4.0 Program Objectives

This section defines the objectives for the overall selenium program and for each of the individual projects.

4.1 Program Objectives

The UDWQ's objective is to define a site-specific, numeric water quality standard for selenium that prevents impairment of the beneficial uses of the open waters of Great Salt Lake. This was to be accomplished through the development of a selenium study program intended to enable the Steering Committee to recommend a standard to the Utah Water Quality Board. As such, the selenium program was designed to complete the appropriate studies (identified by the Science Panel) and evaluation needed to support such a recommendation.

4.1.1 Data Quality Objectives

The EPA has prepared a data quality objectives (DQOs) process (EPA, 2000, 2006) that serves as a useful tool in assessing what questions must be answered (or decisions that need to be made), what information is available to answer those questions, what additional information is needed, how that information will be collected, and how it will be used in making decisions as related to development of a selenium standard for the open waters of Great Salt Lake. Implementation of the DQOs process in the selenium program, along with use of the previously developed conceptual model, helped describe how the physical, chemical, and ecological components of the environment are related, as well as provided the rationale and context for the work that would be done. The DQOs described the objectives and overall approach for conducting studies to support development of the standard and provided more specific information about the work to be done under each of the individual projects. The DQOs developed for the program and for each of the original six projects active in 2006 are included in the Program Manual; DQOs were developed subsequently for the laboratory kinetic studies with brine shrimp. The listed questions and objectives posed in each project's DQOs are included in the following sections.

4.1.2 Program Questions

The central question for the selenium program to resolve can be stated as follows:

- What is the acceptable waterborne concentration of selenium that will prevent impairment of the beneficial uses of the open waters of Great Salt Lake?

More specific questions that support this overall decision were developed to help define the individual projects completed as part of the program. Figure 4-1 illustrates how these questions relate to the development of the program's seven projects.

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1. Are significant ecological effects occurring in aquatic wildlife (i.e., the "Upper Food Chain" box)? If so, to which ones and at which locations? What are the associated selenium concentrations in tissues (including bird blood, liver, and eggs)?

2. What is the relative importance (based on selenium concentrations and their availability) of various food-chain exposure pathways for aquatic wildlife (i.e., linkage of "Lower Food Chain" to "Upper Food Chain" as highlighted in the blue box)?

3. What are the transfer factors that describe relationships between selenium concentrations in the water column, in bird diets, and the concentrations found in bird eggs (i.e., stepping down to the "Aquatic Species" of waterborne selenium highlighted in the green box)?

4. What are the most important processes that affect the partitioning, cycling, and release of selenium in the Great Salt Lake open waters (i.e., transport and fate of selenium in the ecosystem?

5. What are the sources of waterborne selenium entering Great Salt Lake, and what is the relative significance of each of the various sources?

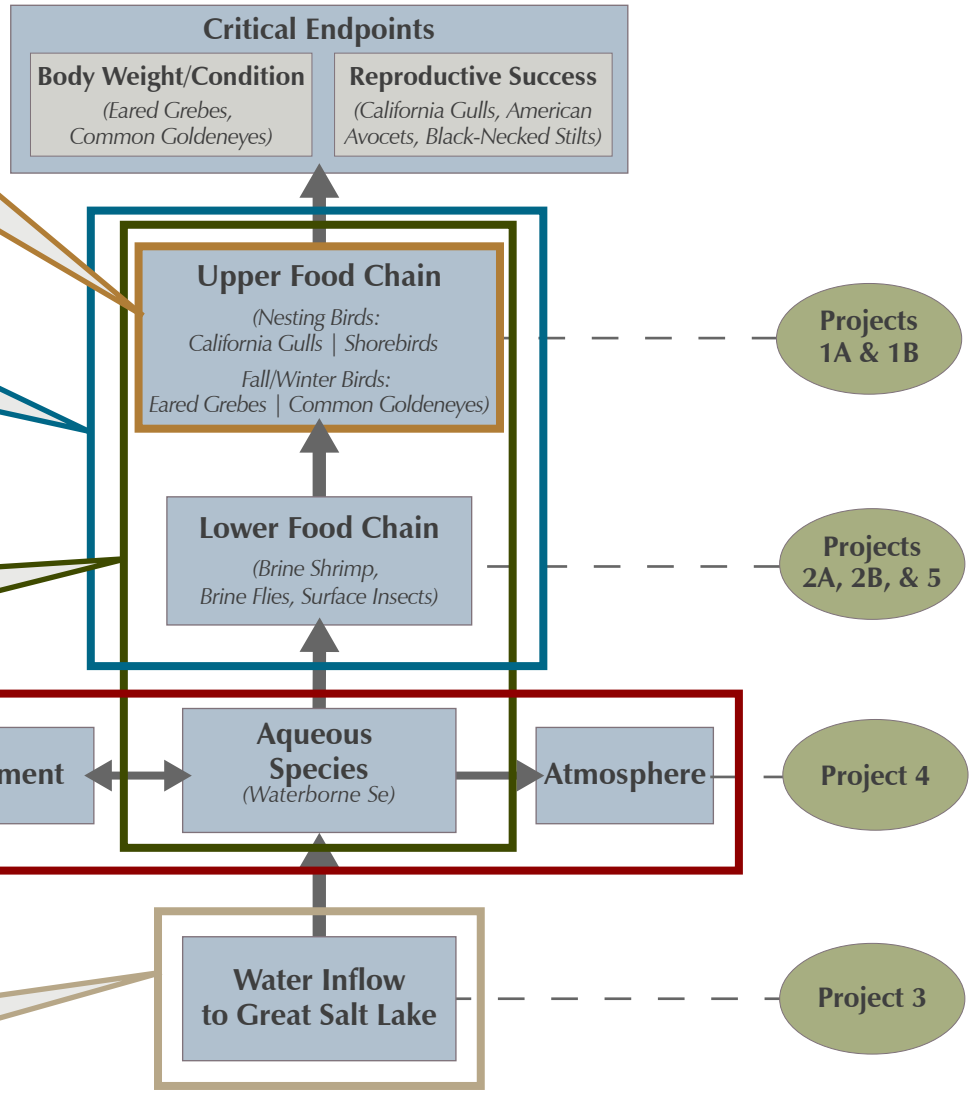

FIGURE 4-1
Program Questions Relative to Projects
Great Salt Lake Water Quality Studies
Final Report – Selenium Program

