8.0 Implementation Issues

This section identifies considerations and recommendations for implementation of a new selenium water quality standard for the open waters of Great Salt Lake.

8.1 Considerations

Implementation of the site-specific standard for the open waters of Great Salt Lake will need to be based on a number of considerations that are specific to the goals for the standard. Studies conducted to date have provided estimates of the loading of selenium from various sources to the lake, the transport and fate of the selenium within the lake (including transfer among the lake's abiotic and biotic "compartments"), losses from the water column (permanent sequestration in sediment and emissions by volatilization), and exposure and potential effects in birds that feed on invertebrates from the lake. There are a number of uncertainties about the mass balance of selenium in the system and concentrations of selenium in field-collected dietary items (as described in Sections 5 and 7), especially because of the short time frame of the data on which the model is based. Thus, it seems essential that monitoring conducted for assessment of selenium status in the lake and its biota should include sampling of water, bird food items, and eggs that can be used to validate the model.

Other important considerations include the following:

- The conversion of the egg-based selenium standard to appropriate water- and diet-based "trigger" values for implementation of the standard.
- Whether a mixing zone should be considered for discharges to the lake, and how that mixing zone should be defined
- Specifically, what the physical boundaries for application of the standard should be (Wuerthele 2004)
- Whether the "lake" should be defined chemically (that is, waters exceeding a certain salinity, perhaps 75 parts per thousand, where brine shrimp and brine flies would be the predominant invertebrates in the lake), given the variations in the physical boundaries over time

Because the standard is based on predictive modeling, assessment monitoring will be essential and should include concentrations of selenium in water and in invertebrates that serve as food sources for aquatic-dependant birds. Both brine shrimp and brine flies are important food resources for aquatic-dependant birds of the open waters of the lake (although other invertebrates also are important for those birds, those other invertebrates are found mainly in areas with lower salinities near freshwater inflows). In addition, periodic assessment of selenium concentrations in bird eggs also would be warranted if concentrations in invertebrates increase from current levels. Frequency of sampling and locations for monitoring sites will need to be determined.

Reproductive success is the most critical endpoint for the protection of birds using the open waters of Great Salt Lake. A secondary critical endpoint is adequate body condition of birds so they can successfully migrate or survive the winter. For implementation purposes, and based on the information that is currently available, it is assumed that a water quality standard protective of the reproductive success of aquatic-dependent birds will also be protective of migratory non-nesting species, such as eared grebes and over-wintering ducks. However, further study of the effects of selenium on seasonally resident or migratory non-breeding birds (such as phalaropes in addition to grebes and ducks) seems warranted. In addition, there seem to be significant interactions between selenium and mercury (which is found at elevated concentrations in some components of the lake ecosystem) that influence bioaccumulation of selenium and resultant tissue concentrations in biota.

