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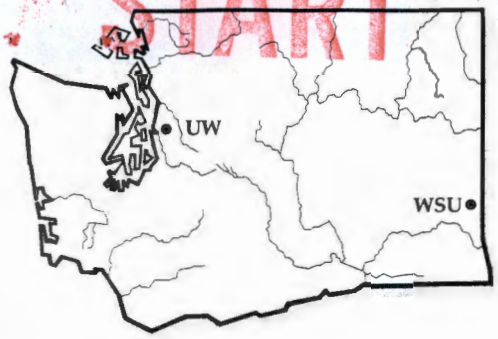

State of Washington Water Research Center

Address correspondence to:
State of Washington
Water Research Center
Washington State University
Pullman, WA 99164-3002
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8, May 1996

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MAY - 9 1996
DOE-RL/DCC

Robert K. Stewart
U.S. Department of Energy
Richland Operations Office
3350 George Washington Way Rm 2D41
Richland, Washington

RE: Submission of Technical Peer Review comment compilation for the draft, *Species for the Screening Assessment*, Contract DE-AC06-96RL-13395.

Dear Bob:

43304

The compilation document, "Compiled Technical Peer Review Comments for the draft, *Species for the Screening Assessment*" was electronically transferred yesterday to Amoret Bunn and yourself via e-mail. Enclosed is a hardcopy of that document as well as two attachments provided by reviewers. Eight technical peer reviewers contributed to this compilation:

J.R. Creighton
E. Faustman
K. Goodman
K. Higley
M.H. O'Brien
G. Suter II
F.R. Taub
F.W. Whicker

Dr. Funk and I are pleased with the cooperation of the peer reviewers and how the review process is progressing. We look forward to our continuing involvement with the CRCLA project.

Sincerely,

Rene Forman Derewetzky

Rene Forman Derewetzky
Research Associate

MAY 1996
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cc Amoret Bunn
encl.

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Compiled Technical Peer Review Comments for

Species for the Screening Assessment

STATE OF WASHINGTON WATER RESEARCH CENTER
Washington State University
Pullman, Washington 99164-3002

for the

COLUMBIA RIVER COMPREHENSIVE IMPACT ASSESSMENT PROJECT[2]

MAY 6, 1996

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[1]Becker, J.M., C.A. Brandt, D.D. Dauble, A.D. Maughan, T.K. O'Neil. March 1996. *Species for the Screening Assessment*. DOE/RL-96-16-b, Revision 0, UC-630 Draft.

[2]Prepared for the U.S. Department of Energy under Contract DE-AC06-96RL13395

Reviewer number	Page, Section, Paragraph	Comment	Resolution
01	General	Too much valuable information about species' response to individual and multiple contaminants is being lost by confining this process to scores, assumptions, and models. Later, too much information will be lost by looking at laboratory information only (i.e., LC_{50}, and Lowest Adverse Effect Level, LOAEL, as noted on p. 4.1). The field study literature should be searched for all Tier 1 species, and that field data should be incorporated in the final description of the potential for adverse impacts on species in the Hanford Reach. Field studies necessarily observe cumulative effects, ambient levels of contaminants, health damage endpoints that have not been examined in laboratory tests, etc. These effects are reality that cannot be ignored by opting for a risk assessment process that considers only one hazardous substance at a time. In laboratory experiments, substances are administered in the never-never world of pristine organisms, unexposed to multiple contaminants and stresses. Field information, when available, must be considered in evaluating the potential impacts of Hanford Reach contamination on plants and animals. Researchers for instance, have found testicular atrophy, low testosterone, and high follicle stimulating hormone and luteinizing hormone levels in mule deer resident at several locations along the Columbia River on the Hanford site (Tiller, Brett, LL Cadwell, and GE Dagle. 1995 Patterns of testicular atrophy in a wild mule deer population. *The Wildlife Society Second Annual Conference Abstracts*. Portland, OR, 12-17 September. Lead author at: Pacific Northwest Laboratory, Richland, WA 99352). These are classical symptoms of endocrine disruption, and yet nearly no laboratory evidence exists on endocrine disruption, compounds responsible for endocrine disruption, etc. The risk assessment process proposed would ignore this incredibly important information, because it is not "toxicological benchmark" information gathered in a laboratory setting that controls doses.	

01	General	Likewise, several Washington researchers recently attempted validation of supposedly conservative exposure assumptions of bioconcentration, dietary intake, home range, and toxicity endpoints (Hummell, Roy, LW Brewer, and M Klope. 1995. Evaluation of an ecological risk-based screening model to protect raptor populations at a National Priority List Site. *The Wildlife Society Second Annual Conference Abstracts*. Portland, OR, 12-17 September 1995). Lead author at: EA Engineering, Science, and Technology; Redmond, WA 98052). As the researchers note, supposedly conservative models are rarely validated "since receptors are rarely present in sufficient numbers on a site to allow field studies." They studied an unusually large density of nesting northern harriers, which were feeding entirely on Townsend's voles. They found that the conservative models weren't conservative: "Based on soil and water concentrations, ecological risk-based screening models were developed to evaluate the effects chemicals may exert on the microtine and hawk populations. These models did not indicate significant risks; <u>however, chemical concentrations in small mammal tissues were greater than predicted, and organ weights varied when compared to reference populations. Northern harrier nestlings had blood levels of contaminants that suggested effects. This study suggests risk-based screening models may not be as conservative as assumed</u>" [emphasis added.] Recommendation: Do searches of published and agency literature on each Tier I species AND Tier II species to see whether valuable field information exists indicating particular sensitivities, cumulative impacts, or other concerns that will not be picked up by the highly restricted process proposed in this document. their presentation	

02	General	This document follows the Hanford Site Risk Assessment Methodology, and in so doing, treats each species as a representative of a trophic level, including potential bioaccumulation and biomagnification. This allows the list of all possible species to be reduced to a more manageable list of organisms typical of a trophic level or exposure scenario. Although this thinking represents the current risk assessment methodology, it fails to take into account the interactions among organisms in the same feeding guild, and the competition among them. Thus the risk assessment will only be able to predict reductions in life span and reproduction, and will not be able to predict increased populations that are likely to occur if more sensitive competitor or predator species are negatively impacted. In evaluating effects of Chernobyl, it has been reported that mammals and fishes are more abundant in the highly radioactive 10 km zone (where human activity has been excluded), but that genetic properties are more diverse. (Szpir, M. 1996. American Scientist, 84:227-228.) Risk assessment is not at this level of sophistication.	
02	General	The names in the text are sometimes more general than those in the Appendix, which makes it difficult to locate some birds in the tables, e.g., Coot (text) is American Coot (p. A.2), Scaup (text) is Greater or Lesser Scaup, Goldeneye (text) is Common Goldeneye). It would be helpful to have text and appendix tables agree.	
05	General	Greater care should be taken in providing non-technical explanations for terms not in common usage.	
08	General	The reviewers were concerned about the comprehensiveness of the report. For example, please see comments for pg. 3.1. The corridor defined is too narrow to adequately address ecological impact.	
08	General	After reviewing the document both of the reviewers were concerned about the qualitative versus semi-quantitative nature of the scoring process used. By arriving at "grand average exposure scores" an air of quantitative sophistication is given that should perhaps be no more then a semi qualitative value such as high, very high, moderate or minimal. At a minimum this should be discussed and acknowledged in the report. Single values also convey a great deal of unwarranted certainty. Ranges are always preferable.	
08	General	The reviewers noted a lack of adequate consideration of life cycle information. See specific comments throughout section 3.	

03	General	The term "receptor species" is used throughout the report. Since it's not a normal term for the non-technical person, I was watching carefully to see how it is defined. Apparently its real definition is that these are the species you agreed to study, and you could just have easily used the term "selected species." If that's correct, this needs to be clearer. I think what's needed is a paragraph explaining why its neither practical nor necessary to assess risk to all 368 species, then spend a little more time defining "receptor species." It's a term non-technical people will stumble over, so you need to help them as much as possible.	
04	General	The general scheme for developing a list of receptor species to be examined in more detail is rather complex, and I think, quite qualitative. This means subjective judgments have to be made, and in many cases, I'm not sure the ratings, or even the basic rating system, can be rigorously defended. I assume that the reason for developing such a system is that good hard data on specific contaminant levels are lacking, as well as good toxicological data on many of the species. My suggestion is to explain the real rationale for the system used. I do think the criteria used in the ratings are reasonable ones, despite their qualitative nature.	
04	General	In several places in the text, it is noted that the CRCIA Team added new species, based apparently on other criteria. However, it was not clear to me what these other criteria were. Why were they not built into the basic rating system?	
04	General	The number of species that ended up on the Tier II list seems far too numerous to assess in detail. It would be my suggestion to try to reduce the list to perhaps a dozen or so "critical" species that should reflect the health of the entire riverine and riparian ecosystems. I think it will be critical for a credible assessment to choose species for which a body of monitoring and toxicological data exist. I believe it would be much better to do a very good job on a small number of representative species than to do a so-so job on a large number of species.	

02	General	This document does not seem to include Friant, S.L. and C.A. Brandt . 1994. Ecological Risk Assessment Case Study: Effects of Radionuclides in the Columbia River System--a Historical Assessment. in A Review of Ecological Assessment Case Studies from a Risk Assessment Perspective, Vol. II. EPA/630/R-94/003, Section 3, 40 pages. [included as an attached document] That document includes calculated doses from a program CRITR2. "Plant-eating ducks had the maximum dose rate, followed by plants, crayfish, fish, and fish-eating ducks. The dose rates to the plant-eating duck and crayfish exceeded the 1 rad/d level." Reference to this document should be made. Should the concentrations and subsequent risk assessment by CRCIA differ, the differences in assumptions or concentrations should be explained. It would be useful to distinguish which ducks are fish eaters and which plant eaters. The current report only distinguished them as "dabblers" and "divers." Given that earlier report, plant-eating ducks should be represented by a number of different species.	
04	General	The species that appear on the lists seem reasonable, based on my knowledge of this system. One surprise, however, was that smallmouth bass did not survive the cut to Tier II. With important gamefish that feed very little in the system, and two species of sucker and carp on the list, this seems surprising. I would think smallmouth to be important game fish, higher predators, that live continuously in the system.	
04	General	In addition to a species focus for the ecological risk assessment, has any thought been given to developing broader indicators of ecosystem health? For example, it would seem important to assess water quality parameters, primary and secondary productivity, and the like.	
08	p. v, para. 1	The term "ecological habitat" does not clearly define the broad range of benefits, goods, and services provided by natural and semi-natural systems. Why not use ecosystems?	

01	p. vi, para. 3	The second sentence should read, "The comprehensive assessment [as opposed to the screening assessment of the current phase] will ESTIMATE the extent of any resulting contamination and determine SOME OF the current AND POTENTIAL FUTURE human and ecological RISKS from the Columbia River attributable to OR CONTRIBUTED TO BY past and present activities at the Hanford Site." Thus, the long-term objective should be stated in terms that accurately reflect what a COMPREHENSIVE assessment is. There is constant confusion in this process about what is comprehensive, versus what is a mere screening assessment. There is confusion over whether a comprehensive assessment is intended at ANY time in the future.	
01	p. vi, para. 3	Eliminate the term "significant" in "Ecological resources in the study area will be evaluated to determine if current contaminant conditions pose significant hazards to biological communities." "Significant" is a political term. It has no reproducible referent. All known or suspected hazards should be described; others can determine whether they think these hazards are "significant."	
03	p. vii, "Scope", para.1	After first sentence insert: A "screening" risk assessment is a risk assessment with a limited scope. The initial phase of CRCIA is a screening assessment or risk because it is restricted to:	
04	p. vii, "Scope", Media	Groundwater seems to be considered here, yet it was not in the "Human scenarios--". How come?	
08	p. ix, 1st sentence	This sentence should probably be rewritten as follows: "Because of the importance of the Columbia River as a cultural and natural resource there is intense public and tribal interest in assessing any residual Hanford site contamination from past nuclear production operations."	
03	p. ix, para. 2	This paragraph would be easier to understand with some simple graphic like the one attached. [see attached figure]	
01	p. ix, para. 3	Eliminate the term "significant." See note for page vi. One of the reasons that there is next to no ecological meaning to the use of the word "significant" is that we have so little understanding of cumulative impacts. Given that the entire proposed risk assessment process is being conducted substance by substance, what basis AT ALL is there for declaring a given impact insignificant, even if there WERE a way to define that meaningfully? Instead, the sentence should read, "...to ESTIMATE THE VARIOUS THREATS CONTAMINANTS FROM THE COLUMBIA RIVER POSE TO SELECTED RECEPTOR SPECIES...."	

01	p. ix, para. 4	It is not true that the species were scored on "5) sensitivity to contaminants." Species groups were scored on sensitivity to immediate mortality from radiation. A grouping such as "birds/mammals" and "amphibians/fish/reptiles" were scored, either 1, 2, 3, or 4. The phrase should say, "5) sensitivity as a group to rapid mortality from radiation." This is an important point, because, for instance, fish receive a score of 3 for sensitivity to radiation, but their fish eggs are HIGHLY sensitive to chromium. Moreover, individual species will be sensitive to particular contaminants, and that is not included at all in the scoring.	

01	p. x, Table S.1	The choice of final Tier II species among tentative Tier II species should pay particular attention to (a) the sensitivity of the tentative Tier II species to contamination; (b) whether the continued existence of the tentative Tier II species is threatened; and (c) whether the species is locally or regionally endemic.. Those species that are more sensitive and/or more threatened as a species should take precedence among species of "similar life style." Selection of the bullfrog to represent Amphibians, for instance, may amount to selection of an invader, one of the "armor-plated species." The bullfrog is displacing native species in some wetlands habitats; seems to be fairly robust to urban contaminants, etc. While many amphibians are declining, apparently in response to a combination of such stresses as habitat loss, UV exposure through the thinned ozone layer, introduced species, and contaminants, the bullfrog is surviving. Meanwhile, Woodhouse's toad, listed as a monitor species by Washington State (see §2.2), was not included as a Tier II species because its life style was similar to the bullfrog (Table S.1). Its life style is enough different that the bullfrog is an invader species and Woodhouse's toad is a species to be watched for declining existence. We should be looking at who is at greatest risk from Columbia River contaminants, NOT who is the most robust. Bull trout and rainbow trout, for instance, were eliminated, apparently because their life styles were similar to steelhead, which were selected. Bull trout are, however, in greater trouble as a species, and it would seem that attention to the effects of contaminants on an endangered (small "e") species is critical. Likewise, mink are highly sensitive to organochlorine contaminants, such as PCBs. Mink were not included in even the tentative Tier II species.	
01	p. x, table S.1	Recommendation: The scientific literature on the Tier I species should be examined for indication of species for which contaminant sensitivity or impacts has been found. Likewise, endemics or species of concern should be noted. That should carry weight in the final scoring.	

01	p. x, table S.1,	The table indicates that the barn owl was not selected as a final Tier II species because it has a "low grand average exposure score," but its grand average exposure score was the same as the American kestrel, which WAS selected (see C.2). Please explain.	
08	p. x, table S.1	The group marked on this page (Periphyton, Caddisfly, Crayfish, Mayfly, Midge, Clams/mussels/snails) have many species in their taxon. How will that be handled? Each species varies in their sensitivity.	
01	p. xi, table S.1	"Fern" and "fungi" are not specific. Presumably different ferns and fungi exhibit different responses to particular contaminants. Will evidence from particularly sensitive or exposed species be included in the assessment?	
01	p. xi, table S.1	No macrophytes were chosen as a Final Tier II species. They are probably used quite differently by wildlife than are emergent vegetation species. It would seem that macrophytes should be represented.	
01	p. xiii; see also p. 3.10, sec. 3.2.2	Shouldn't "biomagnifying" mean "occurring in higher concentrations...", rather than "having a tendency to occur in higher concentrations..."?	
05	p. xiii	The definition of "biomagnification" is unclear; suggested substitution: biomagnification is a synonym for biological accumulation; biological magnification is the increase in concentration of some material in organisms compared with its concentration in the environment.	
08	p. xiii	Glossary definition for Biota: plants and animals, could read Biota: plants, animals, and microorganisms.	
05	p. xiii	The definition of "biotic", which is acceptable, is different than that which appears in the previously reviewed PNNL document "Human scenarios for the screening assessment". The two sets of authors should compare notes, and perhaps definitions, to avoid confusion on the part of the audience.	
05	p. xiii	The definition of "concentration" is unclear; suggested substitution: amount of a substance in an amount of another substance (e.g., milligrams of salt per liter of water).	
07	p. xiii	Definitions for "demersal" and "CPOM" are missing from the glossary	
04	p. xiii, last line	This seems like a strange definition for "ecology".	
08	p. xiii	Under the term "exposure", there needs to be a description for "dose" in the glossary.	
05	p. xiv	The definition of "exposure" is different than that which appears in the previously reviewed PNNL document "Human scenarios for the screening assessment". The two sets of authors should compare notes, and perhaps definitions, to avoid confusion on the part of the audience.	
08	p. xiv	Under the term "foraging guild", the term "similar composition" is too vague.	

