. The assessment procedure utilizes fuzzy composite programming to aggregate individual hazard scores (determined through available data and best professional judgement) into a final overall hazard level for a site. The aggregate hazard is a fuzzy number that reflects the most likely range and the largest range of hazards relative to the best and worst case scenarios.
Ranking/Prioritizing Criteria	• waste volume • first year of operation • adjacent land use • waste boundaries • cover material • liner material • liquid disposal • waste types • landfill emissions • wind direction • distance to city • ground water quality • city size • distance to water body • water body use • flood potential • land slope • peak storm runoff • water body at aquifer • vadose zone thickness • permeability • aquifer character • water supply
Strengths	• not as labor- and data-intensive as other approaches • provides a means of incorporating uncertainties into final score (through range approach) • provides flexibility to incorporate numerous environmentally relevant parameters in the hazard assessment
Weaknesses	When data are lacking for a given parameter, the system relies on judgement to assign hazard levels. Consequently, variability between hazard ranking scores is likely when various contaminant specialists perform this approach.

Agency/Developer	Newcastle City Council (NCC)/Centre for Land Use and Water Resources Research, University of Newcastle
Technical Document	Development of a Contaminated Land Assessment System (CLASS) Based on Hazard to Surface Water Bodies
Date	1999
Application	• identification and characterization of contaminant sources, pathways, and targets • prioritization of monitoring, site investigation, and/or remediation actions based on future pollution potential at contaminated sites
Approach	The prototype system utilizes ARC/INFO to predict pollution migration from contaminated lands using information regarding pollutant sources, pathways, and targets. The hazard index is estimated based on ranks and ranges for various physiochemical and environmental factors for current and historic industrial sites. The index is designed to guide the determination of remediation and monitoring needs for historic and current industrial sites, respectively. Results are displayed in hazard assessment maps containing locations of industrial sites and their corresponding hazard index value. Hazard index modeling allows for the ranking of sites based on their relative hazard potential.
Ranking/Prioritizing Criteria	• site hydrogeology • site area • travel times to nearest target • toxicity (acute and chronic) • persistence • sorption characteristics
Strengths	• allows for comparative assessment and prioritization of sites • incorporates basic site-specific information • ARCVIEW-based system allows for easy interpretation and integration of physical maps, physiochemical data, and hazard assessment results
Weaknesses	• data gaps are not addressed • in the prototype system, only surface water bodies are considered as pollution targets

Agency/Developer	Maryland Department of Natural Resources, Tidewater Administration, Chesapeake Bay Research and Monitoring Division
Technical Document	Demonstration of a toxicological risk ranking method to correlate measures of ambient toxicity and fish community diversity
Date	1997
Application	integration of environmental ambient toxicity testing risk ranking method with a biological community assessment approach
Approach	The ranking scheme is a component of the ambient toxicity program at MD Department of Natural Resources and is designed to evaluate the ambient toxicological data in a site-specific metric that is appropriate for comparison to other metrics (e.g. index of biotic integrity or community diversity indices). The score allows for comparison of individual sites and evaluation of sample trends.
Ranking/Prioritizing Criteria	severity of effect degree of response test variability site consistency number of measured endpoints
Strengths	The toxicological risk ranking score correlates well with fish community metrics. The scoring scheme adequately allows for comparison of individual sites
Weaknesses	Data requirements are more extensive than other approaches and involve water, sediment, and fish community sampling as well as toxicity testing.

Agency/Developer	Western Washington University–Institute of Environmental Toxicology and Chemistry
Technical Document	Design Consideration and a Suggested Approach for Regional and Comparative Ecological Risk Assessment
Date	1997
Application	regional risk assessment and risk ranking
Approach	Approach involves a regional assessment to evaluate various risk components at individual sites within a region, rank the relative importance of these sites, and incorporate available information for individual sites to predict the relative risk among locations in the specified region. The complexity of the relative risk model ranking and scaling matrices increases with the number of stressors and potential effects evaluated. The approach can be tailored to address site-specific source and impact concern.
Ranking/Prioritizing Criteria	sources present habitat areas potential effects
Strengths	• The matrix approach is simplistic. • The data requirements for rank assignment are low and based on relative importance and risks associated with a stressor. • Rules for risk prediction and ranking could be incorporated in this framework
Weaknesses	• Ranking system is based on relative risks and is not quantitative • Model verification is impossible without conducting field investigations to assess the validity of ranking assumptions • Assignment of ranks for source and site importance relative to a given stressor is subjective and variability in results between specialists performing ranking model is possible • The proposed ranking system is designed to deal with regional contamination concerns and would require expansion to evaluate nationwide contaminant concerns on refuges

Agency/Developer	Western Washington University–Institute of Environmental Toxicology and Chemistry, University of Alaska Fairbanks–Institue of Marine Science
Technical Document	A regional multiple-stressor rank-based ecological risk assessment for the fjord of Port Valdez, Alaska
Date	1998
Application	regional risk assessment and risk ranking
Approach	Investigators used the regional risk assessment approach outlined by Landis and Wiegers (1997) to develop a relative risk model for Port Valdez. The model ranked was applied to rank and sum individual risks quantitatively for each designated subarea, source, and habitat effected. For each subarea within the region, the sources of stressors were evaluated to estimate exposure of receptors within the habitats included in the analysis. A list of model assumptions and rules for ranking were established. Comparison of the risk scores for each subarea identified areas of highest risk for management decision-making purposes.
Ranking/Prioritizing Criteria	• 11 subareas in and around Port Valdez • 8 sources (treated discharge, contaminated runoff, accidental spills, fish and seafood processing waste, vessel traffic, construction, hatchery fish, and shoreline activity) • 8 habitats (saltmarsh, mudflat, low-profile beach, rocky shorline, shallow shoreline, deep benthic, open water, stream mouth) • exposure factors • sediment quality factors
Strengths	Approach can integrate information about multiple habitats, stressors, and assessment endpoints for designated region subareas into numeric scores for comparison. The approach is straight-forward and simplistic and can be applied both with and without extensive site-specific data. Rules can be developed to guide model rank and scale assignments.
Weaknesses	• Relative ranks between regions cannot be compared unless the relative risk models are of identical design • The ranking approach is relative and is not a measure of absolute risk • Investigator bias resulting from individual philosophies concerning which stressors are important could influence ranking • Data gaps and potential omissions of important sources or endpoints in the relative risk model can increase the uncertainty of the overall score

Agency/Developer	University of Wisconsin–Green Bay, Wisconsin Department of Natural Resources, U.S. EPA Great Lakes National Program Office
Technical Document	A method for assessing environmental risk: a case study of Green Bay, Lake Michigan, USA
Date	1994
Application	relative ranking of ecosystem stressors for the development of risk reduction strategies
Approach	In this approach, risk values are assigned to each ecosystem stressor-impaired use pair based on the degree of effect that the stressor contributes to ecosystem risk (measured by impaired use criteria). A predefined scale of zero (no impact) to 3 (major impact) was applied to an impact matrix to determine numeric risk values. Risk values for ecosystem stressors are then ranked using fuzzy set theory calculations.
Ranking/Prioritizing Criteria	stressor severity time/duration prevention management remediation management
Strengths	Fuzzy set decision models allow for differentiation between the risk and importance of multiple environmental stressors. The system function is retained even when data are lacking.
Weaknesses	Investigators must have a comprehensive understanding of the ecosystem functions and potential stressor impacts. There is potential for variability in model results based on professional judgement input from individual investigators.

