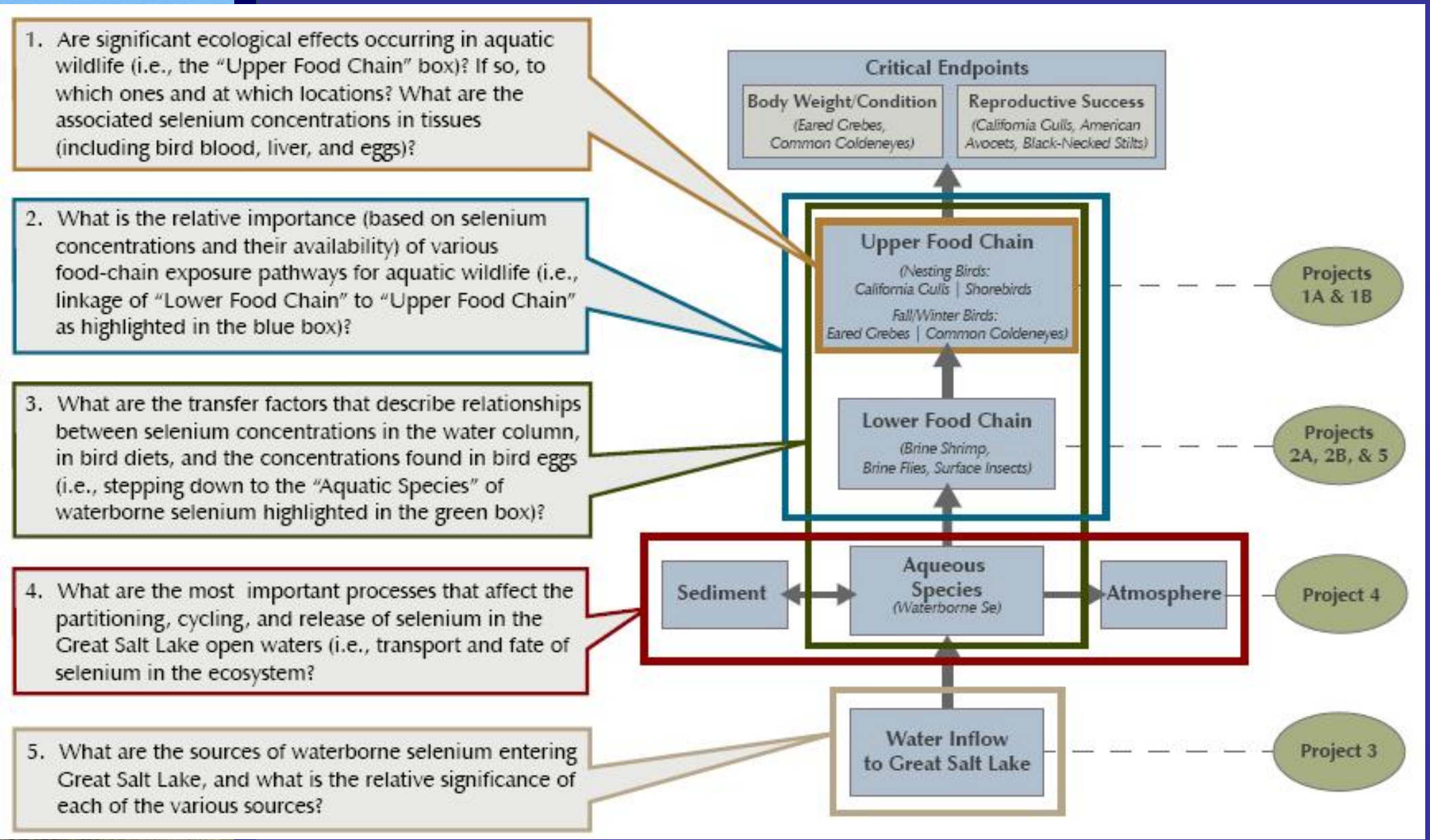
Great Salt Lake Water Quality Studies

Selenium Program Update

November 30, 2007

Program Question Relative to Projects

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?



Body Weight/Condition Endpoint

- **Eared Grebes – Confounding Factors**
  - Physiology unusual, varies depending on point in migration cycle
  - Elevated blood and liver Se & Hg
  - Do not understand interaction of Se & Hg
  - Do not have reliable index or threshold for non-breeding effects

Body Weight/Condition Endpoint

- **Goldeneyes – Confounding Factors**
  - Elevated blood and liver Se & Hg
  - Do not understand interaction of Se & Hg
  - Diet very mixed, open water and wetlands
  - Birds move around a lot
  - Arrival times for birds are unknown
  - Do not have reliable index or threshold for non-breeding effects

Body Weight/Condition Endpoint

- **Until we…**
  - have a good endpoint/threshold developed,
  - understand the interaction b/w Hg & Se, and
  - Se diet approaches threshold

….the information we do have indicates that body weight/condition is not as sensitive as reproductive success

- **Body weight/condition will not be considered in establishing a Se water quality standard at this time**

Reproductive Success Endpoint

- Focusing on shorebirds/gulls
- It is generally recognized that the most significant exposure of birds occurs through their diet.
- The best-documented and most readily-monitored effects are those on reproductive success (particularly egg hatchability, assessed indirectly for GSL on the basis of selenium concentrations in food-chain organisms and bird eggs).
- Laboratory studies with mallards provide the best available data to evaluate avian exposure and effects; because the mallard is relatively sensitive to the effects of selenium, using those threshold values builds in conservatism so that the result can be considered protective of other species.

Reproductive Success Endpoint

- The 95% confidence interval on the mean selenium concentrations in mallard diet and eggs associated with the EC10 for egg hatchability (explained below) would be reasonably protective for birds nesting at the GSL.
- The degree of protectiveness to be applied by the State in setting the water quality standard will be discussed and determined.
- The Panel has identified a range of acceptable values to be used in modeling and derivation of a potential standard.