01	p. xiv; see also p. 3.10, sec. 3.2.2	"Non-biomagnifying" does not mean "having a tendency to decrease in concentration at higher levels in the food chain." The definition should read "having little tendency to increase in concentration at higher levels in the food chain."	
05	p. xiv	The term "non-biomagnifying" encompasses those materials which remain at a constant concentration in the food chain, but the definition excludes this possibility.	
08	p. xiv	Under the term "receptor species", this term implies that the species is being affected by compound rather than selected for study. Is there another term? Selected species versus Receptor species? These two concepts should probably be separated.	
01	p. xv	"Risk assessment" does NOT mean "estimation of...harm...occurring from exposure to a particular substance or activity." That is single-substance, segmented, pretend-pristine-organism risk assessment. It does not address reality. That is how risk assessment is being proposed in this document, but that is not a sufficient definition for risk assessment. Risk assessment is a potentially much more comprehensive assessment than your definition implies. Comprehensive risk assessment means "the estimation of the severity and likelihood of harm to human health and/or the environment, occurring as a result of exposure to toxic or otherwise hazardous substances and other harsh conditions (e.g., habitat loss, low or high temperature, poor nutrition), interacting with genetic and other individual susceptibilities. If the risk of a single factor is calculated in isolation from other factors, the risk assessment is thereby limited." The definition should read, "the estimation of the severity and likelihood of harm to human health and/or the environment from hazardous substances, activities, and conditions."	
07	p. xv	Definitions and distinctions between "riverine" and "riparian" as used in this document should be included in the glossary	
08	p. xv	Under the terms "seeps" and "springs", the descriptions are so similar that they (the descriptions) sound like they are describing the same thing. Can any distinguishing differences be given?	
05	p. xv	"sensitivity", although clearly defined, is different than that which appears in the previously reviewed PNNL document "Human scenarios for the screening assessment". The two sets of authors should compare notes, and perhaps definitions, to avoid confusion on the part of the audience.	
01	p. xv	"medium in which contaminants are deposited and from which there is little or no SHORT-TERM contaminant migration."	

01	p. xv	The definition should read, "a measure of LIKELY VARIATION in model parameters or dose estimates."	
05	secs. 1, 2, and 3	Several of the figures were difficult to read because background shading obscured the text. Consider revising the illustrations to increase legibility.	
03	p. 1.1	For the non-technical person, the real story here is how you selected the species, not the species themselves. Non-technical people have no basis for knowing whether the species are correct, all they can rely on is their assessment of the process you followed. The key questions are: Who did you consult with, and are they credible people? Did it include all the people with concerns about species? Were the criteria you used agreed upon by all the participants? Were there disagreements with the outcome, and how did they get resolved? It appears that this is a consensus product. If so, that's the key message that needs to come through. I suggest you give an overview of the process in the introduction, then provide a more detailed overview at the beginning of each chapter. You really want to make the process stand out if this document is intended for the non-technical reader. You might even want to put all process descriptions is boxes, with shaded backgrounds, so the non-technical reader could scan from box to box and track the process.	
06	p. 1.1	The logic of the screening assessment is unclear. As I indicated in my previous comments, a screening assessment should screen out chemicals and receptors that are clearly not hazardous so that subsequent data collection and assessment can focus on a limited set of hazards. However, the authors indicated that a screening assessment has a limited scope, limited number of species, only direct effects, and some level of hazard other than average. These restrictions suggest that the screening assessment is characterized by leaving things out, a priori. Screening assessments should include as much as possible and things should be left out of subsequent assessments on the basis of screening results. Things can be left out a priori only if that decision can be shown to be conservative.	
04	p. 1.1, line 4	"--contaminants presently within the--"? Define "significant"	

01	p. 1.1, para. 2	What does it mean for a species to be "important to the CRCIA Team"? As noted in a 26 May 1995 memo from James R. Wilkinson (Special Sciences and Resources Program Manager, Confederated Tribes of the Umatilla Indian Reservation) to Randy Brich (U.S. DOE) and David Maughn (PNL), "Although some species are used more commonly than others as food sources or for other cultural purposes, none are considered inherently more important or valuable than any others." Why is "a high potential for exposure" considered, but "sensitivity" to anything other than lethal doses of radiation is not?	
05	p. 1.1, para. 2, sent. 2	The term "exposure" as used in the sentence appears to be at odds with your definition. Do you mean high potential for contact with contaminants?	
07	p. 1.1, para. 3, sent. 1	Please discuss how the word "harm" is defined as used in this sentence. What is the minimum effect that is considered harmful?	
01	p.1.1, para. 3	It is entirely inappropriate to consider indirect effects only if direct effects lower in the food chain have been found to be "significant." The whole point of concern about biomagnification is that sometimes there AREN'T obvious direct effects lower in the food chain.	
01	p. 1.1, para. 3	It continues to make no sense to consider only past and present contaminant fluxes, and omit consideration of likely future contaminant fluxes, in order to "understand what measures are needed to effectively mitigate future impacts" (James Wilkinson memo, see note on p. 1.1, 2nd paragraph).	
04	p. 1.1, para. 3	What "direct effects" will be evaluated?	
08	p. 1.1, para. 3	Finally, acknowledgment that these results/findings will be used to develop subsequent more comprehensive risk assessment!	

03	p. 1.2, fig. 1.1, and p.1.3, fig. 1.2	These pages seem to appear magically at this point, without explanation. They appear to belong as part of Section 2.0, and should be inserted appropriately in that section. Is there agreement or acceptance that these figures accurately portray the food web? If these figures are accepted as accurate by all the scientists involved in the project, tell us that. Don't forget that the non-technical public is sufficiently suspect of DOE and its contractors that a simple assertion of fact almost guarantees skepticism. Finally, the non-technical person needs some help knowing how to read these figures. Spend a few sentences talking about the hierarchical nature of the riparian food web, and also what the arrows mean. Do bigger arrows imply stronger relationships? Also provide more explanation for the aquatic food web. What do the categories in the legend mean? Etc.? Etc.? If you're going to use the figures, make sure the non-technical person learns something from them.	
05	p. 1.2, fig. 1.1	Is the vole appropriately classified as an herbivore considering that, for some, their diet may be ~40% insects?	
05	P 1.2, fig. 1.1	The significance of the arrows in the food web should be explained in the figure heading.	
02	p. 1.3, fig. 1.2,	Nice figure, but a bit hard to read with these colors.	
05	p. 1.3, fig. 1.2	The significance of the arrows in the food web should be explained in the figure heading.	
08	p. 1.3, fig. 1.2	The colors used in this figure look great, but cannot be copied. Key to figure should also explain what a dash line is versus a solid line. Define CPOM.	
03	p. 2.1	This section is lacking a description of the process. I think your real message is: "Fortunately, for purposes of this study, the ecology of the aquatic and riparian systems of the Hanford Reach have been studied extensively over the past 50 years. As a result, we were able to identify existing species based on these studies, without conducting additional field research. In addition, there is a high level of agreement among all the interested agencies that we have accurately identified the existing species." This message isn't coming through now, and needs to be beefed up.	

03	p. 2.1, sec. 2	The non-technical person needs to be reminded what the "riparian community" is. As a minimum, the term needs to be defined. Ideally there would be a simple graphic showing where the riparian community is located alongside the river. Again, this assumes you're trying to make it so a non-technical person can read and understand these reports.	
02	p. 2.1, sec. 2, para. 1, line 11	Clarification on "These documents will not be reviewed in this report." Does "These documents" refer to all of the studies in this paragraph, or just the preceding reference? Are they not reviewed here because the data are included here--or at least the species present? Or, (see following comment) data from DOE are not being used, but lists from other organizations are being used?	
04	p. 2.1, sec. 2, para. 1	Why won't these important documents be reviewed? What might we be missing?	
08	p. 2.1, sec. 2, para. 1	First paragraph mentions relevant reports. The data on these reports is not presented in a useful manner. Several approaches are possible. Paragraphs summarizing key findings from these reports about the river could be included in the text or in the appendix.	
05	p. 2.1, sec. 2, para. 2	The first sentence reads "The Hanford Reach comprises the last unimpounded portion of the Columbia River in the United States above Bonneville Dam." Why is Bonneville Dam the marker and not McNary Dam?	
08	p. 2.1, sec. 2.1, para. 1	Why are the endangered ? species listed yet not specifically followed in the screening assessment?	
06	p. 2.1, sec. 2.1, para. 2	Myotis bats tend to feed over water, and a large proportion of their diet may be emergent aquatic insects. That route is not included in the diagrams. In some circumstances the same is true of swallows.	
08	p. 2.1, sec. 2.1, para. 2	Why are the endangered species bats not on the screening list? The same species list should be applied to all of the other endangered species that do not specifically appear on lists.	
08	p. 2.1, sec. 2.1, para. 2	Fourth paragraph includes a term, "monitor species," which should be defined either in the paragraph itself or in the glossary.	
01	p. 2.1, sec. 2.1 and sec. 2.2	Which of the species listed in these 2 sections have field data re: response to contaminants available?	
08	p. 2.2	Aquatic Communities - good seasonal data is given.	
06	p. 2.2, sec. 2.2	Phytoplankton, periphyton, and macrophytes are not taxonomic groups.	
03	p. 2.2, sec. 2.2	Same comment as above (reviewer 03). Don't assume people know what an "aquatic community" is. Is that like a swim club?	
05	p. 2.2, 1st complete paragraph	The statement is made that <u>all</u> amphibians in the area use the backwater areas to complete their life cycles. Is this statement verified by observation/ reference?	
04	p. 2.3, sec. 2.2, last line	Define "monitor species" in glossary.	

03	sec. 3.1 (entire)	For the non-technical person, this is by far the most important material in the whole report. This is the process, based upon which they will base their judgment as to whether this report is credible. Make the materials in para 1 stand out so that it's clear this is an overall summary of the process. I suggest rearranging para 1 as a list, numbered or bulleted, so each step stands out. Emphasize the interaction and involvement of the other agencies.	
05	p. 3.1, sec. 3	The explanations of the conceptual model are difficult to follow, particularly the explanation of summary of scores provided in section 3.2.11. It might be easier to understand if an equation were presented illustrating the weighting calculations, or if a diagram were presented.	
05	p. 3.1, 1st sentence	The term "exposure" as used in the sentence appears to be at odds with your definition. Do you mean high potential for contact with contaminants?	
08	p. 3.1, para. 2, 2nd sentence	This sentence state that only riparian and aquatic systems were included. This is too narrow and is not comprehensive. A wider corridor must be considered. See paper by Geist in Illahee 11 (2) 1995.	
05	p. 3.1, sec. 3.1, last sentence	What was the basis for adding the additional 88 species to the Tier 1 list?	
02	p. 3.1, sec. 3.1.1	Clarification ... were the non-DOE lists used to compile the list of species present to avoid the appearance of bias by using the DOE studies on Hanford listed on page 2.1? It seems strange to use everyone else's species lists, but not those of the agency (DOE) that has been responsible for studying Hanford.	
08	p. 3.1, sec. 3.1.1, para. 3, 2nd sentence	This sentence states that information on species distribution and habitat preference was used to exclude certain data. This decision has consequences and should be defended as a non-arbitrary decision by providing more information in this report.	
05	p. 3.1, sec. 3.1.1, para. 3	Why were species that primarily use upland areas excluded from the screening approach? Did the exclusion consider seasonal use of the area by the eliminated species?	
01	p. 3.2, fig. 3.1	Sensitivity to radiation is not listed in the criteria for listing (see p. 3.14).	
05	p. 3.2, fig. 3.1	The shading of the arrows makes the text difficult to read.	
08	p. 3.2, fig. 3.1	This page is a flow chart. At the top it is stated: Species in the study area (all species considered to be potential receptors). Comment: All species are potential receptors - you are selecting a subset of receptors to highlight for tracking. See earlier comments on "receptor species" versus "selected species."	

08	p. 3.2, fig. 3.1	Center of page on right lists seven criteria. Comment: Are these the criteria mentioned twice before? If so, there are seven listed this time and six listed in the table on top of page 3.4. What happened to significant cultural criteria on page 3.4?	
01	p. 3.3, table 3.1	The title (e.g., "Biologist") of each of the panel members who developed the criteria used to screen study area species should be listed.	
05	p. 3.4, sec. 3.1.2, bullet 4	The term "exposure" as used in the criteria appears to be at odds with your definition. Do you mean high potential for contact with contaminants?	
04	p. 3.4, sec. 3.1.2, bullet 5	Define "benchmarks" in glossary.	
08	p. 3.4, sec. 3.1.2, para.2, 2nd sentence	Referring to 88th percentile: Why was that level selected? Fourth paragraph;	
05	p 3.4, para. 2, 2nd to last sentence	What was the basis for adding the additional 88 species to the Tier 1 list?	
02	p. 3.4, sec. 3.1.2, para. 2	It might be clearer if it were stated first that all species receiving three of more "yes" responses were included, before explaining the use of the 88th percentile.	
02	p. 3.4, sec. 3.2	Using scoring of exposure and sensitivity seems to do the Risk Assessment as part of selecting the organisms.	
04	p. 3.4, sec. 3.2, para. 2	What is rationale for "largest body weight"?	
08	p. 3.4, sec. 3.2, para. 2	Why were largest body weights excluded? Please give details for these selection approaches in the text. Noted comment on body weight given in section 3.2.12. More this information forwarded.	
05	p. 3.4, sec. 3.2, para. 2	The statement is made that the Tier II receptors were selected based on their rank and ecologic importance, yet Figure 3.1 suggests that the Tier II receptors were selected not necessarily based on rank. Which occurred?	
03	p. 3.4, sec. 3.2, para. 1-2	Again, these are critical paragraphs for the non-technical person. Anything you can do to make them stand out -- putting them in lists, putting them in shaded boxes, etc. -- will help tell the story	
03	sec. 3.2.1 (entire)	Was there agreement with the other agencies on the methods? If so, say so.	
01	p. 3.4, sec. 3.2.1	The exposure model should be "ground-truthed" by seeing how well it predicts the most contaminated species in some sites where species' contamination has been comparatively measured. In particular, I would wonder about "2) the number of media contacted by the individual." If one of the media is particularly contaminated, then a species that functions primarily in that than medium might be more exposed than a species that moves between a number of media.	
06	p. 3.4, sec. 3.2.1	Exposure is also a function of intake and uptake.	

03	p. 3.6 - #8 on page 3.16	Almost none of this is going to be comprehensible to the non-technical person. Just do the best you can to be certain that the process stands out distinctly from the conclusions.	
07	p. 3.6	Defining sensitivity to contaminants in terms of the LD50 is non-conservative. Moreover, it is a test of acute effects more than chronic effects; and given the current environmental conditions at the site, a test for chronic effects would be more realistic. In addition, chronic effects should assessed that include developmental, immunologic, reproduction efficiency, and mutagenic changes. There are bioassays available for juvenile forms and for invertebrates that may be more appropriate to evaluate chronic effects.	
01	p. 3.6	The assumption that exposure duration is a function of residence time in the study area ignores the reality that the species in question may spend non-Hanford Site time in other contaminated areas. While it is not practical to NOT consider residence time in the study area, it is an example of why the scientific literature on the potential Tier II species should be searched for relevant field information on cumulative impacts that could be experienced by each of the species.	
04	p. 3.6, lines 1, 2	"life style" is a poor word choice here.	
06	p. 3.6, para. 1	The "life styles" are actually habitat classes.	
06	p. 3.6, para. 1, 2	The listed "foraging strategies" are actually trophic groups. Examples of foraging strategies are pursuit predators, ambush predators, gleaners, etc.	
05	p. 3.6, Table 3.3	The term pore water is used in the text, but is not defined in the glossary. A definition would be useful.	
03	p. 3.6, last three bullets	The construction of these bullets makes them hard to understand. This is particularly true for the first bullet. How about a construction like this: $ Exposure to Media: Exposure to media occurs when a species ingests a prey which is itself exposed...	
08	p. 3.6, bullet 3	Comment: Was this approach (LD_{50}) used for both radioactive and chemical materials? Sentence only says for radioactive.	
08	p. 3.6, bullets 3 and 4	These paragraphs describing scores do not mention organism life cycle times. Were these considered as an additional factor? This could potentially be important when compared to exposure duration.	
01	p. 3.7-3.9, tables 3.4, 3.5, 3.6	Ingestion of contaminated prey is absent from all these tables as a source of ingestion exposure.	
05	p. 3.7, table 3.4	The term pore water is used in the text, but is not defined in the glossary. A definition would be useful.	

05	p. 3.7, table 3.4	The meaning of the first sentence (in parenthesis) following the table heading is unclear. What is a "complete" exposure pathway? What is an "incomplete" exposure pathway?	
06	p. 3.7, table 3.4	Are the suckers in the Columbia R. Really herbivores? I would guess that most of your suckers are primarily feeding on benthic invertebrates, as in other riverine systems.	
08	p. 3.7, table 3.4	Table 3.4 should just list fish as anadromous (next to last cell).	
04	p. 3.7, table 3.4	For anadromous species, the blanket statement that these species do not feed in the river may not be 100% true. Is there proof they never feed in the river?	
04	p. 3.7-3.9, captions of tables	The word "Potential" seems inappropriate as used in these captions.	
06	p. 3.7 and 3.8, tables 3.4 and 3.5	Where do you include exposure to respired water? This is the major route of uptake for fish for most chemicals. Dermal exposure is small relative to respiratory exposure.	
06	p. 3.7 and 3.8, tables 3.4 and 3.5	Where do you include ingestion of food? It is included in the text but not the "conceptual exposure model."	
01	p. 3.7, table 3.4, footnote g; and 3.8, table 3.5, footnote e	The appropriateness of scoring down a species or species group because it is exposed "only" as a larva should be tested against the scientific literature indicating that exposure to contaminants during development is often more significant than exposure during adulthood. Likewise, the consideration that exposure as a juvenile is on a par with exposure as an adult (see, e.g., Tables 3.8 and 3.10) should similarly be tested against the scientific literature.	
01	p. 3.8, table 3.5, note under the Table heading	What does "where exposure pathways are complete" mean?	
05	p. 3.8, table 3.5	The meaning of the first sentence (in parenthesis) following the table heading is unclear. What is a "complete" exposure pathway? What is an "incomplete" exposure pathway?	
05	p. 3.8, table 3.5	Do any of the contaminated seeps and springs appear at the shoreline where they may be contacted by species such as muskrats, beaver or wading birds?	
05	p. 3.8, table 3.5	The term pore water is used in the text, but is not defined in the glossary. A definition would be useful.	