Agency/Developer	US Environmental Protection Agency–Great Lakes National Program Office, Assessment and Remediation of Contaminated Sediments (ARCS) Program
Technical Document	Hazard ranking of contaminated sediments based on chemical analysis, laboratory toxicity test, and benthic community structure: method of prioritizing sites for remedial action.
Date	October 1994
Application	hazard ranking of contaminated sediments for remedial action
Approach	Hazards associated with contaminants in sediments are assessed using toxicological, ecological, and bioavailability data. Toxic units (defined as the ratio of the bioavailable component of a compound to the USEPA chronic toxicity water quality criteria for that chemical) are summed for all chemicals measured at a site. In addition, normalized toxicity ranks based on laboratory toxicity tests and benthic community structure are figured into a final ranking score. The estimate of relative hazard of sediment contaminants to aquatic life for a site is the mean of the ranks for the sediment chemistry data (reflected in toxic units), laboratory toxicity tests, and benthic community structure.
Ranking/Prioritizing Criteria	sediment chemistry data laboratory sediment toxicity tests benthic community structure
Strengths	This approach allows for the relative comparison and ranking of sites based on existing toxicity data.
Weaknesses	The approach requires the initiation of laboratory toxicity tests of sediments as well as the collection of benthic community data.

Agency/Developer	California State University, Idaho Department of Health and Welfare Division of Environmental Quality
Technical Document	A decision analysis technique for ranking sources of groundwater pollution
Date	1993
Application	groundwater pollution ranking and management
Approach	Potential sources (defined as a type of land use) of groundwater contamination are identified through an inventory of historic data. Sources were ranked based on their regional and/or statewide effects rather than site-specific impacts. For each potential source, a total rating score was developed based on the regulatory adequacy factor, the public health risk factor, and the aquifer vulnerability factor scores. Each factor was developed using criteria for assigning high, medium, or low risk numeric values.
Ranking/Prioritizing Criteria	• potential for existing programs to prevent or remedy groundwater contamination (regulatory adequacy factor) • severity of the potential impact of the pollution source on public health (public health risk factor) - prevalence - toxicity - environmental persistence - mobility - size of population potentially affected • vulnerability of groundwater system to pollution based on hydrogeological characteristics (aquifer vulnerability factor)
Strengths	The ranking scores can be developed rapidly with limited information based on criteria for assigning high, medium, and low risk numeric values for each factor included in the final score.
Weaknesses	This approach evaluates the relative risk of potential sources but is not developed for site-specific comparisons and prioritization. In addition, only human health impacts are considered.

Agency/Developer	U.S. DOD/Roy F. Weston, Inc.
Technical Document	User's Manual for the Defense Priority Model. Version 2.0. Revision
Date	January 1989
Application	ranking of disposal sites to establish priorities for remedial actions
Approach	The Defense Priority Model computes a numeric score (ranging from zero to 100) to reflect the potential threat to human health and the environment based on contaminant pathway, hazard, and receptors using site-specific data typically collected during the preliminary assessment/site investigation (PA/SI) and the remedial investigation/feasibility study (RI/FS) phases. For each pathway (surface water, groundwater, air/soil), hazard, receptor, and pathway subscores are calculated for both human health and environmental hazards. Hazard scores are developed by comparing contaminant levels at the site to toxicological benchmark values. The final site score is the combination of overall subscores for each transport pathway and potential receptor combination.
Ranking/	Transport Factors *waste quantity factor (all pathways)* • size of site • waste quantity • years of use *surface water pathway* • type of site • distance to surface water • net precipitation • surface erosion potential • rainfall intensity • surface permeability • flooding potential *groundwater pathway* • engineering barrier condition • distance to high groundwater • permeability of unsaturated zone • infiltration potential • geochemical properties of vadose zone *air/soil pathway* • cover/venting mechanisms • summer soil temperature • net precipitation • wind velocity • soil porosity Prioritizing Criteria Hazard Factors *with site-specific data* • observed concentration • daily intake rate • toxicity benchmark values *no site-specific data* • maximum acceptable intake • bioaccumulation factor • toxicity benchmark values *volatile hazards* • physical and chemical properties *dust hazards* • soil silt content • precipitation • wind speed • exposed area • site activity Receptor Factors • drinking water population • water use of surface water • population density • installation boundary distance • land use and zoning • important biota near site • critical environment near site • well/surface water travel time • groundwater use • groundwater time to habitat or natural area

Agency/Developer	U.S. DOD/Roy F. Weston, Inc.
Technical Document	User's Manual for the Defense Priority Model. Version 2.0. Revision
Strengths	Ecological effects are considered along with human health effects. Both site-specific and regional data can be used, and procedures for evaluate hazards at sites without observed contamination are available. Default values are established and applied for contaminants for which no benchmark values are available.
Weaknesses	The data requirement for the Defense Priority Model is high and often relies on site-specific data. Not all risk factors are accounted for in the model yielding sometimes high ranked scores. Contaminant mobility is not considered in the model.

