TECHNICAL MEMORANDUM

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RE: **REVIEW OF VAN KIRK AND HILL (2006)**

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to provide the following summary of the recently released “Modeling Predicts Trout Population Response to Selenium Based On Individual-Level Toxicity”, prepared by Drs. Robert Van Kirk and Sheryl Hill of Idaho State University. Our summary comments are based on the Final Report to the Greater Yellowstone Coalition. It is our understanding that the content of this report has also been submitted for publication in a peer-reviewed scientific journal, and the final published version may differ from the content of the report as a result of peer review.

The intent of our summary is to supplement the literature review previously prepared by Golder as an Appendix to the Smoky Canyon Mine Panels F and G Final Environmental Impact Statement (Golder 2006). This summary focuses on the rationale and technical aspects of Van Kirk and Hill’s analysis, and includes a discussion of the implications of this study for selenium management.

2.0 SUMMARY OF VAN KIRK AND HILL (2006)

2.1 Rationale

Van Kirk and Hill (2006) argue that regulatory mechanisms must be based on the effects of chronic contaminant exposure at the population level (the effects of selenium and other contaminants on organisms are almost always evaluated at the individual level). The objective of their analysis was to develop a modeling approach to use individual-level response data to predict population-level effects.

The authors further argue that long-term population size, rather than population growth rate, is the most ecologically relevant assessment endpoint. Their main rationale for this contention is that long-term population size is more closely linked to the probability of long-term population persistence, and is therefore more relevant to management goals.

2.2 Technical Approach

Van Kirk and Hill (2006) used a modeling simulation to predict the population-level response of cutthroat trout to a range of pre-winter juvenile mortality and growth reduction responses predicted to result from exposure to bioaccumulated selenium. The model simulated the cutthroat trout life cycle based on age-structured demographic data for resident and migratory populations from the upper Snake River Basin. Individual-level responses (i.e., selenium toxicity) were modeled based on dose-response curves fitted to laboratory data compiled from the literature on selenium toxicity to rainbow trout and Chinook salmon (i.e., not specific to the upper Snake River population of cutthroat trout). The model also included a density-dependent function for juvenile winter survival, simulating a compensatory decrease in overwinter mortality as pre-winter mortality increased due to selenium toxicity. The parameter defining the strength of this density dependence was estimated by ‘calibrating’ the model, i.e., by testing different parameter values to find the range that produced reasonably realistic model behavior.

The model was used in a Monte Carlo-style analysis to simulate long-term population response to a range of selenium exposures. Modeled selenium whole-body exposures ranged from 0 to 40 μg/g dry weight in steps of 0.5 μg/g. At each modeled selenium exposure level, three sets of 100 population simulations were conducted. Each simulation involved randomly generating a set of model parameters from pre-specified parameter distributions (intended to represent environmental but not demographic stochasticity), running the model for 10 years, and then retaining the final simulated population size after an additional, randomly-determined number of years between 1 and 100. The three sets of simulations used three different estimates of selenium toxicity parameters (upper 95% confidence levels, least-squares expected values, and lower 95% confidence levels for the predicted mortality and growth reduction parameters) to account for uncertainty in individual-level effects.

The output of each set of simulations was a distribution of simulated long-term population sizes associated with each level of selenium exposure. These values were then used to estimate whole-body selenium concentrations equivalent to a NOEC (maximum no-observed-effect concentration), LOEC (lowest-observed-effect concentration), EC50 (concentration producing a 50% effect) and EC90 (concentration producing a 90% effect) for a reduction in long-term population size. The NOEC was considered to be the maximum concentration allowable to protect populations from decline.

2.3 Analysis and Interpretation of Simulation Results

The authors' primary, general conclusion was that population-level effects are lower than individual-level effects at mortality rates of less than 70% (resident populations) to 78% (migratory populations). This is because their model simulates compensatory increases in overwinter survival that ameliorate pre-winter mortality due to selenium toxicity. Figure 9 in Van Kirk and Hill (2006) shows this as a sigmoidal relationship between population-level effects and individual-level effects. That is, population-level effects (reductions in long-term population size) show little response until individual-level effects (mortalities) exceed about 40-50%. ***The implication of this conclusion is that exposures required to elicit a given level of population-level effects are usually higher than exposures that elicit the same level of individual-level effects.*** For example, a 20% reduction in population size does not occur until individual mortality exceeds about 60%.

