The following are the U.S. Geological Survey (USGS) comments on the U.S. Environmental Protection Agency (USEPA) Draft Aquatic Life Ambient Water Quality Criterion for Selenium (Se)—Freshwater. The Draft Criterion Document (DCD) consists of proposed fish-tissue and water-column based Se criteria and an implementation methodology. In general, tissue Se criteria would help to directly connect the toxicological effects of Se in fish to the primary Se exposure pathway of diet in aquatic systems. Implementation of a fish-tissue criterion, however, would also require derivation of a traditional water-column Se concentration to satisfy other regulatory requirements, such as permit and load limits.

Ecosystem-scale Se modeling was developed by the USGS to conceptualize and quantify the current state of knowledge concerning the dietary transfer of Se through ecosystems and to account for the differential bioaccumulation among food webs (Luoma and Presser, 2000, 2009; Presser and Luoma, 2006, 2009, 2010a and b). More recently, two articles detailing the site-specific application of ecosystem-scale Se modeling have been published (Presser and Luoma, 2013; Presser, 2013).

The model developed by the USGS links Se concentrations across environmental media (water, particulate material, invertebrates, and tissue of predators). It can be used to forecast Se toxicity in fish under different management or regulatory proposals and as a methodology for translating a fish-tissue Se concentration guideline to a dissolved Se concentration. The approach also is applicable to predicting Se risk to predators other than fish, including aquatic birds. The model illustrates some critical aspects of implementing a tissue criterion: 1) the choice of fish species determines the food web through which Se should be modeled; 2) the choice of food web is critical because the particulate-to-prey kinetics of bioaccumulation differs widely among invertebrates; 3) the characterization of the type and phase of particulate material is important to quantifying Se exposure to prey through the base of the food web; and 4) the metric describing partitioning between particulate material and dissolved Se concentrations allows determination of a site-specific dissolved Se concentration that would be responsible for that fish body-burden in the specific environment. This linked approach illustrates a central quantitative conclusion that environmentally safe dissolved Se concentrations will differ among ecosystems depending on the ecological pathways and biogeochemical conditions in that system.
Conceptualization or framing of a site-specific ecological occurrence of Se exposure is also paramount to the USGS methodology so that, used optimally, model scenarios adequately represent ecosystem variables and document important implications of ecosystem setting and inhabitants. The species- and site-specificity of modeling based in multi-disciplinary Se science is one of the great strengths of this model. This approach can lead to identifying the predators most at risk from Se and to understanding the location and time of greatest ecological Se sensitivity, thus narrowing model uncertainty. Making choices based on species-specific conceptual models and then applying seasonal analysis in terms of site water-column variability improves the certainty of model outcomes in terms of the broader context of fish communities and watershed management.

Summarized below are the USGS science-based review comments focusing on the implementation of the proposed fish tissue criterion (i.e., the methodology for the derivation of water-column Se concentrations as compiled in DCD Table 12) for consideration by the USEPA as the DCD is further reviewed and finalized. Toxicology sensitivity, as addressed in the DCD via the derivation of fish tissue criteria, is not reviewed here. Further, to correct the record, the USGS did not model from fish egg-ovary tissue to water as stated in the DCD, but rather from fish whole-body to water. Therefore, the USGS research cited in the references below did not investigate the species-specific nature of the conversion factors (i.e., partitioning among whole-body, muscle, or egg-ovary) and the associated uncertainty that it may introduce in the overall outcome of modeling.

The USGS commends the USEPA for moving forward into a new ecosystem-based approach for regulating this important contaminant. The USGS realizes that establishing nationwide Se criteria is a complex process wherein many tradeoffs must be considered; and the USGS respects the hard work that has gone into this document. The USGS consulted extensively with the USEPA staff in headquarters during the early stages of developing the national criteria implementation methodology in 2007-2008 and briefly, on a generalized basis about the methodology, as the USEPA requested in 2010 and 2012. USGS input is evident in the current proposal and is valued. The DCD represents a reasonable summary of the state of knowledge with regard to Se. Although more than a decade in the making, this represents a major step forward from the nearly 30-year-old aquatic life criteria for Se that presently are being applied. The USGS is concerned, however, that at several steps in the series of processes that control Se bioavailability and trophic transfer there are compromises in the proposed USEPA methodology that could add uncertainty, perhaps unnecessarily. This increased uncertainty could result in a regulatory approach, at least in some environments, which may not take full advantage of the current state of environmental Se science. Therefore, described below are the aspects of the proposed criteria which could ultimately create the most uncertainty.