Agency/Developer	USDOE/USDOD–USAF Installation Restoration Program	
Technical Document	Development and demonstration of a hazard assessment rating methodology for phase II (HARM II) of the installation restoration program (IRP)	
Date	February 1986	
Application	priority setting for site investigation and remedial action	
Approach	HARM II is closely related to the MITRE model and the Defense Priority Model (both used by USDOD). HARM II computes a numeric score to reflect the potential threat to human health and the environment based on contaminant pathway, hazard, and receptors using site-specific data typically collected during phase I (background site search and identification of problem sties) of the IRP. For each pathway (surface water and groundwater), hazard, receptor, and pathway subscores are calculated for both human health and environmental hazards. Hazard scores are developed by comparing contaminant levels at the site to toxicological benchmark values. The final site score is the combination of overall subscores on a zero to three rating scale) for each transport pathway and potential receptor combination.	
Ranking/Prioritizing Criteria	*Surface Water Pathway* <u>Pathway Score</u> • distance to surface water • net precipitation • surface erosion potential • rainfall intensity • surface permeability • flooding potential • containment potential <u>Hazards Scores</u> • hazard quotient values • toxicity score • bioaccumulation score • persistence factor • waste quantity <u>Receptor Scores</u> Human Health • population using drinking water • water quality classification • population within 1000 ft • installation boundary distance • land use/zoning Ecological Effects • importance/sensitivity of surface water biota/habitats • importance/sensitivity of critical environments	*Groundwater Pathway* <u>Pathway Score</u> • depth to groundwater from base of contaminated zone • permeability of unsat. zone • infiltration potential • discrete features • containment potential <u>Hazards Scores</u> • hazard quotient values • toxicity score • bioaccumulation score • persistence factor • waste quantity <u>Receptor Scores</u> Human Health • population served by aquifer • uppermost aquifer use • travel time to nearest wells • installation boundary distance • population within 1000 ft Ecological Effects • travel time to natural habitat • importance/sensitivity of critical environments in 1 mi • importance/sensitivity of downgradient areas near discharge points

Agency/Developer	USDOE/USDOD–USAF Installation Restoration Program
Technical Document	Development and demonstration of a hazard assessment rating methodology for phase II (HARM II) of the installation restoration program (IRP)
Strengths	Ecological effects are considered along with human health effects. Both site-specific and regional data can be used, and procedures for evaluate hazards at sites without observed contamination are available. Default values are established and applied for contaminants for which no benchmark values are available.
Weaknesses	The data requirement is high and often relies on site-specific data. Not all risk factors are accounted for in the model yielding sometimes high ranked scores.

Agency/Developer	USDOE
Technical Document	Use of risk to resolve conflicts in assessing hazards at mixed-waste sites
Date	1991
Application	ranking hazardous waste sites based on human health risks
Approach	The site ranking system (SRS) ranks sites based on scoring factors that influence human health risks. The product of three factors (the potentially exposed population, the average amount of waste exposure, and the toxicity of the waste) is determined for three exposure routes (surface water, groundwater, and air) to calculate the relative risk of a release. Special consideration is given to carcinogenic, noncarcinogenic, and radioactive compounds.
Ranking/Prioritizing Criteria	distance from site population at risk, exposure potential chronic toxicity quantity of hazardous material effectiveness of engineering barriers
Strengths	The SRS is a simplified and cost-effective approach to risk-based ranking of chronic human health hazards associated with mixed-waste sites. The approach is applicable to most waste sites and requires only readily available data.
Weaknesses	The SRS only considers chronic human heath risk. Ecological exposure and effects are not incorporated in the model.

Agency/Developer	USDOE
Technical Document	Use of the multimedia environmental pollutant assessment system (MEPAS) for large- and small-scale applications
Date	September 1989
Application	prioritization of hazardous waste sites for further site investigation and potential remediation actions
Approach	The primary output from the MEPAS model is the hazard potential index (HPI). HPI values are developed for each exposure route (groundwater, surface water, overland flow, and atmospheric pathways) and are the combination of the environmental contaminant concentration, the population exposed, and the toxicity. Three types of data are required by the MEPAS model: source-term data (contaminant identity, quantity, concentrations, metabolic breakdown products, and release type), site-specific data (hydrology, geology, meterology, climatology, and demographics), and constituent properties (physiochemical properties and human health toxicity). The MEPAS model is a version of the USDOE's remedial action priority system (RAPS) that is used in an environmental surveying effort as a decision support tool for allocating funds and human resources for site investigations and remediation.
Ranking/Prioritizing Criteria	contaminant transport contaminant retention (mobility, dispersion, decay/degradation) toxicity population distribution routes and types of exposure exposure duration waste type
Strengths	The MEPAS system allows for use of general data when site-specific information is unavailable. The MEPAS system has been demonstrated on both large- and small-scale applications.
Weaknesses	The primary goal of the MEPAS system is to identify and prioritize human health hazards. Ecological concerns are not readily considered; however, the system could be adapted for inclusion of various ecological receptors. The MEPAS model is not predictive and is only applicable as a comparative tool.

Agency/Developer	USDOE/Environmental Assessment Technologies
Technical Document	Workbook for prioritizing petroleum industry exploration and production sites for remediation
Date	August 1998
Application	ranking of human health and ecological hazards resulting from petroleum exploration and production (E&P) sites using a screening-level risk-based corrective action (RBCA) framework
Approach	The workbook outlines a risk-based approach for prioritizing petroleum E&P sites for remediation. A scoring system combines scores for "evaluation factors" relating to the contaminants present onsite, the potential exposure pathways, and the potential receptors. The process is an integration of several existing systems including the Canadian National Classification System for Contaminated Sites and the USFWS lands Biomonitoring Operations Manual. The workbook provides a screening-level approach that incorporates readily available information and does not require extensive site characterization for completion. Scoring guidelines are established and rankings for each "evaluation factor" is based on high, medium, or low categories based on potential risks.
Ranking/Prioritizing Criteria	site location contaminant/waste type depth to water table geologic map/survey data annual rainfall data surface cover information proximity to surface water topographic information flood potential of site proximity to drinking water adjacent water resources uses land use information
Strengths	Existing approaches from the USFWS biomonitoring program (the predecessor to the current CAP manual) are incorporated in the workbook. The workbook relies on basic site and readily available information rather than data collected from extensive site investigations. Qualitative descriptors (high, medium, and low risk) are assigned numeric scores for comparative site ranking. The approach is rapid and inexpensive to perform.
Weaknesses	The workbook has not yet been field tested or evaluated. The approach often relies on qualitative information and best professional judgement to assign risk scores.

Agency/Developer	U.S. EPA/U.S. DOE
Technical Document	A multimedia screening-level model for assessing the potential fate of chemicals released to the environment
Date	June 1982
Application	assessment of the potential for environmental accumulation of contaminants released to air, surface water, or soil
Approach	A screening-level multimedia model (TOX-SCREEN) was developed to assess the potential for human exposure to contaminants in air, water, or soil. Model simplifications include the assumption that water bodies are located adjacent to contaminated air and land sources. In addition, site-specific data is not used (rather regional and nationwide information is preferred) to minimize the data collection needs. Pollutant dispersion models for each media considered (estimated by transfer rate coefficients, deposition velocities, and mass loading parameters) are used to estimate exposure potential.
Ranking/Prioritizing Criteria	atmospheric dispersion aquatic dispersion soil dispersion intermedia transport
Strengths	The system is designed with many default assumptions and relies on limited site-specific data collection.
Weaknesses	This approach assumes generic positioning of media for estimating pollutant dispersion and transport/migration between media. These generalizations, while reducing the data collection requirements, do not facilitate site-specific interpretation or comparisons between contaminated sites. The model also only considers human health effects.