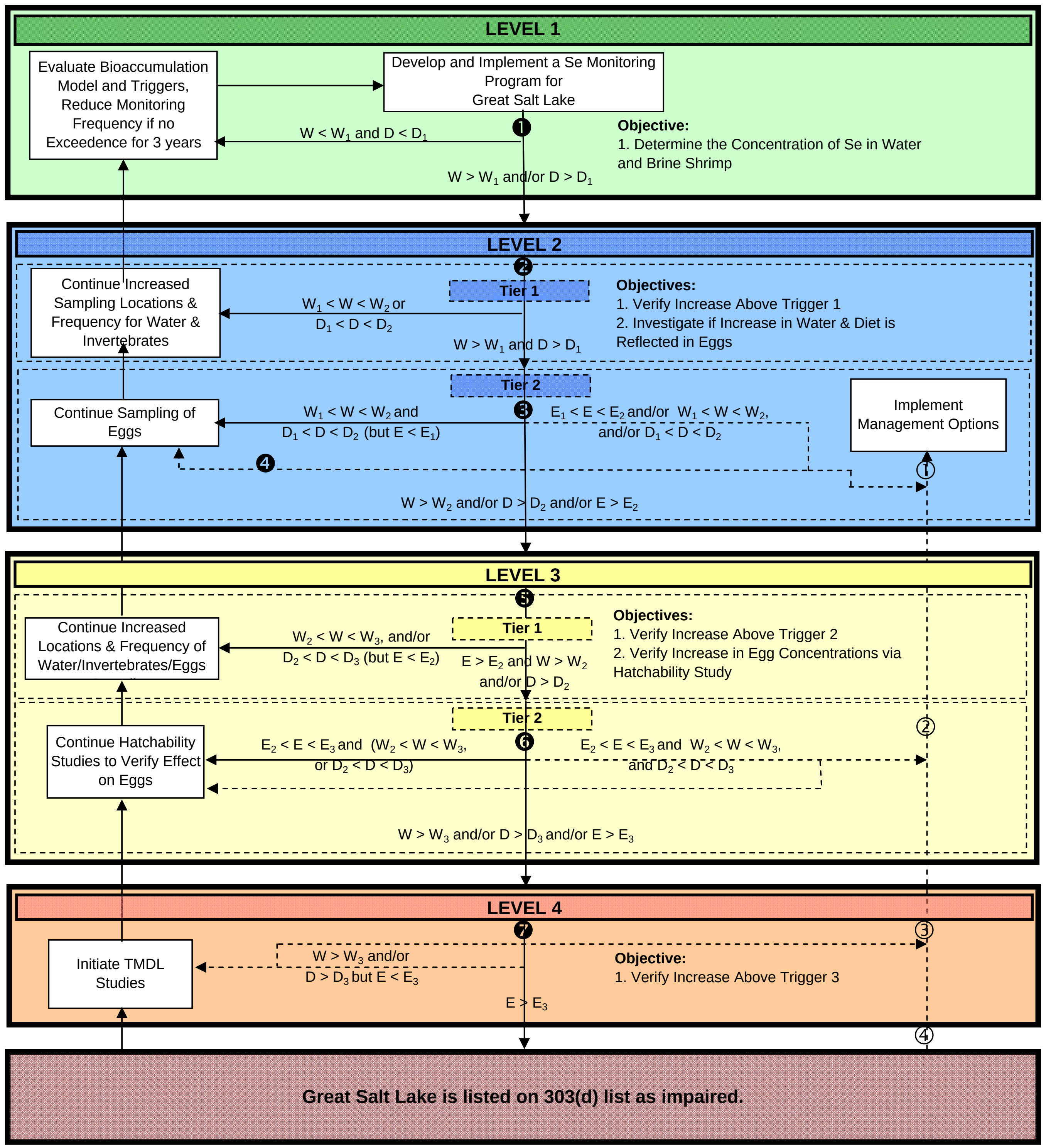
The Science Panel has identified dietary and egg selenium concentrations representing thresholds for statistically significant effects on egg hatchability (see Section 3.5). The following is assumed:

- The egg threshold will be used to identify a water column concentration corresponding to egg concentrations that will protect avian endpoints and serve as a standard, but the dietary concentration will be an important focus of the assessment monitoring. The Science Panel concluded that there is more certainty in the predicted effect of egg selenium concentrations on Great Salt Lake birds than diet selenium concentrations; therefore, the standard will be based only on the egg selenium concentration.
- The standard will address water quality of open waters and not that in open channels or pipelines discharging to the lake.
- Based on the selected water quality standard (including biological and water media), it will be necessary to develop discharge permits for implementation of the standard.

8.2 Assessment and Management Framework

The Science Panel has discussed various alternatives for implementing a water quality standard for selenium in the open waters of Great Salt Lake throughout the execution of this program. Given the uncertainties of the current understanding of selenium cycling in Great Salt Lake, the bioaccumulative nature of selenium, the need to incorporate both waterborne and tissue-based selenium concentrations, and the desire to proactively protect and manage the water quality of Great Salt Lake, the Science Panel has developed a concept for a tiered approach to implementing the selenium water quality standard. The approach assumes the use of the Bioaccumulation Model developed as part of this program to relate water, diet, and egg concentrations. Figure 8-1 illustrates the proposed framework of this approach. The final framework may be revised by UDWQ and the Water Quality Board after the water quality standard is established.