Perhaps most important is the overall concept that the USGS methodology is not designed to provide a single choice for a site-specific standard. The model is designed to a) incorporate site-specific information into a guideline; b) constrain variability in the choices of a guideline value (e.g. when calculating a dissolved guideline from the fish tissue guideline); and c) give regulators and stakeholders a sense for the outcome of different choices and why those outcomes differ. The DCD does not explain this concept clearly. There is some variability in the data available at every step in the model and choices must be made; ultimately the DCD should give readers a
well-defined strategy for understanding and constraining those choices within site- and species-specific applications. Hence, setting up the implementation process for informed choices is a critical part of criterion development and understanding.

There are other specific points that are problematic. In summary they include:
1. The DCD does not adequately capture the importance of choosing one or more fish species of concern as a first step in any aspect of the local or regional process. A local conceptual model is necessary to complete this step.
2. The DCD is insufficiently transparent as to what sites were chosen, the criteria for choosing sites, and the reason some data and not others were employed in designing a guideline.
3. Comparing the choice of a) modeled invertebrate taxa made in the DCD to those commonly occurring in ecosystems; and b) the quantitative trophic transfer factors (TTFs) associated with those invertebrates to those derived in the literature shows a downward bias in both cases (Table 1).
4. A downward bias in overall model predictions is also evidenced by the relationship shown in Figure 16 of the DCD. If a local entity employed the model parameters in the DCD, then the calculated water-column guideline is likely to be under-protective.
5. Consolidation of steps in the USEPA model will reduce the site-specific flexibility that is the strength of the USGS approach. Readers should at least be made aware of this problem.
6. The DCD needs to emphasize the large uncertainties associated with proceeding with lotic and lentic guidelines; and clearly state the value in collecting local data and employing the model where stakeholders are unsatisfied with the dissolved guidelines.
7. There are errors (e.g., discrepancies between text and tables; missing references) throughout the DCD which suggest it is not yet ready for release.

The DCD proposes a new approach to regulating. Its credibility rests with transparency in documentation of the choices and a clear basis as to how it should be implemented. While the regulation is appropriate in using a tissue guideline to address Se bioaccumulation as the basis of toxicity, it falls short with regard to site-specific application of the approach. Details follow on the short-comings listed above.

**Construct food-web models that represent a cross-section of common species with differing bioaccumulation potentials**

Research by the USGS indicates that the first step in modeling should be the construction of conceptual models to document the interaction of site ecology, biochemistry, and hydrology and species’ physiology and ecotoxicology as described in our publications (see especially Presser and Luoma, 2010a, Figure 6). In the context here, this means that sites and food webs chosen for modeling should encompass the range of known bioaccumulative potentials that exist within common ecosystems across the U.S. Fifty-three sites from 13 referenced citations have been selected by the USEPA for this task (DCD Table 12). Little information is given on how this set of sites was selected. The food webs for these sites were not illustrated in any comprehensive way. Our main concerns here are 3-fold:
- the type and number of sites in the database;
the need to provide conceptual models for these sites to document choices and understand species-specific food web complexity; and

- the lack of representation of benthic food webs indicative of clams, mussels, snails, or worms (TTF\textsubscript{invertebrate} > 2.5) in the site-specific criteria development dataset.

The sites chosen by the USEPA for analysis used a limited number of invertebrate taxa and some sites were represented by non-taxa specific invertebrate samples based on checking the data given in the original studies for the listed sites. Common taxa such as clam, mussels, and snails were not used in the DCD food web examples for derivation of water-column criteria.

Matching these prey taxa to predators is of further concern. For example, erroneously including crayfish in the diet of Iowa darter or speckled dace may result from not explicitly documenting choices in data analysis and lack of consideration of ecologically appropriate food webs. Selenium concentration data for particulate material, invertebrates, and fish need to be shown, along with dates of sampling to ascertain the spatial and temporal context for the modeled species and ecosystem. Limiting the suite of taxa analyzed limits the basis for prediction and the applicability of the derivation of water-column criteria. Without systematic assessment, compilation, and conceptual models, the underlying strength of derived water-column Se criteria is uncertain and the developed criteria may not be ecologically meaningful nor consistent. The number of sites and fish species in Table 12 is not so large as to preclude construction of food-web models as a practical matter. Linking ecological choices to mathematical decisions during data analysis is crucial to narrowing uncertainty.