Reproductive Success Endpoint

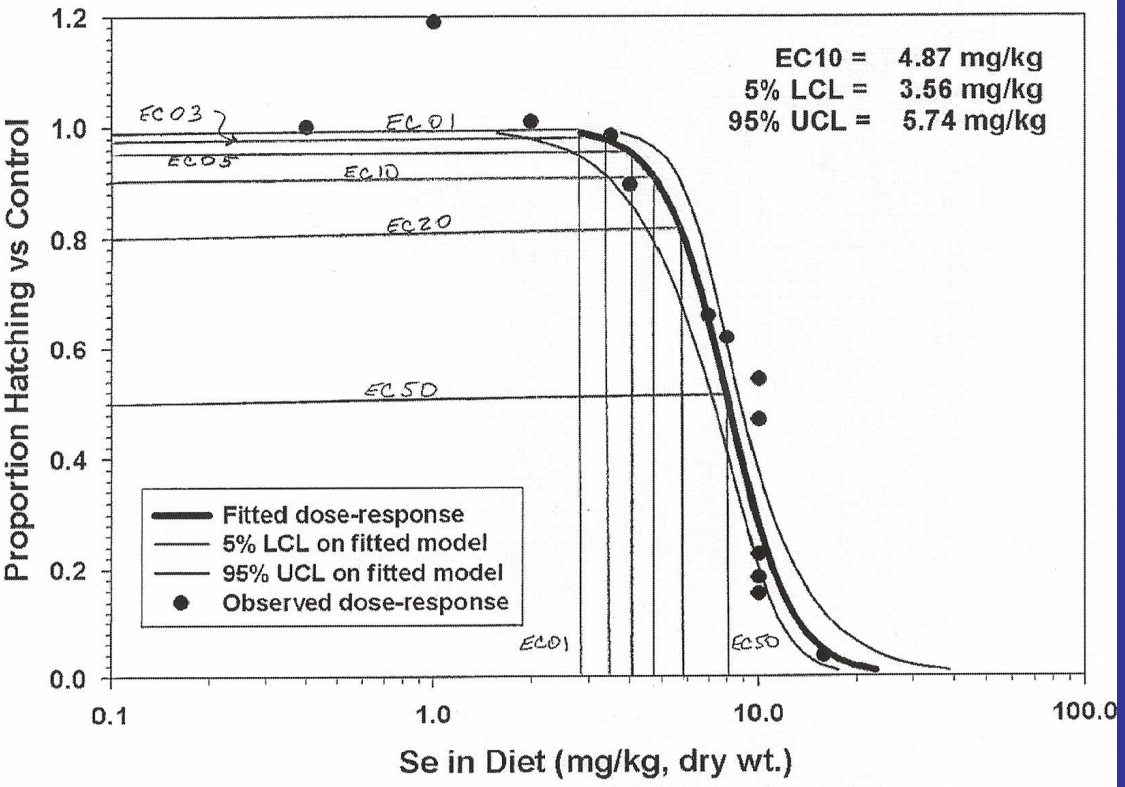


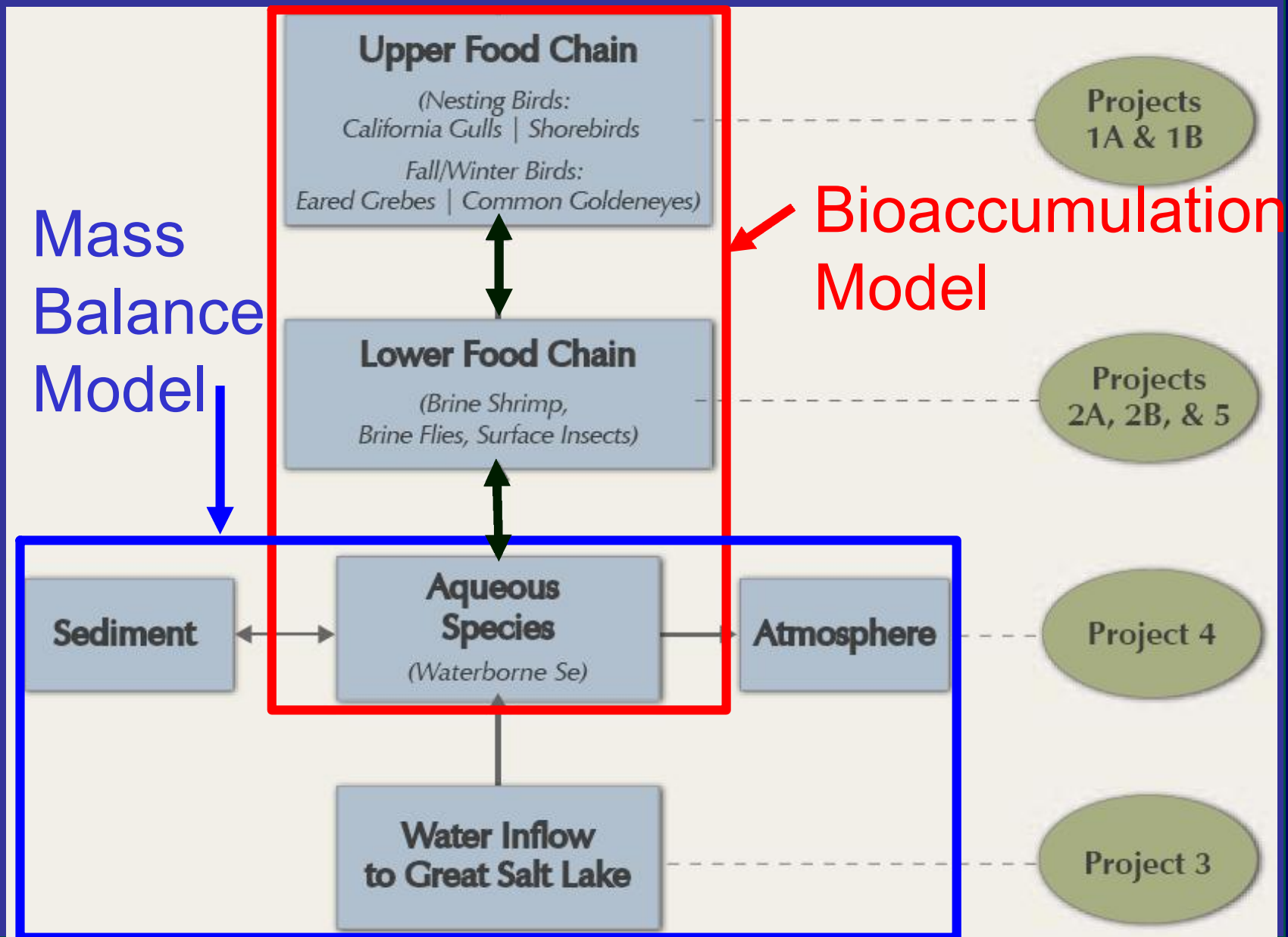
Figure 1. Mallard egg hatchability vs control as a function of selenium concentration in diet.

Reproductive Success Endpoint

Threshold Values

Concentration (mg Se/kg)	Best Estimate for Best Case % Reduction	Maximum Likelihood	Best Estimate for Worst Case % Reduction
Diet			
3.56 (LCL)	<1%	3%	10%
4.87 (Mean)	4%	10%	24%
5.74 (UCL)	10%	18.50%	32%
Egg			
6.4 (LCL)	<1%	1.50%	10%
12.5 (Mean)	3.50%	10%	26.50%
16.5 (UCL)	10%	21%	37.50%

Two Models


Upper Food Chain
(Nesting Birds:
California Gulls | Shorebirds
Fall/Winter Birds:
Eared Grebes | Common Goldeneyes)
Lower Food Chain
(Brine Shrimp,
Brine Flies, Surface Insects)
Sediment
Aqueous Species
(Waterborne Se)
Atmosphere
Water Inflow to Great Salt Lake
Mass Balance Model
Bioaccumulation Model
Projects 1A & 1B
Projects 2A, 2B, & 5
Project 4
Project 3

Bioaccumulation Model

- **End goal is to:**
  - Allow user to change water concentration and/or input values to evaluate critical endpoints, and
  - Allow user to change threshold values and look at associated water concentration
- **Thus, Panel will be able to recommend water quality standard**

