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Table 11-1. Summary of Uncertainties by Receptor

Tennessee Valley Authority Kingston, Tennessee

Receptor(s)	Line(s) of Evidence	Type	Description
All Receptors (Sections 3 - 10)	Tissue Concentrations, Abiotic Media, and Dietary Exposure Model	Analytical	Chemical and physical analyses were performed using the best commercially available methods and the results were reported to the lowest technically defensible level. Non-detected concentrations of all constituents were conservatively assumed to be present at the RL to compensate for this uncertainty. For percent moisture, sufficient sample volume or mass was not available for some biological media. Default wet weight to dry weight conversion factors were used in the absence of sample-specific results. This may bias the results high or low.
All Receptors (Sections 3 - 10)	Tissue Concentrations, Abiotic Media, and Dietary Exposure Model	River System Complexity	The study location consists of confluences of three river systems, potential legacy metals contamination in upstream reaches, and potential upstream migration and deposition of constituents. Each of these factors can confound interpretation of spatial trends, which subsequently introduces uncertainty into estimates of risk.
All Receptors (Sections 3 - 10)	Tissue Concentrations	Effects Values	Literature-derived effects values are not available for all constituents in all media. This is particularly an issue for CBRs. Potential risks are unknown in the absence of relevant dose-response relationships.
All Receptors (Sections 3 - 10)	Tissue Concentrations	Bioavailability of Constituents	Metal and metalloid COPECs bioavailability can be influenced by environmental conditions (e.g., pH, organic carbon content, and suspended solids) and the presence of other co-occurring elements. Risk estimates based on comparing measured media concentrations to literature-derived effects values are likely overestimates of risks, because the bioavailability of constituents in environmental media is expected to be less than in exposure media used in toxicity tests. Bioavailability of metal and metalloid COPECs to amphibians is conservatively estimated in this assessment and likely over-estimates of risks. For most species of wildlife and amphibians, the bioavailability of COPECs in environmental media is generally lower than in the exposure media used in toxicity tests.
All Receptors (Sections 3 - 10)	Tissue Concentrations	COPEC Selection	Essential elements were generally not analyzed or evaluated; however, both essential (e.g., potassium, magnesium, and iron) and non-essential (e.g., mercury, cadmium, and lead) can result in growth inhibition and toxicity.
All Receptors (Sections 3 - 10)	Tissue Concentrations	Representativeness of Exposure Periods	A portion of the samples were collected during or shortly after dredging was completed. Dredging occurred only in the Emory River reaches B and C, and engineering controls were used to minimize migration of disturbed sediment and ash. Therefore, the potential influence of dredging on tissue and egg concentrations is likely limited.
All Receptors (Sections 3 - 10)	Tissue Concentrations	Effects of COPEC Mixtures	Complex COPEC mixtures can have antagonistic or synergistic effects not elucidated in single-analyte toxicity studies. For example, selenium and arsenic have antagonistic modes of action, whereby doses of both in combination have lower toxicity than doses of each individually. Thus the risk estimates may be biased high for some COPECs such as selenium and arsenic.