Agency/Developer	U.S. DOE
Technical Document	Demonstration of the applicability of implementing the enhanced remedial action priority system (RAPS) for environmental releases
Date	December 1989
Application	waste site multimedia assessment and ranking based on human health risks
Approach	The RAPS approach prioritizes hazardous and radioactive waste disposal sties using limited site-specific data. The system is used by the U.S. DOE as a management tool for fund allocation and determination of additional investigation and remediation needs at waste sites. Environmental surveying applications of this system for both active and inactive sites are referred to as the Multimedia Environmental Pollutant Assessment System (MEPAS). This document demonstrates the RAPS methodology at three separate sites. The primary output from the RAPS system is the hazard potential index (HPI). HPI values are developed for each exposure route (groundwater, surface water, overland flow, and atmospheric pathways) and are the combination of the environmental contaminant concentration, the population exposed, and the toxicity. Three types of data are required by the RAPS model: source-term data (contaminant identity, quantity, concentrations, metabolic breakdown products, and release type), site-specific data (hydrology, geology, meterology, climatology, and demographics), and constituent properties (physiochemical properties and human health toxicity).
Ranking/Prioritizing Criteria	contaminant transport contaminant retention (mobility, dispersion, decay/degradation) toxicity population distribution routes and types of exposure exposure duration waste type
Strengths	The RAPS system allows for use of general data when site-specific information is unavailable. The RAPS system has been demonstrated on both large- and small-scale applications.
Weaknesses	The primary goal of the RAPS methodology is to identify and prioritize human health hazards. Ecological concerns are not readily considered; however, the system could be adapted for inclusion of various ecological receptors. The RAPS model is not predictive and is only applicable as a comparative tool.

Agency/Developer	U.S. DOE
Technical Document	Environmental restoration risk-based prioritization work package planning and risk ranking methodology
Date	June 1995
Application	prioritization of environmental restoration program activities to establish budget priorities
Approach	This approach relies on qualitative data to identify, evaluate, and prioritize environmental restoration (ER) program funding decisions. Initially, a work package planning form is completed by technical site experts familiar with proposed restoration projects. Completion of these forms are guided by specific rules to provide consistency. Review of forms is conducted by an objective decision making body (ER prioritization board) to develop risk-based work package priorities based on risk/benefit estimates developed by site technical experts. The board uses a decision support tool, the Environmental Restoration Benefit Assessment Matrix (ERBAM) to determine a risk score for each proposed work package. This tool evaluates six selection criteria along with information about impact severity and event likelihood. Matrix output includes numeric values to describe both existing site risk as well as anticipated risk reduction following completion of the work package. The overall risk score is evaluated by management to rank work packages and program activities.
Ranking/Prioritizing Criteria	public health environmental protection site personnel safety stakeholder preference site mission cost effectiveness
Strengths	The approach does not require site-specific data collection. Qualitative information regarding each selection criteria is compiled using professional judgement by technical experts. Specific guidelines are established for assigning values for impact severity and event likelihood.
Weaknesses	Overall ranking of program priorities is based on a numeric score; however, the ultimate prioritization process relies heavily on technical expertise and management/professional judgement. Although rules are established to minimize bias and standardize the process, this approach is still heavily subjective.

Agency/Developer	Lehigh University
Technical Document	Assessment of waste disposal sites utilizing expert systems
Date	1985
Application	hazard assessment of waste sites and remedial decision support
Approach	The system, known as GEOTOX, is designed to function score a variety of factors related to hazards at waste sites based on readily available information. When data are lacking, the model can calculate a score with incomplete information. For each criteria evaluated, there is a set of rules that determine a score for that parameter based on set input conditions. The scoring process is similar to that used by USEPA's Hazard Ranking System. The goal of the system is to derive an estimate of the degree of potential hazard associated with a site. The overall site hazard score is the weighted sum of 3 site hazard components: the permanent hazard (related to soil and hydrogeologic factors), the local hazard (related to contamination severity), and the global hazard (related to environmental sensitivity).
Ranking/Prioritizing Criteria	*Local Hazard* • contaminant quantity • toxicity • persistence • treatment *Permanent Hazard* • transport route characteristics • distance • depth • slope • permeability/sorption of unsaturated zone *Global Hazard* • aquifer sorption • permeability • depth • extent of contamination • importance • targets • containment
Strengths	The approach is appropriate for preliminary ranking of waste site concerns. The data requirements for running the model are not extensive and the GEOTOX output can be modified as additional data become available. Specific rules are established for assigning scores for each criteria.
Weaknesses	Data gaps are addressed by using default values in the model. Depending on the relative weights of missing data in the model, these defaults could skew the output results when compared to other sites.

Agency/Developer	U.S. EPA
Technical Document	Hazard Ranking System; Final Rule
Date	December 1990
Application	National Priority List (NPL) hazard ranking of uncontrolled waste sites
Approach	The hazard ranking system (HRS) uses a structured analysis approach to scoring sites based on detailed guidelines. Numeric values are assigned to risk factors associated with 1) likelihood of an existing or potential contaminant release; 2) waste characteristics; and 3) people or sensitive environments affected by the release. These factors are scored for four pathways or exposure routes (ground water, surface water, soil, and air). Individual factor scores are combined into an overall site score using a root-mean-square equation. U.S. EPA has developed scoring software (PREscore) to facilitate scoring calculations. Pathway scores are normalized to a 100-point scale. An overall site score of 28.5 or greater qualifies a site for listing on the NPL.
Ranking/Prioritizing Criteria	*Groundwater Route* • observed/potential release • depth to aquifer • net precipitation • permeability of unsaturated zone • physical state • containment • toxicity/persistence • waste quantity • ground water use • distance to nearest well/population served *Surface Water Route* • observed/potential release • distance to surface water • 1-yr, 24-hr rainfall amount • terrain slope • physical state • containment • toxicity persistence • waste quantity • surface water use • distance to sensitive environment • distance to nearest population served *Soil Exposure* • observed/potential release • toxicity/persistence • waste quantity • area of contamination • distance to nearest population • distance to terrestrial sensitive environments • population within one mile • containment *Air Route* • observed/potential release • reactivity and incompatibility • toxicity • waste quantity • land use • distance to sensitive environment • population in 4 mile radius
Strengths	The HRS is widely used and has established guidelines for assigning numeric values to increase scoring uniformity. U.S. EPA has developed support tools for HRS that facilitate deriving scores including PREscore and the Superfund Chemical Data Matrix (SCDM). This system has been successfully applied to a variety of sites with varying waste hazard concerns.