In terms of quantifying trophic transfer for the set of analyzed sites by the USEPA, a TTF\textsubscript{composite} (a combined TTF\textsubscript{fish} and TTF\textsubscript{inver}) is shown in DCD Table 12. This type of approach is not helpful to understanding and quantifying the trophic transfer in an ecosystem and does not provide an adequate conceptualization on which to base protection. If values for TTF\textsubscript{invertebrate} are calculated from the composite TTFs shown in DCD Table 12, then direct information on particulate material to invertebrate trophic transfer for the cross-section of invertebrates sampled is possible (Table 1). Table 1 compares the calculated TTF\textsubscript{invertebrate} values shown in DCD Table 12 and the taxa-specific TTF\textsubscript{invertebrate} shown in DCD Table 9 to those compiled in the literature. As shown, few calculated TTFs for invertebrates used in the derivation of criteria exceeded two, while those compiled to represent a cross-section of taxa do. A lower TTF means less bioaccumulation and therefore a higher predicted water-column criterion. By limiting the value of TTF\textsubscript{invertebrate} mathematically to < 2, there is a negative bias in the model predictions that does not match ecological reality and would not provide adequate protection to ecosystems. This topic is discussed further below.

Additionally, the data set compiled in Table 12 mainly does not take advantage of the entire set of sites sampled by the referenced authors (e.g., Hamilton et al, 1 of 28 sites; Birkner, 7 of 17 sites). In the case of studies by Hamilton et al., the one site chosen from his work was a site (East Mill Creek in Idaho) that was severely contaminated to the point of no fish being present at times and those that were present probably representing survivors. Particularly concerning is that the sites and data included from the National Irrigation Water Quality Program (e.g., Butler, Grasso and Stephens) seem to represent but a small fraction of the sites and biological data available (8,218 analysis of plant, invert and fish in the NIWQP database; on-line at...
http://www.usbr.gov/niwqp/datasynthesis/index.html). Additionally, other studies also are available for consideration by the USEPA (e.g., Presser and Luoma, 2010a; Presser, 2013). As noted in our summary comments, the DCD should be sufficiently transparent concerning what sites were chosen, the criteria for choosing sites, and the reason some data and not others were employed in designing a guideline.

Assemblage of the raw data also is made difficult for readers because many reference citations shown for Table 12 are not listed (Butler et al. 1995, 1997; Casey 2005; Formation 2012; Grasso et al. 1995; Hamilton and Buhl, 2004; and Stephens et al. 1988). Errors such as mischaracterizing Mud Slough and Salt Slough as lentic and accepting an unrealistic enrichment factor (EF) [or environmental partitioning factor (Kd) as described by the USGS] of 100 for Marsh 4720 site (DCD Table 12) also need to be corrected. Based on original referenced data, the flowing water-column Se concentration can be replaced with a marsh pond water-column Se concentration and matched with a particulate Se concentration from the pond ecosystem; then, an EF of 1,229 is calculated, which is within the range for lentic systems.

Revise compilation of TTF_invertebrate values to correct negative bias (especially to reconcile the difference in the value cited for TTF_mayfly with values given in the literature)

Specific concerns to the application of science to the derivation of the water-column Se criteria are that 1) the values used by the USEPA to reflect the trophic transfer for mayfly, chironomid, corixid, and daphnia are less than those reported in the literature; and 2) TTFs were not derived for cranefly, stonefly, caddisfly, snail, and leech (Table 1).

The derivation of TTF_mayfly of 1.28 from laboratory data (DCD pg B-51; Riedel and Cole, 2001) fails to consider a dietary pathway thus underestimating the bioaccumulative potential of a common food web used throughout modeling in the DCD. The TTF_mayfly derivation from field data was not used because of a calculated anomalously high ratio (DCD page B-61). However, documentation of the derivation of TTF_mayfly and other aquatic insects from the literature showed successful determinations from both field and laboratory data, with a concurrence around the value of 2.8 (Presser and Luoma 2010a; Conley et al., 2009). For example, Presser and Luoma (2010a) derived a mean TTF_insect of 2.8 (range 2.3 to 3.2) based on matched field data sets for particulate and insect Se concentrations in freshwater environments for several species of aquatic insect larvae including mayfly, caddisfly, dragonfly, midge, and water boatman. These values generally compare well to laboratory-derived TTFs for aquatic insect larvae (e.g., combined mean 2.2; range 1.9-2.9; Conley and others 2009). A recent site-specific derivation for chironomid showed a value higher than 2.8 (i.e., 4.2). Similarly, a field TTF_snail of 5.5 was determined (Presser, 2013).