FIGURE 8-1
Recommended Assessment and Management Framework for Selenium (Se) in Great Salt Lake
Great Salt Lake Water Quality Studies Final Report - Selenium Program



Objective for Each Level

Level 1 Determine the concentration of Se in water and brine shrimp.
Level 2 Verify increase above Trigger 1.
Investigate if increase in water & diet is reflected in eggs.
Level 3 Verify increase above Trigger 2.
Verify increase in egg concentrations via hatchability study.
Level 4 Verify increase above Trigger 3.

Sampling Programs:

❶ Sample water and brine shrimp at four locations semi-annually.
❷ Increase sampling of water and brine shrimp to eight locations on quarterly basis.
❸ Add sampling of eggs at two locations for two bird species on annual basis.
❹ Increase sampling of eggs to three locations for two bird species on annual basis.
❺ Increase sampling of water and brine shrimp to eight locations on monthly basis, eggs at three locations for two bird species on annual basis.
❻ Add completion of hatchability study for one bird species on annual basis.
❼ Expand hatchability study to two bird species on annual basis.

Management Options

① Require Antidegradation Review Level II for all new discharges.
② Implement caps on Se loads from existing point discharges.
③ Initiate preliminary studies for load reductions
④ Implement load reduction and declare impairment.

Definitions

W_1: Trigger 1 for water concentration
D_1: Trigger 1 for diet concentration
E_1: Trigger 1 for egg concentration
W_2: Trigger 2 for water concentration
D_2: Trigger 2 for diet concentration
E_2: Trigger 2 for egg concentration
W_3: Trigger 3 for water concentration
D_3: Trigger 3 for diet concentration
E_3: Trigger 3 for egg concentration
Trigger 3 represents the site-specific numeric water quality standard; this may be a water or tissue-based concentration.

Scenarios for Consideration

ALL VALUES LISTED IN SCENARIOS FOR CONSIDERATION ARE SUBJECT TO CHANGE BY SCIENCE PANEL.

Scenario No.	Matrix	Conc. Units	Trigger 1 Conc.	Trigger 1 EC	Trigger 2 Conc	Trigger 2 EC	Trigger 3 Conc	Trigger 3 EC	Remarks
1	Water Diet Egg	ppb ppm ppm	3	Bckgrnd	4.7		6.4	$EC_{1.5}$	Uses LCL for EC_{10} as trigger for impairment and background level for initial action.
2	Water Diet Egg	ppb ppm ppm	3	Bckgrnd	6.4	$EC_{1.5}$	12	EC_{10}	Uses EC_{10} as trigger for impairment and background level for initial action.
3	Water Diet Egg	ppb ppm ppm	6.4	$EC_{1.5}$	9.2	EC_5	12	EC_{10}	Uses EC_{10} as trigger for impairment and LCL for EC_{10} for initial action.
4	Water Diet Egg	ppb ppm ppm	6.4	$EC_{1.5}$	12	EC_{10}	16	EC_{21}	Uses UCL for EC_{10} as trigger for impairment and LCL for EC_{10} for initial action.

Note: 1. These scenarios are offered for consideration. Trigger 3 to be determined by water quality standard.
2. EC values determined from Ohlendorf 2003.
3. Egg concentration of 3ppm used as background level of Se (Skorupa & Ohlendorf 1991).

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The intent of the approach is for analytical results to be summarized by statistical measures of lake-wide results for each medium that is sampled (for example, geometric mean of analytical results for annual water and diet samples and from one nesting season for egg samples). The UDWQ will begin at Level 1 and use the defined criteria to determine the actions to be implemented for the following year.

The tiered approach was developed to address the following objectives:

- Monitor Great Salt Lake to assess trends in selenium concentrations and determine whether they are approaching or exceeding the water quality standard in eggs, using water and diet (measured in brine shrimp and estimated in brine flies by a "translation factor") as indicators of whether the standard is likely to be exceeded in eggs
- Address current uncertainty in modeled bioaccumulation relationships by validating expected bioaccumulation with new data for water and diet concentrations and, if appropriate, egg selenium and hatchability
- Evaluate trigger selenium concentrations that initiate various monitoring, assessment and management actions identified in the assessment framework
- Evaluate the lake with respect to the numeric water quality standard for selenium
- Initiate management actions to mitigate further increases in selenium concentration if an upward trend is observed

The approach implements various trigger concentrations for water, diet, and egg selenium that increase monitoring levels and management options if and when actual selenium concentrations increase.