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4.2 Project Objectives

As described in Section 3.0, each of the selenium program's studies was initially identified and prioritized by the Science Panel through an evaluation of the conceptual model, available information, and discussion with principal investigators. A key element in developing and refining the work plan for each project was definition and discussion of each project's objectives and targeted questions to be answered. The project's DQOs, work plan, and standard operating procedures (SOPs) were subsequently developed and revised per Science Panel input. This section summarizes the objectives and questions for each project, and it illustrates which components of the conceptual model were to be addressed by each project.

Project DQOs, workplans, and SOPs for the six initial projects are included in the *Selenium Program Manual*. Detailed discussion of project background, objectives, methods, and results are found in each project's final report, and included in Appendices C through I of this document.

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4.2.1 Project 1A, Concentration and Effects of Selenium in Shorebirds

Principal Investigator: Dr. John Cavitt, Weber State University

Project Objectives (2006)

- Determine ambient selenium concentrations in water, sediment, brine shrimp, brine flies, and unidentified food items in nesting shorebird foraging areas, bird eggs, bird blood, and bird livers
- Determine stomach contents of nesting birds
- Determine if selenium concentrations affect reproductive success of American avocets and black-necked stilts at Great Salt Lake

Project Objectives (2007)

- Determine ambient selenium concentrations in brine fly larvae and in American avocet eggs
- Determine stomach contents of nesting birds
- Verify 2006 selenium concentrations by determining selenium and mercury concentrations in nesting American avocet blood and liver

Project Questions

The guiding questions for Project 1A include the following:

- What do the shorebirds eat at Great Salt Lake, and what are the transfer factors for selenium from the diet to bird eggs?
- Are significant ecological effects occurring in American avocets and black-necked stilts? If so, to which ones and at which locations?
- What are the associated selenium concentrations in bird eggs, blood, and liver?

To understand the potential effects of selenium on shorebirds at Great Salt Lake, the following questions needed to be addressed:

- What is the diet of American avocets and black-necked stilts at Great Salt Lake?
- What is the ambient concentration of selenium in the water and macro-invertebrates consumed by shorebirds?
- What is the concentration of selenium within the liver and blood of American avocets and black-necked stilts?
- What is the concentration of selenium within the eggs of American avocets and black-necked stilts?
- What is the hatching success of American avocet and black-necked stilt eggs?

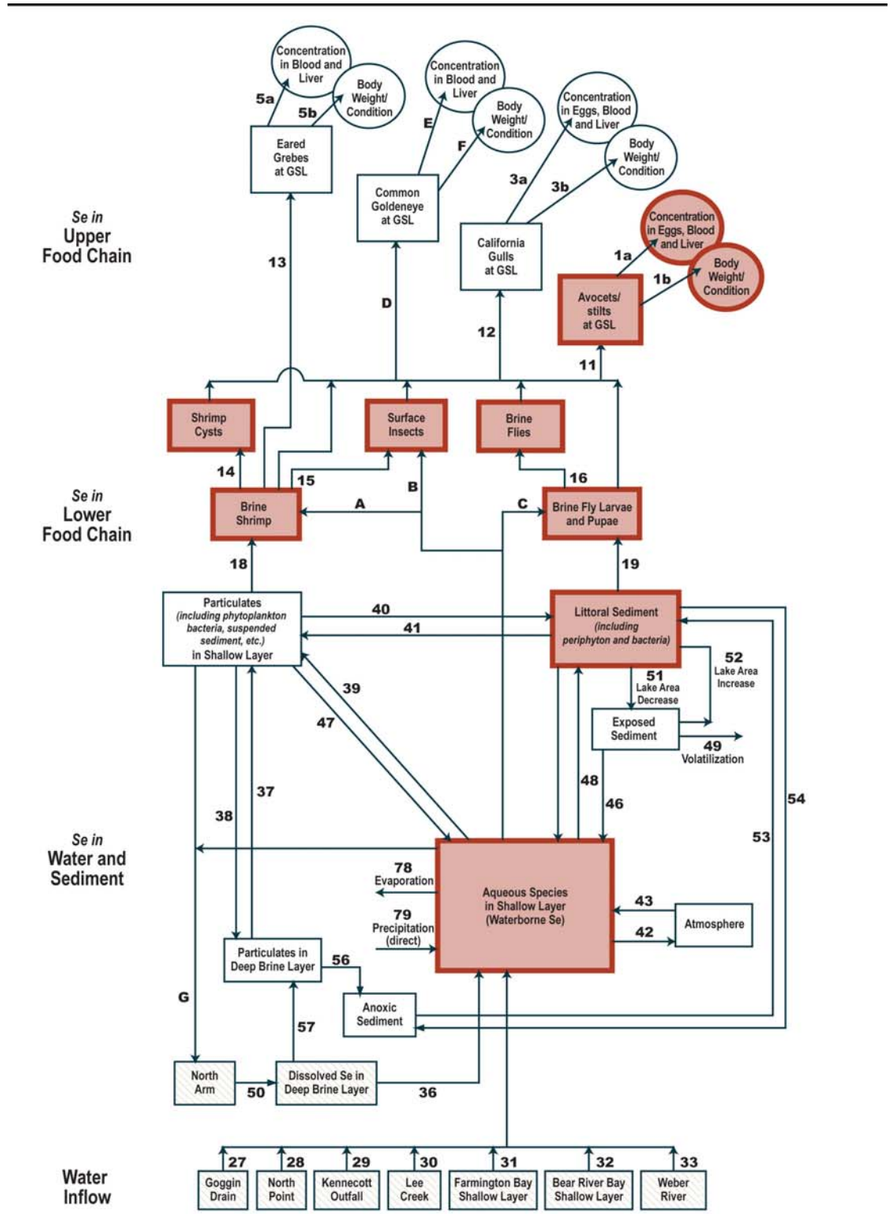

FIGURE 4-2
Project 1A – Shorebirds
Great Salt Lake Water Quality Studies
Final Report – Selenium Program