Agency/Developer	U.S. EPA
Technical Document	Hazard Ranking System; Final Rule
Weaknesses	Guidelines for the HRS prohibit scoring of factors/criteria for which there is insufficient supporting data; consequently, these data gaps can significantly affect the overall score depending on the relative weight assigned to the factor in question. The HRS has been revised from its original version in 1990, therefore, there are concerns regarding the comparability of site scores prior to and following the revision. A common criticism of this approach is that the level of data collection effort can unduly influence the scoring outcome because scoring is based on the presence or absence of **observed** contamination in a given pathway. Consequently, there is a tendency for sites with extensive data collection efforts to have higher overall scores.

Agency/Developer	U.S. EPA
Technical Document	Classification of hazardous wastes
Date	1980
Application	hazardous waste site ranking
Approach	Statistical analysis techniques (linear discriminant analysis) were used to rank hazardous waste sites. This approach uses "training data" to classify sites into defined risk groups (very hazardous, moderately hazardous, and slightly hazardous) based on specific criteria (variables) using statistical analysis. Regions of variable space are graphically displayed using discriminant analysis. New sites are classified into risk groups categories based on the proximity of the boundaries of groups to the designated test case boundaries. U.S. EPA has used this approach to rank sanitary landfill sites based on the groundwater pathway.
Ranking/Prioritizing Criteria	can vary, but for the U.S. EPA sanitary landfill ranking application: unsaturated soil permeability distance to groundwater waste hazard potential yearly infiltration
Strengths	The multivariate methods used are able to systematically classify sites into risk categories based on reference "training data". According to the method developer, statistic model ranking systems are easy to implement and are robust (e.g. variations in the variables do not affect the overall site ranking).
Weaknesses	Sensitivity and uncertainty analysis is not possible with this approach. Considerable technical expertise and training is needed for application of this method.

Agency/Developer	Canadian Council of Ministers of the Environment (CCME)
Technical Document	National Classification System for Contaminated Sites
Date	March 1992
Application	contaminated sites screening based on qualitative risk for prioritization of funding needs for additional action
Approach	This approach was developed as part of the National Contaminated Sites Remediation Program initiated by the CCME in order to improve consistency in the evaluation of contaminated sites. The system is designed to be applicable to all types of contaminated sites using readily available information (including site characteristics, contaminant presence and location). In this approach, site characteristics are assigned numeric scores which are then prioritized based on an additive factorial method where various characteristics are weighted according to their relevance to the overall hazard associated with a given site. The evaluation factors used to prioritize site needs encompass the contaminant characteristics, exposure pathways, and receptors associated with a contaminated site.
Ranking/Prioritizing Criteria	description of site location contaminant type (known or potentially present) contaminant amount (including size of contaminated area) approximate depth to water table geologic map or survey information annual rainfall data surface cover information proximity to surface water topographic information flood potential of site proximity to drinking water supplies adjacent water resources uses land use information
Strengths	The National Classification System is available in electronic database format to facilitate data input and retrieval of scores. The system includes procedures to address information gaps. The approach incorporates site-specific considerations and has separate procedures for sites with known versus potential contamination.
Weaknesses	The approach is not intended for relative ranking of contaminant concerns. Depending on data availability, significant margins of error could be incorporated in final scores.

APPENDIX B - REVIEW OF ECOLOGICAL CLASSIFICATION APPROACHES

Appendix B – Summary tables for ecological classification approaches identified in the literature search

Agency	USEPA
Technical Document	Screening level ecological risk assessment protocol for hazardous waste combustion facilities, volume 1
Date	August 1999
Application	Screening and risk assessment
Approach	Habitat-specific food webs were developed by identifying the major feeding guilds for birds, mammals, reptiles, amphibians, and fish based on the dietary habits and feeding strategies of receptors. Invertebrates and plants were categorized based on the communities and various environmental media they inhabit. Within each major feeding guild, species are grouped into individual classes for which several representative receptors were identified
Trophic Classes	Aquatic: aquatic plants, water invertebrates, herbivorous/planktivorous fish, omnivorous fish, carnivorous fish Sediment: sediment invertebrates Soil: terrestrial plants, soil invertebrates Terrestrial: herbivorous mammals, herbivorous birds, omnivorous mammals, omnivorous birds, omnivorous amphibians and reptiles, carnivorous mammals, carnivorous birds, carnivorous shore birds, and carnivorous reptiles
Strength	Representative receptors are grouped both by class-specific guilds and by media type so exposure can be addressed in terms of media and trophic effects
Weakness	A more generalized approach that does not rely on the development of habitat-specific food webs would be preferred to allow for consistency in the selection of surrogate species for CAP
Surrogate Selection Criteria	ecological relevance exposure potential sensitivity social or economic importance availability of natural history information

Agency	USEPA
Technical Document	Technical Support Document for the Hazardous Waste Identification Program: Risk Assessment for Human and Ecological Receptors, Volumes 1 and 2
Date	August 1995
Application	risk assessment, multipathway analysis (MPA)
Approach	Ecological receptors were selected to represent major trophic elements of generalized aquatic and terrestrial food webs. Each generic system was subdivided into compartments representing potential exposure media.
Trophic Classes	Aquatic Freshwater Limnetic: phytoplanton, zooplankton, small fish, larger piscivorous fish, and piscivorous mammals and birds Littoral: phytoplankton/detritus, zooplankton, benthic invertebrates, small forage fish, larger piscivorous fish, and piscivorous mammals and birds Terrestrial Plants: vascular Nonsoil: herbivores, insectivores/vermivores, opportunistic species, mammals and birds Soil: microphytic, saprophytic, phytophagous, and carnivorous
Strengths	Consistency is provided by selecting receptors with nationwide distribution and by focusing on only two generic ecosystems (rather than several site-specific food webs)
Weakness	Potential for inconsistencies due to reliance on rules to select representative species for functional groups where a surrogate has not been identified
Surrogate Selection Criteria	ecological significance trophic interactions with other species relation to likely exposure pathways nationwide distribution of species

Agency	USEPA
Technical Document	Wildlife Exposure Factors Handbook
Date	December 1993
Application	screening-level risk assessments
Approach	Species selected from several functional groups (mammals, birds, amphibians, and reptiles) are divided into guilds based on diet and habitat. From each guild, surrogates are selected as representative of the entire guild.
Trophic Classes	Birds: insectivore, herbivore, omnivore, carnivore, carmivore/piscivore/scavenger, piscivore, aquatic insectivore, aquatic herbivore/insectivore Mammals: insectivore, herbivore, omnivore, carnivore, piscivore, aquatic herbivore Reptiles: terrestrial carnivore, aquatic piscivore, omnivore, aquatic hervibore Amphibians: insectivore, aquatic piscivore/insectivore
Strengths	Widely accepted and applied tool used in screening-level risk assessments; toxicological data is typically available for many of the representative species; and the grouping system used is generic and widely applicable allowing for consistent results
Weaknesses	System is not appropriate for site-specific risk assessments and fish and aquatic and terrestrial vertebrates have not been included in the Handbook
Surrogate Selection Criteria	major taxonomic groups range of diets likely to be associated with contaminated media various habitat types range in body sizes widespread geographic distribution societal and regulatory significance