02	p. 3.8 and 3.9, tables 3.5 and 3.6	How will sediment/soil concentration be determined? Specifically, will the concentration be calculated as being in equilibrium with the current water concentrations, or will measured values of soil contaminants be used? The Hanford Site Risk Assessment Methodology is not clear on this point. The difference would be that (1) a soil/sediment concentration based on calculated values would provide a theoretical exposure of the effects of Columbia River water (ignoring past airborne emissions and River concentrations); (2) using measured values would include these. The latter method would be more likely to agree with other published reports.	
07	p. 3.8 and 3.9, tables 3.5 and 3.6	Dermal and Ingestion Exposures to groundwater can occur in areas of seeps, particularly those seeps that do not directly discharge to the river but rather, discharge to ponds, puddles, and backwater areas. Although ponded seep water is not by definition groundwater, it is closer to groundwater contaminant concentrations than to surface water concentrations, and for the purposes of this exercise, the groundwater concentrations should be those used in the exposure model.	
08	p. 3.8 and 3.9, tables 3.5 and 3.6	What happened to the air exposure pathways for the semi-aquatic and terrestrial species? See Table 3.3 for comparison	
08	p. 3.8 and 3.9, tables 3.5 and 3.6	This reviewer was concerned on how the scoring schemes were designed for contaminant exposures. Although consideration of frequency of exposure was included for section 3.2.3 no estimate were given on relative amounts of exposure relative to body weights. For example the Chinook Salmon was listed as a species where feeding occurs both on river bottom and in water column. The channel catfish was listed as primarily a bottom feeder. When both species' bottom feeding patterns are compared is there a difference in their types of bottom feeding activities that would suggest a difference in exposure? For example, does one forage deeper into sediments? Sole consideration of frequency of exposure might not capture these differences. Other categories in this section may also be affected by more than just frequency of activity.	
05	p. 3.9, table 3.6,	The meaning of the first sentence (in parenthesis) following the table heading is unclear. What is a "complete" exposure pathway? What is an "incomplete" exposure pathway?	
05	p. 3.9, table 3.6	The term pore water is used in the text, but is not defined in the glossary. A definition would be useful.	
05	p. 3.9, table 3.6	Are the seeps and springs not considered a media of contact for shallow rooted plants, or omnivores such as the coyote and skunk?	
05	p. 3.9, table 3.6	Inadvertent soil ingestion by carnivores/omnivores such as the coyote and skunk would seem a likely path of exposure through digging and grooming activities.	

05	p. 3.10, para. 1	Were specific contaminants identified as biomagnifying or not? Is there a list of contaminants and their specific assignment in one of these classes?	
06	p. 3.10, para. 1	Nonbiomagnifying contaminants do not necessarily occur at lower concentrations in higher level consumers, than in lower level species. Exposures for those chemicals are independent of trophic level.	
07	p. 3.10, para. 1	The assumption in this analysis that all media contribute equally to exposure is probably adequate for a screening level evaluation; however, a sensitivity analysis and attempt at more complex weighting of media will be necessary for the detailed evaluation.	
04	p. 3.10, line 3	How can we assume that "--all media--contribute equally to exposure." In the first place, I don't believe this; in the second, this would depend highly on species and contaminant.	
05	p. 3.10, para. 2	The statement is made that scores were summed at the "two types of source areas". This statement was confusing since in Table 3.3 five distinct "source areas" are identified. If only two general categories of source area are to be considered (in river and outfall) Table 3.3 should be modified to match subsequent text.	
05	p. 3.10, 3rd full para.	Explanation is given for the calculation of the composite effect score. At the end of section 3.2.11 (point 8) the composite effect score is dismissed as not useful. Why present it in the text?	
01	p.3.10, sec. 3.2.2	I do not understand why exposure to non-biomagnifying contaminants is MORE important to producers and herbivores than exposure to biomagnifying contaminants. I am supposing that this is tied to the conception stated in this document that non-biomagnifying contaminants tend to DECREASE in concentration at high levels in the food web. It is important to run the scheme in §3.2.2 past the scientific field evidence for 20 or 30 biomagnifying and non-biomagnifying contaminants.	
01	p. 3.10, table 3.7	Why is there no distinction among Level I, II, and III carnivores in terms of exposure to biomagnifying contaminants?	
05	p. 3.11, sec. 3.2.3	The term pore water is used in the title and text, but is not defined in the glossary. A definition would be useful.	
07	p. 3.11, para. 1	Egg and juvenile exposures should weight more heavily than exposures during other life stages. However, calculating the weighting factor for the early life stages will be difficult if trying to get an average over the range of taxonomic groups. Suggestion: it will be complex, but for the final analysis, weight the life stage exposures differently. For your Chinook example in this paragraph, it is likely that the ingestion exposure is underestimated with the current evaluation method.	

07	p. 3.11, para. 1	The study considered the ingestion exposure of groundwater/pore water pathway in the harvest mouse to be zero. This scenario is not accurate if you consider that this organism and others may be in contact with seep water that is similar in concentration to groundwater than to river water.	
05	p. 3.12, sec. 3.2.5	The term pore water is used in the title and the text, but is not defined in the glossary. A definition would be useful.	
07	p. 3.12, sec. 3.2.5, para. 1	The dermal exposure pathway to contaminants in groundwater/pore water should not be assumed to be zero. Avian species can be in contact with seep water that is higher in contaminant concentrations than river water.	
08	p. 3.12, sec. 3.2.5, para. 1	"...species virtually never make dermal contact with pore water" needs further elaboration.	
01	p. 3.12, sec. 3.2.6	Is the difference in dermal exposure to contaminants in surface water only a ratio of 4:1 between species that are "always" immersed in water versus those that are "seldom" immersed in water? The difference between 24 hours a day and perhaps 5 minutes a day is not 4:1.	
06	p. 3.13, sec. 3.2.7	Buried in the section on contaminants in air, is the statement that respiring water is a type of dermal exposure. This causes unnecessary confusion.	
05	p. 3.13, sec. 3.2.7, 2nd sentence	Is there a technical basis for the 0.5 m cutoff for inhalation distance, or is it an arbitrary selection?	
06	p. 3.13, sec. 3.2.8	There needs to be a little more explanation of what these outfalls are, how they contaminate soils, etc.	
01	p. 3.13, sec. 3.2.8	Exposure to contaminants in air is given 0 at the in-river source areas, but this was considered a source of contamination in the Human Scenarios Screening Assessment. This is inconsistent.	
01	p. 3.13, sec. 3.2.8, para. 2,	"For the in-river source areas, most of the contaminant burden is associated with in-flowing contaminated groundwater, pore water, NEAR-SHORE AREAS, and groundwater."	
07	p. 3.14	The authors have expended tremendous effort at devising a rather complex analysis of the exposure pathways. However, the Exposure Duration and Sensitivity to Contaminants criteria are weighted the same as the Exposure Pathways and yet have only a cursory analysis. A more detailed analysis of the Exposure Duration and Sensitivity to Contaminants criteria would be appropriate if all of the criteria are to be weighted equally.	

07	p. 3.14, sec. 3.2.9	The scoring scheme for exposure duration is very simplistic, particularly in light of the complex analysis conducted for exposure pathways. One would expect juvenile and egg exposure to have a higher degree of negative impact than adult exposure. In addition, exposure duration should be weighted based on the percentage of the organism's lifetime. This would correct for widely variable differences in longevity between species.	
08	p. 3.14, sec. 3.2.9, table 3.14	Is length of life an important issue? This reviewer felt that it should be considered here, at least by comment. Probably exposure duration should be presented as proportion of total life.	
01	p. 3.14, sec. 3.2.10	This section states, "Because most of the contaminants are radionuclides....[only sensitivity to rapid mortality from radiation exposure will be considered in relation to species' sensitivity to contaminants]." Most of the contaminants being considered are NOT radionuclides. 48 of the 73 analytes listed in Table B.1, "Parameters Used to Screen Columbia River and Groundwater Near the Columbia River," in the *Draft Identification of Contaminants of Concern,* are chemicals and metals, not radionuclides. Sixty-four of the 92 analytes listed in Table B.2, "Parameters Used to Screen Soil and Sediment," in the *Draft Identification of Contaminants of Concern,* are chemicals and metals, not radionuclides. Reduction of scoring for contaminant sensitivity to immediate mortality from radionuclides is not acceptable. The scientific literature needs to be searched regarding sensitivity of Tier I species in relation to both chemical and radioactive substances.	
05	p. 3.1.4, sec. 3.2.10	The scoring scheme for radiosensitivity ignores the fact that the radiosensitivity of organisms changes with age. This may be important for fish, where the developing embryos are the most radiosensitive. Also, radiosensitivity varies with taxa, but the most radiosensitive species includes birds, reptiles, mammals and a few trees. A more current reference to use as the basis for assessing radiosensitivity would be the IAEA document entitled "Effects of ionizing radiation on plants and animals at levels implied by current radiation protection standards".	

07		This Sensitivity to Contaminants analysis that is based on LD50 is grossly inadequate and yet has significant influence on the composite effect score. I suggest that additional analysis would be valuable to prepare for the more complex evaluation needed in the screening assessment. In addition, I recommend that the species eliminated from Tier II based primarily on this criterion be re-evaluated.	
08	p. 3.14, sec. 3.2.10	If the report makes the assumption that radioactivity will be used as the primary risk driver then some reference of other reports or other risk assessments confirming this fact need to be given here. This reviewer wonders if the chromium information would still be less important than all of the radioactive contamination. Give details to convince the reviewer that this assumption is true.	
05	p. 3.15	The explanations of the summary of scores provided in section 3.2.11 is difficult to follow, particularly because of the parenthetical references to Appendix C. It might be easier to understand if an equation were presented illustrating the weighting calculations, or if a diagram were presented.	
05	p. 3.15, item 2	The statement is made that in summing the dermal exposure all media were treated equally, yet the values in Table 3.13 are meant to account for the variation in media contamination. Isn't this a contradiction?	
05	p. 3.15, item 6.	Does the grand average score include summing the scores from biomagnifying and nonbiomagnifying contaminants? If this is true wouldn't it tend to mask information on the more significant contaminant?	
05	p. 3.16, item 8	Explanation is given for the calculation of the composite effect score on page 3.10. At the end of section 3.2.11 (point 8) the composite effect score is dismissed as not useful. Why present it in the text?	
06	p. 3.16, item 8	Just because acute test data are for 48-96 hours does not mean that you should not care about longer durations or differences in exposure duration. You should be assessing risks of chronic effects, particularly for Rad exposures.	
03	p. 3.16, sec. 3.2.12	Was there agreement with the other agencies on the reduction of the list from 65 to 43 species? If so, say so.	
06	p. 3.16, sec. 3.2.12	You need to read Opresko et al. more carefully. Smaller species have a higher ingestion rate per unit body mass, but they are less sensitive per unit intake (dose), according to the EPA and conventional wisdom. Therefore, the higher the body weight the higher the toxicity threshold. However, none of these arguments have to do with Rad sensitivity.	
08	p. 3.16, sec. 3.2.12,	Here and elsewhere information is provided that should be earlier in report when the topic is first introduced to make the task of the reader easier.	

08	p. 3.16, sec. 3.2.12,	Body weight discussion in section 3.2.12 - This reviewer was interested to learn about the allometric agreement in toxicity. Although one reference is given to support this conclusion there are volumes of mammalian information that suggest dramatic deviation from simple allometric comparison within that one category let alone across all of these very different species and strains! At least add some acknowledgment that some deviation from this rule might exist and discussion of what impact it might have on your conclusions.	
03	p. 3.16, sec. 3.2.12, para. 2	The sentence "The number and percent of Tier I species..." is not particularly informative. How about: "Table 3.16 shows how Tier I species were ranked, based on Grand Average Exposure Scores and Composite Effect Scores, and what decision was made in Tier II about whether they would be included. Those with a (+) in the right hand column are on the final list of receptor species. Letters (a, b or c) in the right hand column indicate a species was not selected, for the reasons specified in the legend on pg. 3.18."	
05	p. 3.17, table 3.16	A foot note, or other notation should be made to the table indicating that a high score represents a high potential for contact with the contaminants	
02	p. 3.18, table 3.16	Suggest that duckweed be added. It has been the subject of toxicology studies. Since both macrophytes are shown with the letter "b", it is not clear that any macrophytes are to be included.	
03	p. 4.1, sec. 4.0	Most of this is over the head of the non-technical person. The crucial question for them is: Was this methodology agreed upon with the other agencies? Some description of any consultation process used to develop the methodology would be helpful.	
06	p. 4.1, sec. 4.0	Usually, NOAELs or CVs are used for screening, not LOAELs.	
08	p. 4.1, sec. 4.0	Are these risks of death, cancer or what? What risks (ecological) are not included by use of these models? What are the consequences of leaving those considerations out of the assessment?	
01	p. 4.1, sec. 4.0, para. 1	In this brief section, the document indicates what will next be done with the list of Tier II Receptor Species. The section notes, "Exposure estimates [for each species] will be compared to toxicological benchmarks...that reflect [rapid] mortality (for example, LC_{50}...) or the lowest observed adverse effect level." There is a WORLD of difference between lowest observed adverse effect level, and immediate mortality. Adult organisms, for instance, are relatively robust to dioxin exposure in terms of immediate mortality, while there is no known level of exposure of an embryo to dioxin that does not cause alterations.	

01	p. 4.1, sec. 4.0, para. 1	Recommendations: 1. Search the "toxicological benchmark" literature and find the 90th percentile of the largest differences between LD_{50}s and LC_{50}s, and use that ratio to reduce the mortality benchmark for any given species if no "lowest observed adverse effect level" data are available. It is absurd to use immediate mortality as a measure ogf toxicity. 2. Search the scientific field literature for any examples of sensitivity of any of the Tier I species or closely-related species to any of the contaminants considered present on the Hanford Site. This information can be used to supplement judgment of which Hanford Site contaminants pose potential health damage problems.	
05	p. 4.1, para. 2	The term "toxicological benchmark" is used but not clearly defined in the text or the glossary; it is explained as "equivalent to measurement endpoints" but these are not defined in the text or glossary either.	
06	p. 4.1, sec. 4.0, para. 2	I will be interested to see how you put uncertainties on benchmarks. That will not be easy to do in a defensible manner.	
01	p. 4.1, sec. 4.0, para. 3	This paragraph refers to the proposed use of stochastic models in a Monte Carlo regime "...that will have the probability density functions for the both the input parameters to the exposure model and the toxicological benchmarks." This is a case of statistics outrunning by a thousand kilometers the data. You are going to be using extraordinarily sparse and crude data regarding individual species, with the effects of most of the Hanford Site contaminants on most of the Hanford Site biota totally unknown. This is why all information available from scientific field literature for Tier I species and related species needs to be searched and used in the narrative for the impact assessment. The proposed process is unbelievably alienated from real-world, cumulative impacts data in order to obsessively fit numbers into Monte Carlo regimes. Reality would thus be sacrificed within this process.	
06	p. 4.1, sec. 4.0, para. 3	Usually, screening assessments are conservative and deterministic, and probabilistic analyses are reserved for definitive assessments.	
05	p. C.2 -C.5	The table is extremely difficult to read in its present reduced state. Consider expanding it 10% or so for readability.	
08	p. C.2 -C.5	The graphs could be enlarged and the shading removed for legibility.	

ATTACHMENT 1

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July 1994

A REVIEW OF ECOLOGICAL ASSESSMENT CASE STUDIES FROM A RISK ASSESSMENT PERSPECTIVE

VOLUME II

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SECTION THREE

ECOLOGICAL RISK ASSESSMENT CASE STUDY:

EFFECTS OF RADIONUCLIDES IN THE COLUMBIA RIVER SYSTEM— A HISTORICAL ASSESSMENT

9613441.0192

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LIST OF ACRONYMS

BCF	bioconcentration factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	Department of Energy
HQ	hazard quotient
NRDA	Natural Resource Damage Assessment
PNL	Pacific Northwest Laboratory
RM	River Mile
USGS	United States Geological Survey

ABSTRACT

In 1943, nuclear production activities began at the U.S. Department of Energy's (DOE) Hanford site in south-central Washington State. These activities continued for many years. During this time, the site discharged radioactive effluents into the Columbia River, which runs through the northern portion of the site and borders it on the east (the Hanford Reach). The DOE requested the Pacific Northwest Laboratory (PNL) to conduct an ecological risk assessment to determine whether the ecological risk assessment framework (EPA, 1992) used for hazardous chemicals is applicable to radionuclides as stressors. PNL conducted this ecological risk assessment using historical Hanford site monitoring data, which had been collected to characterize human dose. The data characterized exposure by measuring radioactivity in water, sediments, and biota. The data used in the current investigation were collected during 1963-1964, a period of peak production of nuclear material. During this time, the maximum number of eight reactors were operational.