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4.2.2 Project 1B, Concentration and Effects of Selenium in Gulls, Grebes, and Ducks

Principal Investigator: Dr. Mike Conover, Utah State University

Project Objectives (2006)

- Determine stomach contents of nesting birds and ambient selenium concentrations in water, sediment, brine shrimp, brine flies, and other identified food items in nesting California gull foraging areas and in bird eggs, blood, and livers
- Determine if selenium concentrations affect reproductive success of California gulls at Great Salt Lake
- Determine selenium concentrations in eared grebes during the fall and male common goldeneyes during the winter, and determine if selenium concentrations affect body condition of those birds

Project Objectives (2007)

- Determine body condition, diet, and ambient selenium concentrations in blood and liver of nesting California gulls from two salt water colonies (Hat Island and Great Salt Lake Minerals) and a "fresh" water colony (Neponset Reservoir)
- Compare blood/liver selenium concentrations and diet found in crop of sampled birds from different nesting sites and opportunistically sample brine shrimp in area where gulls are feeding to link diet to blood and liver selenium levels

Project Questions

The guiding questions for Project 1B include the following:

- What are the transfer factors for selenium from the diet to bird eggs?
- Are significant ecological effects occurring in California gulls, eared grebes, or common goldeneye? If so, to which ones and at which locations?
- What are the associated selenium concentrations bird eggs, blood, and livers?

To understand the potential effects of selenium on these birds at Great Salt Lake, the following questions needed to be addressed:

- Where do California gulls nest and forage within Great Salt Lake and what is the diet of nesting gulls?
- What are the ambient selenium concentrations in the water, sediment, and diet items at the foraging sites of nesting California gulls in Great Salt Lake?
- What are the associated selenium concentrations in nesting California gulls (blood and liver), a random sample of gull eggs, gull eggs with dead or abnormal embryos, and deformed gull chicks?
- What are selenium concentrations in adult eared grebes staging on Great Salt Lake when they first arrive and right before they leave, and how does body condition of grebes relate to selenium concentrations in their tissues?
- What are selenium concentrations in overwintering ducks (adult male common goldeneye), and how does body condition of ducks relate to selenium concentrations in their tissues?