It is assumed that the water quality standard will be a tissue-based standard that is protective of the most sensitive endpoint for Great Salt Lake's beneficial uses—reproductive success for birds using the open waters of Great Salt Lake. As such, impairment of the water body will be defined by an observed selenium concentration in eggs. Selenium concentrations in water or diet are indicative of expected effects; however, a measure of selenium in eggs can be related to hatchability success with more confidence than a measure of selenium in water or diet items. It is assumed that the Bioaccumulation Model will be used to relate egg selenium concentrations to corresponding water and diet selenium concentrations. These water selenium concentrations can then be used to develop required discharge permits.

The rationale of using selenium concentration in eggs as the water quality standard is supported by work of Skorupa and Ohlendorf (1991) showing that selenium concentrations in eggs can be most directly associated with exposure of the embryo and resultant effects on its viability/development. Waterborne and diet selenium determine the *potential* and not the *actual* selenium bioaccumulation in eggs. There are many variables, each with its own uncertainty, that affect extrapolation from waterborne or dietary selenium levels to the exposure endpoint (embryo), as illustrated in Figure 8-2. Only one variable affects extrapolation from egg selenium levels to egg hatchability—species sensitivity to selenium. This was the basis for selecting an egg concentration for the recommended selenium water quality standard for the open waters of Great Salt Lake. The Bioaccumulation Model was

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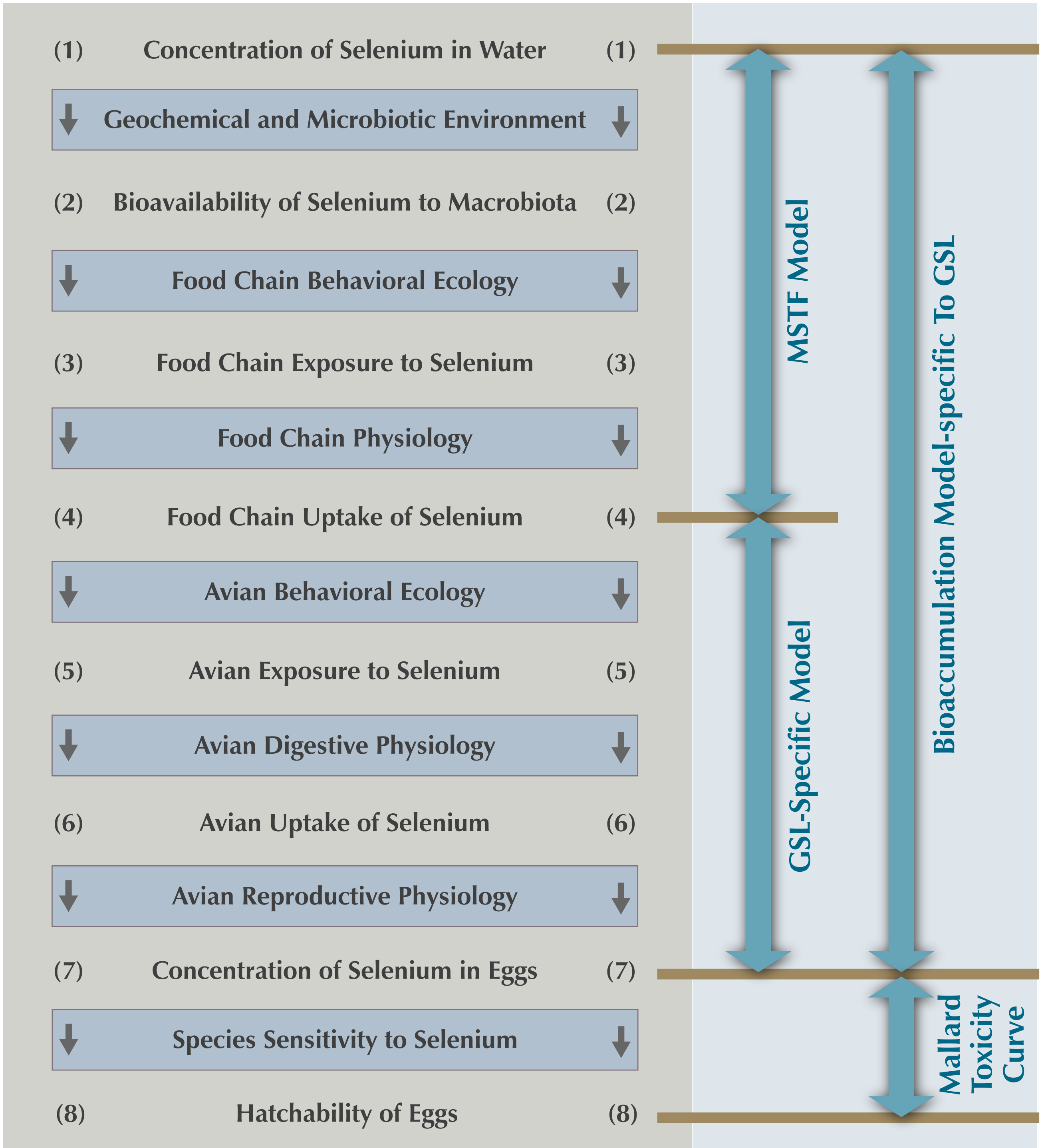