Program Question Relative to Projects

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)?
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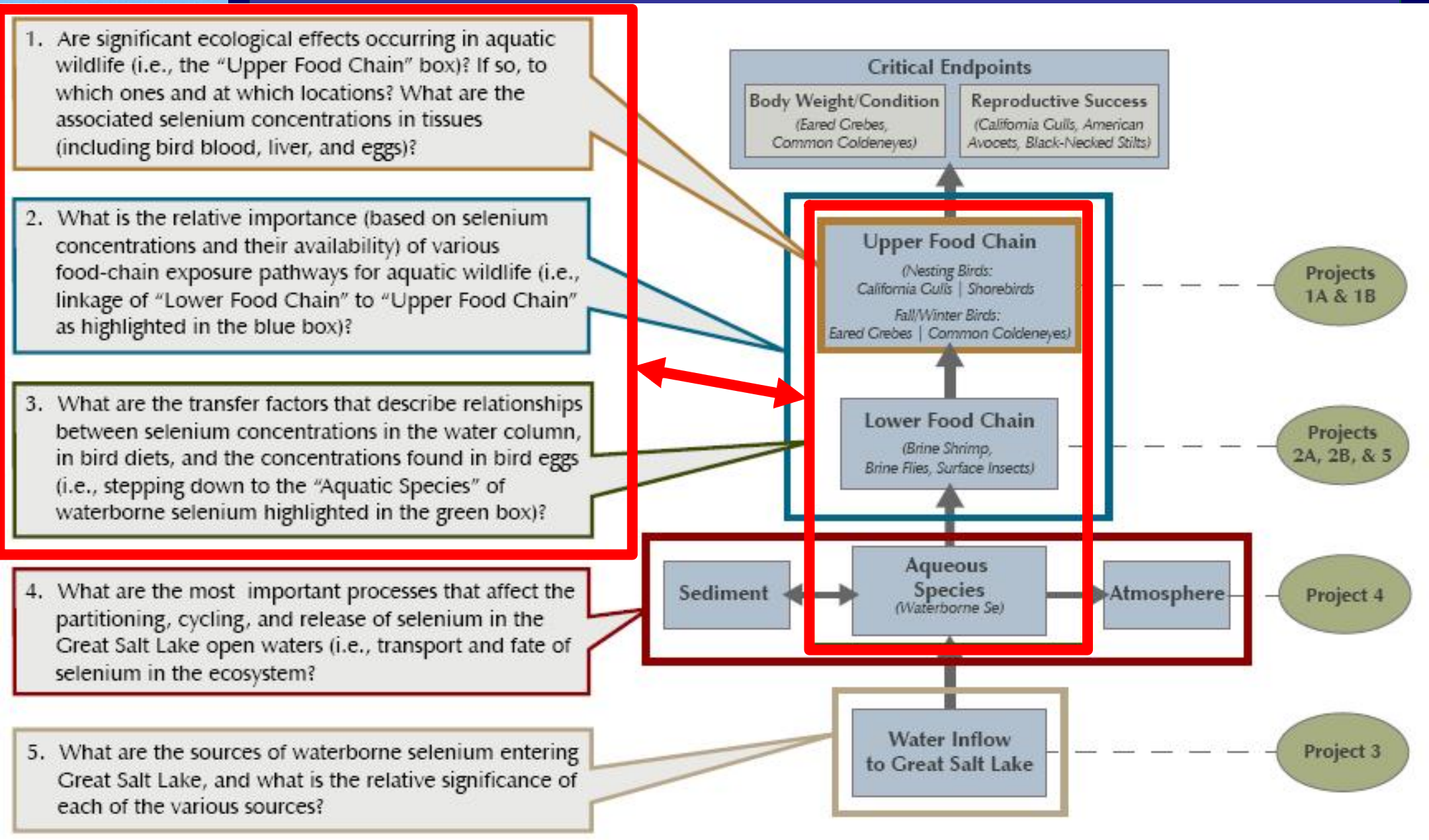


Bioaccumulation Model

- **Collected data to develop transfer factors for Se from water/sediment to diet for:**
  - Periphyton
  - Phytoplankton (seston)
  - Brine flies
  - Midges
  - Corixids
  - Brine shrimp

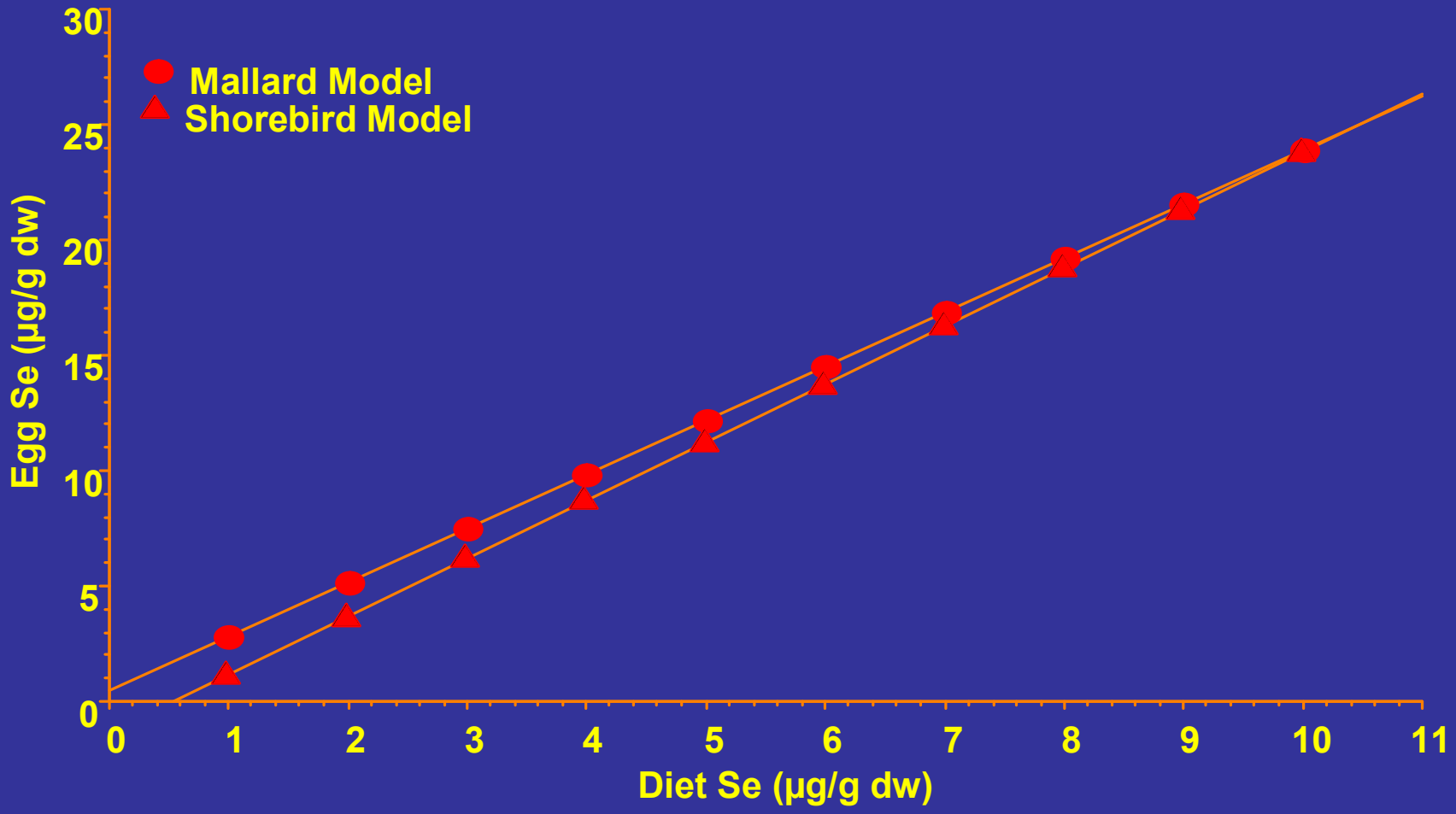
Bioaccumulation Model

- We are finalizing lab derived predictive model for water/seston to brine shrimp in addition to simple transfer factor from field study
- Model will allow user to vary food item concentration and transfer factor
- Model allows user to vary diet mix to derive diet Se concentration from water concentration

Bioaccumulation Model

- **Looked at simple transfer factors and regressions for diet to egg**
- **Looked at three regressions for diet to egg:**
  - Shorebird model
  - Gull model
  - Mallard model
- **Panel selected Shorebird Model**

Bird models


Mallard Model
Shorebird Model
Egg Se (µg/g dw)
Diet Se (µg/g dw)
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
9
10
11

Resulting Tissue Concentrations of Diet Options (µg Se/g dw)

Choose brine shrimp model:
(●) Grosell Model ( ) Simple TF

Please specify concentrations of diet options for each species (not functional for all diet options)