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Receptor(s)	Line(s) of Evidence	Type	Description
All Receptors (Sections 3 - 10)	Surface Water	Site Data and Time Period of Collections	Surface water data used in this BERA were only collected during a relatively brief period in 2010, which may not reflect conditions during other seasons.
Fish (Section 3)	Toxicity Tests	Organism Sensitivity	Test procedures were based on standard testing protocols using laboratory-raised organisms which may be more or less sensitive than field organisms. Although the test durations were relatively short, sensitive life stages were tested, which should adequately reflect potential for adverse effects.
Fish (Section 3)	Tissue Concentrations	Analytical	Mercury analyses of fish muscle tissue were found to be biased and a CF of 1.3 was developed. It is yet unknown whether other tissues were similarly biased and, if so, what CF should be used. The fish fillet data used in the BERA were not re-evaluated using this CF. However, it is unlikely that a 30 percent increase in the reported concentrations would alter the characterization of risks to fish in this BERA, given the low concentrations and associated low risk of mercury.
Fish (Section 3)	Toxicity Tests	Recently Collected Data	In 2011 a fish developmental study was conducted on rehear sunfish and bluegill that were collected during the spring 2011 breeding season from up to five sites in the Emory and Clinch Rivers. Test endpoints included fertilization success, survival, hatching success, and incidences of developmental abnormalities through the yolk-absorption stage of development. Although the data are currently being evaluated, embryo larval survival for both species was relatively high >70% for all study sites with both sunfish species. This preliminary evaluation does not change the overall interpretation of risk to fish.
Fish (Section 3)	Tissue Concentrations	Recently Collected Data	A preliminary comparison of fish tissue concentrations of selected metals in samples collected in 2010 and 2011 was conducted. Metals included in this analysis were aluminum, arsenic, cadmium, copper, lead, selenium, and zinc. Samples from both the Emory and Clinch Rivers were included from all river reaches. Fillet samples of largemouth bass, bluegill, and channel catfish were included as well as whole body samples of gizzard shad with and without the gut or its contents. Considering all of the species, the seven metals previously mentioned, and all the sample reaches collectively, the average tissue concentrations went up slightly from 2010 to 2011 (4%). This preliminary evaluation does not change the overall interpretation of risk to fish.
Fish (Section 3)	Health and Reproduction	Applicability Towards Population-level Effects	These studies were carefully designed, but the actual implication of these measures towards population-level effects on fish is uncertain. For example, individual health responses can be highly variable as a function of location, season, and species, and it is uncertain whether these sub-lethal effects (e.g., changes in bioenergetic status) are predictive of ecologically significant health effects (i.e., obvious damage or injury).

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Table 11-1. Summary of Uncertainties by Receptor

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Receptor(s)	Line(s) of Evidence	Type	Description
Fish and Benthic Invertebrates (Sections 3 - 4)	Community Surveys	Number of Sampling Locations	The fish and benthic invertebrate community data represent a robust dataset with observations recorded for several locations and time periods, providing a relatively high degree of certainty that they are representative of current conditions and appropriately reflect the localized populations.
Fish and Benthic Invertebrates (Sections 3 - 4)	Toxicity Tests	Effects on Individuals Versus Populations	The toxicity evaluation for benthic invertebrates and fish used toxicological data that were collected on an individual basis, not at the population level.
Fish and Benthic Invertebrates (Sections 3 - 4)	Toxicity Tests	Effects of COPEC Mixtures	Complex COPEC mixtures can have antagonistic or synergistic effects not elucidated in single-analyte toxicity studies. For example, selenium and arsenic have antagonistic modes of action, whereby doses of both in combination have lower toxicity than dose.
Fish and Benthic Invertebrates (Sections 3 - 4)	Tissue Concentrations	Toxicity Benchmarks and CBRs	These benchmarks are not site-specific and there is a relatively high level of uncertainty in their application for evaluating risks, especially tissue CBRs. These benchmarks may not accurately predict actual risks, as evidenced by the fact that background tissue concentrations frequently exceed CBRs. There are also various practical constraints on the quantity and quality of available CBRs, and constituent interactions cannot be reliably predicted.
Benthic Invertebrates (Section 4)	Benthic Invertebrate Community	Changes in River Morphology	Upstream to downstream changes in river morphology and the presence of river confluences influences sediment characteristics and BIC compositions. The availability of comparable upstream reference locations was limited by change in morphology to more riverine conditions upstream of the Site.
Benthic Invertebrates (Section 4)	Sediment Toxicity Tests	Representativeness of Test Species	The species of laboratory test organisms (i.e., cladocerans, amphipods, and insect larvae) are assumed to be suitable and representative surrogates for the BIC at the Site. Species selected for study are generally those with a high degree of sensitivity to the COPECs being evaluated, with results being protective of certain sensitive species and conservative when used as representative for the overall community response.
Benthic Invertebrates (Section 4)	Sediment Toxicity Tests	Representativeness of Test Conditions	Toxicity data were derived from laboratory studies conducted in settings that do not reflect field conditions. Site water was used for the sediment toxicity tests to help reduce the uncertainty and have the toxicological exposures more closely resemble location conditions; however, other variables (e.g., aeration, pH, diet, light, and temperature) remained controlled.