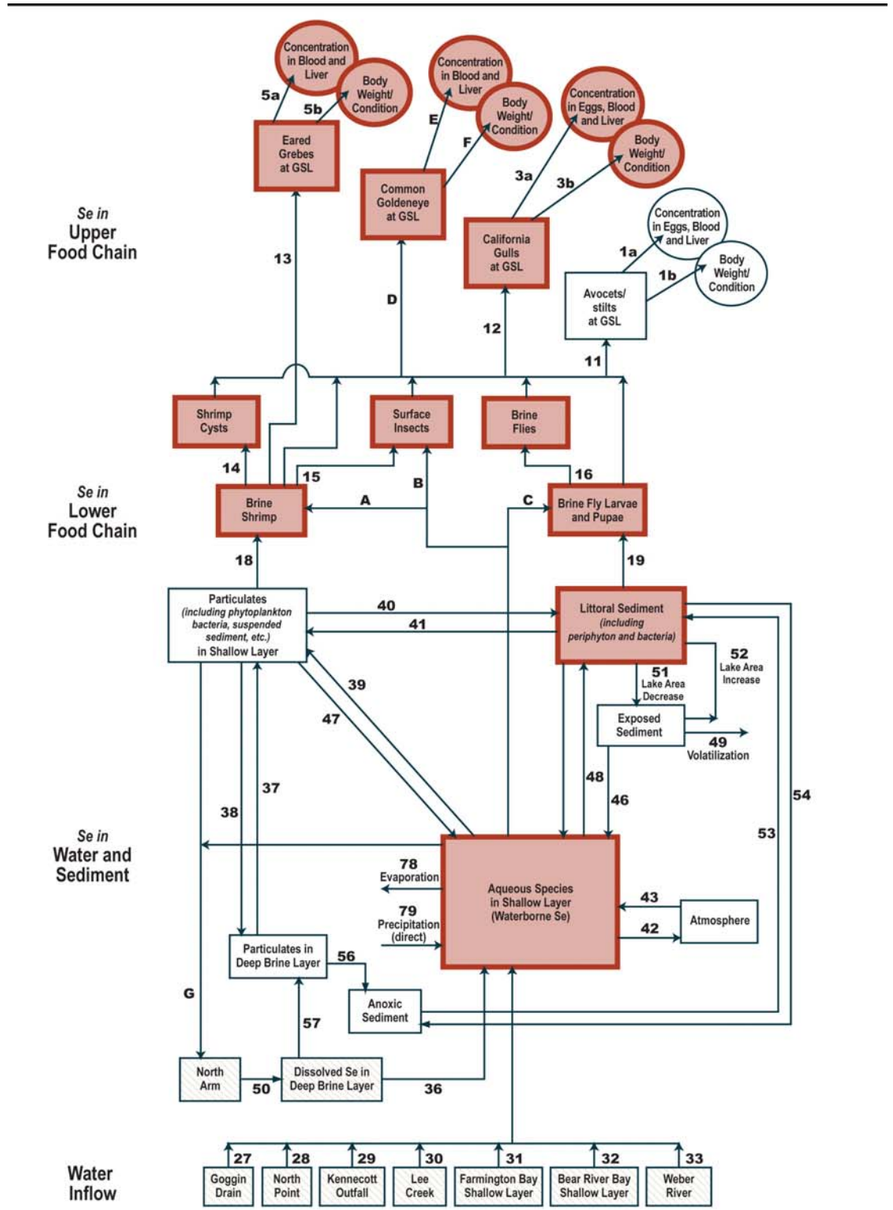

FIGURE 4-3
Project 1B – California Gulls, Eared Crebes, Common Goldeneye
Great Salt Lake Water Quality Studies
Final Report – Selenium Program

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4.2.3 Project 2A, Synoptic Survey of Selenium in Periphyton and Brine Fly Larvae from the Benthic Zone

Principal Investigator: Dr. Wayne Wurtsbaugh, Utah State University

Project Objectives

Determine the importance of the benthic food web for bioaccumulation of selenium in birds by:

- Developing methods to sample the benthic zone of the lake
- Determining chlorophyll concentrations in periphyton and selenium concentrations in periphyton brine fly larvae and detritus found on sand, mud, and biostromes (stromatolite) substrates in Great Salt Lake as well as in adult brine flies
- Determining ambient selenium concentrations in co-located water and substrate samples

Project Questions

The guiding question for Project 2A was:

- What are the transfer factors for selenium from the benthic zone (water and sediment) to the brine fly component of the food web?

To understand the potential effects of selenium on the benthic zone and food web of Great Salt Lake, the following questions needed to be addressed:

- Can brine fly larvae and pupae be sampled quantitatively using a SCUBA-operated vacuum sampler on stromatolite substrates?
- Can soft substrates be sampled quantitatively using a Ponar dredge?
- What is the time cost for each of these sampling procedures?
- What is the selenium content in periphyton/detrital material?
- What is the selenium content in brine fly larvae and adults?
- What is the selenium content in the overlying water above the benthic substrates?

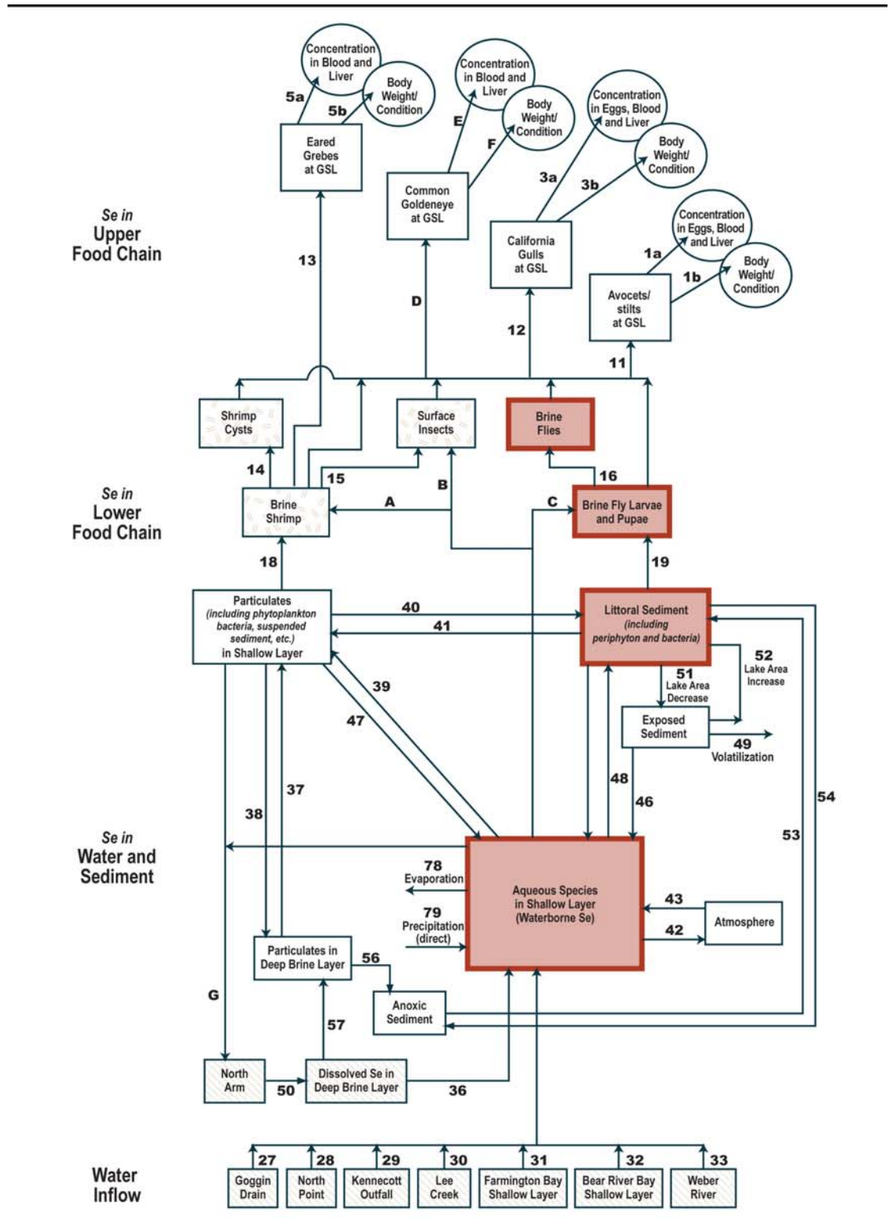

FIGURE 4-4
Project 2A – Benthic Zone
Great Salt Lake Water Quality Studies
Final Report – Selenium Program