Diet Options	Concentration	Shorebird	Gull
Brine shrimp	1.90	0%	100%
Brine shrimp cysts	1.91	0%	0%
Brine fly	1.87	100%	0%
Corixid	2.34	0%	0%
Midge	2.01	0%	0%
Total Before Sediment		**100%**	**100%**
Sediment	0.55	5%	0%
Please specify dietary concentrations onsite			
Onsite		90%	90%
Offsite	1.90	10%	10%

Limits and Predicted Diet Concentrations for Each Species (µg Se/g dw)

Limits for Diet Concentration	4.9	4.9
Predicted Diet Concentration	**1.9**	**1.9**

Resulting Egg Concentrations and Indices for Each Species (µg Se/g dw)

s and which model to use to estimate Egg Concentration for Shorebirds & Gulls

(●) AMAV/Gull Model ( ) Mallard Model

	Egg Concentration	Egg Concentration
Limits for each parameter	12.5	12.5
Predicted parameters	3.4	2.8

Diet Concentrations Back-Calculated from Egg Se Concentration (µg Se/g dw) (Using Mallard Model and Parameter Limit Specified Above)

Geometric Mean	4.7	4.7
95% Lower Confidence Limit	2.5	2.5
95% Upper Confidence Limit	6.7	6.7

Diet Threshold

Predicted Reduction in Egg Hatchability

As a Function of Diet, Egg Selenium Concentration and Loading Multiplier

Please specify the Tributary Loading multiplier (1X = measured values)	1

Choose Species to Analyze: (•) Shorebird ( ) Gull *

Resulting Water and Tissue Concentrations

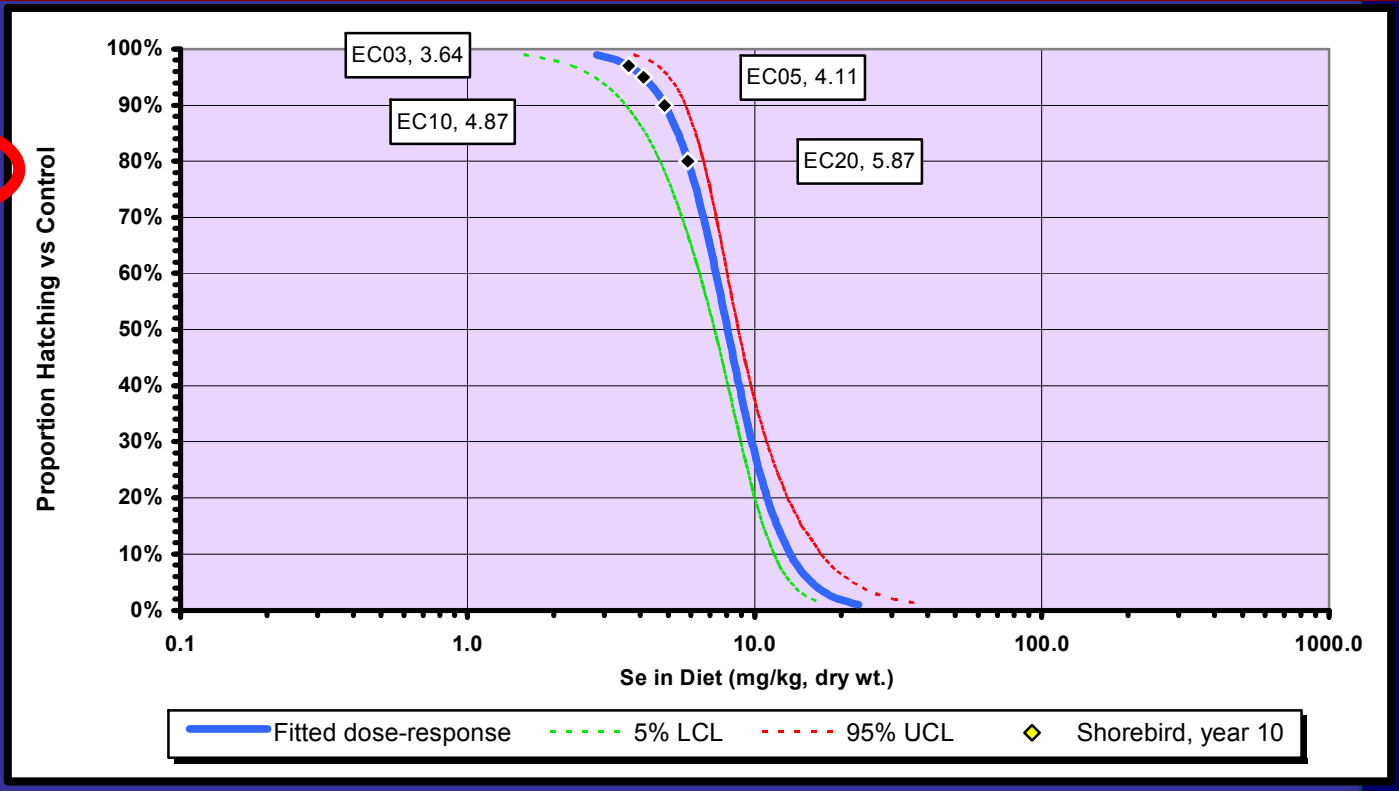
	Year 1	Year 10
Water Concentration (µg Se/L)	0.60	0.75
Diet Concentration (µg Se/g dw)	1.88	2.02
Egg Concentration (µg Se/g dw)	3.39	4.50

Estimated Range of Reduction in Egg Hatchability

Choose EC Curve to Display: (•) DIET ( ) EGG

	Year 1	Year 10
As a Function of Diet Concentration		
Max. Likelihood %	< 1%	< 1%
Lower Bound %	< 1%	< 1%
Upper Bound %	1%	3%
As a Function of Egg Concentration		
Max. Likelihood %	< 1%	< 1%
Lower Bound %	< 1%	< 1%
Upper Bound %	3%	5%