PNL employed two approaches in assessing ecological risk to Columbia River organisms. The first approach used environmental exposure data (water concentrations for radionuclides) to calculate dose to a variety of aquatic organisms, including the most sensitive receptors (fish). The second approach made use of measured tissue concentrations of selected aquatic organisms to calculate organism internal dose.

PNL used dose to assess potential toxic effects and assess regulatory compliance. Risk characterization was developed by comparing dose levels in fish and other organisms found in the Columbia River to known effect concentrations through a hazard quotient for acute dose and possible developmental effects. The assessment endpoint was protection of fishes in the Columbia River, and the measurement endpoint was increases in mortality and sublethal effects. One of the most sensitive ecological receptors was the early developmental stage of chinook salmon.

The major conclusions of the study are:

- The ecological risk assessment paradigm is applicable to radionuclides as well as to hazardous chemicals, as evidenced from the exposure, effect, and risk characterization.

- The most sensitive life stage of fish (i.e., salmon embryo) did not appear to be at risk from radionuclide exposure in sediments or water.

- During peak production at Hanford, releases of radionuclides did not result in any measurable risk to the Columbia River ecosystem, as evidenced by indicator species and regulatory benchmarks.

- Dose rates to Columbia River animals during the study period did not exceed the DOE standard of 1 rad/d per DOE Order 5400.5 (DOE, 1989). Based on the computer code CRITR2, only crayfish and a plant-eating duck received a dose rate exceeding 1 rad/d. However, this risk assessment did not include ducks, and the actual calculation of dose to crayfish from whole organism counts gave values considerably less than both the modeled dose and 1 rad/d.

3.1. RISK ASSESSMENT APPROACH

The ecological risk assessment follows the sequence of the U.S. Environmental Protection Agency's Framework for Ecological Risk Assessment (EPA, 1992). This arrangement includes problem formulation, analysis, and risk characterization, respectively (figure 3-1).

Exposure of aquatic organisms to radioactivity can elicit a toxic response depending on the organism, level of dose, type of radionuclide, and habitat requirements of the exposed organism. In this study, the assessment endpoint was defined as the maintenance of important recreational and commercial fish populations in the Columbia River. The measurement endpoint from radioactive dose was toxicological response. This assessment did not consider elemental chemical toxicity of each radionuclide.

The major ecological components are benthic macroinvertebrates, zooplankton, phytoplankton, and fish of the Columbia River. Fish species in the Columbia River are important commercial, recreational, cultural, and regional assets.

Data analysis included exposure and effects characterization. Exposure characterization consisted of an assessment of radioactivity at several river stations downstream from the Hanford site. Measured river activity was used to calculate ionizing radiation dose from water to selected organisms using bioaccumulation factors and computer modeling. A second and more direct means of estimating dose to aquatic organisms used measured fish tissue concentrations. Available sampling data included sediments, water, and biota.

Characterization of effects to aquatic organisms entailed using available toxicity data and regulatory standards. The characterization was conducted at the individual level, qualitatively interpreted, and applied to the population level of ecological organization. Risk characterization was based on a hazard quotient (HQ), defined as the ratio of radionuclide organism dose (exposure or tissue value) to benchmark dose values.

3.2. STATUTORY AND REGULATORY BACKGROUND

Although federal regulations do not require quantitative ecological risk assessments, they can be used effectively to support regulatory requirements under nearly all of the major federal environmental statutes (e.g., the Comprehensive Environmental Response, Compensation, and Liability Act, CERCLA). Other potential applications include supporting compliance with federal Executive Orders and with policy directives of various government agencies (e.g., DOE Orders).

A number of federal statutes have promulgated risk-based and technology-based standards for the protection of ecological resources (e.g., water quality criteria under the Clean Water Act). However, only one standard has been published for the protection of ecological resources from exposure to radioactive materials. DOE Order 5400.5 (DOE, 1989) stipulates that the interim dose limit for native aquatic animal organisms "shall not exceed 1 rad per day from exposure to the radioactive material in liquid wastes discharged to natural waterways."

PROBLEM FORMULATION

Stressors: Ionizing radiation from radionuclides associated with the Hanford site. Other chemical and physical stressors were not considered.

Ecosystem(s) at Risk: Columbia River downstream of the Hanford Site, Richland, Washington

Ecological Components: Fish, zooplankton, phytoplankton, and benthic macroinvertebrates in the Columbia River.

Endpoints: Assessment endpoint was the maintenance of important recreational and commercial fish populations in the Columbia River. The measurement endpoints included dose-response information for radiation and single species of aquatic organisms.

ANALYSIS

Characterization of Exposure

Radioactivity of river water samples was measured and used to calculate ionizing radiation dose to selected species using bioaccumulation factors and models. Dose also was determined by direct measurement of fish tissues and sediments.

Characterization of Ecological Effects

Radiation effects were evaluated based on available laboratory stressor-response information on mortality and developmental effects and regulatory standards.

RISK CHARACTERIZATION

Hazard quotients were used to compare maximum exposure doses to the lowest reported doses causing adverse effects to aquatic organisms. Major uncertainties associated with this approach were described.

Figure 3-1. Structure of assessment for effects of radionuclides

3.3. CASE STUDY DESCRIPTION

3.3.1. Background Information and Objective

It is generally assumed that human health risk standards for radionuclides protect wildlife sufficiently. However, under some circumstances the risk to wildlife from radionuclides may need to be considered, such as managing risks, developing cleanup strategies, and identifying injury under the Natural Resource Damage Assessment (NRDA) process. The objective of this case study is to evaluate the applicability of the ecological risk assessment paradigm for radionuclides as stressors in the Columbia River.

The Hanford site, an area of slightly more than 1,400 km^2 (560 mi^2), straddles the Columbia River just north of Richland, Washington. Three northwest-southeast-trending basalt ridges cross this broad, relatively level gravel plain. The semiarid climate supports various communities of shrubs—steppe and grassland.

The Columbia River extends 1,954 km (1,214 mi) from its origin in Columbia Lake in British Columbia to its mouth at Astoria, Oregon, making it the fourth-longest river in North America. Typical flow rates of the Columbia River at Priest Rapids Dam range from 2,800 to 3,400 cubic meters per second (cms), or 99,000 to 122,000 cubic feet per second (cfs) (Woodruff et al., 1991).

The Columbia River has eight primary uses:

1. River navigation through navigation locks from the Pacific Ocean to the Port of Benton in Richland.
2. Agricultural purposes, primarily irrigation. Approximately 6 percent of the Columbia Basin's water is diverted for agricultural use.
3. Nonagricultural irrigation.
4. Electric power generation, provided by the system of 11 dams along the Columbia River in the United States.
5. Flood control, also provided by the dams.
6. Fish and wildlife habitat, especially for anadromous salmon. The Hanford Reach comprises the last major salmon and steelhead spawning area within the Columbia River proper. The Columbia River also supports the vast majority of mesic terrestrial habitat in the semiarid Hanford Reach.
7. Water supplies to numerous municipalities and industries.
8. Recreational use.

The Hanford Reach of the Columbia River runs from Priest Rapids Dam to just north of the City of Richland and flows past the reactor areas of the Hanford site (figure 3-2). The average annual flow of the Columbia River in the Hanford Reach, based on 65 years of record, is about 3,400 cms (120,100 cfs) (DOE, 1988). Flows in the Hanford Reach vary widely, not only because of the annual flood flow but also because of daily regulation by the upstream power-producing Priest Rapids Dam. Flow rates during the late summer, fall, and winter may vary from a low of

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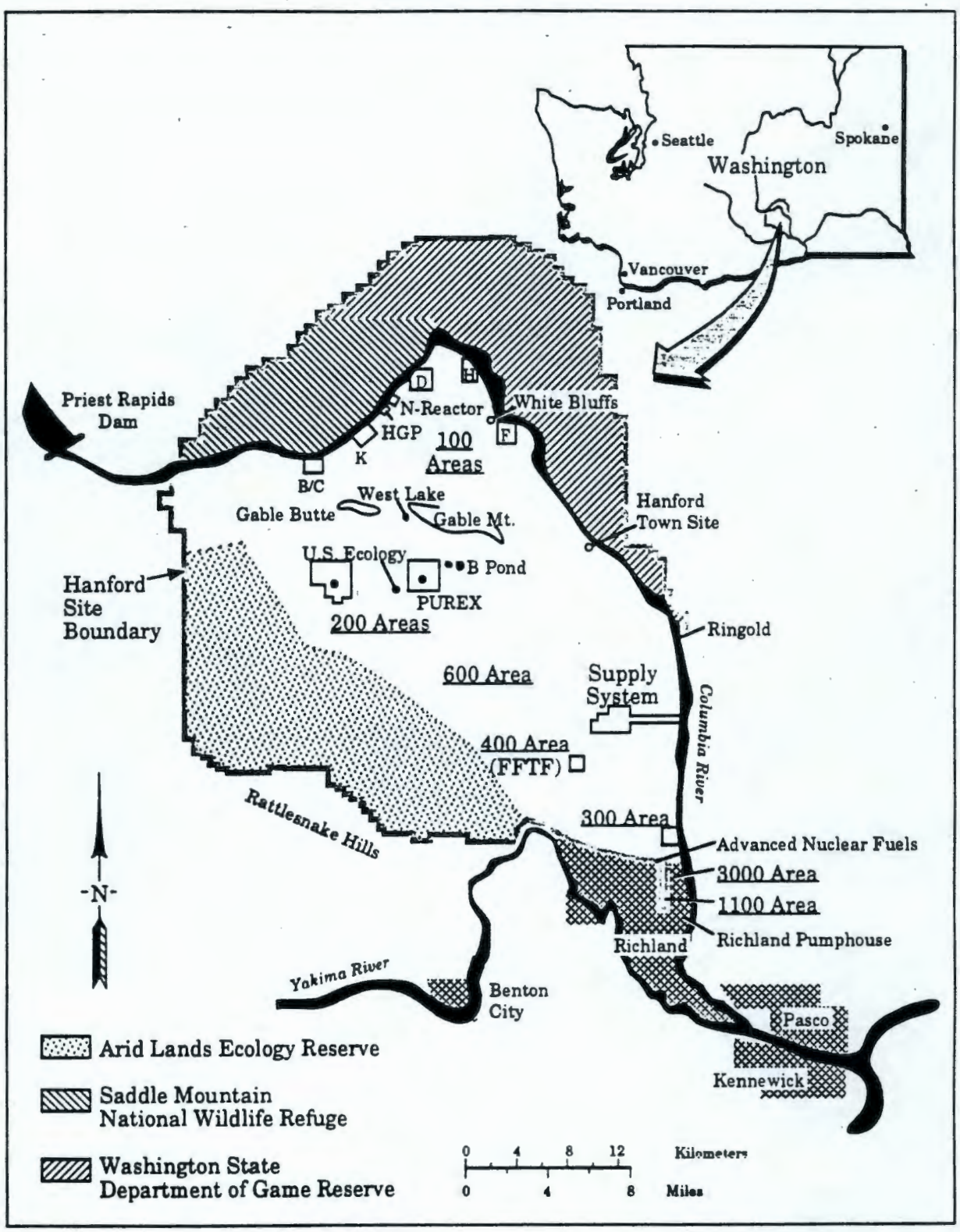

Figure 3-2. Location of the Hanford Reach of the Columbia River

1,100 cms (36,000 cfs) to as much as 4,800 cms (160,000 cfs) each day. During the spring runoff, peak flow rates from 4,800 to 20,000 cms (160,000 to 650,000 cfs) can occur.

The Washington State Department of Ecology classifies the Columbia River water quality as Class A (excellent) between Grand Coulee Dam and the mouth of the Columbia River (DOE, 1988). Table 3-1 shows water quality data between Priest Rapids Dam and Pasco, Washington, for the years 1957-1973. The dominant physical feature of the Columbia River through the Hanford Reach is the high flow rate, which is subject to large, diurnal water-level fluctuations that change the shoreline configuration and expose gravel substrate and periphyton to alternate periods of wetting and drying. The Reach has a low level of suspended sediment, 1 to 7 mg/L.

The river-bottom sediments from Priest Rapids Dam to several kilometers below the confluence of the Snake and Columbia Rivers are primarily mixed sands and gravels with some cobbles (maximum diameter ≈ 20 cm). Coarser sediments predominate from Priest Rapids Dam through the reactor areas (DOE, 1988). The streambed near Richland consists of sand in deep channels and a mixture of sand, silt, and some clay in shallow areas (DOE, 1988). Most of the Hanford-produced cationic radionuclides are associated with suspended particulates and subsequent fine sediments (Beasly and Jennings, 1984).

Because of the many dams on the Columbia River, the only free-flowing U.S. section occurs between Priest Rapids Dam (River Mile [RM] 397) and McNary Reservoir (RM 351). The Priest Rapids Dam immediately upstream from the Hanford site regulates flow. No significant tributaries enter the stream in this section, which lies mostly within the Hanford site.

The main channel of the Hanford Reach is braided around the island reaches and submerged rock ledges and gravel bars, causing repeated pooling and channeling. The riverbed material is mobile and dependent on river velocities; it typically is composed of sand, gravel, and rocks up to 20 cm (8 in) in diameter. Small fractions of silts and clays are associated with the sands in areas of low-velocity deposition.

3.3.2. Problem Formulation

3.3.2.1. Stressors

The release of radionuclides from Hanford operations is one of several possible stressors to the ecosystems of the Columbia River. Other possible stressors include thermal discharges from Hanford reactors; varying river levels because of dams; the physical barrier to fish migration from the dams; and heavy agricultural, commercial, and recreational activities along the river. However, this assessment concerns only radionuclides as stressors of concern.

The cooling effluents of Hanford reactors contain over 60 radionuclides. Becker (1990) has reported that during the period of maximum reactor production (mid-1960s), the Hanford site discharged over 300,000 curies per year to the river. Radioactive decay influenced the relative abundance of different radionuclides in the river (Becker, 1990). In fact, many of the radionuclides discharged by the Hanford site have a short half-life and were not detected in the effluent discharge. Others could not be detected in the river after dilution. Becker (1990)

Table 3-1. Summary of Water Quality Data, 1957-1973 (DOE, 1988)

Location/ Statistic	DO[a] (mg/L)	Temperature (°C)	Coliform (MPN[a]/100 mL)	pH	Color (PT-CO[a] units)	Hardness (mg/L)	Turbidity (JTU[a])	PO_4-P (mg/L)	Ortho NO_3-N (mg/L)
Below Priest Rapids (River Mile 395)									
Minimum	9.5	1.8	0	6.5	0	55	0	0.01	0.02
Mean	11.9	11.4	131	7.7	5	69	3	0.08	0.10
Maximum	15.9	19.2	2,000	8.5	33	81	29	0.15	1.50
Pasco (River Mile 330)									
Minimum	6.8	3.0	1	6.8	0	40	0	0.01	0.05
Mean	10.8	12.2	182	8.1	8	73	15	0.10	0.19
Maximum	14.3	22.0	4,800	8.6	68	90	140	0.02	0.37

[a]DO = Dissolved oxygen.
JTU = Jackson turbidity units.
MPN = Most probable number.
PT-CO = Platinum-cobalt.

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identified three radionuclides as being of concern because of their potential biological significance: phosphorus-32, chromium-51, and zinc-65. Together they account for over 90 percent of potential radiological dose to aquatic organisms. All are nuclear activation products that are activated as Columbia River water cools the reactor core. The potential for some radionuclides to bioaccumulate in aquatic food webs causes concern with respect to both the human exposure pathways and potential ecosystem effects.

Among radionuclides, phosphorus-32 and zinc-65 are potential stressors because of their biological importance and fate: they are essential elements for organism growth and are incorporated into the aquatic food web. One study conducted in the Hanford Reach from 1961 to 1968 noted a seasonal pattern of uptake by algae, with higher radioactivity in winter and lower in summer (Becker, 1990). This pattern reflects concentration and dilution phenomena from river flows.

Unlike phosphorus-32 and zinc-65, chromium-51 is not considered a major biological hazard. This radionuclide has a short half-life, low biological mobility (i.e., it has no known essential role in the physiology of organisms), and weak radiations. It does not accumulate to any extent in aquatic organisms and is transported with river-suspended particulate material with little dissolution (Becker, 1990). However, the risk assessment included it because it was a significant activation product.

The half-lives of the three radionuclides considered in the risk assessment are:

- Phosphorus-32: 14.2 days
- Chromium-51: 27.8 days
- Zinc-65: 245.0 days

Phosphorus-32 is a beta emitter (negatrons); chromium-51 emits gamma radiation and electrons; and zinc-65 is primarily a gamma emitter, but also emits positrons and electrons.