Source: Adapted from Skorupa & Ohlendorf, 1991.

FIGURE 8-2
Major Variables Potentially Confounding the Relationship Between Waterborne and Egg Selenium
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selected by the Science Panel to address the transfer of selenium between water and bird egg and to predict an egg selenium concentration. The mallard selenium toxicity curve for eggs (Ohlendorf, 2003) was selected by the Science Panel to represent the effect of selenium in eggs upon reduction in egg hatchability.

As previously described, waterborne selenium concentrations that correspond to diet and egg concentrations will be back-calculated using the Bioaccumulation Model developed as part of this program. The monitoring program described by the approach will be used to continually assess and improve upon the relationships included in the bioaccumulation model and the trigger levels included in the approach. The increasing levels of monitoring and implementation of management options, when necessary, are intended to provide a more robust and defensible dataset to confirm an apparent upward trend in selenium concentrations as well as provide a means to mitigate the upward trend, if one occurs. The level of protection that defines the trigger level for each of the tier levels will be based upon the levels of protection recommended by the Steering Committee and decided by the Water Quality Board.

The Great Salt Lake waterborne concentration used for implementation of UPDES permits is expected to be back-calculated from the egg concentration that relates to the expected level of effect defining impairment. This level of effect will be determined by the Steering Committee and Water Quality Board.

8.3 Long-term Verification

A water quality standard defined for Great Salt Lake will be subject to revision at least every 3 years and more frequently if deemed appropriate. For example, an update may be appropriate if there is a change in beneficial uses, water quality changes (for example, reaching levels of potential impairment), or new scientific information on the cycling of selenium in Great Salt Lake becomes available. Given the uncertainties of our current understanding of the Great Salt Lake ecosystem, it is prudent to identify potential actions the UDWQ could take to verify and validate the current model, the new water quality standard, and future permit limits. It is recommended that the UDWQ consider the following:

1. The highest priority research need identified by the Science Panel was to verify the transfer of selenium between the water column and brine shrimp for waterborne concentrations of 0.5 to 5.0 µg Se/L. The current Bioaccumulation Model includes two relationships (BAF and MS-TF models) developed from Great Salt Lake data that describe this transfer; however, both were created from a dataset represented by waterborne concentrations of 0.4 to 0.8 µg Se/L. Predictions using these models of brine shrimp selenium concentrations from waterborne concentrations greater than 0.8 µg Se/L should be used with caution. The Grosell model (Grosell, 2008) was developed in the laboratory for waterborne concentrations of 0 to 2.5 µg Se/L; however, comparisons with data from other water bodies indicate that selenium concentrations in brine shrimp may be over-predicted. Further studies would verify these site-specific relationships.