Mallard Egg Hatchability vs Control as a Function of Selenium Concentration



Diet Threshold

Predicted Reduction in Egg Hatchability

As a Function of Diet, Egg Selenium Concentration and Loading Multiplier

Please specify the Tributary Loading multiplier (1X = measured values) **2**

Choose Species to Analyze: (•) Shorebird ( ) Gull *

Resulting Water and Tissue Concentrations

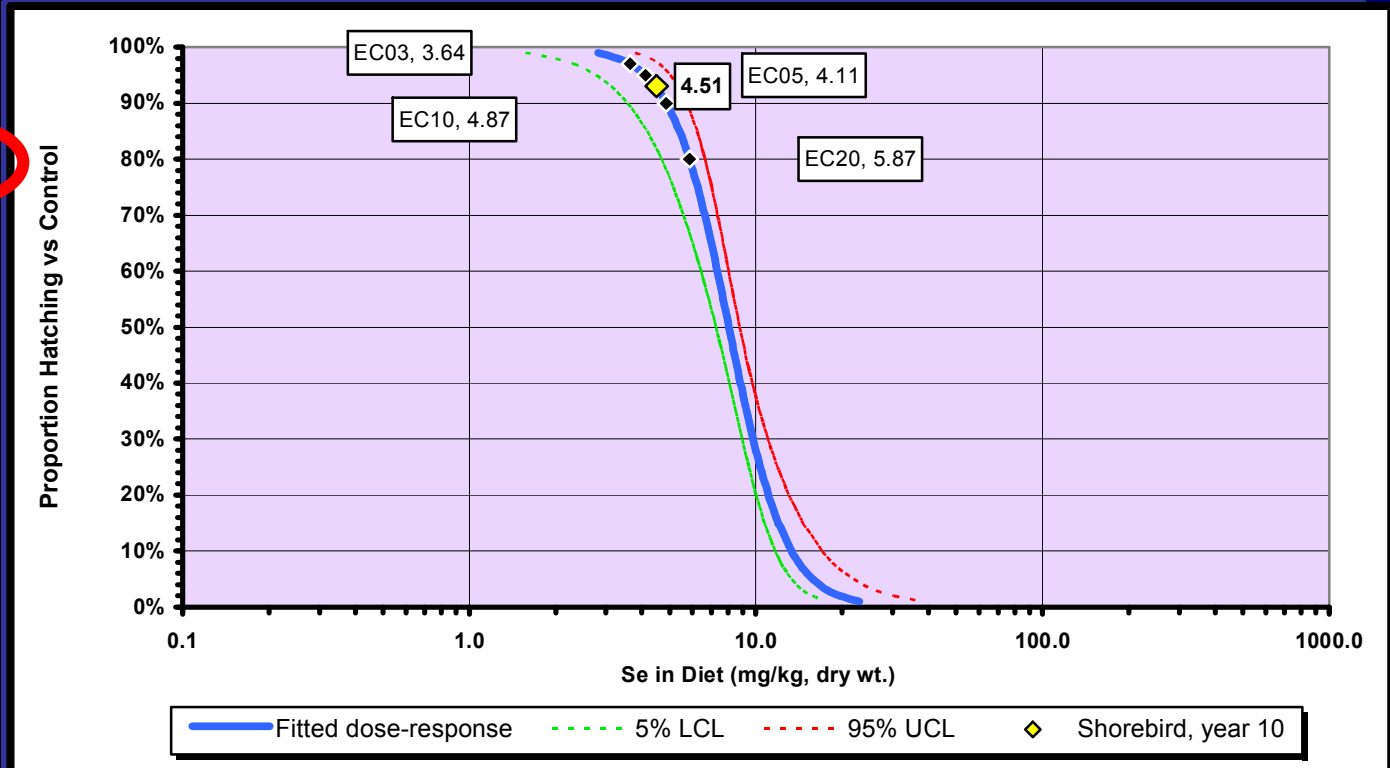
	Year 1	Year 10
Water Concentration (µg Se/L)	0.63	1.52
Diet Concentration (µg Se/g dw)	1.96	4.51
Egg Concentration (µg Se/g dw)	3.60	10.01

Estimated Range of Reduction in Egg Hatchability

Choose EC Curve to Display: (•) DIET ( ) EGG

	Year 1	Year 10
As a Function of Diet Concentration		
Max. Likelihood %	< 1%	7%
Lower Bound %	< 1%	2%
Upper Bound %	1%	18%
As a Function of Egg Concentration		
Max. Likelihood %	< 1%	5%
Lower Bound %	< 1%	1%
Upper Bound %	3%	19%

Mallard Egg Hatchability vs Control as a Function of Selenium Concentration



Egg Threshold

Predicted Reduction in Egg Hatchability

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Choose EC Curve to Display: ( ) DIET (●) EGG

	Year 1	Year 10
As a Function of Diet Concentration		
Max. Likelihood %	< 1%	< 1%
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Upper Bound %	1%	3%
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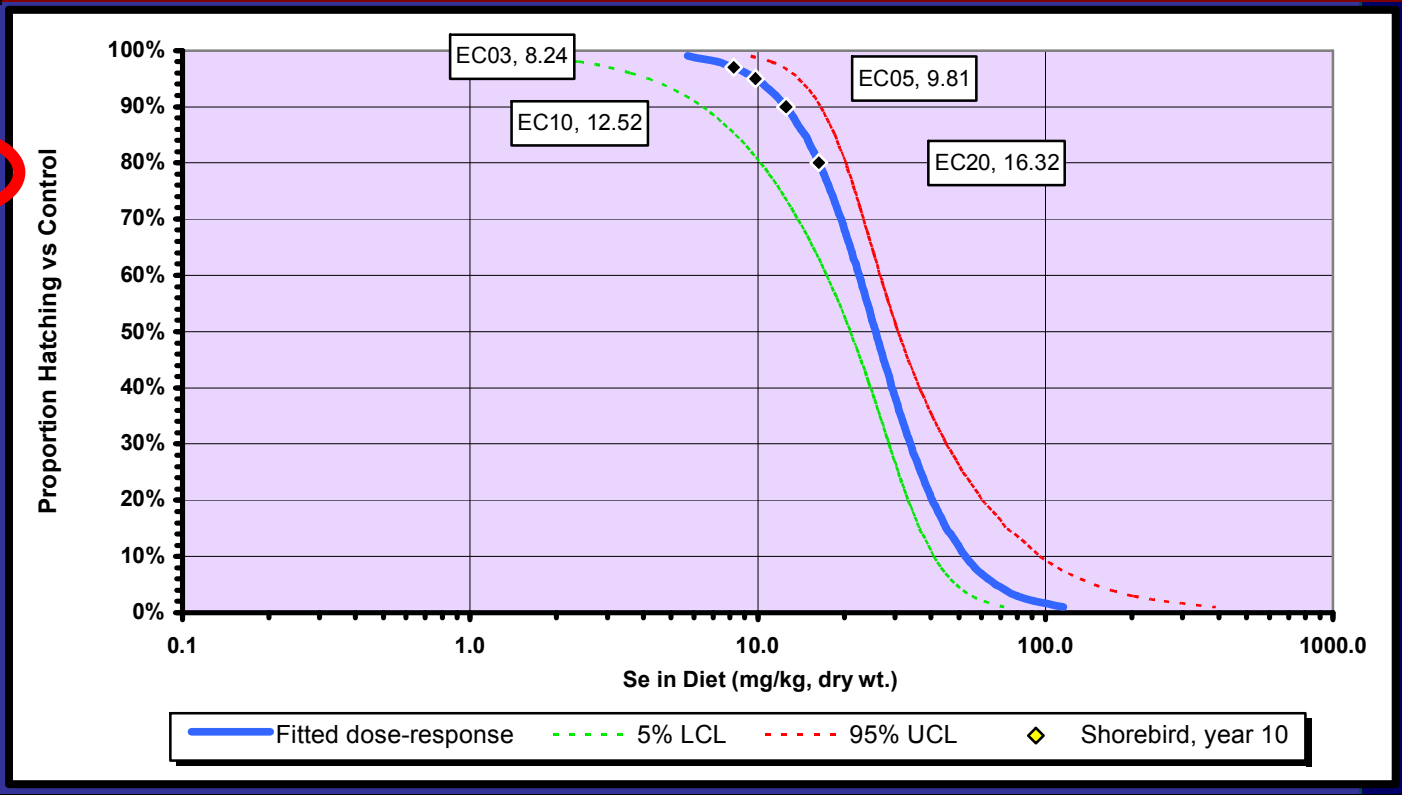