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4.2.4 Project 2B, Synoptic Survey of Selenium in Water, Seston, and Brine Shrimp

Principal Investigator: Brad Marden, Parliament Fisheries, LLC

Project Objectives (2006)

This project evaluated the trophic transfer of selenium within food webs from water to particulate matter (seston) to brine shrimp (*Artemia franciscana)* through the following objectives*:*

- Document the temporal and spatial characteristics of total selenium concentrations in water and correlate with seston and brine shrimp tissue selenium concentrations
- Correlate isotopic nitrogen (15N) and carbon (13C) levels in seston with selenium concentrations in brine shrimp tissue to identify dietary sources
- Monitor primary production indicators (chlorophyll a concentration) and record brine shrimp population dynamics (all life stages)
- Document algal population abundance and diversity over time

Project Objectives (2007)

This project was extended to collect samples through July 2007 with the same objectives as in 2006.

Project Questions

The guiding question for Project 2B was:

- What are the transfer factors for selenium from the pelagic zone (water and seston) to the brine shrimp component of the food web?

To understand the potential effects of selenium on the pelagic zone and food web of Great Salt Lake, the following questions needed to be addressed:

- What are the concentrations of selenium in Great Salt Lake water, seston, and brine shrimp tissue?
  - What is the correlation between waterborne concentrations of selenium and levels found in seston and brine shrimp?
  - What is the potential dietary selenium risk to avian species from consuming brine shrimp (not part of Marden's study)?
- What are the temporal and spatial patterns of isotopic carbon (13C) and nitrogen (15N) in particulate organic matter and brine shrimp tissue as may be indicative of dietary sources?
  - Do 13C and 15N correlate with selenium concentrations in particulate organic matter and brine shrimp?
  - Do selenium, 13C, and 15N in brine shrimp correlate with seston abundance (surrogate forphytoplankton abundance)?
  - Do the stable isotope fractions in diet indicate discrete sources of selenium that account for brine shrimp tissue levels of selenium? Do the sources supporting the brine shrimp body-burdens of selenium vary seasonally?
- What are the population size, age-structure, and biomass of brine shrimp in Great Salt Lake?
  - What is the total selenium load in Great Salt Lake brine shrimp population (How do changing brine shrimp tissue concentrations of selenium and the abundance of adults or cysts correlate with avian consumers and avian seasonality and nesting at Great Salt Lake?)?

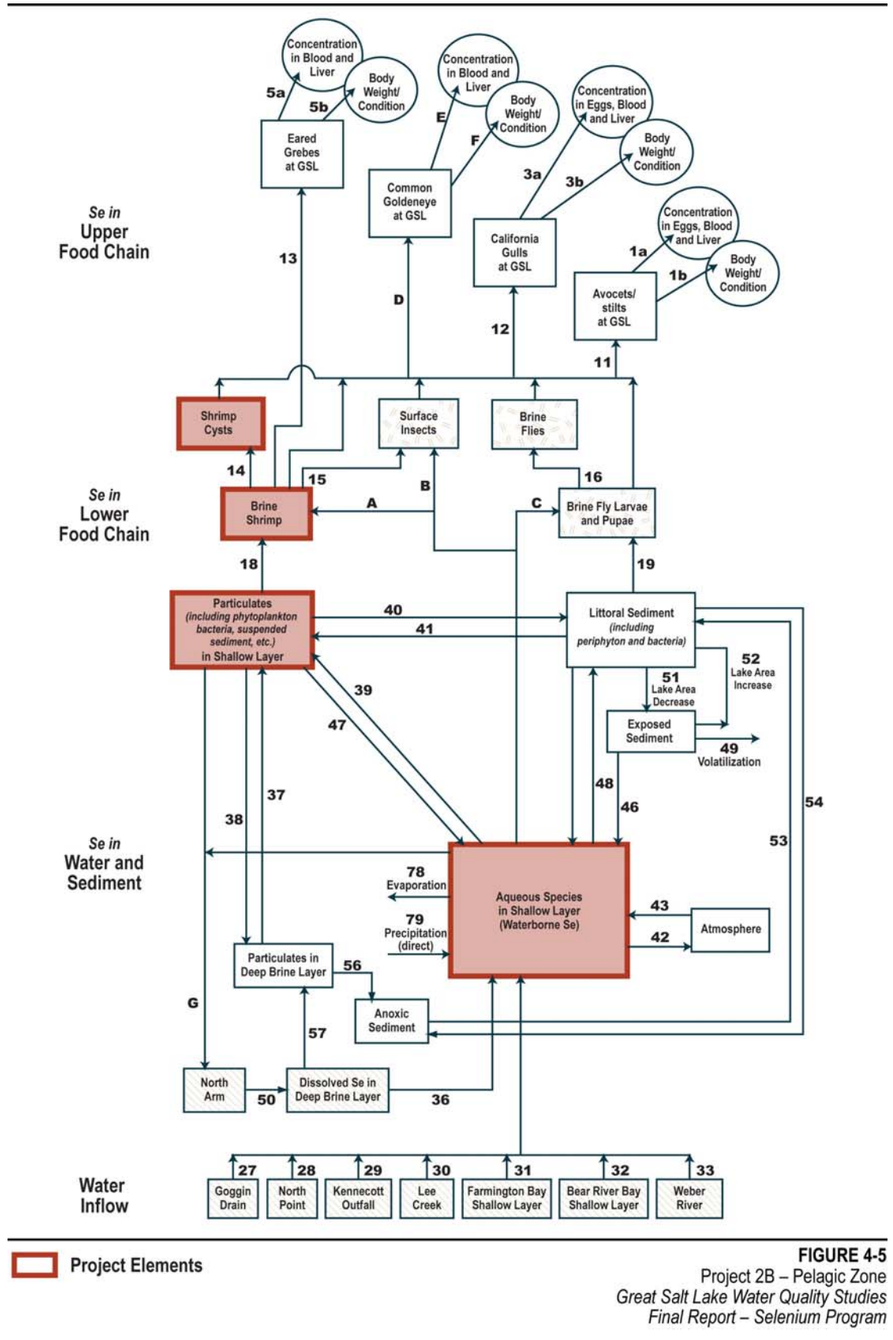

FIGURE 4-5
Project 2B – Pelagic Zone
Great Salt Lake Water Quality Studies
Final Report – Selenium Program