Agency	USEPA
Technical Document	Data collection for the hazardous waste identification rule. Section 14.0 Ecological benchmarks
Date	October 1999
Application	risk estimation for the HWIR
Approach	Protective chemical stressor concentration limits were derived for specific communities and populations in direct contact with contaminated media
Trophic Classes	mammalian, avian, terrestrial plants, aquatic plants and algae, herpetofauna, soil community, aquatic community and the benthic community
Strengths	Functional groupings described have been successfully applied to a risk estimation approach
Weaknesses	System is more complex and application of the surrogate concept has not been considered
Surrogate Selection Criteria	n/a

Agency	USEPA
Technical Document	Aquatic food web module: background and implementation for the multimedia, multipathway, and multireceptor risk assessment (EMRA) for HWIR99
Date	October 1999
Application	prediction of contaminant concentrations in aquatic organisms
Approach	System is designed to predict contaminant concentrations in aquatic species. Module framework includes four representative freshwater habitats (streams/rivers, permanently flooded wetlands, ponds, and lakes) for warmwater and coldwater systems
Trophic Classes	Algae/phytoplankton/plants: periphyton, phytoplankton, aquatic macrophytes Zooplankton Benthos: benthic detritivores, benthic filter feeders Fish: trophic level 3 (TL3) fish feeding on benthos (small, medium, and large), TL3 fish feeding on zooplankton (small, medium, and large), TL3 omnivorous fish (small, medium, and large), trophic level 4 piscivorous fish
Strengths	Provides a classification system based on trophic interactions for aquatic habitats that could be applicable to the proposed CAP system
Weaknesses	The application of the functional species grouping to a predictive model is beyond the scope of the proposed system. Approach is very habitat-specific and requires that surrogates be selected on a case-by-case basis
Surrogate Selection Criteria	Determined individually for each habitat-specific food web

Agency	USDOE
Technical Document	Toxicological Benchmarks for Wildlife
Date	June 1995
Application	screening-level and baseline ecological risk assessments
Approach	NOAEL and LOAEL data for 8 representative mammalian and 11 avian wildlife species are presented as toxicological benchmarks for 85 chemicals of concern for application in screening-level and baseline ecological risk assessments.
Trophic Classes	Mammals: short-tailed shrew, little brown bat, meadow vole, white footed mouse, cottontail rabbit, mink, red fox, and whitetail deer Birds: American robin, rough-winged swallow, American woodcock, wild turkey, belted kingfisher, great blue heron, barred owl, barn owl, Cooper's hawk, osprey, and red-tailed hawk
Strengths	Widespread use by risk assessment professionals nationwide. Adequate toxicological data available for representative species selected
Weaknesses	Representative species are only selected for mammals and birds.
Surrogate Selection Criteria	Widespread national distribution. Presence of species at USDOE sites. Represents a range of dietary preferences Represents a range of body sizes.

Agency	USDOE
Technical Document	Development and Validation of Bioaccumulation Models for Small Mammals
Date	February 1998
Application	bioaccumulation models
Approach	Whole-body contaminant concentrations for 16 chemicals in small mammals are estimated to evaluate exposure risks to predatory wildlife. Uptake factors were estimated in order to determine body burdens for both individual species and trophic groups.
Trophic Classes	Insectivore: northern short-tailed shrew, American least shrew, hairy-tailed (brewer's) mole, common shrew, masked (Cinereus) shrew, pygmy (lesser) shrew Herbivore: bank vole, wood (long-tailed field) mouse, field vole, common vole, meadow vole, pine vole, rice rat, hispid cotton rat Omnivore: southern flying squirrel, house mouse, white-footed mouse, deer mouse, eastern harvest mouse, Norway rat, meadow jumping mouse
Strengths	Good source of information for a small mammal subgroup of the proposed system
Weaknesses	Species selection criteria based only on data availability for each given species on a site specific basis. Nationwide applicability of representative species requires further investigation.
Surrogate Selection Criteria	Based on data availability from studies where chemical concentrations in co-located small mammal and soil samples were determined

Agency	USDOE
Technical Document	Methods and tools for estimation of the exposure of terrestrial wildlife to contaminants
Date	October 1997
Application	exposure estimates
Approach	The report provides general methods for estimating exposure of terrestrial wildlife to contaminants of concern. Life history parameters (including distribution, body size and weight, diet, metabolism, habitat requirements, and food/water/soil ingestion rates) are provided for selected mammalian and avian species.
Trophic Classes	Mammals: little brown bat, Great Basin pocket mouse, pine vole, black-tailed jackrabbit, mule deer, coyote, kit fox, weasels Birds: green heron, burrowing owl, Cooper's hawk, western meadowlark, swallows
Strengths	Adequate toxicological data available for representative species selected
Weaknesses	Representative species are only selected for mammals and birds
Surrogate Selection Criteria	Species are potential receptors at USDOE facilities Species are chosen to avoid repetition with species selected for other exposure estimation approaches

Agency	Canadian Wildlife Service
Technical Document	Wildlife Contaminant Exposure Model
Date	1999
Application	wildlife risk assessments
Approach	WCEM was developed as a tool to improve the quality of wildlife risk assessments. This approach can be applied to both screening level and more detailed risk characterizations and allows for consistent and efficient estimates of exposure.
Trophic Levels	Mammals: caribou, white-tailed deer, deer mouse, eastern cottontail, little brown bat, masked shrew, short-tailed shrew, raccoon, river otter, meadow vole, mink, muskrat, red fox, wolf, moose, harbor seal, prarie vole Birds: American Kestrel, bald eagle, bay-breasted warbler, belted kingfisher, Canada goose, great blue heron, great horned owl, American woodcock, herring gull, mallard duck, marsh wren, northern bobshite, red-winged blackbird, American robin, ruffed grouse, red-tailed hawk, Savannah sparrow, scaup species (lesser/greater), tree swallow, yellow warbler, osprey, common loon, spatted sandpiper, black scoter Reptiles: eastern box turtle, racer, northern water snake, painted turtle, snapping turtle Amphibians: eastern newt, greenfrog, bullfrog
Strengths	Adequate toxicological data available for representative species selected Expands the list of 32 representative species from USEPA's *Wildlife Exposure Factors Handbook*
Weaknesses	Modeling tool is highly site-specific and requires the development of contaminant and wildlife profiles by the user
Surrogate Selection Criteria	Species selected with emphasis on data suitable for the Canadian environment