2. Periodically reassess the current conceptual model and update it with any new scientific information, as appropriate. The current model is based largely upon only 15 months of data. It is recognized that the lake is a dynamic lake and the current model does not account for long-term trends. The objective of continual reassessments of the model is to improve upon the accuracy of current relationships used in the bioaccumulation and mass balance models to minimize current uncertainties.

3. Monitor brine shrimp (tissue selenium concentrations and waterborne selenium concentrations) at predetermined intervals (1 time, 2 times, 4 times, etc. per year) throughout Great Salt Lake. The frequency and number of sampling locations would depend on the assumed homogeneity of brine shrimp and waterborne selenium concentrations throughout the lake. The objective is to improve upon the current understanding of the transfer of selenium from the water to these diet items and long-term trends. While the bioaccumulation model and recommended monitoring program emphasize brine shrimp as the primary diet item for birds, additional information is needed to improve upon the current understanding of selenium concentrations in brine flies. Thus, until that information becomes available, selenium concentrations in brine flies will be estimated using a "translation factor" based on measured brine shrimp selenium concentrations.

4. Complete additional collocated sampling of brine fly larvae and adults and sediment and water. Current brine fly levels are based on a "translation factor" developed from limited brine fly data and brine shrimp data. Additional measurements should be made to improve this "translation factor" or develop a new relationship as brine flies are also an important food source for birds using the open waters of Great Salt Lake.

5. Complete additional egg sampling studies that relate transfer of selenium from diet to eggs. The objective is to provide additional data points that will improve the statistical power of the current Great Salt Lake Shorebird Model (that is, the regression equation developed from data collected to date). Another objective is to further develop the Great Salt Lake Gull Regression Model.

6. Continue monitoring tributary inflows and selenium loads to Great Salt Lake in conjunction with lake water column concentrations. The objective is to understand long-term trends, identify other potential selenium sources, and improve upon the current mass balance model. Long-term flow records will provide benefits beyond the assessment of selenium in Great Salt Lake, as this information is important for any study where the mass balance of water inputs to the lake and outputs to sediment, biota, or the atmosphere is required. Special emphasis should be placed upon understanding flow inputs/outputs to the North Arm as very little information describing these processes is currently available.

7. Sample atmospheric deposition of selenium to verify assumptions made in the mass balance model. Current deposition rates in the model are based solely upon literature values from other locales. The objective of this study is to measure both wet and dry atmospheric deposition of selenium and other pertinent meteorological parameters at Great Salt Lake to quantify actual atmospheric selenium loads to Great Salt Lake.

8. Evaluate other potential sources of selenium to Great Salt Lake such as lake sediment pore water diffusion into the overlying water column, submarine groundwater discharge or wind blown dust that is deposited directly onto the lake surface.

9. Conduct a one-time study to determine selenium concentrations in phalaropes when they arrive at Great Salt Lake and before their departure during their season of peak abundance at the lake. Phalaropes were not studied as part of this project but were identified as another bird species that relies heavily upon the open waters of Great Salt Lake for their food source. The objective of this study is to identify any potential effects of selenium upon their body condition and ability to migrate.

10. Conduct further studies to evaluate the potential effects of selenium upon non-reproductive endpoints in birds. Confounding variables and insufficient information available during the completion of this project did not allow for a determination of effects due to selenium on those endpoints for Great Salt Lake birds. More information is needed to understand the diet composition of migratory birds and potential effects of selenium upon successful fall migration and survival of over-wintering birds using the open waters of Great Salt Lake.

11. Conduct further studies to understand the potential interaction of selenium and mercury and their effects on aquatic birds using open waters of Great Salt Lake.

12. Verify waterborne selenium concentrations at the outer limit of mixing zones at predetermined intervals. This should apply to current discharges at the shore and to submerged outfalls. The objective is to verify current mixing zone assumptions and potential effects to beneficial uses in these zones.

13. Continue verifying discharge concentrations per permit requirements.

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