

The Great Salt Lake - Utah

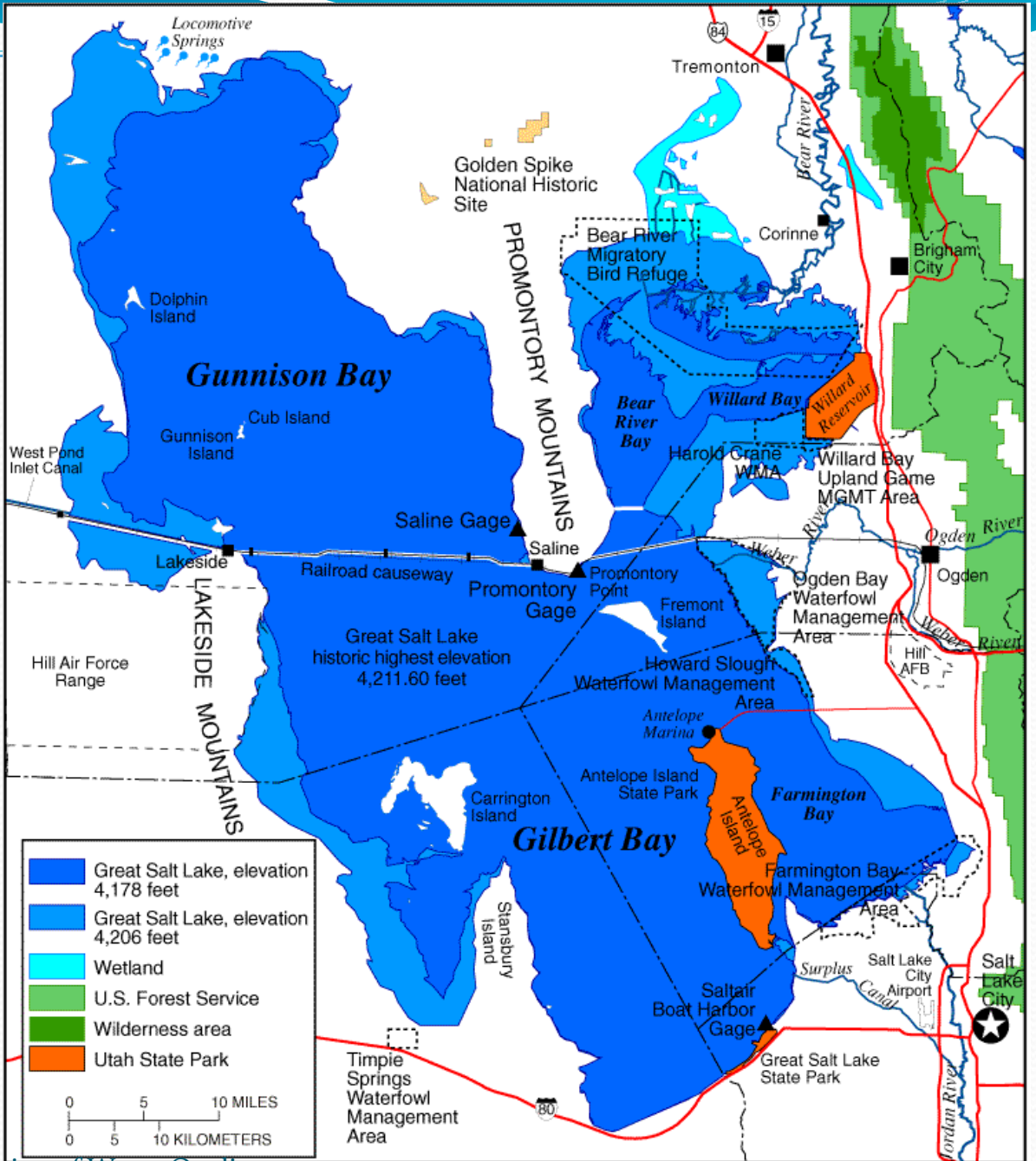


(c) Copyright 2005 Sandia Software - DVD Image is Double this Size



April 2008

Utah Division of Water Quality

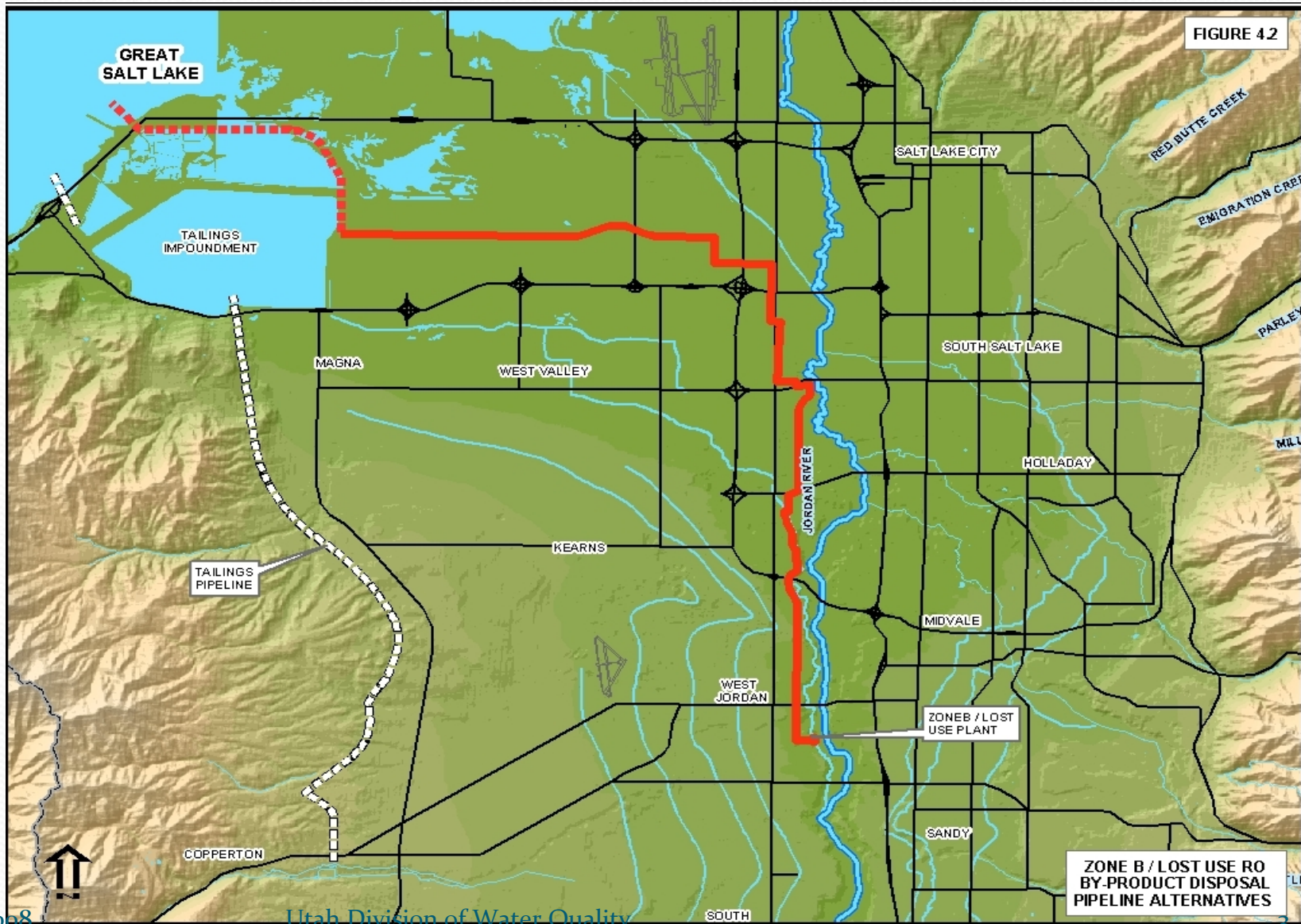




April 2008

Utah Division of Water Quality

R.O. Brines Pipeline



Wildlife Selenium Problem



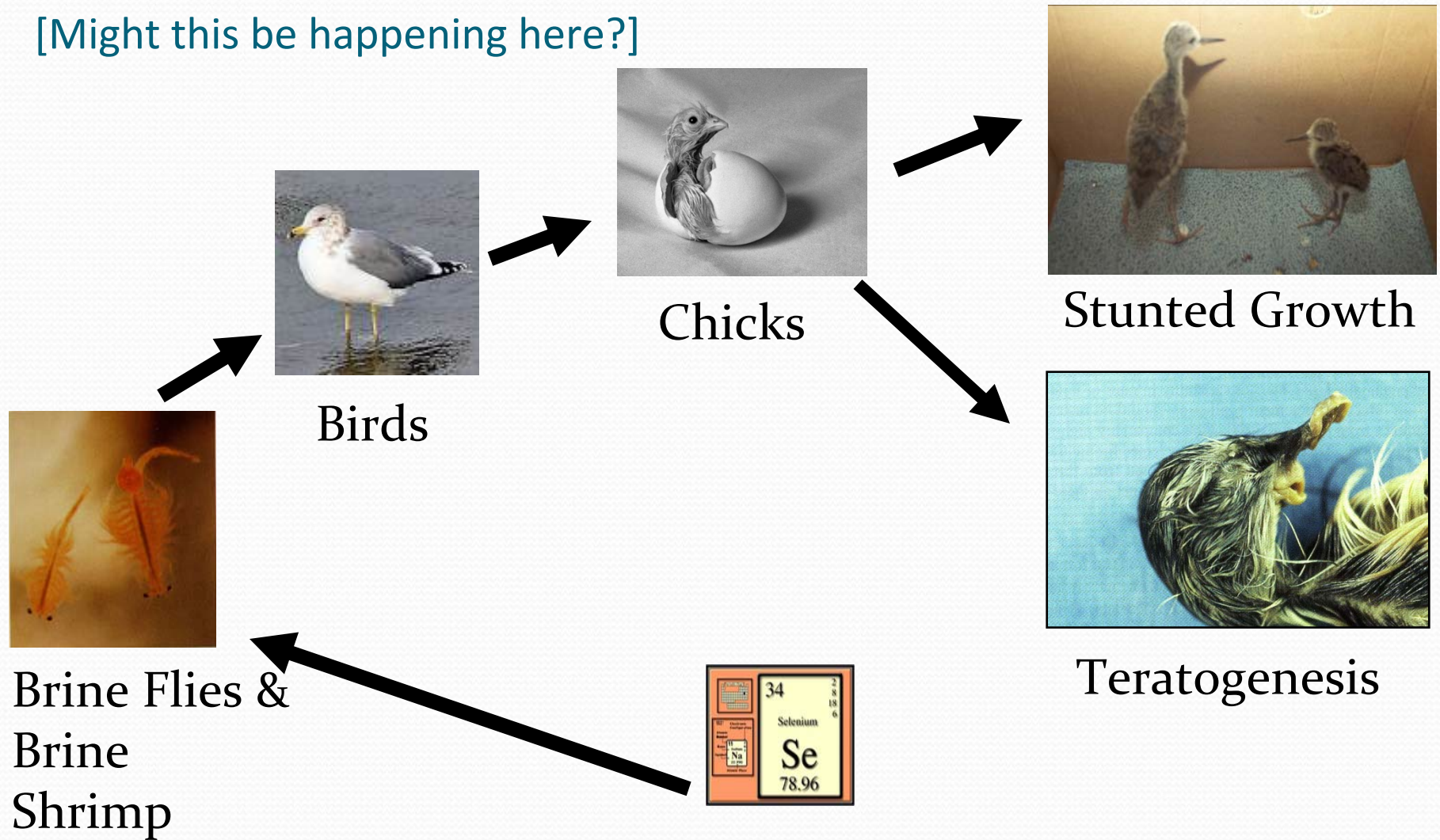
Kesterson Reservoir California – 1980's

- Subsurface agricultural drainage water was used for marsh management in Merced County, CA.
- Inflow Avg. $\sim 300 \mu\text{g/L}$ selenium.
- All fish except mosquitofish disappeared.
- Selenium-induced effects, including dead or deformed embryos or chicks, were found in 39% of the nests.
- Many dead birds were found.



Biomagnification up the GSL Food Chain

[Might this be happening here?]



Selenium Growth Effects



13 and 14 day-old avocet chicks from clean and seleniferous environments prior to hatching with same diet after hatching.

Examples of Teratogenic Effects

(from Seiler et al. 2003)



Gadwall (Kesterson Reservoir, California) with arrested development of lower bill, spoonbill narrowing of upper bill, and missing eyes