Egg Threshold

Predicted Reduction in Egg Hatchability

As a Function of Diet, Egg Selenium Concentration and Loading Multiplier

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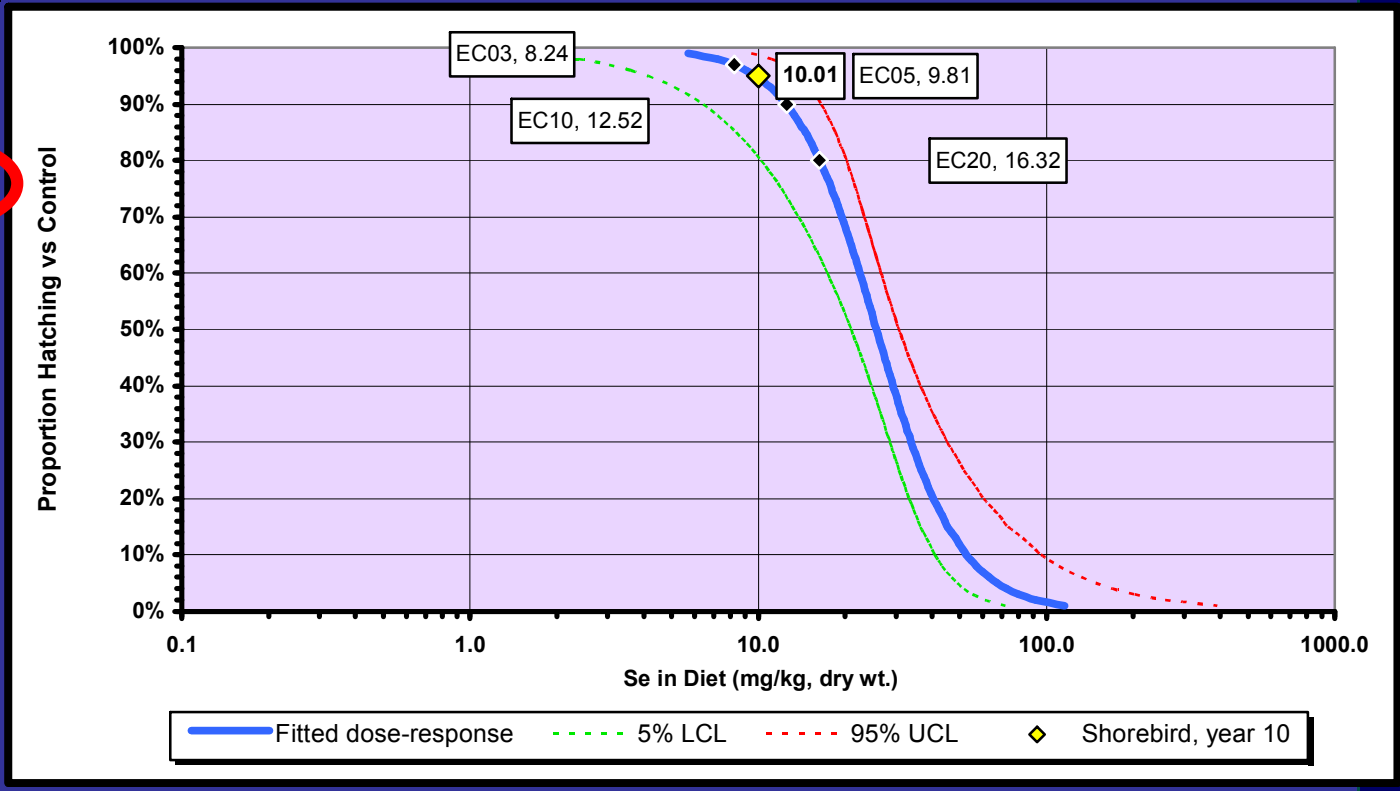

Bioaccumulation Model

- **Next Steps:**
  - Finalize Grosell brine shrimp model
  - Finalize review of seston/brine shrimp field data
  - Review gull diet/egg model
  - Finish capability to back-calculate from diet to water concentration
  - Add functionality to foodweb calcs

Mass Balance Model

- **End Goal:**
  - Using data from 1 year study period, allow user to better understand processes driving lake water concentration
  - Eventually provide ability to predict water concentrations into the future (ongoing)

- **Thus, DWQ will be able to manage permit limits**

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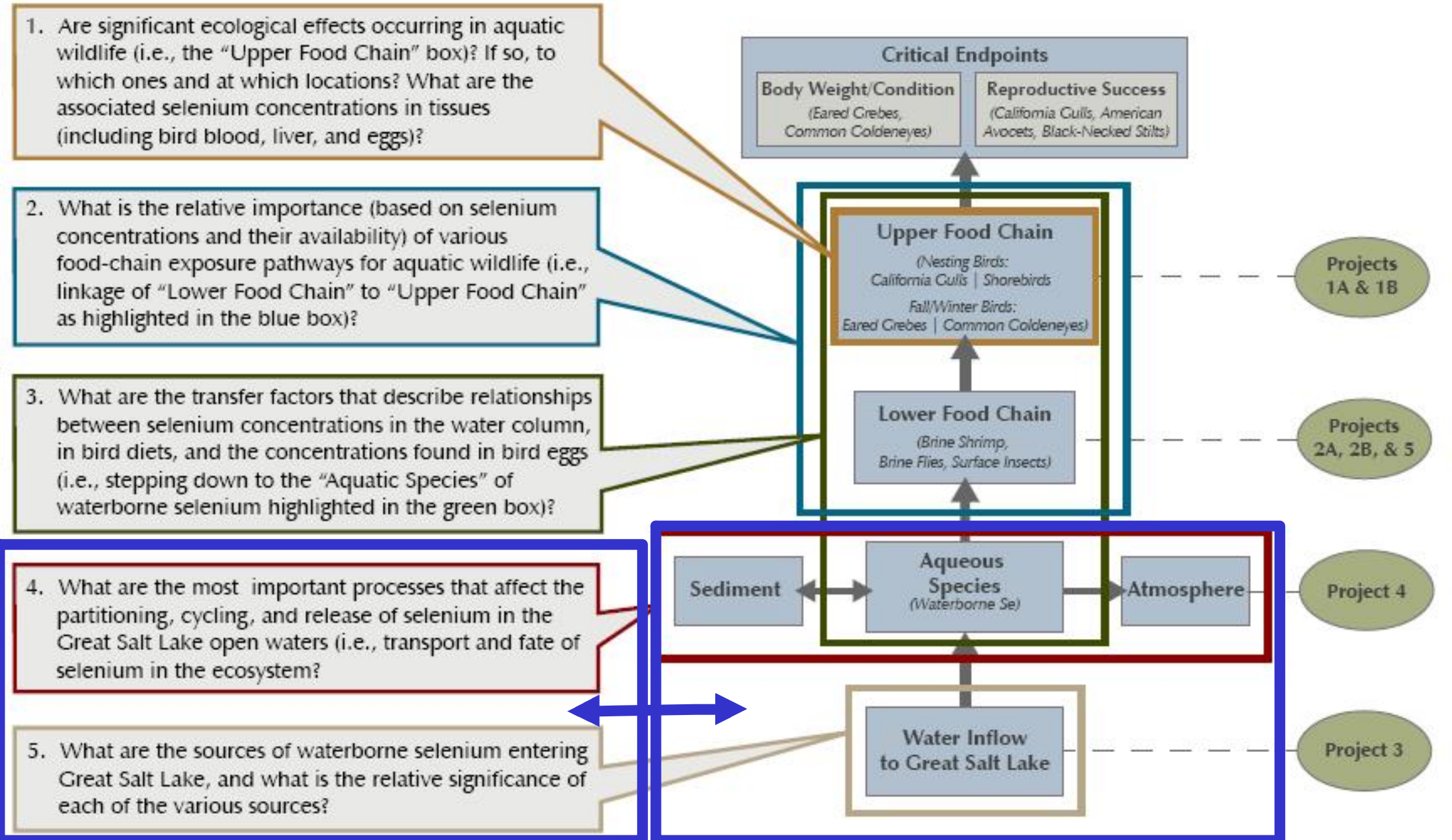
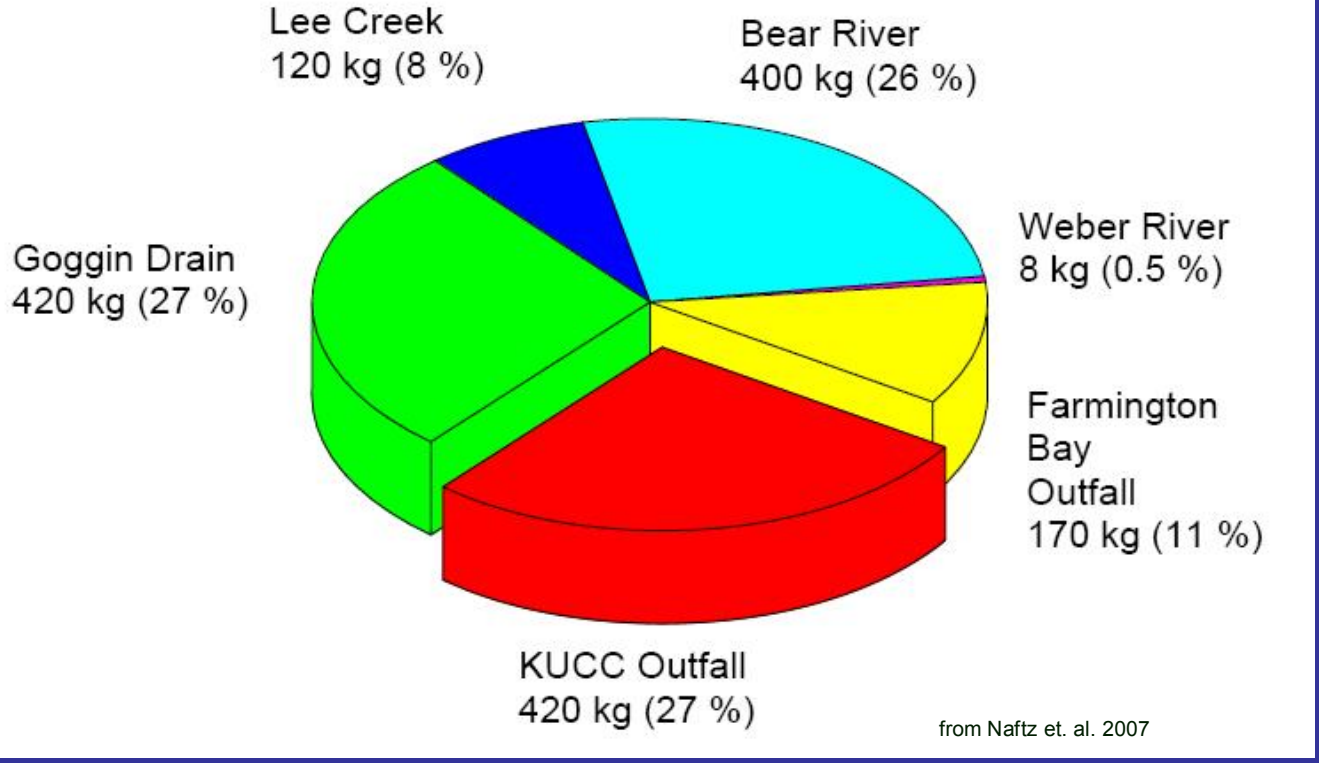