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4.2.5 Project 3, Measurement of Selenium Loads to Great Salt Lake

Principal Investigator: Dr. David Naftz, USGS, Dr. Bill Johnson, University of Utah

Project Objectives

Most rivers that flow into Great Salt Lake are monitored by the USGS with respect to discharge and concentration of chemical constituents. Unfortunately, all of the established gaging sites are located significant distances upstream of where the outflow actually enters the open waters of Great Salt Lake. Significant changes in the selenium concentration, as well as other chemical constituents, can occur between the established gaging stations and where the inflow enters into the open waters of the lake.

The objective of this project was to establish new stream gaging station locations that facilitate the measurement of selenium loads entering the open waters of Great Salt Lake. Data gathered from the new gaging infrastructure were used to model mean daily selenium loads from all surface water inflow sources to Great Salt Lake. The modeling results were used to determine an annual selenium budget for the open waters of Great Salt Lake. For purposes of this project, it was assumed that loading from groundwater and atmospheric deposition was negligible.

Project Questions

The guiding question for Project 3 was:

- What are the sources of waterborne selenium entering Great Salt Lake, and what is the relative significance of each of the various sources?

To understand the relative significance of each of the potential sources of selenium to Great Salt Lake, the following questions needed to be addressed:

- What is the potential selenium load from the following sources?
  - Farmington Bay
  - Bear River Bay
  - Goggin Drain
  - Weber River
  - Lee Creek
  - Kennecott Utah Copper outfall
  - North Arm flow through Union Pacific Railroad Causeway
  - Morton Salt Outfall
  - Great Salt Lake Minerals outfall
- What are the seasonal and geographic variations in selenium loadings with respect to seasonal biological cycles in the Great Salt Lake ecosystem?

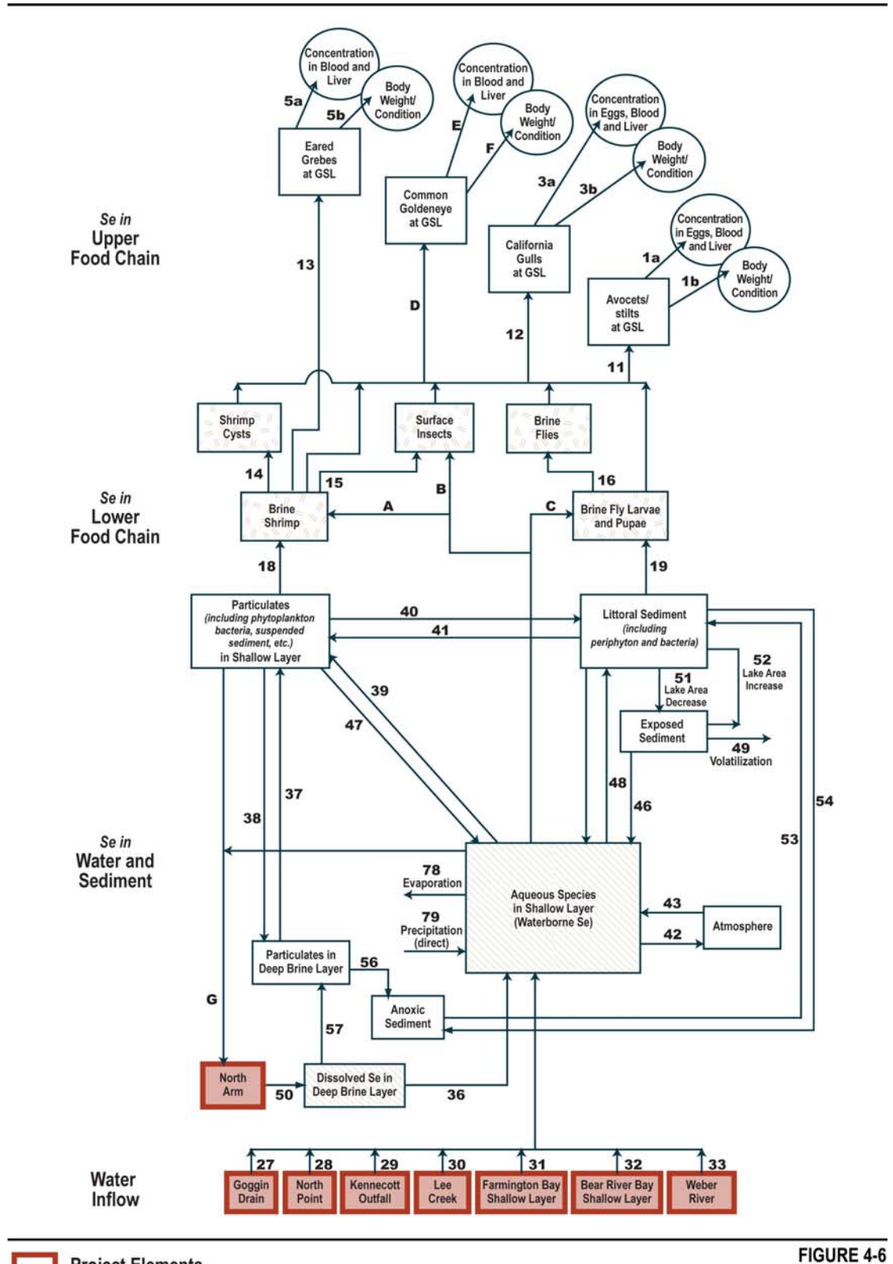

FIGURE 4-6
Project 3 – Selenium Loads
Great Salt Lake Water Quality Studies
Final Report – Selenium Program