Bioaccumulation

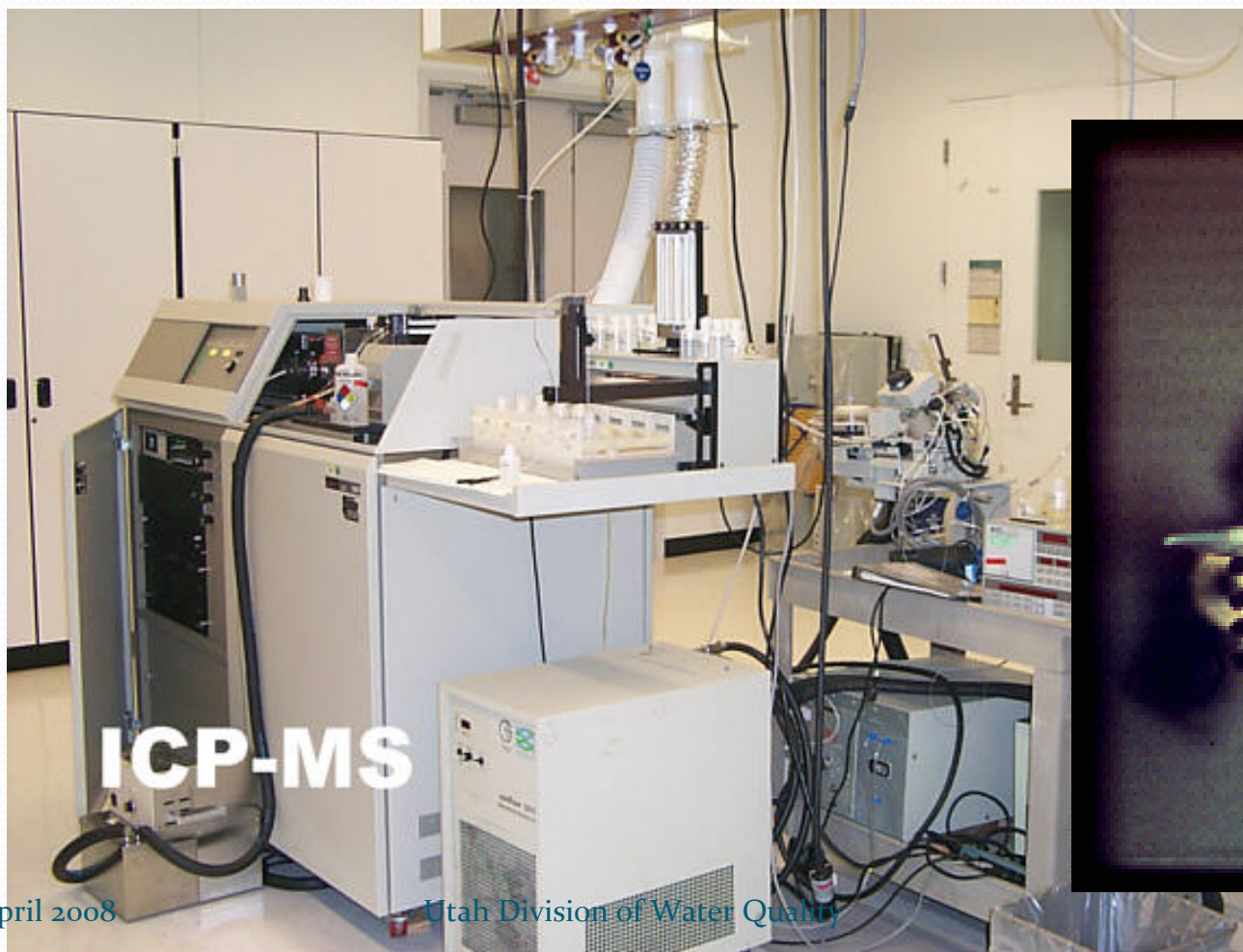
- Selenium bioaccumulates in both aquatic and terrestrial food chains
 - Water to aquatic plants (algae) or invertebrates (brine shrimp) often 1000X waterborne concentration.
 - Function of chemical form (organic>selenite>selenate).
 - Ingestion is the main uptake pathway.
- It all starts with the water.
What is the concentration of Se in Great Salt Lake?

Concentration of Se in GSL

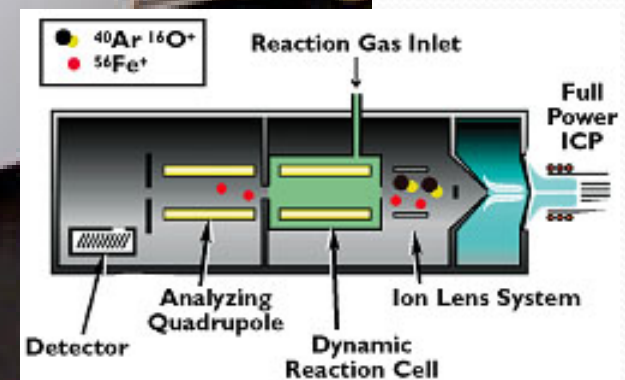
- It all starts with the water.
What is the concentration of Se in Great Salt Lake?
- Data was very scattered
- Instrumentation was improving
- Samples taken and sent to ERA Aurora, CO for:
 - Spiking
 - Round Robin (EPA \$15,000 grant)
 - Concentration
 - Instrument