In summary, Table 1 shows a tendency in the DCD towards the consideration of lower TTF_invertebrate than those available from the literature and exclusion of invertebrate taxa with higher bioaccumulative potentials. Overall, use of the DCD TTFs leads to several negative-bias quantitative consequences in modeling outcomes. For example, if the model is run using a single Kd but different TTFs for mayfly (i.e., the DCD derived TTF_mayfly of 1.28 versus literature and laboratory derived TTF_mayfly of 2.8), then a 2.2-fold higher aquatic criterion for Se is derived (6.75 µg/L versus 14.8 µg/L).
Finally, consider revising the statement (DCD, pg 140): …selenium does not significantly biomagnify moving up the food chain except in specific ecosystems with mollusk-based food-webs, unlike bioaccumulative chemicals such as mercury…because it is not an accurate assessment of Se food-web biodynamics as documented in the scientific literature and acknowledged by the rational of basing aquatic protection on a fish tissue concentration. Selenium concentrations are at least conserved and usually magnified at every step in a food web (Presser and Luoma, 2010a, Figure 6; Chapman et al., 2010).

**Consider separating species-specific modeling from site-specific modeling to narrow uncertainty in modeling and ecologically define protection.**

Consideration of the quantitative importance of food-web influence in comparison to the influence of site hydrology is of concern. The USEPA has chosen the categories of lotic (rivers, streams) and lentic (ponds, lakes) for ecosystems sites on which to base their criteria. The values for K_d vary widely among hydrologic environments (i.e., in parts of a watershed such as wetlands, streams, or estuaries) and potentially among seasons and stream gradients (Presser and Luoma, 2010a; Presser, 2013). Consideration of the characteristics of the environment such as speciation, residence time, and/or particle type can be used to narrow this potential variability, but K_d remains a large source of uncertainty if translation to a water-column Se concentration is required. The ranges of water-column Se concentrations derived from a proposed egg-ovary criterion for lotic and lentic sites by the USEPA are considerable (1.37-98.08 µg/L and 0.38-64.94 µg/L, respectively). Choices concerning food webs are folded into this primary consideration by the USEPA, but it is unclear how the range of outcomes is linked to predator species to be protected.

Modeling by the USGS showed that site biogeochemical transformation (K_d or EF) determines the concentration of Se available to the food web, but variability in TTFs, especially at the consumer level, is influential in determining how much Se different predators accumulate (Luoma and Presser, 2009; Presser and Luoma, 2010). Thus, choice of fish species is critical to protection of an ecosystem because it determines the food web, and hence the magnitude of biotransfer, through which Se is modeled.

In the USGS approach, modeling is initiated from a particulate Se concentration and food-web biodynamics is the basis for validation. This approach is step-wise so that food-web modeling can be checked against field data at each media point for ecological consistency (Presser and Luoma, 2010a, Figures 3 and 4). Site hydrology is expressed by K_d (or EF) and is applied as a separate step in order to enable isolation of the most uncertain step.

The consolidated approach of the USEPA also has ramifications for validating model predictions. In our understanding of USEPA’s approach, validation encompasses direct correlation of water-column and egg-ovary Se concentrations (DCD, Figure 16) (see further discussion below).

**Acknowledge under-estimation as shown in validation of model (Figure 16) and show line of regression (not the one-to-one line)**

Concern here is whether predicted Se concentrations calculated in the DCD are accurate based on the validation of the USEPA model. Figure 16 in the DCD shows the validation of the
USEPA model to predict egg-ovary Se concentrations. Validation is necessary to establish sufficient confidence that the predictions from the developed model can be usefully applied to the selected ecosystems. This validation essentially tests if applied TTFs and Kd$\text{s}$ are accurate. The validation graph is unconventional in two respects. In Figure 16, the x-axis shows the predicted Se concentrations and the y-axis shows the observed Se concentrations. The usual case would be for the predicted Se concentrations to be on the y-axis since this parameter is the dependent variable. Secondly, the line of regression is not shown on Figure 16. It would be helpful if the regression line were shown, in order to demonstrate the deviation from the unity (one-to-one) line and give a realistic illustrative context for the data. Rather than using the correlation coefficient as proof-of-concept, it would be helpful to test the difference between the regression and the one-to-one relationship.