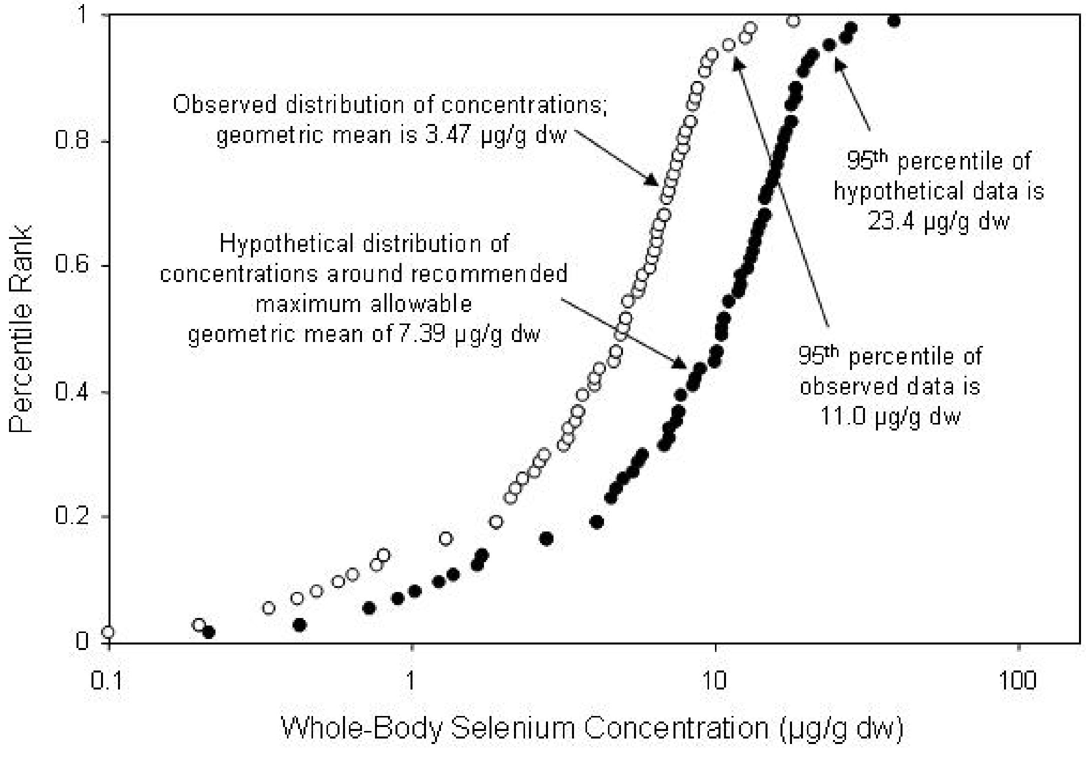
The authors' main conclusion regarding upper Snake River cutthroat trout was that selenium concentrations in some locations are high enough to cause significant population declines. The NOEC was estimated to be a whole-body concentration of 7.39 µg/g dry weight for resident populations and 10.6 µg/g for migratory populations. The authors therefore recommended that 7.39 µg/g (or, more conservatively, their lower-95% confidence level of 5.5 µg/g) be considered a "maximum allowable [mean] concentration in whole-body fish tissue to protect cutthroat trout in the upper Snake River basin". Reported tissue selenium concentrations in the Blackfoot and Salt river drainages range from 1.8 to 52.3 µg/g, with a geometric mean of 9.81 µg/g. The mean of these reported values exceeds the estimated threshold for population declines, and the authors therefore predict (with several caveats) that population declines may be occurring. They also note, however, that a statistically significant decline does not necessarily constitute a threat to the long-term persistence of a population – i.e., the magnitude of decline is important.

3.0 IMPLICATIONS FOR SELENIUM MANAGEMENT

Van Kirk and Hill's (2006) recommended maximum allowable whole-body concentration of 7.39 µg/g dry weight is the highest mean concentration that produced no statistically significant decline in long-term resident population size in their simulations. The authors note that this value is lower than the USEPA's (2004) draft selenium aquatic life criterion of 7.91 µg/g dry weight. Given the distribution of selenium concentrations reported for Simplot's Panels F and G (Golder 2006), we can estimate the distribution of selenium concentrations that would result within this area if the population mean was equal to Van Kirk and Hill's (2006) recommended maximum allowable mean whole-body concentration.

The geometric mean observed whole-body selenium concentration in cutthroat trout sampled within this area ($n = 73$) is 3.47 µg/g dry weight, with individual fish concentrations ranging from 0.1 to 18.0 µg/g dry weight and a 95th percentile value of 11.0 µg/g dry weight (Golder 2006). Assuming that the approximately log-normal distribution remains the same but is simply shifted to a new geometric mean of 7.39 µg/g dry weight, individual fish concentrations in a sample of 73 fish would be expected to range from 0.2 to 38.3 µg/g dry weight, with a 95th percentile value of 23.4 µg/g dry weight (Figure 1). That is, a population that would be considered "protected" according to Van Kirk and Hill's (2006) criteria would contain many fish (~60% of individuals) with whole-body selenium concentrations exceeding 7.91 µg/g dry weight. This is consistent with Van Kirk and Hill's (2006) conclusion that population-level endpoints (on which their value is based) are more tolerant of selenium exposure than individual-level endpoints (on which the USEPA value is based). It is also consistent with the fact that fish populations at Belews and Hyco Lakes, which have now recovered from selenium impacts and are considered healthy, have whole body selenium concentrations about twice the USEPA draft criterion value (Finley and Garrett 2007).

Figure 1. Observed distribution of whole-body selenium concentrations in cutthroat trout within the Panels F and G area (from Golder 2006) compared to hypothesized distribution with the geometric mean shifted to 7.39 µg/g dry weight



4.0 CONCLUSION

Van Kirk and Hill (2006) present a modeling approach for extrapolating from individual-level toxicity information to population-level effects. They apply this approach to simulate the effects of whole-body selenium concentrations on long-term population size of upper Snake River cutthroat trout, and from this simulation exercise derive a recommended maximum allowable whole-body selenium concentration for cutthroat trout. This work represents a significant advance in ecological relevance over previous attempts to estimate protective selenium exposures based on effects to individual fish. However, it is important to note that the population simulation results are unverified, and the uncertainty in the population simulation model is not well characterized.

The main implication of this work for selenium management stems from the shift in focus from individual- to population-level effects. According to Van Kirk and Hill's (2006) simulations, whole-body selenium concentrations that produce moderate levels of individual mortality may have negligible effects on population endpoints. Tissue residue criteria based on individual-level effects may therefore be overprotective of population-level endpoints.

5.0 REFERENCES

Finley, K. and R. Garrett. 2007. Recovery at Belews and Hyco Lakes: Implications for fish tissue selenium thresholds. Integrated Environmental Assessment and Management 3(2): in press.

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