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Receptor(s)	Line(s) of Evidence	Type	Description
Benthic Invertebrates (Section 4)	Tissue Concentrations	Recently Collected Data	Emory River BIC data collected in January 2012 was evaluated and compared with 2010 results. Emory River BIC habitat, composition, diversity, abundance, and metric results were generally consistent between the 2 years. Differences in the 2012 Emory River BIC data (taxa and counts) are correlated more to substrate type and water depth, similar to 2010, than percent ash composition or sediment chemistry. Snail and mayfly bioaccumulation data collected in 2011 from the Emory, Clinch, and Tennessee Rivers was evaluated and compared with 2010 results. While fluctuations in arsenic and selenium concentrations occurred at several reaches in the Emory, Clinch and Tennessee Rivers, this preliminary evaluation does not change the overall interpretation of risk.
Benthic Invertebrates (Section 4)	Abiotic Media	Representativeness of "Co-Located" Samples	Samples for BIC surveys, sediment and porewater chemistry, toxicity testing, physicochemical parameters, and water quality measurements were often collected at different locations and times. When possible, nearby samples were grouped together for the purpose of evaluating potential correlations.
Benthic Invertebrates (Section 4)	Abiotic Media	Physical Content/Conditions of the Sediment	Physicochemical parameters (e.g., grain size, organic content, and pH) may cause differences in the BIC structure and sediment toxicity test results that are unrelated to COPEC exposures. These factors may also affect bioaccessibility and bioavailability of COPECs and other constituents.
Plants (Section 5)	Tissue Concentrations	Inter-Species Extrapolations	Inter-species differences in bioaccumulation of metal and metalloid COPECs typically observed for aquatic plant species may bias the spatial trends observed in results. Aquatic plant species also exhibit wide ranges in their sensitivity to metal and metalloid COPECs. Together, these differences comprise the degree to which the available data adequately represent the range of aquatic plant exposures and sensitivities at the Site.
Plants (Section 5)	Tissue Concentrations	Representativeness of Sampled Tissues	The collection of plant biomass emerging from the ground or water may underestimate concentrations in aquatic vegetation, because plant roots can be significant source of accumulated metal and metalloid COPECs relative to aboveground biomass.
Plants, Birds, and Mammals (Sections 5 - 8)	Tissue Concentrations	Number of Samples	Relatively small sample sizes decrease statistical power and the ability to detect significant differences between groups. For aerial-feeding birds, simpler logistics allowed sample sizes, particularly in 2010 for eggs (n = 10 to 15), to be higher for the tree swallow egg tissue study than for the heron and osprey egg tissue studies reducing uncertainty for the tree swallow analyses. Sample sizes for eggshells and nestlings were not as robust, thus have reduced power to detect differences between reference and impacted locations. This could bias risk estimates low. However, instrument detection limits were used as worst-case estimates for egg concentrations that were below detection limits. This biases the risk estimates high for those COPECs.
Heron and Osprey (Section 6)	Tissue Concentrations	Time Period of Collections	Nests were visited only once per year, and not always during the best window of time to verify clutch size (sometimes just hatched nestlings were found).

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Receptor(s)	Line(s) of Evidence	Type	Description
Aquatic- or Riparian-Feeding Birds (Section 6)	Tissue Concentrations	Recently Collected Data	Representativeness of post-dredging exposures would be improved if 2011 egg data are included in the statistical analyses for the risk assessment. Some heron egg EPCs (maximum detected concentrations) were lower in 2011 than in 2010. Furthermore, 2011 maximum concentrations of selenium, mercury, and copper did not exceed potential adverse effect thresholds.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Applicability of Literature-Derived Dietary TRVs	Literature-derived effects levels are associated with significant uncertainty. Toxicity data are only available for a limited number of species, mostly laboratory test species, under strictly defined set of test conditions that deviate from natural conditions. Tolerance and adaptation of the receptors are not considered for laboratory studies, but do play a role in field TRV studies included in some of the Monte Carlo probabilistic models (arsenic and selenium).
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Relevance of Dietary TRVs to Populations	Relatively few studies evaluate the effects of toxicity at the population scale integrating reproduction and survival or incorporating concepts of carrying capacity, intra-specific competition, density-dependence, or dispersal; thus the TRV studies used for the receptor groups rarely represent population-level effects.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Dietary TRVs for Potential Risk Drivers	The large uncertainty in TRVs for aluminum and arsenic makes assessment of risk for these COPECs very uncertain. The probabilistic risk assessment performed for these TRVs supported with moderate confidence estimates of very little risk from arsenic, but unknown risk from aluminum (low confidence of risk for aluminum). Dietary TRVs for selenium are best established for the mallard, hence the confidence in the risk assessment for omnivorous birds such as the mallard is highest, with lower confidences in the other assessment endpoints.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Representativeness of EPCs	The EPCs used in the deterministic dietary exposure model were very conservative, biasing the dose high, because the EPCs were the 95 UCL or maximum concentration for a reach, rather than the average. The probability analysis used the average and standard deviation of these concentrations, which is more accurate.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Representativeness of Food-Item EPCs	These data were obtained from tissues of one or a few species that may not represent the full set of food items of a receptor, particularly because groups that have terrestrial food items in their diets were assumed to only consume aquatic food items (e.g., benthic invertebrates), biasing risk estimates high.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Representativeness of Plant Tissues	Only the leaves of emergent and shoreline vegetation were collected, but many receptors (ducks) can also feed on the roots of emergent vegetation. Roots tend to concentrate more selenium and arsenic than other plant parts. Risk to herbivorous birds could be biased low; however, the HQs were sufficiently low to suggest that HQs based on root consumption would not be likely to exceed 1. Furthermore, it is unclear to what extent herbivorous birds would consume roots when an abundance of leaves and stems are available.