Agency	Texas Natural Resource Conservation Commission
Technical Document	Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas
Date	August 2000
Application	screening-level risk assessments
Approach	Communities, feeding guilds, and representative species that could potentially be exposed at a given site are identified as part of the screening-level ecological risk assessment. The Commission adapted the surrogate species list presented in *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities: Volume One* to be representative of specific ecological receptors of concern in Texas.
Trophic Levels	Aquatic: algae/aquatic vegetation, water invertebrates, herbivorous/planktivorous fish, omnivorous fish, omnivorous crustaceans, carnivorous fish Sediment: benthic invertebrates Soil: terrestrial plants, terrestrial invertebrates Upper Trophic Level Wildlife: herbivorous mammals, herbivorous birds, omnivorous mammals, omnivorous birds, omnivorous amphibians/reptiles, insectivorous reptiles, carnivorous mammals, carnivorous birds, insectivorous/carnivorous shore birds, and carnivorous reptiles/amphibians
Strengths	Habitat-specific receptors provide more meaningful information about contaminant problems at a given site
Weaknesses	Specificity of the receptors selected limits the ability for the ranking system to be consistently interpreted on a national scale
Surrogate Selection Criteria	Identical to those listed in USEPA (1999) with particular focus on the species of concern in Texas ecosystems

Agency	USFWS
Technical Document	Pesticide Bulletin for T&E Species and Migratory Birds in USFWS Region 2 - DRAFT
Date	July 2001
Application	protection of USFWS trust resources from pesticide application
Approach	The bulletin contains information on protecting T&E species and migratory birds from adverse effects associated with pesticide applications. Protection measures for applications are determined by examining the toxicity class of the pesticide and the ecotox class of the receptor of concern
Trophic Levels	Predatory Mammal Small Mammal Gallinaceous Avian Large Avian Small Avian Waterfowl Avian Reptile Amphibian Cold Water Fish Warm Water Fish Aquatic Arthropod Terrestrial Arthropod Bee pollinator Fresh water Mollusk Plant
Strengths	Approach was designed to be representative of USFWS trust resources
Weaknesses	Additional ecotox groups would need to be added for application on a national scale Surrogate species should be identified for each ecotox group
Surrogate Selection Criteria	Based on their similarity of toxicological responses of species to pesticides

APPENDIX C - PHYLOGENIC INFORMATION FOR SURROGATE SPECIES IDENTIFIED IN PROPOSED ECOLOGICAL GROUPING SYSTEMS

Appendix C – Phylogenetic information for each surrogate identified for the basic and detailed functional grouping systems.

Surrogate Species (common name)	**Phylum**	**Class**	**Order**	**Family**	**Genus**	**Species**
rainbow trout	Chordata	Acinopterygii	Salmoniformes	Salmonidae	*Oncorhynchus*	*mykiss*
bluegill sunfish	Chordata	Acinopterygii	Perciformes	Centrarchidae	*Lepomis*	*macrochirus*
fathead minnow	Chordata	Actinopterygii	Cypriniformes	Cyprinidae	*Pimephales*	*promelas*
water flea	Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*	*magna*
zebra mussel	Mollusca	Bivalvia	Veneroida	Dreissenidae	*Dreissena*	*polymorpha*
duckweed	Enbryophyta	Liliopsida	n/a	Araceae	*Lemna*	*gibba*
freshwater diatom	Bacillariophyta	Bacillariophyceae	Naviculales	Naviculaceae	*Navicula*	*pelliculosa*
mummichog	Chordata	Actinopterygii	Cyprinodontiformes	Fundulidae	*Fundulus*	*heteroclitus*
sheepshead minnow	Chordata	Actinopterygii	Cyprinodontiformes	Cyprinodontidae	*Cyprinodon*	*variegatus*
mysid shrimp	Arthropoda	Malacostraca	Mysida	Mysidae	*Mysidopsis (Americamysis)*	*bahia*
marine copepod	Arthropoda	Maxillopoda	Calanoida	Acartiidae	*Acartia*	*tonsa*
eastern oyster	Mollusca	Bivalvia	Ostreoida	Ostreidae	*Crassostrea*	*virginica*
eelgrass	Enbryophyta	Liliopsida	n/a	Zosteraceae	*Zostera*	*marina*
marine diatom	Bacillariophyta	Coscinodiscophyceae	n/a	Skeletonemataceae	*Skeletonema*	*costatum*
freshwater midge	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	*tentans*
freshwater amphipod	Arthropoda	Insecta	Hymenoptera	Formicidae	*Hyalella*	*azteca*

Surrogate Species (common name)	Phylum	Class	Order	Family	Genus	Species
freshwater amphipod	Arthropoda	Insecta	Hymenoptera	Formicidae	*Hyalella*	*riparius*
freshwater oligochaete	Annelida	Oligochaeta*	Lumbriculida	Lumbriculidae	*Lumbriculus*	*variegatus*
marine amphipod	n/a	n/a	n/a	n/a	*Ampelisca*	*abdita*
estuarine amphipod	n/a	n/a	n/a	n/a	*Leptocheirus*	*variegatus*
marine polychaete	Annelida	Polychaeta	Phyllodocida	Neredidae	*Neanthes*	*arenaceodentata*
corn	Embryophyta	Liliopsida	Poales	Poaceae	*Zea*	*mays*
soybean	Embryophyta	Rosidae*	Fabales	Fabaceae	*Glycine*	*max*
earthworm	Annelida	Oligochaeta*	Haplotaxida	Lumbricidae	*Lumbricus*	*terrestris*
common brandling worm	Annelida	Oligochaeta	Haplotaxida	Lumbricidae	*Eisenia*	*foetida*
Norway rat	Chordata	Mammalia	Rodentia	Muridae	*Rattus*	*norvegicus*
raccoon	Chordata	Mammalia	Carnivora	Procyonidae	*Procyon*	*lotor*
mink	Chordata	Mammalia	Carnivora	Mustelidae	*Mustela*	*vison*
red-tailed hawk	Chordata	Aves	Falconiformes	Accipitridae	*Buteo*	*jamaicensis*
northern bobwhite	Chordata	Aves	Galliformes	Phasianidae	*Colinus*	*virginianus*
mallard duck	Chordata	Aves	Anseriformes	Anatidae	*Anas*	*platyrhynchos*
Canada goose	Chordata	Aves	Anseriformes	Anatidae	*Branta*	*canadensis*
water snake	Chordata	Reptilia	Squamata	Colubridae	*Nerodia*	*sipedon*
bullfrog	Chordata	Amphibia	Anura	Ranidae	*Rana*	*catesbeiana*