COMPONENT	LOAD OR CONCENTRATION	COMMENTS
Lake		
In-place load	5,718 kg	Based on average concentrations and lake volume. Varies with lake volume and Se concentration. Firm.
In-place concentration	0.3 – 0.7 ug/L Mean = 0.60 ug/L	Based on many measurements, several investigators. Firm.
Inputs to water column		
Stream inputs (6 gages)	1,139 kg, annual load (July 06 through June 07) (add 80kg for Weber R)	USGS daily load estimates. Other months available, too. Potentially missing some surface flows. Firm.
Atmospheric deposition directly to lake surface	598 kg annual load Could range 300 - 800 kg	Literature estimate only. Ballpark (?). Weak
Remineralization	135 kg	Subtracting permanent burial from sedimentation
Groundwater	Unmeasured, unestimated	Needs to be studied. USGS work underway.
Shoreline rewetting	12 kg last year	OK, variable but appears to be a small contribution.
DBL contribution (changing sediment "cap")	Unknown at this time	Could be significant. Bill Johnson currently developing estimate.

Loads from Tributaries



from Naftz et. al. 2007

Mass Balance Model – Flux out

REMOVAL MECHANISMS	LOAD OR CONCENTRATION	COMMENTS
Permanent sedimentation	248 kg annual	Good estimate based on weighted averaging from several cores.
Loss to North Lake	880 kg last year Could be highly variable, from 0 – 2,000 kg(?)	Weak estimate, based on 5 samples without continuous flow records, could be highly variable.
Volatilization	750 kg last year (?) Could range from 245 – 14,553kg, GM - 1,848kg	Highly variable, important estimate but may not be able to be improve accuracy or precision.
Brine shrimp cyst removal	4 kg	Good estimate. Small contribution to balance.

Annual Mass Balance

Please specify the Tributary Loading multiplier (1X = measured values)	1

Water Column Selenium Inputs (kg)	
Tributaries	1,139
Atmospheric Deposition	598
DBL Contribution	-
Shoreline Rewetting	12
Total kg	**1,749**

Water Column Selenium Outputs (kg)	
Loss to North Arm	880
Permanent Sediment Burial	248
Sedimentation (not added)	383
Volatilization	1,890
Brineshrimp Cyst Harvest	4
Total kg	**3,022**

Inputs Exceed Outputs by:	**(1,273)**

Year 1 Water Column Concentration	
Water Column Se Mass (kg)	5,404
Water Column Concentration	0.56

Annual Mass Balance

Please specify the Tributary Loading multiplier (1X = measured values)	1

Water Column Selenium Inputs (kg)	
Tributaries	1,139
Atmospheric Deposition	598
DBL Contribution	-
Shoreline Rewetting	12
Total kg	**1,749**

Water Column Selenium Outputs (kg)	
Loss to North Arm	880
Permanent Sediment Burial	248
Sedimentation (not added)	383
Volatilization	750
Brineshrimp Cyst Harvest	4
Total kg	**1,882**

Inputs Exceed Outputs by:	**(133)**

Year 1 Water Column Concentration	
Water Column Se Mass (kg)	5,691
Water Column Concentration	0.59

Annual Mass Balance

Please specify the Tributary Loading multiplier (1X = measured values)	1

Water Column Selenium Inputs (kg)	
Tributaries	1,139
Atmospheric Deposition	598
New Load	37
Shoreline Rewetting	12
Total kg	**1,786**

Water Column Selenium Outputs (kg)	
Loss to North Arm	880
Permanent Sediment Burial	248
Sedimentation (not added)	*383*
Volatilization	750
Brineshrimp Cyst Harvest	4
Total kg	**1,882**
Inputs Exceed Outputs by:	**(96)**

Year 1 Water Column Concentration	
Water Column Se Mass (kg)	5,700
Water Column Concentration	0.59

Annual Mass Balance

Please specify the Tributary Loading multiplier (1X = measured values)	2

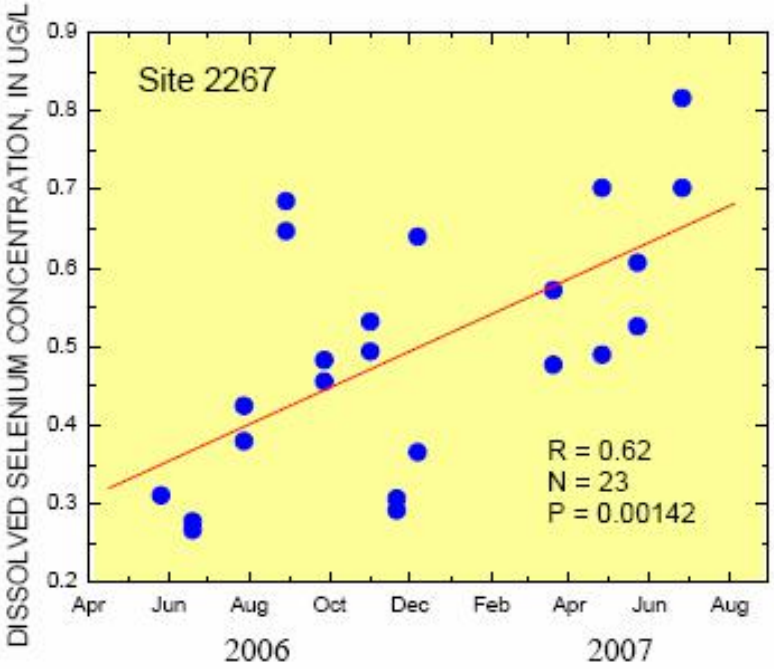
Water Column Selenium Inputs (kg)	
Tributaries	2,278
Atmospheric Deposition	598
New Load	37
Shoreline Rewetting	12
Total kg	**2,925**