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Receptor(s)	Line(s) of Evidence	Type	Description
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Distribution and Timing of Tissue Collections	Tissue sample collection was often clustered and limited in each reach. Good representation of reach exposure concentrations and their distribution is uncertain and may under- or over-represent exposures. The timing of sample collections varied from pre-dredging to post-dredging, making representation of post-dredging conditions less certain. Analysis of the 2011 results is pending review of those data which have only recently become available.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Estimation of Incidental Sediment Ingestion	Whole body tissue concentrations for fish and mayfly nymphs were used to derive EPCs used in the exposure calculations. Where bioavailability of COPECs was not adjusted, the use of whole body prey tissue concentrations in addition to incorporating incidental sediment ingestion rates is conservative and probably over-estimates risks to wildlife.
Birds and Mammals (Sections 6 - 8)	Dietary Exposure Model	Analytical Methods	The detection limits for some constituents, notably selenium in water and sediment, may lead to underestimation of exposures and obscure the identification of exposure pathways. Non-detected concentrations of all constituents were conservatively assumed to be present at the reporting limit to compensate for this uncertainty. Default wet weight to dry weight conversion factors were used in the absence of sample-specific percent moisture results. This may bias the results high or low. Mercury analyses of fish muscle tissue were biased low, based on a quality assurance/quality control study that determined the use of a CF of 1.3 was appropriate for fish fillet samples. Only whole body data were used in the dietary exposure models. It is yet unknown whether other tissues were similarly biased and, if so, what CF should be used. However, it is unlikely that a 30 percent increase in the reported concentrations would alter the characterization of risks in this BERA, given the low concentrations and associated low risk of mercury.
Mammals (Section 7)	Tissue Concentrations	Relevance of Tissue Concentrations	Reproductive measures and survival rates at the Site were not available to interpret potential effects of observed tissue concentrations of most COPECs on productivity of omnivorous mammal populations. The exception is selenium, for which raccoon populations have been studied for adverse effects at a selenium-contaminated site; no adverse effects were found, supporting the results showing negligible risk to raccoons from selenium in ash.
Mammals (Section 7)	Tissue Concentrations	Limited Datasets for Reference Areas	Aluminum risk is uncertain because the reference location in 2009 is a positive control that may have elevated aluminum risk. The reference location in 2010 had no such history and should have negligible aluminum risk, but sample size from that location was low. Had raccoon collections at that location been more successful, the observed difference in aluminum concentrations in raccoon hair may or may not have been significant.