ICP-MS

Inductively Coupled Plasma Mass Spectrometer



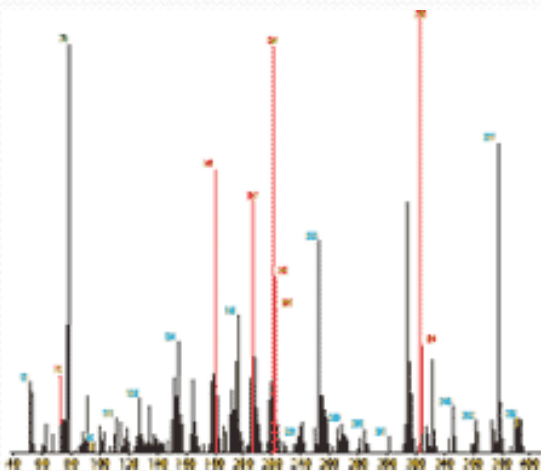
ICP-MS with Dynamic Reaction Cell (DRC) [P&E]



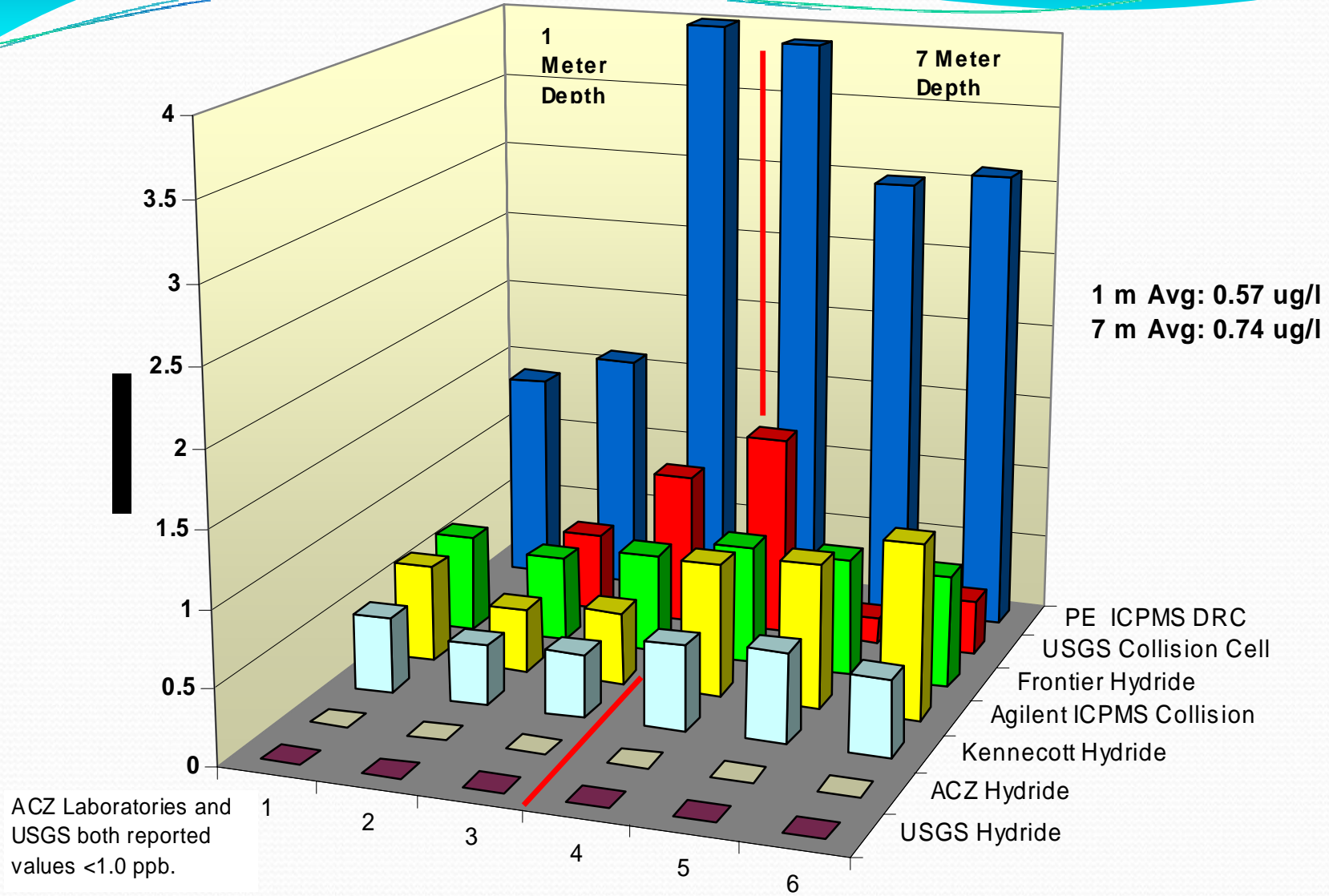
April 2008

Utah Division of Water Quality

ICP-MS with Collision Cell [Agilent Technologies]



Concentration of Se in Gilbert Bay @ USGS Site



- USGS Hydride
- ACZ Hydride
- Kennecott Hydride
- Agilent ICPMS Collision
- Frontier Hydride
- USGS Collision Cell
- PE ICPMS DRC



A local Steering Committee was established to offer guidance and make a recommendation to the Water Quality Board.