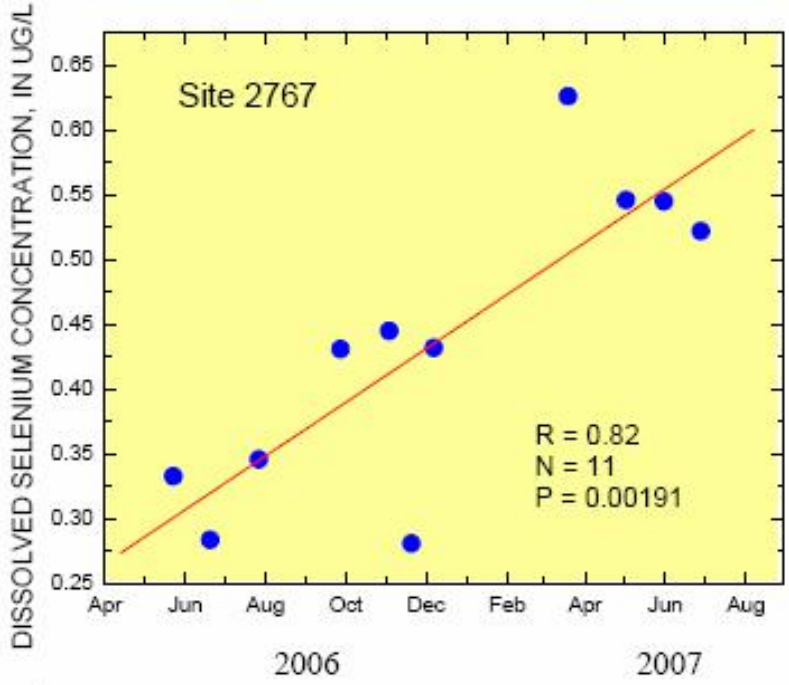
Water Column Selenium Outputs (kg)	
Loss to North Arm	880
Permanent Sediment Burial	248
Sedimentation (not added)	*383*
Volatilization	786
Brineshrimp Cyst Harvest	4
Total kg	**1,918**
Inputs Exceed Outputs by:	**1,007**

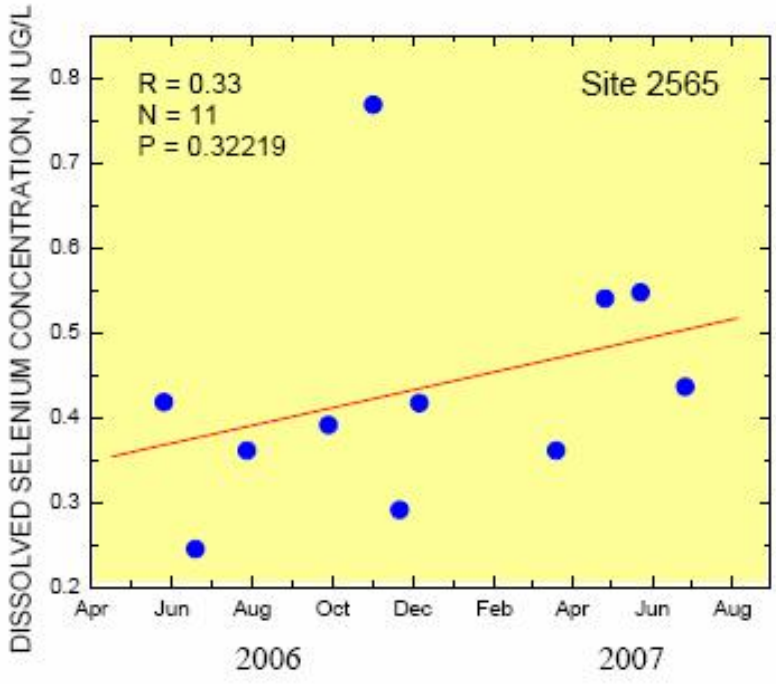
Year 1 Water Column Concentration	
Water Column Se Mass (kg)	5,988
Water Column Concentration	0.62

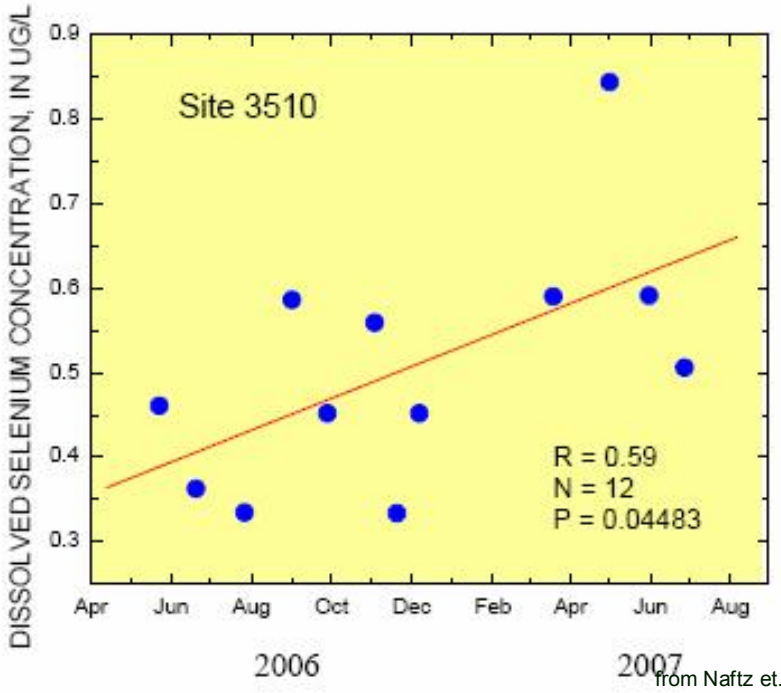
Mass Balance Model

- Field data has provided much data to describe loads and fluxes from the GSL for one year
- GSL is variable, may have multi-year cycle
- Identified variability and areas for future evaluation
- For example…..









from Naftz et. al. 2007

Figure 23. Trends in dissolved (0.45 micron) selenium concentration from May 2006 through June 2007 at open water sites,

Mass Balance Model

- **Next Steps:**
  - Estimate DBL contribution, adjust Weber R load, revisit atmospheric deposition
  - Look at changing to monthly step from current quarterly step
  - Model will only be for study period, not predictive of future years
  - Add functionality describing ranges that allow user to select values for sensitivity analysis

Where to from here?

- Panel proposed to extend schedule to allow thorough review of materials
- Panel to review all reports with goal to release all comments by the end of January 2008
- This will allow Steering Committee to begin their review of final documents

Proposed Schedule

- **December 2007 – January 2008**
  - Panel review of all reports
  - Provide all comments by end of January
- **February 2008**
  - CH2M HILL to address comments & revise model,
  - Panel meeting in SLC to discuss final model (Feb 20-21 Rm 201, Feb 22 Rm 101)
  - Provide final report to Panel end of February

Proposed Schedule

- **March 2008**
  - Panel to review revisions, discuss implementation
- **April 2008**
  - Panel to prepare individual recommendations for review by Panel
  - Panel meeting April 30- May 1 to provide recommendation to Steering Committee
  - Joint Panel/Steering Committee meeting May 2