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Receptor(s)	Line(s) of Evidence	Type	Description
Mammals (Section 7)	Tissue Concentrations	Unknown Concentrations Below Detection Limits	Non-detects in this third-party study were not set to the reporting limit, but instead were eliminated from the sample population, which inflates means and likely reduces power to detect differences from reference locations.
Mammals (Section 7)	Tissue Concentrations	Recently Collected Data	Representativeness of post-dredging exposures is uncertain given post-dredging raccoon data were collected in 2010 not long after dredging. The 2011 data may show different results and currently are being evaluated since they have only recently become available.
Mammals (Section 7)	Health Metrics	Representativeness of Reference Sites	The 2009 reference location was a positive control subject to historical ash contamination, making comparisons difficult to interpret that year. The 2010 reference locations may be more representative of background conditions, provided the habitat in these areas is similar to the Site.
Mammals (Section 7)	Health Metrics	Extrapolation to Reproduction and Population Viability	The relevance to reproductive measures and survival rates of factors such as lesions in individual animals and blood chemistry is unknown. Nevertheless, the clinical finding of no abnormalities indicative of disease in the collected raccoons, as well as tissue concentrations not likely to be of concern supports with moderate confidence that risk is negligible.
Aerial-Feeding Birds and Mammals (Section 8)	Tissue Concentrations and Reproduction	Relationships Between Exposure and Reproductive Measures	Tissue concentrations of COPECs are difficult to confidently link directly to productivity of aerial-feeding insectivorous bird populations. For example, the finding of a negative correlation between selenium dose and fledglings produced per female creates uncertainty, because the reproductive measure was not significantly lower than at the reference locations.
Aerial-Feeding Birds and Mammals (Section 8)	Tissue Concentrations and Reproduction	Recently Collected Data	The study of tree swallow reproductive success and trace elements in tissue was continued in 2011 by Virginia Tech. Preliminary results are available on reproductive success. The 2011 study evaluated egg, nestling, and survival parameters as in the previous year but it also included endocrine responses to stress of fledglings and composition of the nestling diet. It is premature to draw firm conclusions in the absence of trace element data, but this preliminary evaluation does not change the overall interpretation of risk to aerial-feeding insectivorous birds.
Amphibians and Reptiles (Sections 9 - 10)	Tissue Concentrations	Representativeness of Selected Receptors	Differences in feeding habits, habitat, behavior, and activity patterns of amphibians and reptiles can result in varying exposure to COPECs. Frogs, toads, and turtles were assumed to be appropriate indicator species based on knowledge of the potential species that may use the Site and their exposure potential. There is a chance that these indicator species may not represent the most sensitive species that occur at the Site. However, given that the HQ results for frogs, toads, and turtle species under very conservative exposure and effects assumptions were below 1, it is unlikely that risks to both rare and common amphibian or reptile species exist.

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Receptor(s)	Line(s) of Evidence	Type	Description
Amphibians and Reptiles (Sections 9 - 10)	Tissue Concentrations	COPEC Exposure Estimation	Estimation of the COPEC exposure involves several uncertainties including the measurement of COPEC concentrations and the concentrations estimated to be taken up from the environmental media. Based on the conservative assumptions used throughout this assessment, risk results were likely over-estimated; not under-estimated.
Amphibians and Reptiles (Sections 9 - 10)	Tissue Concentrations	Effects on Individual Organisms versus Populations	Toxicological evaluation of chemical concentrations generally relies on information that is most applicable to individual organisms. Site-specific population-level data are not available for amphibians or reptiles. The lack of information on relationships between individual and population-level effects is a significant source of uncertainty for amphibians and reptiles.
Amphibians and Reptiles (Sections 9 - 10)	Tissue Concentrations	Representativeness of Exposures	As with most field surveys, uncertainties exist when evaluating species that have the ability to migrate or in systems of complex COPEC mixtures. The evaluations in the tissue study focused on comparisons among locations, between years, and with literature-derived concentrations in order to assess the relationship between the ash release and metal and metalloid COPECs in amphibians and reptiles. Furthermore, the natural variability or historical contamination associated with the sample locations has potentially contributed to the differences found among locations.
Amphibians and Reptiles (Sections 9 - 10)	Tissue Concentrations	Recently Collected Data	A review of 2011 data for selenium and strontium indicates lower concentrations for spring peeper and upland chorus frog, but increased concentrations in American toad from the West Embayment only. Overall, there does not appear to be a clear trend of bioaccumulation over time in amphibians. Results from the 2011 Virginia Tech turtle tissue sampling and population surveys reported no differences in turtle body size, species composition or relative abundance among river locations that could be attributable to the ash spill. Although trace element concentration data in tissues were not yet available for a determination of bioaccumulation patterns at the site, this preliminary evaluation of the potential effects on turtles supports the conclusions of the BERA and does not change the overall interpretation of risk to turtles.

BIC= Benthic Invertebrate Community
BERA= Baseline Ecological Risk Assessment
CBR= Critical Body Residue
CF= Correction Factor
COPEC= Constituent of Potential Ecological Concern
EPC= Exposure Point Concentration
RL= Reporting Limit
TRV= Toxicity Reference Value
UCL= Upper Confidence Limit
Virginia Tech= Virginia Polytechnic Institute and State University