The Committee established a Science Panel composed of the following members:

- **Anne Fairbrother, Ph.D. - EPA / Parametrix, Seattle, WA**
- **Joseph Skorupa, Ph.D. - US Fish & Wildlife Service, Washington, D.C.**
- **Theresa Presser, Ph.D. - US Geological Survey, Menlo Park, CA**
- **William Wuerthele - EPA / Consultant, Denver, CO**
- **Theron Miller, Ph.D. - Utah Division of Water Quality, Park City, UT**
- **William Adams, Ph.D. - Rio Tinto (Kennecott), Salt Lake City, UT**
- **Brad Marden - Artemia Assoc. / Parliament, Ogden, UT**
- **Don Hayes, Ph.D. - Univ. of Louisiana (Lafayette), Lafayette, LA**
- **William Moellmer, Ph.D. - Utah Division of Water Quality, SLC, UT**
- **Harry Ohlendorf, Ph.D. - CH2M-Hill, Sacramento, CA [Consultant]**

Evaluating the Toxicity Curve

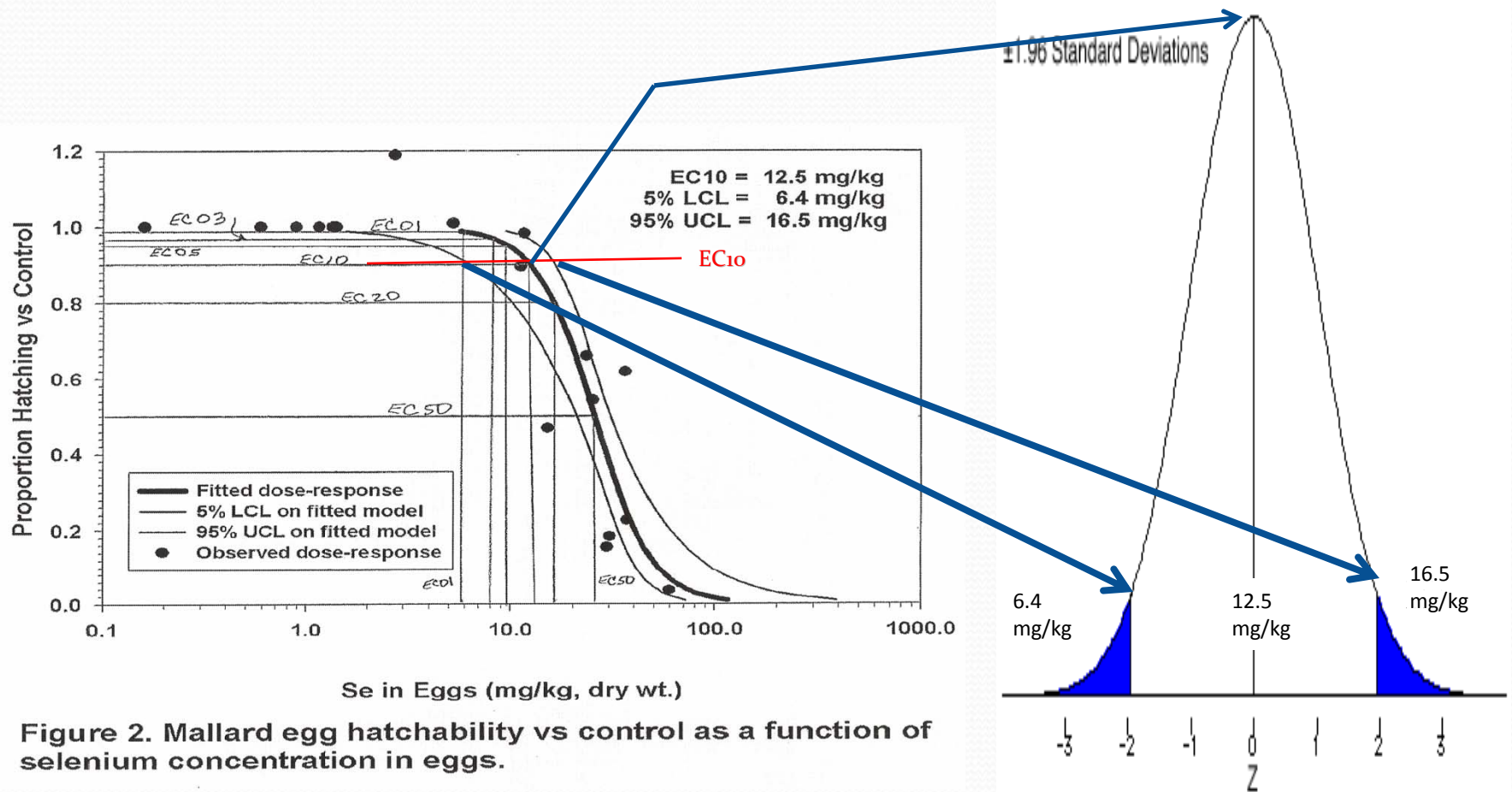


Figure 2. Mallard egg hatchability vs control as a function of selenium concentration in eggs.

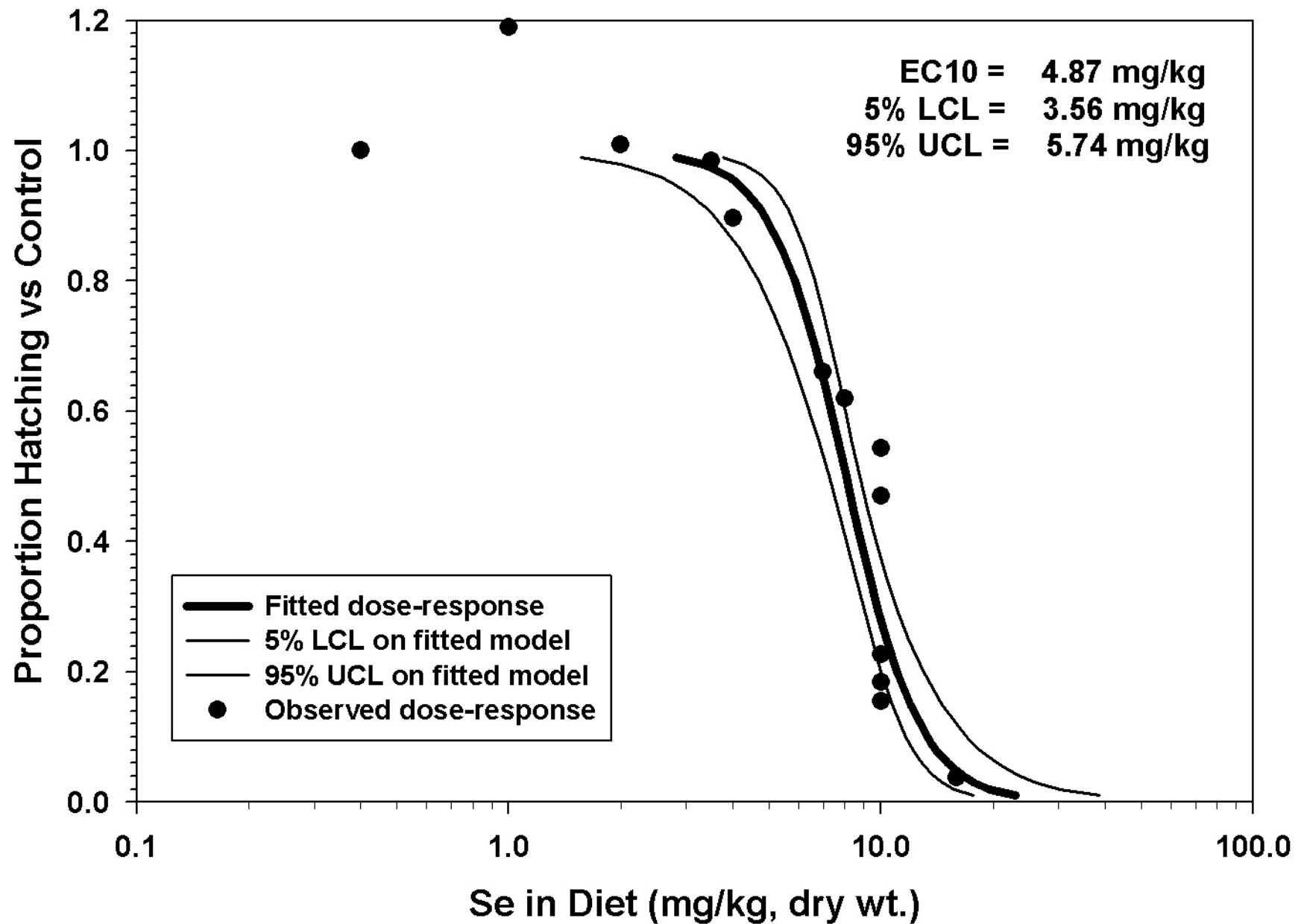


Figure 1. Mallard egg hatchability vs control as a function of selenium concentration in diet.