3.3.2.2. Biological Fate of Radionuclides

Phosphorus, including phosphorus-32, is a building block of various tissues and is a key element in many biochemical transformations, especially energy transduction (ATP, ADP, GTP, etc.). The element is comparatively scarce in the environment. Organisms can concentrate phosphorus, including phosphorus-32, to levels that greatly exceed the concentration in the ambient media. Phosphorus has a bioconcentration factor (BCF) of 24,000 for freshwater plants and 8,000 for freshwater animals (Becker, 1990).

Terrestrial plants take up little chromium-51 from soils, <0.5 percent (Becker, 1990). In aquatic systems, this element sorbs to particulate material and is transported along with it. Becker (1990) reported that in biological systems chromium-51 has an affinity for the blood of fish.

Organisms accumulate a measurable fraction of zinc-65. In aquatic systems, this radionuclide is transported through aquatic food webs. With chronic uptake, substantial tissue accumulation can occur. In the Pacific Ocean, Becker (1990) noted BCFs of up to 10^3 for algae

and 10^5 for certain molluscs. The BCF for plankton in the Columbia River ranges from 300 to 19,000 (Cushing and Watson, 1966; Cushing, 1967a, b), with adsorption as the primary means of uptake. Because of its long half-life and biological mobility, zinc-65 can be transported through food webs.

3.3.2.3. Ecosystem Potentially at Risk

The Columbia River supports a diversity of aquatic and terrestrial wildlife. The major ecological components are benthic macroinvertebrates, zooplankton, phytoplankton, and fish. Although a detailed description of the wildlife exceeds the scope of this effort, appendix A lists the fish species and shows the generalized aquatic food web. This risk assessment focuses on the fish of the Columbia River because they are aquatic organisms sensitive to ionizing radiation and because the Columbia River supports a wide variety of fish, including several species that are commercial, recreational, and cultural assets of the region.

3.3.2.4. Endpoint Selection

Exposure of aquatic organisms to radioactivity can elicit a toxic response depending on the dose level, the length of exposure, the particular species, and the life stage at the time of exposure. The magnitude of the response is proportional to radiological dose. In this study., the assessment endpoint was the health and condition of local populations of selected fish species that were of commercial, recreational, and cultural interest.

The risk assessment evaluated multiple measurement endpoints. They included literature investigations of adverse effects on fish, such as acute mortality and sublethal and developmental effects. Dose from ionizing radiation was evaluated in the maximally exposed individual fish and fish in early developmental stages during the study period. Because no net increase occurred in the concentration of elements, the assessment considered only toxicity resulting from ionizing radiation, not toxicity resulting from chemical characteristics.

3.3.2.5. Conceptual Model

Radionuclides in the Columbia River are partitioned between river water, sediment, and the aquatic food web. Organisms become exposed through direct contact with river water, through contact or ingestion of contaminated sediments, or through food web incorporation of radionuclides.

Two organism exposure pathways exist for ionizing radiation. In the external exposure pathway, an organism receives a dose from its external environment, such as ionizing radiation from the water. If the energy of the radiation is high enough, it may penetrate the organism's external tissue. In the internal exposure pathway, an organism receives a dose of ionizing radiation as a result of uptake of a radionuclide. Consequently, exposure occurs to internal organs and tissues. The significance of each exposure pathway depends on the aquatic fate of the radionuclide, its concentration, the energy of its radiation, and also on the pathway of bioaccumulation.

The level of organism dose from either external or internal exposure depends on the length of time an organism spends in the Hanford Reach feeding and breeding habitats, the degree of interaction with the sediments (i.e., living on or in the sediments), the discharged levels of radionuclides, and the river flows. Potential dose to aquatic organisms equals the sum of the total ionizing radiation dose from multiple radionuclides.

Possible exposure scenarios include organisms living near or in reactor effluent discharges, at various locations downriver of Hanford, and on or in contaminated sediments. A resident fish, such as whitefish, can spend its entire life in the Hanford Reach. The adult chinook salmon, on the other hand, is present only during selected periods of the year.

Generally, higher-level organisms such as fish have greater sensitivity to ionizing radiation than lower-level organisms such as algae and invertebrates (Frank, 1973). Consequently, fish can serve as indicators or benchmarks of the health of fish populations and the ecosystem. For fish, sensitivity varies with developmental stage, (i.e., adult fish being less sensitive then juveniles), amount of time required for various developmental stages, and number of fertilized eggs produced (Whicker and Shultz, 1982). Species fecundity factors into extrapolating individual organism effects to a population. For example, species with high fecundity rates most likely will not experience adverse effects to the same degree as species with low fecundity rates. In addition, the exposure of organisms to low-level ionizing radiation can promote injury repair mechanisms.

For Hanford, most of the available monitoring data for radionuclides were for river water activity and tissue concentrations of selected species of fish, including mountain whitefish (*Prosopium williamsoni*). One of the most fished species in the Columbia River, mountain whitefish remains resident throughout the year, making it a useful biomonitor of radionuclide incorporation into the human food chain. The food chain accumulation of radionuclides by whitefish occurs in a three step process:

Water → Algae → Insects → Whitefish

Calculated dose to whitefish can be extrapolated to other fish species, such as adult chinook salmon that occur seasonally in the Hanford Reach of the Columbia River. In the risk assessment, whitefish served as an indicator or "generic" fish to develop a potential exposure/dose scenario. Where available, the risk assessment incorporated data for other fish species along with supportive or ecosystem descriptive data for phytoplankton, snails, and crayfish. Dose was estimated from exposure to measured radionuclides in the river to salmon embryos, identified as one of the most sensitive organisms to ionizing radiation.

Comments on Problem Formulation

Strengths of the case study include:

- *This case study was well written and well organized. It is an ideal case for the application of the EPA Risk Assessment Framework because discrete stressors are easily identified and measured and substantial data are available on their biological impacts. Assessment and measurement endpoints are identified and fit nicely into the risk assessment paradigm.*

Limitations include:

- *Because the Columbia River ecosystem has been affected by many other factors, radiation may have a relatively small impact on salmon. Therefore, although it may be valid to restrict the risk assessment to a single stressor that does not reflect the "real world" situation, other stressors on salmon should be identified.*
- *The authors should point out that data were developed for the specific case study, rather than for a full-ranging risk assessment that could consider other stressors. DOE and EPA need to know whether radionuclides are a major problem or risk to the ecosystem is negligible.*
- *The total biological community is not well characterized.*

3.3.3. Analysis: Characterization of Exposure

Making use of the 1963-1964 data for sediments, water, and biota, the exposure characterization employed two approaches to evaluate dose, which provided independent assessments of dose. The first approach evaluated river radioactivity at several stations downstream of the Hanford site. This approach then modeled organism dose using biological accumulation factors for several "generic" aquatic organisms from measured radionuclide water concentrations during the study period, 1963-1964. The second approach used measured radionuclide tissue concentrations to calculate dose to whitefish. Directly measured tissue activity has the advantage of considering all environmental pathways: water and food uptake, excretion, sediments, etc. However, this approach has the disadvantage of measuring selected radionuclides only in fish muscle tissue. As a result, the approach reflects the human pathway and places less emphasis on effects to the fish. For example, although organs and bones also accumulate radionuclides, they were not included in the dose calculation.

3.3.3.1. Sample Location

The initial exposure characterization was limited to the Richland Station (RM 344), although ultimately all available data from the Hanford Reach were reviewed and considered. The U.S. Geological Survey (USGS, 1966) indicated that the river is vertically and horizontally mixed at this point. This approach was used because of the potential for large spatial and temporal

variability of radionuclide concentrations upstream. This variability resulted from the discharge of eight production reactors with individual production schedules. Once established, the relationship between exposure and potential effects can be applied to upstream locations.

3.3.3.2. Data Analysis

The risk assessment reviewed three data sets to characterize exposure: measured radionuclide river concentrations, measured sediment concentrations, and measured fish tissue concentrations. The data were collected during routine monitoring of radionuclide concentrations in the Columbia River system. River water was collected as composite, grab, or cumulative samples. The sampling scheme varied over the 2-year period (table 3-2). Figures 3-3 and 3-4 show the monthly water grab sample concentrations for selected radionuclides over the 2-year period. Water concentrations were generally highest during the winter and late fall and lowest in the spring and summer.

3.3.3.3. Exposure From Measured River Water Concentrations

Exposure concentrations were established by reviewing measured river activity data to determine the relationships among composite, grab, and continuous samples: that is, to see whether one form of sampling yielded consistently higher water concentrations than another. The results of this analysis showed that the highest river concentrations of radionuclides occurred in whole-water grab samples.

An upper-boundary exposure concentration was derived by using the maximum observed grab sample water concentration for the 2-year study period for each radionuclide shown in table 3-3. These concentrations were assumed to represent the maximum concentration for exposure of river organisms. If the effect characterization indicated a potential risk, then more typical exposure concentration scenarios could be developed.

The maximum sediment concentration measured for each radionuclide was used to calculate organism dose.

3.3.3.4. Calculation of Organism Dose

The internal total-body dose rate to an organism from water exposure for a number (N) of radionuclides is given as:

$$R_c = \sum_{i=1}^{N} b_{i,c} E_{i,c} \qquad (3\text{-}1)$$

where R_c is the dose rate to total body of organism c (rad d^{-1}), $b_{i,c}$ is the specific body burden of nuclide i in organism c (Bq kg^{-1}), and $E_{i,c}$ is the effective absorbed energy rate for nuclide i per unit activity in organism c (rad Ci^{-1} d^{-1}):

Table 3-2. Water Sampling Matrix (1963-1964) (Dirkes, 1992; Haushild et al., 1966; Nelson et al., 1964)

Station Location	Type	Frequency[a]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1963													
Richland	Grab		x[b]			x		x	x	x	x	x	x
Hanford	Grab	x	x	x	x	x	x	x	x		x		
1964													
Richland	Grab	x	x	x	x	x	x	x	x	x	x	x	x
	Cum	o	o	o	o	o	o	o	o	o	o	o	o
	Comp						*	*	*	*	*	*	*
Hanford	Grab	*	*	*	*	*	*	*	*				
	Comp	o	o	o	o	o	o	o	o				
	Cum	o	o	o	o	o	o	o	o				

[a]Totals for 1963: Grab--159.
Totals for 1964: Grab--149.
Comp--194.
Cum --300.

[b]Legend: x--every 2 weeks.
o--weekly.
*--monthly.

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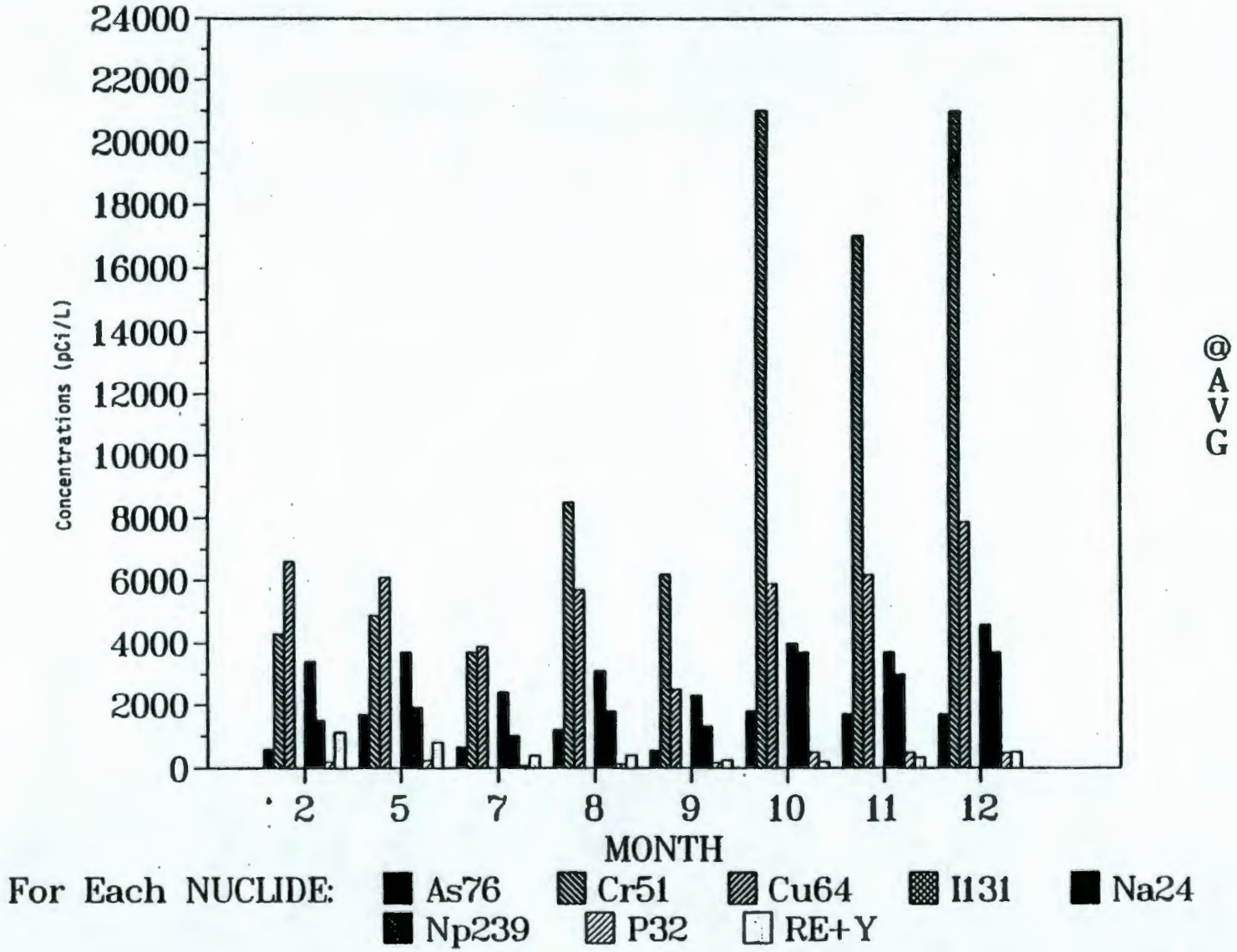

Figure 3-3. Monthly concentrations for selected radionuclides in Columbia River grab samples, 1963 (Dirkes, 1992; Nelson et al., 1964)

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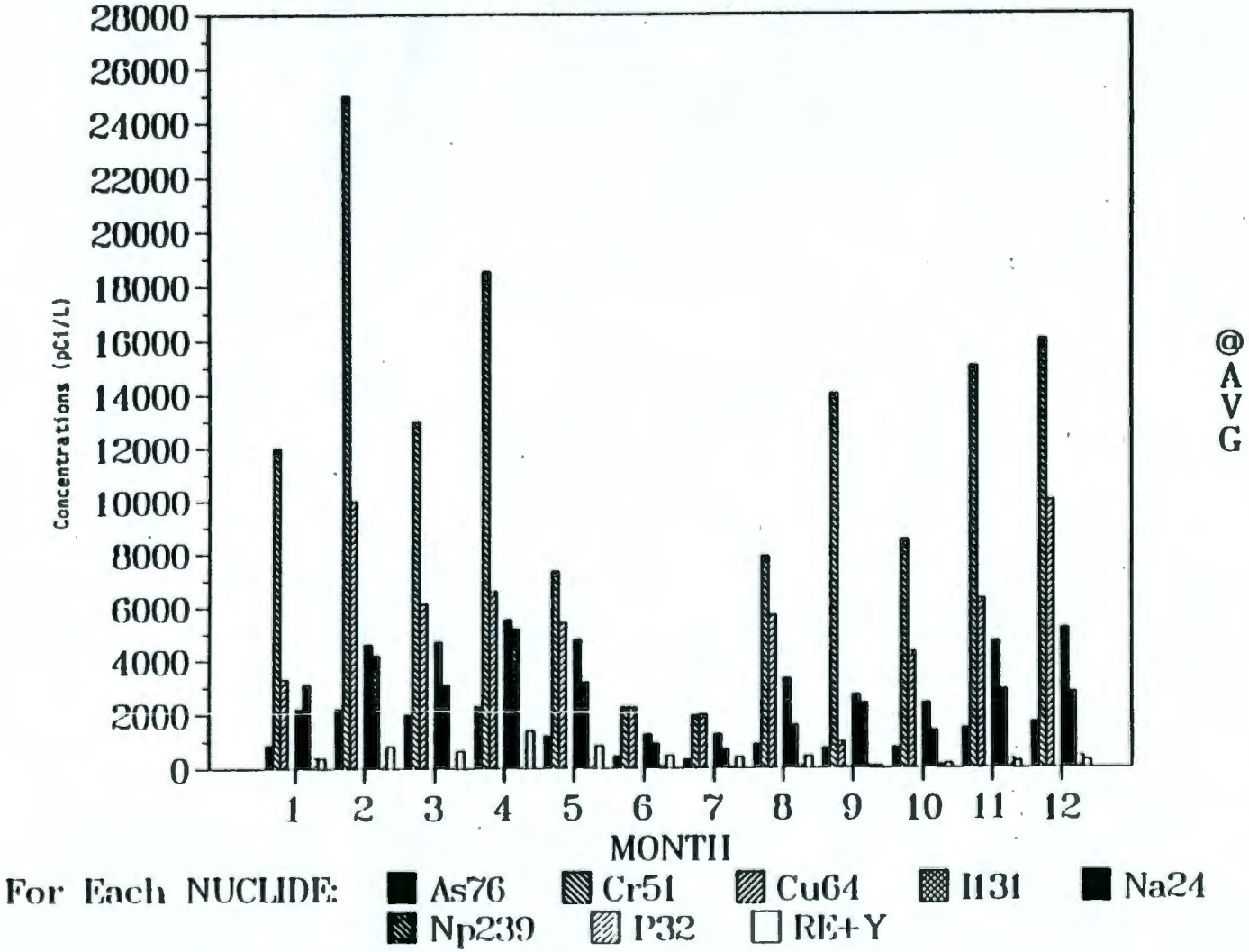

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Figure 3-4. Monthly concentrations for selected radionuclides in Columbia River grab samples, 1964 (Dirkes, 1992; Nelson et al., 1964)

Table 3-3. Maximum Grab Sample Water Exposure Concentrations for 1963-1964 Time Period (Dirkes, 1992; Nelson et al., 1964)

Radionuclide	Concentration (pCi/L)
As-76	2,300
Co-60	120
Cr-51	25,000
Cu-64	10,000
I-131	34
Na-24	5,600
Np-239	5,600
P-32	630
RE+Y	1,400
Sr-90	2.6
Zn-65	1,800

$$E_{i,c} = \epsilon_{i,c} \text{MeV dis}^{-1} \times 3.70\text{E}10 \text{ dis s}^{-1} \text{ Ci}^{-1}$$

$$86{,}400 \text{ sd}^{-1} \times 1.602\text{E-}11 \text{ rad}^{-1} \text{ MeV} = 5.12\text{E}4 \ \epsilon_{i,c}$$

(where ϵ is the effective absorbed energy for nuclide i in organism c).