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4.2.6 Project 4, Measurement of Selenium Flux

Principal Investigators: Dr. Bill Johnson, University of Utah; Dr. David Naftz, USGS

Project Objectives

The selenium inputs determined in Project 3 must be balanced against selenium outputs, which are expected to occur mainly via two mechanisms: (1) release of selenium vapor to the atmosphere; and/or (2) permanent burial of selenium in the sediment. These output fluxes cannot be estimated from published literature because these two release processes in Great Salt Lake have not been heavily investigated. Furthermore, the existing literature for other systems does not address a system of the size, salinity, vertical and spatial heterogeneity, and temporal variability as represented in Great Salt Lake.

The objective of Project 4 was to complete appropriate measurements to:

- Estimate the flux rates of volatilization, ebullition, and permanent burial via sedimentation
- Estimate the effects re-suspension and re-solubilization of selenium have in mass balance to the water column
- Estimate the potential internal selenium load to the water column from rising lake levels

Project Questions

The guiding question for Project 4 was:

- What are the most important processes that affect the partitioning, cycling, and release of selenium in Great Salt Lake open waters (that is, where does the selenium go once it is in Great Salt Lake)?

To understand the partitioning, cycling, and release of selenium in Great Salt Lake, the following questions needed to be addressed:

- What are the rates of selenium removal via volatilization and ebullition from Great Salt Lake?
- What is the rate of permanent sequestration of selenium via sedimentation?
- Do transient events or ongoing processes re-suspend and re-solubilize selenium into the water column to an extent that has biological significance?
- Do lake level rises re-introduce selenium into the water column to an extent that has biological significance?

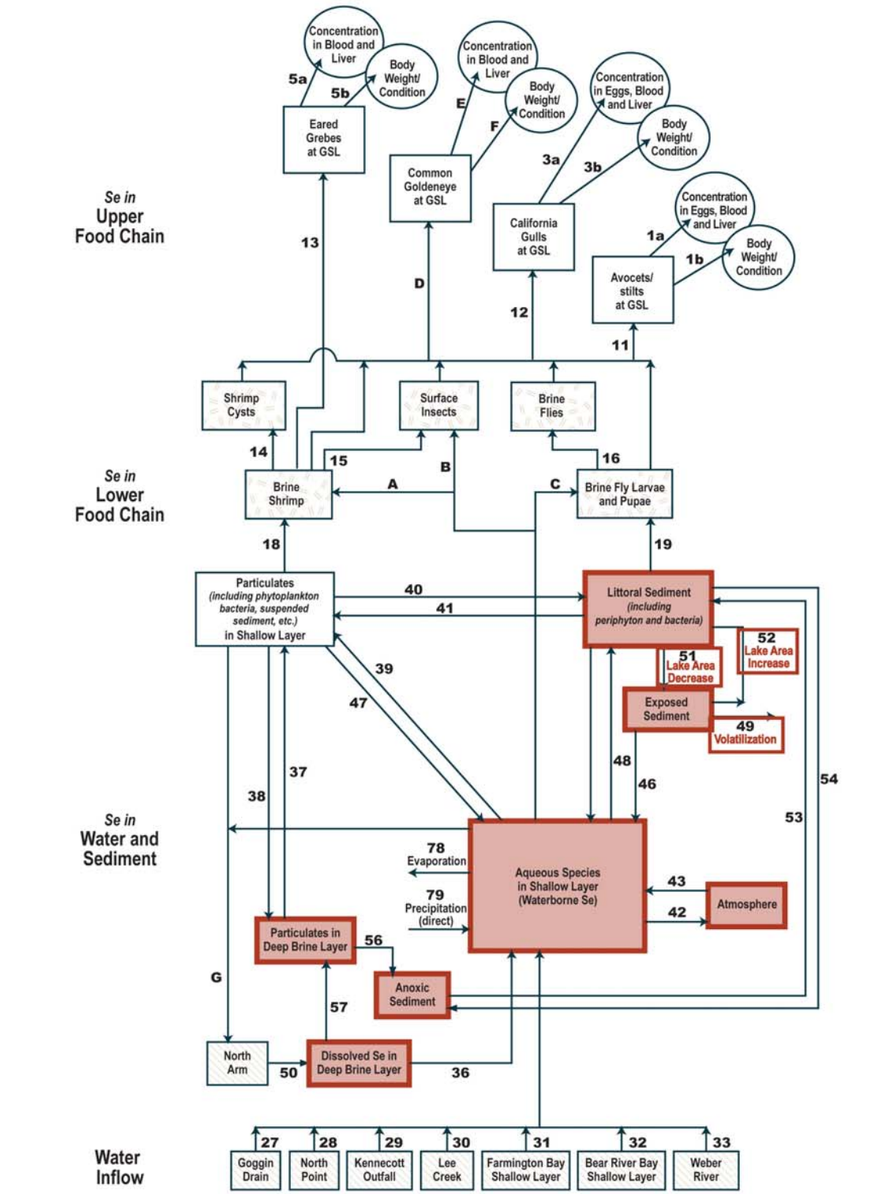

FIGURE 4-7
Project 4 – Selenium Flux
Great Salt Lake Water Quality Studies
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4.2.7 Project 5, Predictions of Selenium Accumulation in ***Artemia franciscana*** under Conditions Realistic for the Populations Residing in the Great Salt Lake (Brine Shrimp Kinetics)

Principal Investigator: Dr. Martin Grosell, University of Miami

Project Objectives

The primary objective for Project 5 was to provide reliable predictions of selenium accumulation in brine shrimp under conditions realistic for the populations residing in Great Salt Lake.