APPENDIX D - REVIEW OF CHEMICAL RANKING AND SCORING SYSTEMS DEVELOPED AFTER 1995

Appendix D - Summary of Chemical Ranking and Scoring Systems Developed after 1995

Agency/Developer	Michigan Department of Environmental Quality
Technical Document	Chemical Scoring and Ranking Assessment Model (SCRAM)
Date	2002
Application	chemical ranking and scoring
Approach	The Chemical Scoring and Ranking Assessment Model (SCRAM) was developed to score and rank the relative hazards of chemicals in the Great Lakes region. SCRAM provides a prioritization tool for risk assessors and managers to help evaluate the concern posed by over 140 chemicals to human and ecological health. Media-specific information used for persistence and toxicity data include many mechanisms and endpoints.
Ranking/Prioritizing Criteria	persistence bioaccumulation toxicity to humans and ecosystem components uncertainty
Strengths	Algorithms are clear and explicit, easily modified, and based on sound science. Uncertainty is explicitly considered and allows the used to see the chemical and uncertainty scores separately and as a composite score. Database is based on current information (2000).
Weaknesses	The system uses a database that is not currently in the public domain, so modification of the database requires special permission.

Agency/Developer	U.S. EPA
Technical Document	Waste Minimization Prioritization Tool
Date	1997
Application	chemical ranking and scoring
Approach	The Waste Minimization Prioritization Tool (WMPT) provides relative rankings of chemicals that can be considered in making waste management and waste minimization decisions. The WMPT generates an overal chemical score incorporating toxicity and potential for exposure (persistence and bioaccumulation) for both humans and ecological systems. The WMPT also icorporates a *subfactor mass*, which is based on the amount of a chemical generated and its potential for release into the environment (i.e., it considers loading but not transport). The latter information could be regional or national in scale. The WMPT retains the numerical score so that arbitrary classifications are more transparent.
Ranking/Prioritizing Criteria	persistence bioaccumulation toxicity
Strengths	The incorporation of the subfactor mass allows chemical loading to be explicitly considered. The algorithms are clear and simple.
Weaknesses	Modification is necessary to use the subfactor mass for DOI applications. Does not consider uncertainty. Database does not include much data from the past decade. Persistence and toxicity calculations are very simple, requiring many assumptions that are not explicitly stated.

Agency/Developer	U.S. EPA
Technical Document	Use Cluster Scoring System
Date	January 2000
Application	chemical screening and prioritization
Approach	U.S. EPA developed the use cluster scoring system (UCSS) to prioritize chemicals and chemical groups, or clusters, for risk reduction purposes targeting specific industries and chemical users. The system is a computer program that contains hazard and exposure data compiled from various sources and databases for chemicals and chemical clusters. A use cluster is a set of chemicals that are used (and can be substituted) for a particular use. Scoring of individual chemicals within clusters allows the user to rank high, medium, and low concern compounds and subsequently substitute lower risk chemicals for risk reduction initiatives. Scores are assigned for 6 components that are combined to produce an overall UCSS score for individual compounds. The system currently contains data for 400 different use clusters and approximately 5,000 individual chemicals.
Ranking/Prioritizing Criteria	potential human exposure potential ecological exposure potential human hazard potential ecological hazard U.S. EPA interest for each cluster chemical pollution prevention potential
Strengths	The UCSS database is established and contains toxicity and exposure information for hazard assessment. The system is not complex and rapidly assigns chemicals or chemical groupings into qualitative risk categories of high, medium and low. The chemical grouping approach is similar to the proposed chemical classification/surrogate system for CAP R&P and could serve as a template or allow determination of the relative representativeness of surrogates based on hazard potential.
Weaknesses	While in many cases, individual compounds in a use cluster will have similar physiochemical properties (as is the goal with the chemical classes in the proposed CAP R&P approach), the primary focus of the grouping arrangements is the particular functions and applications of the compound.

Agency/Developer	University of Oslow and the Center for International Studies at MIT
Technical Document	A Hazard Ranking of Organic Contaminants in Refinery Effluents
Date	1997
Application	hazard ranking of constituents in petroleum effluents based on physiochemical properties
Approach	A benchmark ranking model is used to rank organic compounds found in petroleum refinery effluents. The hazard level for this model is a function of the product of physiochemical variables for individual compounds. The final score for each chemical is obtained by normalizing the hazard level calculation.
Ranking/Prioritizing Criteria	toxicity (LC_{50}) octanol-water ratio (K_{ow}) soil adsorption (K_{oc}) solubility (S) biodegradation ($T_{1/2}$)
Strengths	The benchmark ranking model approach considers toxicity, bioaccumulation, and degradation of individual compounds.
Weaknesses	This system adequately ranks and prioritizes the environmental hazards associated with various chemicals at a site; however, it will not allow for comparison of risk between sites without modification of the existing model. Model does not address data gaps (e.g., the only species for which toxicity data was available for all compounds considered in the trial run was *Daphnia magna*).

Agency/Developer	Center for Clean Products and Clean Technologies, University of Tennessee
Technical Document	A screening method for ranking and scoring chemicals by potential human health and environmental impacts
Date	1997
Application	chemical ranking and priority setting
Approach	The chemical ranking and scoring method, Chemical Hazard Evaluation for Management Strategies (CHEMS-1) was developed as a screening tool for the evaluation of chemical hazards to human health and the environment. The system includes measures of human health and environmental toxicity data, release amounts, and physiochemical data. Several tasks were discussed including selecting estimation methods for data gaps, establishing rules to assign scores for toxicity and exposure potential, and developing a weighted algorithm to combine individual scores into a rank for each chemical
Ranking/Prioritizing Criteria	Human Health Effects • acute (oral and inhalation) • chronic (carcinogenicity, mutagenicity, developmental and reproductive effects, neurotoxicity) Environmental Effects • terrestrial acute • aquatic acute and chronic Exposure potential • persistence (BOD and hydrolysis half-life) • bioaccumulation • amount released
Strengths	The ranking and scoring approach allows for interpretation of chemical release data with information on the environmental persistence and bioaccumulation potential of individual compounds.
Weaknesses	CHEMS-1 is a first tier approach that relies on fish toxicity data only for evaluation of environmental effects. Proposed future work includes expansion of the system to include toxicity data for various trophic levels and expanding the scoring capabilities for exposure assessment to include fate and transport modeling; however, at this time, the utility of this system when assessing diverse environmental hazards is limited. Data gaps are likely as the system attempts to incorporate physiochemical data for all TRI compounds in the algorithm.