For a primary organism:

$$b_{i,c} = C_{i,c} B_{i,c} \tag{3-2}$$

where $C_{i,c}$ is the concentration of nuclide i in the water to which organism c is exposed (Bq m^{-3}) and $B_{i,c}$ is the bioaccumulation factor for nuclide i and organism c (m^3 kg^{-1}). Here the water concentration already has been corrected for dilution and radioactive decay during transit from the point of release into the receiving water body to the region of the organism's habitat.

Combining equations 3-1 and 3-2 yields the dose rate in rad/d to the primary organism, as shown in equation 3-3 below. The calculation of internal dose from tissue concentration is the same as equations 3-1 and 3-2, except the radionuclide-specific BCF is not used and correction for decay and dilution is unnecessary.

$$R_c = \sum_{i=1}^{N} C_{i,c} B_{i,c} \epsilon_{i,c} \quad (3\text{-}3)$$

For a secondary organism, such as an herbivore or carnivore, an expression can be written for a single radionuclide equating the change in body burden to the uptake and removal of the radionuclide.

3.3.3.5. Dose From Water Exposure

Table 3-4 shows the CRITR2 code calculations of organism dose from water exposure to various radionuclides. Appendix B provides a more detailed listing of CRITR2 code calculations and bioaccumulation factors used. Water concentrations were maximum values for the 2-year period. Table 3-4 indicates internal dose, immersion or surface dose (external water dose), and sediment dose. Internal exposure gave the maximum dose. Since immersion and sediment doses made only minor contributions, they were not considered in the risk characterization.

Table 3-4 summarizes dose for each organism. CRITR2 default organisms are generic plants, fish, crayfish, and ducks that eat plants and fish (DUCK-P and DUCK-F, respectively). Plant-eating ducks had the maximum dose rate, followed by plants, crayfish, fish, and fish-eating ducks. The dose rates to the plant-eating duck and crayfish exceeded the 1 rad/d level. The maximally exposed fish had a dose rate of 0.42 rad/d.

The dose to salmon eggs was estimated from measured river water radionuclide activities (table 3-3). Bioconcentration factors were estimated for salmon embryos from bioconcentration data reported for developing plaice (*Pleuronectes platessa*) embryos with respect to various fission product radionuclides (Woodhead, 1970). Concentration factors for day 4 of embryonic development ranged from <1 to 10 as a function of the radionuclide. This assessment used a whole egg concentration factor of 10 for all radionuclides shown in table 3-3. Dose calculations employed an overall egg diameter of 2 mm. Dose to whole eggs was 0.00442 rad/d.

3.3.3.6. Dose From Measured Tissue Concentrations

Table 3-5 lists calculated dose from measured tissue concentrations to selected organisms in the Columbia River. Phytoplankton had the highest dose at 14 rad/d, followed by limpet hard parts (shell) at 0.39 rad/d and caddisfly at 0.38 rad/d. The maximally exposed fish dose was calculated to be 0.73 rad/d. For fish, table 3-5 concentrations used to calculate dose represent the maximum values observed for whitefish during 1963-1964. Dose was evaluated for other species, but whitefish had the highest body dose for the study period. Unfortunately, most of the fish data were muscle tissue concentrations and therefore underestimated whole-body burdens. Consequently, the assessment adjusted these values to whole-body values. Based on limited Hanford data and published literature, the correction factors between whole body and muscle were 9:1 for phosphorus-32 and chromium-51 and 4:1 for zinc-65 (Poston and Strenge, 1989; U.S.

Table 3-4. CRITR2 Code Calculation of Organism Dose From Water Exposure to Various Radionuclides (Baker and Soldat, 1992)

OUT File Name: RMAX.OUT Created: 09:52 18-MAY-92

USR File Name and Header: RMAX.USR RMAX.USR Columbia River Max Concentrations 18 May 92

Version of Program used: V 1.0 of 26-Mar-92

****** CRITR2 -- Aquatic Biota Screening Dose Rates ******

TITLE: Columbia River Max Concentrations -- Ecological Risk Assessment

Organism Dose Rates

	Release	Plant	Fish	Crayfish	Duck-P	Duck-F
	Ci/y	---------- Internal (rad/d) ----------				
AS-76	---	3.9E-02	3.9E-02	3.9E-02	3.1E-03	6.1E-03
CO-60	---	2.7E-03	8.9E-04	2.9E-03	1.1E-03	7.3E-04
CR-51	---	2.7E-02	1.4E-04	7.1E-03	1.0E-02	1.0E-04
CU-64	---	1.6E-01	2.0E-01	2.8E-02	6.0E-03	1.5E-02
I-131	---	1.3E-04	2.1E-05	3.7E-05	1.4E-04	4.6E-05
NA-24	---	3.0E-02	3.0E-02	2.2E-02	2.6E-03	5.1E-03
NP-239	---	1.8E-02	1.5E-01	1.8E-03	6.2E-06	1.0E-04
P-32	---	1.1E+01	3.8E-03	2.2E+00	1.8E+01	1.2E-02
SR-90	---	4.6E-04	7.6E-06	1.5E-05	4.8E-03	1.6E-04
ZN-65	---	1.6E-01	5.0E-04	3.6E-02	1.6E+00	1.0E-02
Totals ------->		1.2E+01	4.2E-01	2.4E+00	1.9E+01	4.9E-02
	Ci/y	---------- Immersion or Surface (rad/d) ----------				
AS-76	---	3.0E-05	3.0E-05	1.5E-05	1.7E-05	1.7E-05
CO-60	---	9.3E-06	9.3E-06	4.6E-06	5.1E-06	5.1E-06
CR-51	---	2.4E-05	2.4E-05	1.2E-05	1.3E-05	1.3E-05
CU-64	---	5.6E-05	5.6E-05	2.8E-05	3.1E-05	3.1E-05
I-131	---	3.9E-07	3.9E-07	1.9E-07	2.1E-07	2.1E-07
NA-24	---	7.9E-04	7.9E-04	4.0E-04	4.4E-04	4.4E-04
NP-239	---	2.9E-05	2.9E-05	1.4E-05	1.6E-05	1.6E-05
P-32	---	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SR-90	---	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ZN-65	---	3.2E-05	3.2E-05	1.6E-05	1.8E-05	1.8E-05
Totals ------->		9.7E-04	9.7E-04	4.9E-04	5.3E-04	5.3E-04
	Ci/y	---------- Sediment (rad/d) ----------				
AS-76	---	2.9E-06	2.9E-06	5.9E-06	1.2E-06	1.2E-06
CO-60	---	1.8E-04	1.8E-04	3.5E-04	7.1E-05	7.1E-05
CR-51	---	6.5E-05	6.5E-05	1.3E-04	2.6E-05	2.6E-05
CU-64	---	2.8E-06	2.8E-06	5.7E-06	1.1E-06	1.1E-06
I-131	---	3.0E-07	3.0E-07	6.0E-07	1.2E-07	1.2E-07
NA-24	---	3.4E-05	3.4E-05	6.8E-05	1.4E-05	1.4E-05
NP-239	---	6.9E-06	6.9E-06	1.4E-05	2.8E-06	2.8E-06
P-32	---	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SR-90	---	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ZN-65	---	4.3E-04	4.3E-04	8.5E-04	1.7E-04	1.7E-04
Totals ------->		7.1E-04	7.1E-04	1.4E-03	2.9E-04	2.9E-04
Grand Totals >>>>>		1.2E+01	4.3E-01	2.4E+00	1.9E+01	5.0E-02

Table 3-4. CRITR2 Code Calculation of Organism Dose From Water Exposure to Various Radionuclides (continued)

OUT File Name: RMAX.OUT Created: 10:21 18-MAY-92

USR File Name: RMAX.USR

Version of Program used: V 1.0 of 26-Mar-92

Parameters and Water Concentrations

No dilution model used.

Bioaccumulation Factors for: Fresh No bioaccumulation factor corrections used.

	Release Outfall Concentration	Plant	Fish	Crayfish	Duck-P	Duck-F
Distance (m) ------		1	1	1	1	1
Mixing Ratio ------		1	1	1	1	1
Radius (cm) -------		5.0	5.0	2.0	5.0	5.0
Mass (kg) ---------		--	--	--	1.0	1.0
Intake rate (g/d) -		--	--	--	100	200
Diet ----------		--	--	--	P	F
Transit Time (h) --		0	0	0	0	0

Water Concentrations , (Decay during transit included)

	H. L.	--Ci/y-	Ci/m3 or uCi/mL					
AS-76	26.32 H	---	2.3E-06	2.3E-06	2.3E-06	2.3E-06	2.3E-06	2.3E-06
CO-60	5.271 Y	---	1.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07
CR-51	27.704 D	---	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05
CU-64	12.701 H	---	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05
I-131	8.04 D	---	3.4E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08
NA-24	15.00 H	---	5.6E-06	5.6E-06	5.6E-06	5.6E-06	5.6E-06	5.6E-06
NP-239	2.355 D	---	5.6E-06	5.6E-06	5.6E-06	5.6E-06	5.6E-06	5.6E-06
P-32	14.29 D	---	6.3E-07	6.3E-07	6.3E-07	6.3E-07	6.3E-07	6.3E-07
SR-90	29.12 Y	---	2.6E-09	2.6E-09	2.6E-09	2.6E-09	2.6E-09	2.6E-09
ZN-65	243.9 D	---	1.8E-06	1.8E-06	1.8E-06	1.8E-06	1.8E-06	1.8E-06

Table 3-5. Calculated Dose Based on Tissue Concentration for Selected Organisms of the Columbia River[a]

	Tissue Concentration (pCi/g wet weight)							
Organism	Na-24	Cr-51	Mn-56	Cu-64	Zn-65	La-140	P-32	Total
Plankton	1,414	59,500	291,000	102,000	14,000	5.900	23,000	14.8
Dose, rad/d	5.2E-2	6.8E-3	13.1	0.70	0.021	0.21	0.80	
Caddisfly	764	1,390	6,490	8,560	2,980			
Dose, rad/d	0.028	1.6E-4	0.29	0.058	3.1E-3			0.38
Chironimids	1,595	1,940	1,700	2,230	658	113		
Dose, rad/d	0.058	2.2E-4	0.076	0.015	9.7E-4	4.4E-3		0.15
Limpets (soft parts)	1,595	1,940	2,230	4,500	2,820	73		
Dose, rad/d	0.050	2.2E-4	0.076	0.031	4.2E-3	2.6E-3		0.17
Limpets (shell)	644	1,080	7,480	2,230	658	113		
Dose, rad/d	0.024	1.2E-4	0.35	0.015	9.7E-4	4.0E-3		0.39
Clams (soft parts)	393	620	556	3,320	1,100	47		
rad/d	0.014	7.0E-5	0.025	0.022	1.6E-3	1.7E-3		0.065
Clam (shell)	136	181	617	383	441	5		
Dose, rad/d	5.0E-3	2.1E-5	0.028	2.6E-3	6.5E-4	1.8E-4		0.036
Crayfish	955	536	982	48	811	12		
Dose, rad/d	0.035	6.1E-5	0.044	5.1E-3	1.2E-3	4.5E-4		0.085
Fish (whitefish)					270		20,700	
Dose, rad/d					1.7E-3		0.73	0.73

[a]Using minimum effective radius of 1.4 cm.

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Congress, Joint Committee on Atomic Energy, 1959). This correction introduces uncertainty into the effects characterization, but uncorrected muscle values could underestimate individual dose.

3.3.3.7. Dose From Measured Sediment Concentrations

Table 3-6 shows the calculated dose from exposure to radioactivity reported in sediments of the Columbia River. The calculated dose was quite small compared with other pathways.

Comments on Characterization of Exposure

Strengths of the case study include:

- *The ability to evaluate the worst case (maximally exposed individual) at the most sensitive life stage is an efficient method of screening for population-level effects. This study also benefits from the availability of long-term data sets collected on site.*

Limitations include:

- *Analysis also should consider potential uptake from food rather than only exposure or direct uptake from the water. Large variance in BCF values suggest that activity in water cannot reliably predict exposure.*
- *In the computer model scenario, algae, crayfish, and fish were not growing or eating and did not accumulate a food chain dose. Although the computer code included ducks, they were not included in the ecological risk assessment because of limited data and limited ability to verify the model estimate.*

3.3.4. Analysis: Characterization of Ecological Effects

Characterization of effects was based on dose-response information for fish from available toxicity data and also on regulatory standards. Conducted at the individual level, the characterization was interpreted qualitatively and applied to the population level of ecological organization.

The general response of aquatic organisms to ionizing radiation occurs at both the cellular and biochemical levels. Environmental factors also can affect the level of response. An NCRP (1991) report, *Effects of Ionizing Radiation on Aquatic Organisms*, provided the basis for stressor-response relationships developed in this report. Figures 3-5 and 3-6 were adapted from the NCRP report and summarize the information on acute effects of ionizing radiation on aquatic organisms.

One would expect different fish species to accumulate different concentrations of radionuclides based on their feedings habits, age, length of time spent at the site, and other factors. Depending on the level of exposure, mortality can occur. The threshold level of radiation dose

Table 3-6. Maximum Sediment Radionuclide Concentrations in the Hanford Reach and Dose to an Organism Living in the Sediments (Dirkes, 1992; Haushild et al., 1966; Nelson et al., 1964)

Nuclide	Concentration (pCi/Kg dry weight)[a]
Cr-51	13,000
Co-60	100
Sc-46	46
Zn-65	3,900

[a]Total dose: Organism buried in sediment—0.16 rad/d.
Organism on surface of sediment—0.08 rad/d.

that can cause acute mortality occurs at approximately 100 rad (1 Gy) for amphibians and 1,000 rad (10 Gy) for crustaceans and fish (figure 3-5). Figure 3-5 summarizes the relationship between organism dose and response and also shows the range for LD_{50}s. Under no circumstances did calculated dose to fish or other organisms exceed the boundary dose where acute effects would be observed. Dose calculations based on tissue concentrations for selected Columbia River organisms confirmed this finding. No aquatic animal organism used in the risk assessment exceeded the DOE dose limit of 1 rad/d.

Few studies have evaluated the effects of chronic exposure to ionizing radiation. However, it is known that the early developmental stages of chinook salmon are especially sensitive to ionizing radiation. NCRP (1991) reported that exposure to 5.1 rad/d (51 mGy/d) for up to 69 days produced no increase in mortality to chinook salmon embryos and alevins up to release as smolts. Hershberger et al. (1978) reported lower return of spawning adult chinook salmon after exposure of eggs and alevins at approximately 10 rad/d of gamma radiation. Gonadal development was retarded in chinook salmon on exposure to 10 rad/d delivered to embryos (Bonham and Donaldson, 1972). Other laboratory research (Erickson, 1973) found that an exposure of 0.4 rad/d (4.0 mGy/d) reduced courting activity for male *Poecilia reticulata* exposed as embryos. Chronic gamma radiation (190 days at an exposure of 18.5 rad/d) causes sterility in young adult *Ameca splendens* (Rackham and Woodhead, 1984).

Based on available literature, the dose used in DOE Order 5400.5 appears sufficiently conservative to protect most aquatic organisms. Consequently, unless future data indicate otherwise, this dose can be considered protective of populations and the ecosystem in general. To date, the sole qualifier is the work of Erickson (1973), who reported reduced male guppy courting activity when exposed to 0.4 rad/d. Little other information exists with regard to behavioral changes in fish exposed to ionizing radiation.