This general objective was addressed by pursuing the following specific objectives:

1. Determine the influence of salinity on selenium uptake and feeding rate by brine shrimp
2. Determine selenium uptake rates in brine shrimp from dissolved selenium concentrations in artificial Great Salt Lake water (uptake kinetics)
3. Determine dietary selenium intake and subsequent selenium assimilation efficiency in brine shrimp fed a diet of selenium-loaded algae cells (*Dunaliella viridis*)
4. Determine selenium elimination rates from brine shrimp following selenium accumulation from elevated ambient concentrations
5. Model selenium accumulation in brine shrimp based on the results from Objectives 1 through 3 to provide predictions of selenium accumulation during realistic exposure scenarios
6. Determine the "knee" of the dissolved selenium accumulation rate curve in brine shrimp
7. Investigate possible regulation of selenium accumulation in brine shrimp during prolonged exposure to selenium

Project Questions

The guiding question for Project 5 was:

- What are the transfer factors for selenium from water and algae to the brine shrimp component of the food web as determined under laboratory conditions?

To understand the transfer of selenium from water and algae to brine shrimp, the following questions needed to be addressed:

- What is the influence of salinity on selenium uptake and feeding rate by brine shrimp?
- What are the uptake kinetics, assimilation efficiencies, and elimination rates for brine shrimp in artificial Great Salt Lake water and shrimp fed a diet of selenium-loaded algae cells?
- What is the "knee" of the dissolved selenium accumulation rate curve in brine shrimp?
- How can we predict how selenium will accumulate in brine shrimp during realistic exposure scenarios?

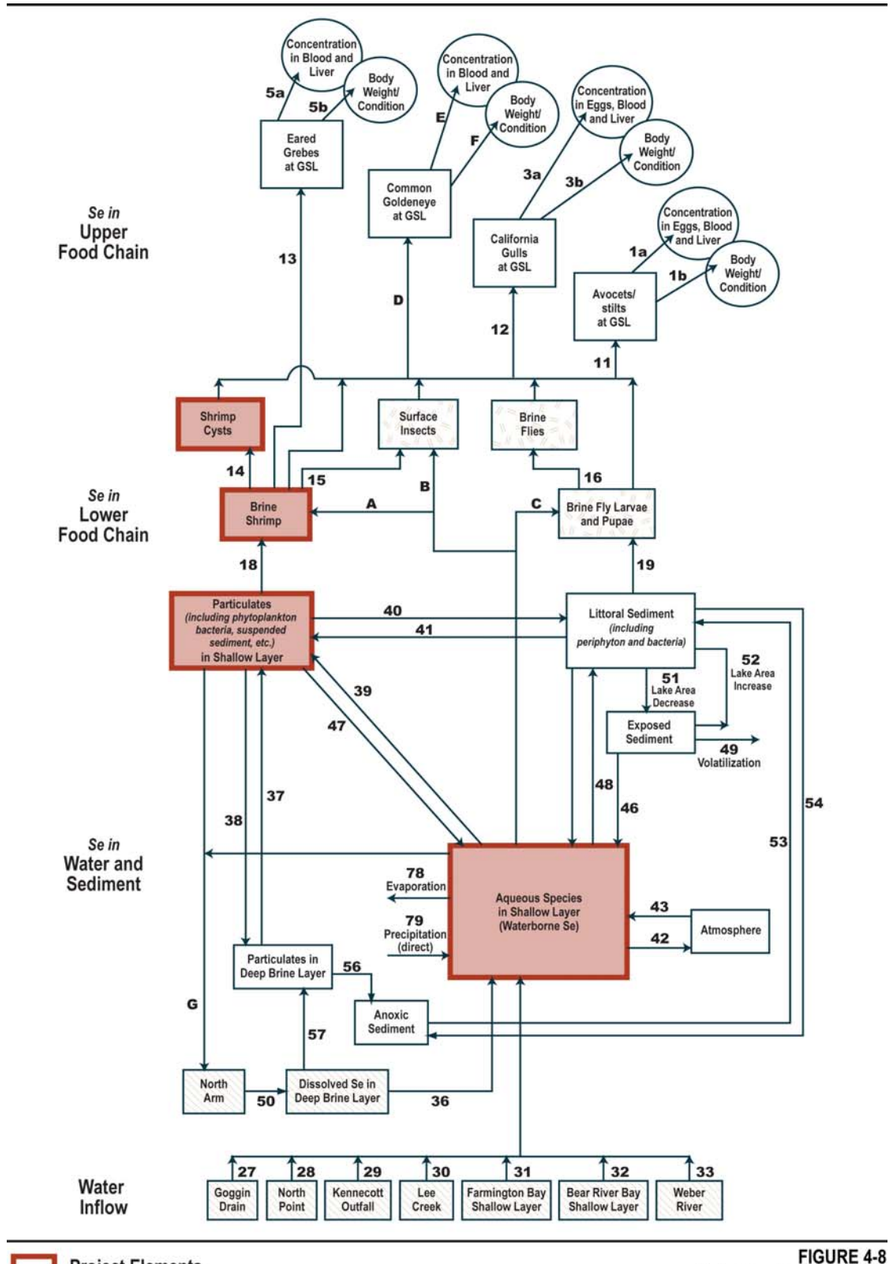

FIGURE 4-8
Project 5 – Great Salt Lake
Great Salt Lake Water Quality Studies
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