Specifically, DCD Figure 16 shows that the USEPA model systematically under-predicts the egg-ovary Se concentration at the lower end of the curve by a factor of 4-5 (e.g., an observed concentration of 8 µg/g is a predicted concentration of 2 µg/g). The USGS estimation here would be improved if the regression line had been depicted on the graph or if the dataset for the graph was available. In terms of the higher end of the curve, we are unaware of observed fish egg-ovary Se concentrations of 250-600 µg/g dw and would be interested in obtaining the dataset for the generation of DCD Figure 16.

The variability in DCD Figure 16 can be due to either variability of TTF or Kd in a consolidated approach, which will reduce the strength of the approach. The USGS approach separates prediction into a series of linked steps thereby reducing uncertainty and facilitating the documentation of the fundamentals underlying the derivation of effective Se criteria for the protection of aquatic life. This includes the importance of TTFs in determining toxicity for a fish community approach and Kd in determining the effect of hydrology for a watershed approach. Ecologically-defined scenarios can then quantify for decision-makers a range of predator vulnerabilities (measured as a combination of food-web bioaccumulation and response in Se toxicity tests) and site sensitivities. Encouraging the regulated community to collect local spatially and temporally matched Se data across media (water, particulate material, invertebrates, and predator tissue) with specificity of species and particulate type to add to the national database can ultimately assist in the development of site-specific criteria.

Additional Detailed Comments

1) It would be helpful to explain or enumerate the various subsets of EPA’s database that are cited in the different stages of the derivation and validation of the water column-based Se criteria. For example: page 134, 300 predicted egg-ovary concentrations; page 136, 140 instances in lentic systems and 688 instances in lotic systems; and Table 12, 132 predicted water-column concentrations.

2) Similarly, note that the number of total, lentic, and lotic sites differs between the text and what is shown in DCD Table 12.

3) It would be helpful to summarize the results of the TTF and EF derivations in tables or figures to address the variability of the values.
4) As noted previously, data shown in Table 12 are difficult to confirm against food-web and predator datasets given in original reports, especially data cited in the Idaho study (i.e., Formation Environmental, DCD Table 12).

5) While the USGS appreciates the working nature of the DCD, there are errors and discrepancies throughout the report. Some errors (Tables J1 and J2 in Appendix I) and missing references (7 missing out of 12 cited for Table 12) could have been corrected by an editorial review process prior to release. Errors concerning site names, site codes, and species names (e.g., Twin Butter Reservoir versus Twin Buttes Reservoir; Sweitzer Lake versus Sweltzer Lake; red sunfish versus red shiner; Carquinezitist vs Carquinez) occur throughout the DCD giving a lack of confidence for those familiar with the literature. For those looking closely at the document in order to follow the derivation of TTFs, the fact that paragraph two on page I-18 is replete with errors is disconcerting (i.e., there is no mangrove snapper nor roundtail chub in the analysis and there are three taxa instead of five for consideration) and may undermine the accuracy of the derivations in the minds of some reviewers.

Thank you for the opportunity to comment. The USGS looks forward to receiving your responses. Given the length and complexity of the material in the DCD and the brief amount of time given for comment, you may have questions. If you wish to follow-up with the USGS concerning our comments, we can schedule future discussions. Previous discussions with the USEPA mentioned other concepts and details for applications of modeling by the USGS that may be helpful to you. Considerable detail is given in a recent USGS publication (Presser, 2013) that applied ecosystem-scale Se modeling to watersheds in southern West Virginia affected by mountaintop coal mining. For further assistance please contact Theresa Presser (tpresser@usgs.gov).
References

Modeling basis, approach, and site-specific application

General selenium science and invertebrate trophic transfer
Table 1. Freshwater trophic transfer factors (TTF\textsubscript{invertebrate}) for aquatic invertebrates as compiled 1) by the USEPA in the DCD; and 2) from the recent literature

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<th>USEPA (DCD table 12)</th>
<th>field (Presser and Luoma, 2010a)</th>
<th>laboratory (Presser and Luoma, 2010a)</th>
<th>site-specific (Presser, 2013)</th>
<th>site-specific (Presser and Luoma, 2009)</th>
<th>laboratory (Conley et al., 2009)</th>
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<td>2.5 (n=2)</td>
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*composite; **generic worm