Figure 3-6 summarizes the effects of acute irradiation on development of fish. The threshold for developmental effects on fish occurs at approximately 5 rad (0.05 Gy), as observed for the one-cell-stage developing chinook salmon embryos. Radiosensitivity reportedly decreases

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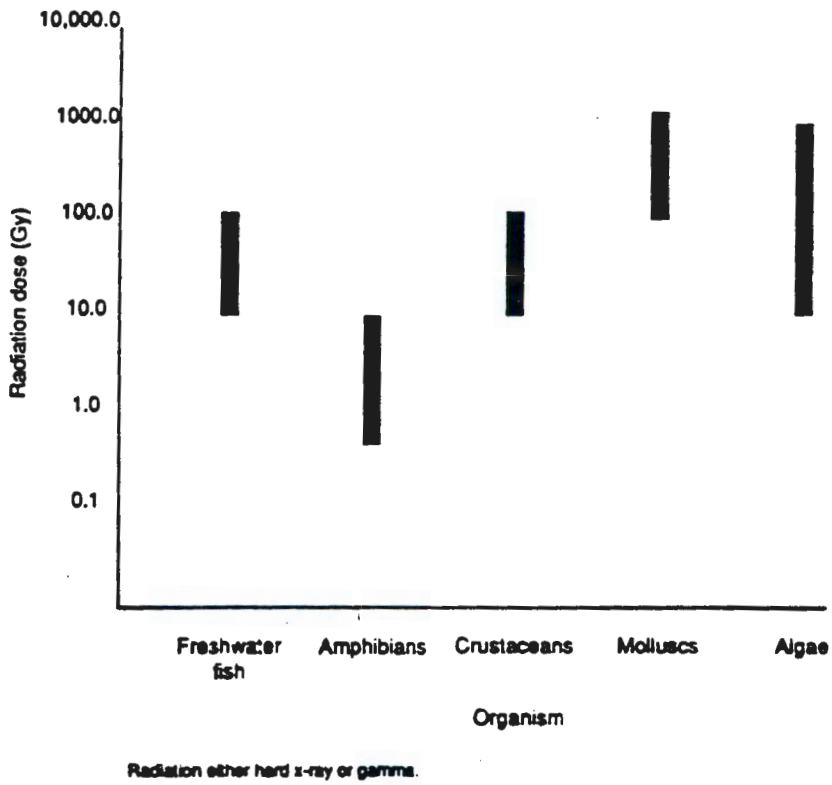

Figure 3-5. Ranges of sensitivities of aquatic organisms to acute radiation exposure (adapted from NCRP, 1991)

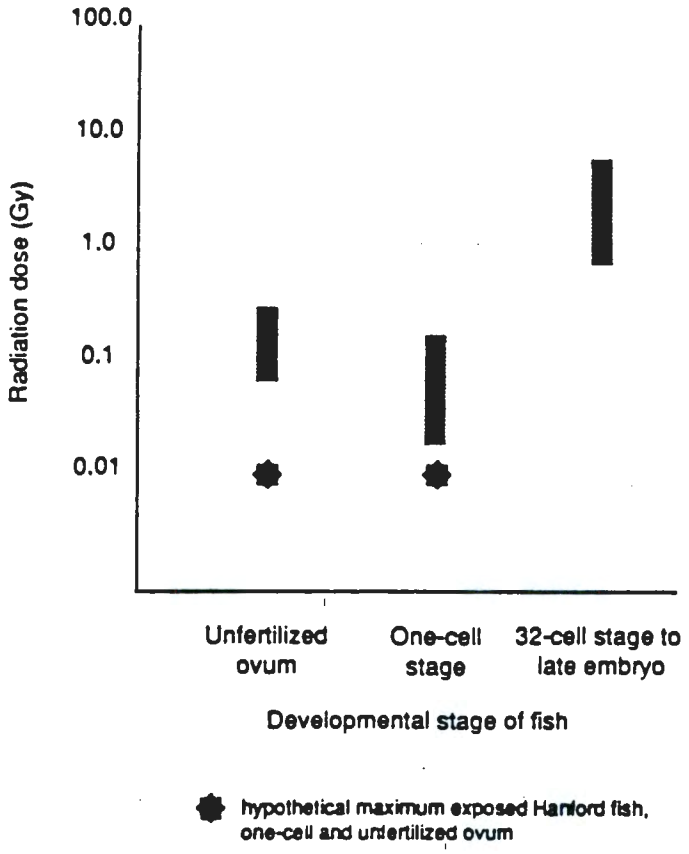

Figure 3-6. Ranges of sensitivities of the early developmental stages of fish to acute exposures (adapted from NCRP, 1991)

with increasing level of embryo development (Frank, 1973). Laboratory studies with the chinook salmon identify early life stages as the most sensitive for fish. Damage occurred when the dose reached 9.64 rad/d (4 mGy/h) over an 81-day development period (Hyodo-Taguchi, 1980). Studies have shown that 224 rad (2.24 Gy) reduced female germ cells in chinook salmon; a dose of 600 rad (6 Gy) produced the same effect in rainbow trout.

Comments on Characterization of Ecological Effects

Strengths of the case study include:

- *Direct experimental observations (dose-response curves) were provided to characterize effects. Figures 3-5 and 3-6 include ranges of acute toxicity data for various taxonomic groups and different life stages of salmon.*

General reviewer comments:

- *It was suggested that more sensitive measures than mortality should be used to assess effects. Dose-response curves could be provided to indicate the conservative nature of the DOE regulatory limit.*
- *No data are presented to show that protecting salmon embryos protects the ecosystem.*

3.3.5. Risk Characterization

Ecological risk was characterized by assessing dose to fish and, as indicators of ecosystem integrity, other aquatic organisms; by comparing doses to DOE Order 5400.5; and by comparing doses to published toxicity data.

3.3.5.1. Acute Exposure to Ionizing Radiation

The level of potential risk from ionizing radiation was assessed for fish under both acute and chronic exposure scenarios. The acute exposure considered mortality, while chronic exposure considered developmental effects as measurement endpoints.

To determine the potential risk to fish, both water and organism concentrations of radionuclides were converted to dose (tables 3-4 and 3-5, respectively). A comparison of these values (0.43 and 0.73 rad/d) to the range of acute toxicity (LD_{50}) reported for fish shows that no acute mortality would be expected from these levels. To assess exposure effects on a developing embryo, the whole egg dose was calculated to be 0.00442 rad/d.

The characterization of the level of potential risk to fish during early developmental stages and as adults was expressed as a hazard quotient (HQ), defined as the ratio of radionuclide organism dose (exposure or tissue value) to a dose-response benchmark value:

$$HQ = \frac{\text{Exposure Dose}}{\text{Dose Benchmark Value}} \tag{3-4}$$

If the HQ is equal to or greater than 1, the likelihood of an adverse effect or high risk exists. The characterization was completed for the maximally exposed individual for the study period. It was assumed that if risk to the individual was low, the population was not at risk.

The hazard quotients shown in table 3-7 for early developmental stages of fish and adults were compared with toxicity values and DOE Order 5400.5. The maximum hazard quotient was 0.73 for adult fish. Assuming that this was the maximally exposed individual, the likelihood of an adverse effect to an individual was low.

Table 3-7. Hazard Quotient for Early Development Stage of Fish and Adult Fish

	Maximum Exposure	Minimum Effect Level	Hazard Quotient
Unfertilized ovum, One-cell stage	0.00442	0.96,[a] 0.4[b]	0.004,[a] 0.11[b]
Adult	0.73	1	0.73[a,c]

[a]Based on recommendation of the NCRP (1991).
[b]Based on male courting activity in guppies (Erickson, 1973).
[c]DOE Order 5400.5.

3.3.5.2. Chronic Exposure to Ionizing Radiation

Mortality from chronic exposure presented minimal risk to fish. Chronic exposure to 5.1 rad/d for up to 69 days did not produce any mortality to chinook salmon embryos or alevins (NCRP, 1991). Hershberger et al. (1978) reported lower return of spawning chinook salmon after exposure of eggs and alevins to 10 rad/d and effects on gonadal development in chinook salmon was reported to occur at 9.5 rad/d. Because the maximum dose rate to Columbia River adult fish and developing embryos was 0.73 and 0.00442 rad/d respectively, no chronic effects or mortality would be expected. Applying the behavior response noted for guppy embryo exposure (Erickson, 1973), the benchmark concentration would be 0.4 rad/d with an HQ of 0.1.

3.3.5.3. Uncertainty

Extrapolation of individual effects of radionuclides to populations and communities suffers from the same constraints as similar extrapolations for hazardous chemicals. The quantitative

relationship between potential effects to fish or fish embryos and population and community response is not known. However, the effects data available for radionuclides showed that the single-cell stage in salmon is one of the more sensitive indicators of irradiation effects in fish and that protection of this stage of development should be protective of the population. Although specific data were not available for salmon embryo, data for embryo development of plaice was used to estimate dose.

The NCRP (1991) suggests that a "maximum dose rate 0.4 mGy/h (0.96 rad/d) would provide protection for endemic populations of aquatic organisms in environments receiving discharges of radioactive effluent." It further states, "adoption of a reference level of 0.4 mGy/h appears to represent a reasonable compromise based on current literature, i.e., considering both the nature of the effects observed at this dose rate and the limited amount of information on effects of radiation in natural populations, including interactions between ionizing radiation and ecological conditions." This value is also in agreement with DOE Order 5400.5.

Because whitefish are resident species in the Columbia River and can accumulate radionuclides throughout their life cycle, the assessment assumed that the whitefish tissue dose would be sufficiently conservative to extrapolate dose levels to other adult fish, including salmon. Salmon, on the other hand, spend only a short period of time in the river and do not feed when present. In addition, during the spring and early fall when salmon are present, river concentrations of radionuclides were generally the lowest.

The risk characterization used the maximally exposed individual to calculate organism dose. The risk characterization assumed that if an organism dose is below any known effect level with some degree of certainty, then the likelihood of an adverse effect is minimal. (The assessment endpoint was maintenance of important recreational fish populations in the Columbia River measured by protection of fish populations and specifically salmon embryos.) Results indicate that this is a reasonable assumption. Fish appear to be a suitable choice of receptor for screening risk from ionizing radiation. In addition, a fish dose of less than 1 rad/d should be protective of the ecosystem in general. However, since CRITR2 indicate that ducks could have received a dose higher than 1 rad/d, further studies are warranted.

Another area of uncertainty in the risk assessment is the extrapolation of muscle tissue concentration to whole fish concentrations for radionuclides. The assumption that protection of the maximally exposed individual extrapolated to sensitive life stages constitutes an adequate measure of the assessment endpoint also is a source of uncertainty. Alternatively, the hazard quotient is a reasonable approach for radionuclides for baseline or screening assessments.

3.3.5.4. Conclusions

This study demonstrates that the ecological risk assessment paradigm is applicable to radioactive substances. However, stressor-response data were limited to acute exposures; few data addressed chronic sublethal exposures. Most endpoints used for hazardous chemicals are expected to be equally appropriate for radionuclides. This study uncovered only one benchmark that specifically addressed protecting aquatic organisms from exposure to radiation. DOE Order 5400.5 limits exposure to aquatic animals to 1 rad/d.

Risk characterization did not indicate any measurable risk to the most sensitive aquatic organism (early life stage of chinook salmon) from exposure to radionuclides in sediments or water in the Columbia River. During peak production at Hanford, releases of radionuclides to the river did not result in a dose to fish that would exceed those specified in DOE Order 5400.5.

Dose calculations for radionuclide exposure from water and tissue concentrations provide for two methods for assessing the potential risks. This study investigated both methods and found that both provided reasonable results for fish, algae, and crayfish. Areas of uncertainty included the relationship between muscle and whole fish concentrations, the lack of a strong data base for organism exposure to chronic radiation, and a quantitative measure of ecosystem-level response to radionuclides. During the study period, the major thrust of monitoring at Hanford was to protect human health. Few studies examined ecosystem structure and function. Another significant area of uncertainty was the use of adult whitefish tissue concentration as a surrogate for chinook salmon. The study located no data suggesting that salmon accumulate a higher dose than whitefish, which spend their whole lives in the Columbia River. Although using fish data tends to increase uncertainty, fish are particularly sensitive to ionizing radiation and should provide a reasonable level of protection for fish populations and communities (figures 3-5 and 3-6) and a screen or benchmark indicator of ecosystem-level effects.

Comments on Risk Characterization

Strengths of the case study include:

- *The case study provides an opportunity to distinguish between screening assessments and more rigorous (realistic) assessments. The CRITR2 computer model is intended to provide a first pass that can be refined if there appear to be significant concerns.*

Limitations include:

- *The hazard quotient should be described in more detail by addressing the potential range of values, the establishment of confidence intervals, the degree of confidence that the value of 1.00 is safe, etc. This study uses the most sensitive individual to be conservative, but the selection of the most sensitive or highest exposed individual biases the assessment. The establishment of confidence bounds would result in a less biased measure of uncertainty.*
- *Many assumptions are chained together in this case study to obtain highly conservative assessments. A table should be developed that specifies these assumptions and the types of uncertainties they introduce.*
- *The focus on salmon limits an extrapolation to overall ecosystem effects.*

Comments on Risk Characterization (continued)

General reviewer comments:

- *This section should emphasize that risk to the salmon populations is based on an analysis of risk to the most sensitive individuals and that risk from chemical exposure or other stressors was not evaluated. Nevertheless, risk from radionuclides is addressed adequately.*
- *It would be helpful to have additional emphasis placed on estimating and using variability and confidence intervals. This could be the primary content for the section on uncertainty analysis.*

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APPENDIX A

COLUMBIA RIVER FISH SPECIES AND FOOD WEB

Table 3-A1. Fish Species in the Hanford Reach of the Columbia River

Common Name	Scientific Name
White sturgeon	*Acipenser transmontanus*
Bridgelip sucker	*Catostomus columbianus*
Largescale sucker	*Catostomus macrocheilus*
Mountain sucker	*Catostomus platyrhynchus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
American shad	*Alosa sapidissima*
Prickly sculpin	*Cottus asper*
Mottled sculpin	*Cottus bairdi*
Piute sculpin	*Cottus beldingi*
Reticulate sculpin	*Cottus perplexus*
Torrent sculpin	*Cottus rotheus*
Chiselmouth	*Acrocheilus alutaceus*
Carp	*Cyprinus carpio*
Peamouth	*Mylocheilus caurinus*
Northern squawfish	*Ptychocheilus oregonensis*
Longnose dace	*Rhinichthys cataractae*
Leopard dace	*Rhinichthys falcatus*
Speckled dace	*Rhinichthys osculus*
Redside shiner	*Richardsonius balteatus*
Tench	*Tinca tinca*
Burbot	*Lota lota*

Table 3-A1. Fish Species in the Hanford Reach of the Columbia River (continued)

Common Name	Scientific Name
Threespine stickleback	*Gasterosteus aculeatus*
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Brown bullhead	*Ictalurus nebulosus*
Channel catfish	*Ictalurus punctatus*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Sand roller	*Percopsis transmontana*
Pacific lamprey	*Entosphenus tridentatus*
River lamprey	*Lampetra ayresi*
Lake whitefish	*Coregonus clupeaformis*
Coho salmon	*Oncorhynchus kisutch*
Sockeye salmon	*Oncorhynchus nerka*
Chinook salmon	*Oncorhynchus tshawytscha*
Mountain whitefish	*Prosopium williamsoni*
Cutthroat trout	*Oncorhynchus clarki*
Rainbow trout (steelhead)	*Oncorhynchus mykiss*
Dolly Varden trout	*Salvelinus malma*

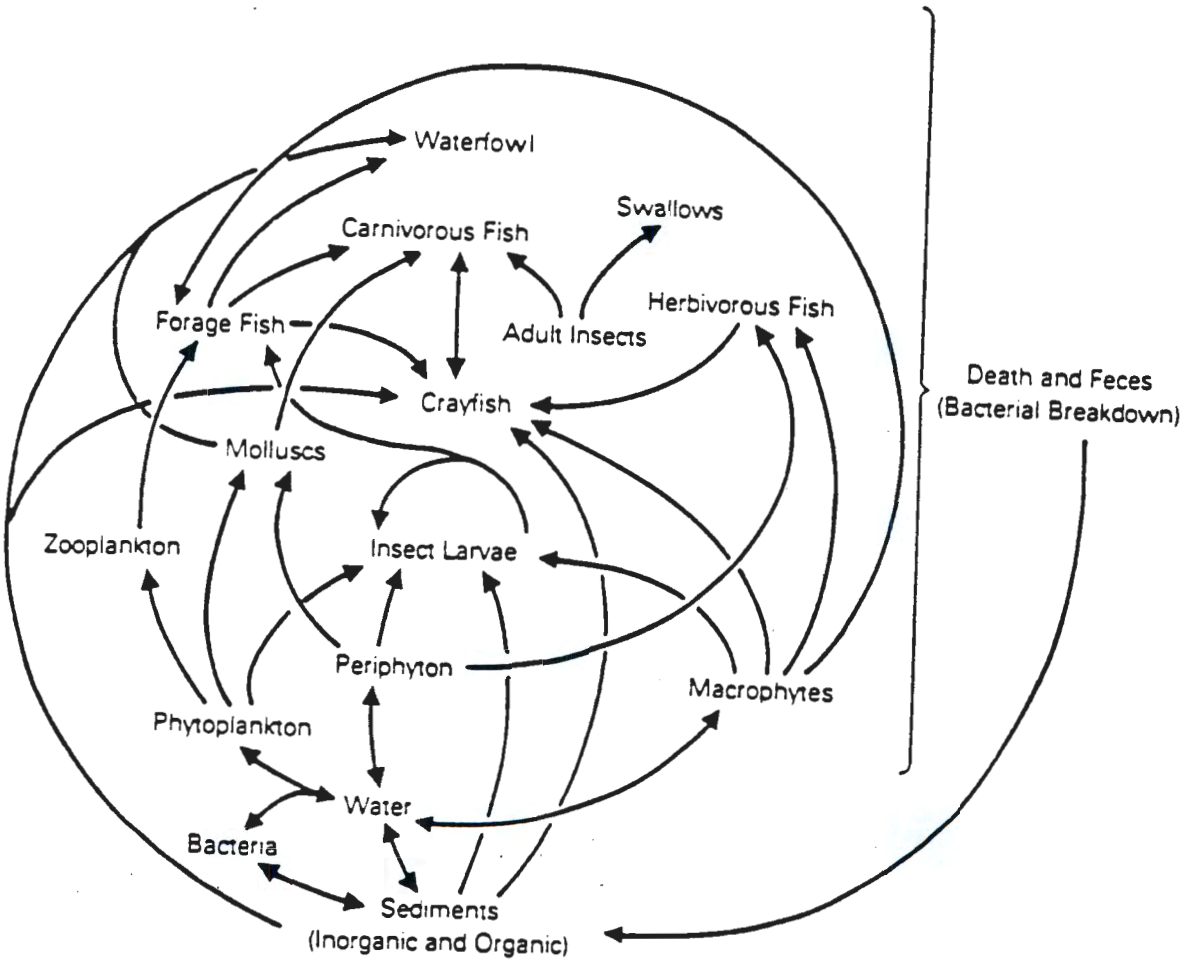

Figure 3-A1. Columbia River aquatic ecosystem

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APPENDIX B

CRITR2 CODE CALCULATIONS AND BIOACCUMULATION FACTORS

CRITR Code Calculation of Organism Dose from Water Exposure to Various Radionuclides

CRITR QA Printout --- User File: RMAX.USR Run of: 09:52 18-MAY-92

No Dilution Model used.

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
3.5E-12	3.2E-11	6.9E-02	0.2	3.7E+02	1.6E+00	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
1	1	AS-76	P	8.5E+04	3.0E-01	1.000	0.000	1.5E-08	280.0	5.0E-01	0.0E+00	0.0	3.9E-04	PLANT	eats -
1	2	AS-76	F	8.5E+04	3.0E-01	1.000	0.000	1.5E-08	280.0	5.0E-01	0.0E+00	0.0	3.9E-04	FISH	eats -
1	3	AS-76	C	8.5E+04	3.0E-01	1.000	0.000	1.5E-08	280.0	5.0E-01	0.0E+00	0.0	3.9E-04	CRAWDAD	eats -
1	4	AS-76	P	8.5E+04	3.0E-01	1.000	0.100	1.5E-08	280.0	5.0E-01	6.3E-01	1.0	3.1E-05	DUCK-P	eats P
1	5	AS-76	F	8.5E+04	3.0E-01	1.000	0.200	1.5E-08	280.0	5.0E-01	6.3E-01	1.0	6.1E-05	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
2.1E-11	1.7E-10	6.9E-02	0.2	3.7E+02	3.4E+02	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
2	1	CO-60	P	4.4E+03	1.0E+00	1.000	0.000	6.0E-09	9.5	3.0E-01	0.0E+00	0.0	2.7E-05	PLANT	eats -
2	2	CO-60	F	4.4E+03	3.3E-01	1.000	0.000	6.0E-09	9.5	3.0E-01	0.0E+00	0.0	8.9E-06	FISH	eats -
2	3	CO-60	C	4.4E+03	2.0E+00	1.000	0.000	3.3E-09	9.5	3.0E-01	0.0E+00	0.0	2.9E-05	CRAWDAD	eats -
2	4	CO-60	P	4.4E+03	1.0E+00	1.000	0.100	6.0E-09	9.5	3.0E-01	7.3E-02	1.0	1.1E-05	DUCK-P	eats P
2	5	CO-60	F	4.4E+03	3.3E-01	1.000	0.200	6.0E-09	9.5	3.0E-01	7.3E-02	1.0	7.3E-06	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
2.6E-13	2.5E-12	6.9E-02	0.2	3.7E+02	4.0E+01	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
3	1	CR-51	P	9.3E+05	4.0E+00	1.000	0.000	7.3E-11	616.0	1.0E-01	0.0E+00	0.0	2.7E-04	PLANT	eats -
3	2	CR-51	F	9.3E+05	2.0E-02	1.000	0.000	7.3E-11	616.0	1.0E-01	0.0E+00	0.0	1.4E-06	FISH	eats -
3	3	CR-51	C	9.3E+05	2.0E+00	1.000	0.000	3.8E-11	616.0	1.0E-01	0.0E+00	0.0	7.1E-05	CRAWDAD	eats -
3	4	CR-51	P	9.3E+05	4.0E+00	1.000	0.100	7.3E-11	616.0	1.0E-01	2.6E-02	1.0	1.0E-04	DUCK-P	eats P
3	5	CR-51	F	9.3E+05	2.0E-02	1.000	0.200	7.3E-11	616.0	1.0E-01	2.6E-02	1.0	1.0E-06	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
1.5E-12	1.4E-11	6.9E-02	0.2	3.7E+02	7.6E-01	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
4	1	CU-64	P	3.7E+05	2.0E+00	1.000	0.000	2.1E-09	80.0	5.0E-01	0.0E+00	0.0	1.6E-03	PLANT	eats -
4	2	CU-64	F	3.7E+05	2.5E+00	1.000	0.000	2.1E-09	80.0	5.0E-01	0.0E+00	0.0	2.0E-03	FISH	eats -
4	3	CU-64	C	3.7E+05	4.0E-01	1.000	0.000	1.9E-09	80.0	5.0E-01	0.0E+00	0.0	2.8E-04	CRAWDAD	eats -
4	4	CU-64	P	3.7E+05	2.0E+00	1.000	0.100	2.1E-09	80.0	5.0E-01	1.3E+00	1.0	6.0E-05	DUCK-P	eats P
4	5	CU-64	F	3.7E+05	2.5E+00	1.000	0.200	2.1E-09	80.0	5.0E-01	1.3E+00	1.0	1.5E-04	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
3.1E-12	3.0E-11	6.9E-02	0.2	3.7E+02	1.2E+01	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
5	1	I-131	P	1.3E+03	3.0E-01	1.000	0.000	3.4E-09	100.0	1.0E+00	0.0E+00	0.0	1.3E-06	PLANT	eats -
5	2	I-131	F	1.3E+03	5.0E-02	1.000	0.000	3.4E-09	100.0	1.0E+00	0.0E+00	0.0	2.1E-07	FISH	eats -
5	3	I-131	C	1.3E+03	1.0E-01	1.000	0.000	2.9E-09	100.0	1.0E+00	0.0E+00	0.0	3.7E-07	CRAWDAD	eats -
5	4	I-131	P	1.3E+03	3.0E-01	1.000	0.100	3.4E-09	100.0	1.0E+00	9.3E-02	1.0	1.4E-06	DUCK-P	eats P
5	5	I-131	F	1.3E+03	5.0E-02	1.000	0.200	3.4E-09	100.0	1.0E+00	9.3E-02	1.0	4.6E-07	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
3.8E-11	2.6E-10	6.9E-02	0.2	3.7E+02	9.0E-01	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
6	1	NA-24	P	2.1E+05	1.0E-01	1.000	0.000	1.5E-08	11.0	1.0E+00	0.0E+00	0.0	3.0E-04	PLANT	eats -
6	2	NA-24	F	2.1E+05	1.0E-01	1.000	0.000	1.5E-08	11.0	1.0E+00	0.0E+00	0.0	3.0E-04	FISH	eats -
6	3	NA-24	C	2.1E+05	1.0E-01	1.000	0.000	1.1E-08	11.0	1.0E+00	0.0E+00	0.0	2.2E-04	CRAWDAD	eats -
6	4	NA-24	P	2.1E+05	1.0E-01	1.000	0.100	1.5E-08	11.0	1.0E+00	1.2E+00	1.0	2.6E-05	DUCK-P	eats P
6	5	NA-24	F	2.1E+05	1.0E-01	1.000	0.200	1.5E-08	11.0	1.0E+00	1.2E+00	1.0	5.1E-05	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
1.4E-12	1.4E-11	6.9E-02	0.2	3.7E+02	3.4E+00	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
7	1	NP-239	P	2.1E+05	3.0E-01	1.000	0.000	2.9E-09	39000.0	1.0E-03	0.0E+00	0.0	1.8E-04	PLANT	eats -
7	2	NP-239	F	2.1E+05	2.5E+00	1.000	0.000	2.9E-09	39000.0	1.0E-03	0.0E+00	0.0	1.5E-03	FISH	eats -
7	3	NP-239	C	2.1E+05	3.0E-02	1.000	0.000	2.8E-09	39000.0	1.0E-03	0.0E+00	0.0	1.8E-05	CRAWDAD	eats -
7	4	NP-239	P	2.1E+05	3.0E-01	1.000	0.100	2.9E-09	39000.0	1.0E-03	2.9E-01	1.0	6.2E-08	DUCK-P	eats P
7	5	NP-239	F	2.1E+05	2.5E+00	1.000	0.200	2.9E-09	39000.0	1.0E-03	2.9E-01	1.0	1.0E-06	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
0.0E+00	0.0E+00	6.9E-02	0.2	3.7E+02	2.1E+01	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
8	1	P-32	P	2.3E+04	5.0E+02	1.000	0.000	9.6E-09	257.0	8.0E-01	0.0E+00	0.0	1.1E-01	PLANT	eats -
8	2	P-32	F	2.3E+04	1.7E-01	1.000	0.000	9.6E-09	257.0	8.0E-01	0.0E+00	0.0	3.8E-05	FISH	eats -
8	3	P-32	C	2.3E+04	1.0E+02	1.000	0.000	9.6E-09	257.0	8.0E-01	0.0E+00	0.0	2.2E-02	CRAWDAD	eats -
8	4	P-32	P	2.3E+04	5.0E+02	1.000	0.100	9.6E-09	257.0	8.0E-01	5.1E-02	1.0	1.8E-01	DUCK-P	eats P
8	5	P-32	F	2.3E+04	1.7E-01	1.000	0.200	9.6E-09	257.0	8.0E-01	5.1E-02	1.0	1.2E-04	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
0.0E+00	0.0E+00	6.9E-02	0.2	3.7E+02	3.6E+02	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
9	1	SR-90	P	9.6E+01	3.0E+00	1.000	0.000	1.6E-08	4000.0	3.0E-01	0.0E+00	0.0	4.6E-06	PLANT	eats -
9	2	SR-90	F	9.6E+01	5.0E-02	1.000	0.000	1.6E-08	4000.0	3.0E-01	0.0E+00	0.0	7.6E-08	FISH	eats -
9	3	SR-90	C	9.6E+01	1.0E-01	1.000	0.000	1.6E-08	4000.0	3.0E-01	0.0E+00	0.0	1.5E-07	CRAWDAD	eats -
9	4	SR-90	P	9.6E+01	3.0E+00	1.000	0.100	1.6E-08	4000.0	3.0E-01	2.4E-04	1.0	4.8E-05	DUCK-P	eats P
9	5	SR-90	F	9.6E+01	5.0E-02	1.000	0.200	1.6E-08	4000.0	3.0E-01	2.4E-04	1.0	1.6E-06	DUCK-F	eats F

DFSWIM	DFSED	FSOLD	FRUF	TB	BUILDUP	TTRANS	EXP
4.8E-12	4.1E-11	6.9E-02	0.2	3.7E+02	2.3E+02	0.0E+00	1.0E+00

INUC	K	NUKSYMS	NS	CONCRIT	BIO	KB	RINTAKE	ECRIT	TBIO	F1	LAMC	MASS	DOSECRIT		
10	1	ZN-65	P	6.7E+04	2.0E+01	1.000	0.000	1.2E-09	933.0	5.0E-01	0.0E+00	0.0	1.6E-03	PLANT	eats -
10	2	ZN-65	F	6.7E+04	6.4E-02	1.000	0.000	1.2E-09	933.0	5.0E-01	0.0E+00	0.0	5.0E-06	FISH	eats -
10	3	ZN-65	C	6.7E+04	1.0E+01	1.000	0.000	5.3E-10	933.0	5.0E-01	0.0E+00	0.0	3.6E-04	CRAWDAD	eats -
10	4	ZN-65	P	6.7E+04	2.0E+01	1.000	0.100	1.2E-09	933.0	5.0E-01	3.6E-03	1.0	1.6E-02	DUCK-P	eats P
10	5	ZN-65	F	6.7E+04	6.4E-02	1.000	0.200	1.2E-09	933.0	5.0E-01	3.6E-03	1.0	1.0E-04	DUCK-F	eats F

Notes & Units:

Hanford biofactors used.

No bioaccumulation factor corrections used.

LAMDA	Rad. Decay constant	1/d	CONCRIT	Conc. in Water	Bq/m3
DFSWIM	Immersion DF	Sv/d per Bq	BIO	Bioaccum factor	m3/kg
DFSED	Sediment DF	Sv/d per Bq	RINTAKE	Intake rate	kg/d
FSOLD	Nuclide sed. buildup rate	m3/m2-d	ECRIT	Energy absorbed	J/Bq-d
FRUF	Roughness factor	--	TBIO	Biological half time	d
TB	Sed. Buildup time	d	F1	Fraction to total body	--
BUILDUP	Sed. Buildup	Bq-d/Bq	LAMC	Effective decay const.	1/d
TTRANS	Transport time	d	MASS	Organism mass	kg
EXP	Fractional decay during trans.	--	DOSECRIT	Organism Dose	Gy/d

Hanford-Specific Bioaccumulation Factors and Human Biological Half-Lives and Uptake Fractions (Baker and Soldat, 1992)

	Fish		Crustacean		Mollusc		Plant		T_b	f_1
	Fresh	Salt	Fresh	Salt	Fresh	Salt	Fresh	Salt		
	L/kg								d	
As	300	300	300	300	300	300	300	300	280	0.5
Cr	20	600	2000	500	2000	1140	4000	4000	616	0.1
Cs	2000	100	100	30	100	30	500	700	115	1
Cu	2500	1000	400	5000	400	5000	2000	1000	80	0.5
Fe	2000	3000	100	5000	100	30000	1000	50000	800	0.1
Mn	400	400	100000	800	100000	6000	10000	10000	17	0.1
Na	100	1	100	0.1	100	0.3	100	1	11	1
Ni	100	100	500	500	500	500	500	3000	667	0.05
Np	2500	2500	30	10	30	150	300	6	39000	0.001
P	170	28000	100000	38000	1100000	45000	500000	00000	257	0.8
Sc	100	750	1000	300	1000	100000	10000	1000	30	1E-4
Zn	64	1000	10000	50000	10000	30000	20000	50000	933	0.5

9613441.0238

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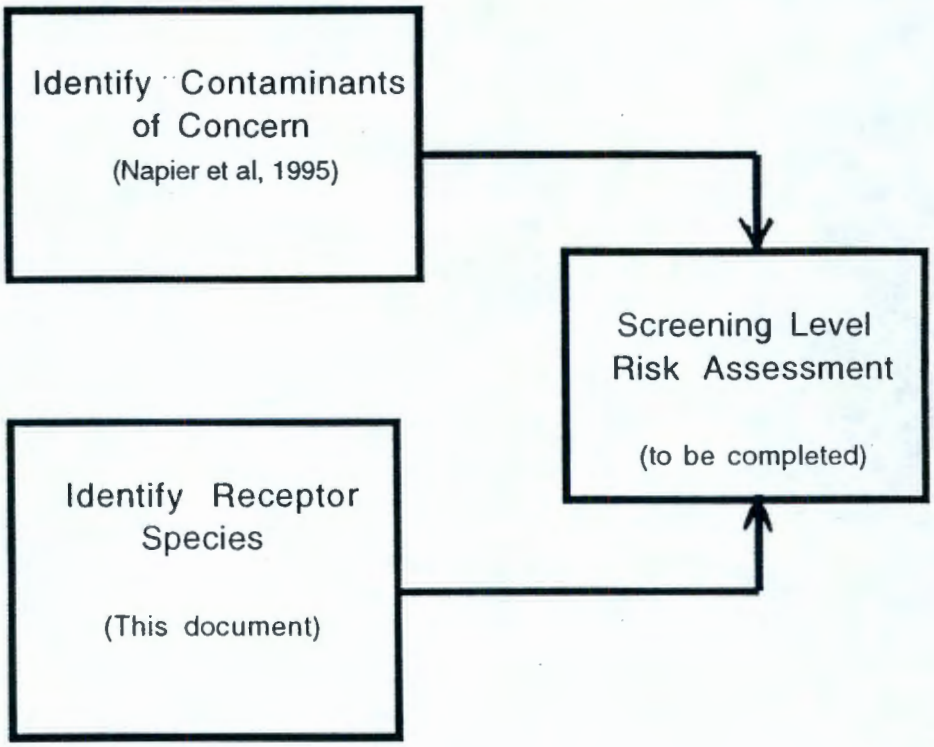
ATTACHMENT 2

REVIEWER 03 Figure Attachment

Section 4.0	Most of this is over the head of the non-technical person. The crucial question for them is: Was this methodology agreed upon with the other agencies? Some description of any consultation process used to develop the methodology would be helpful.