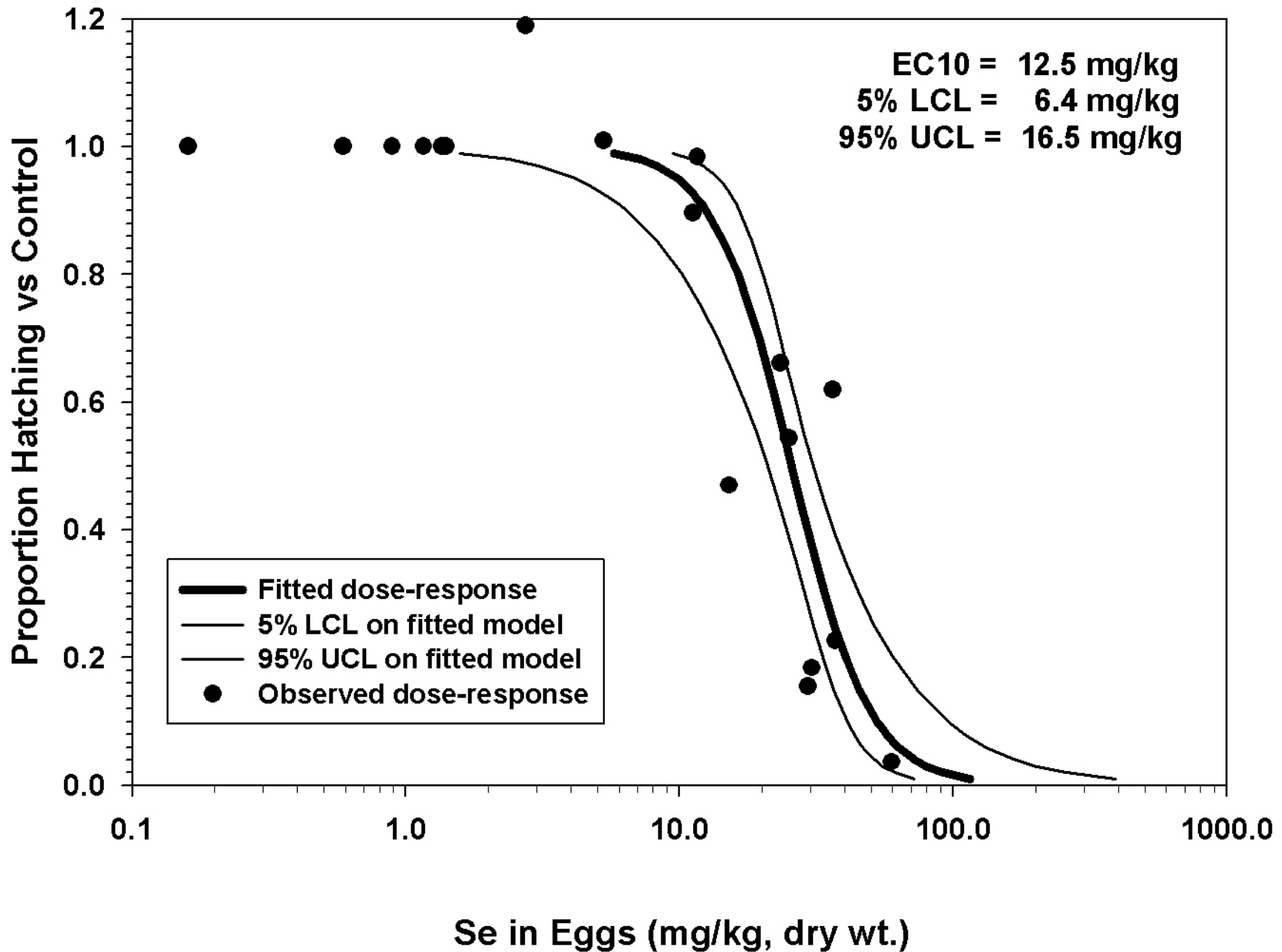
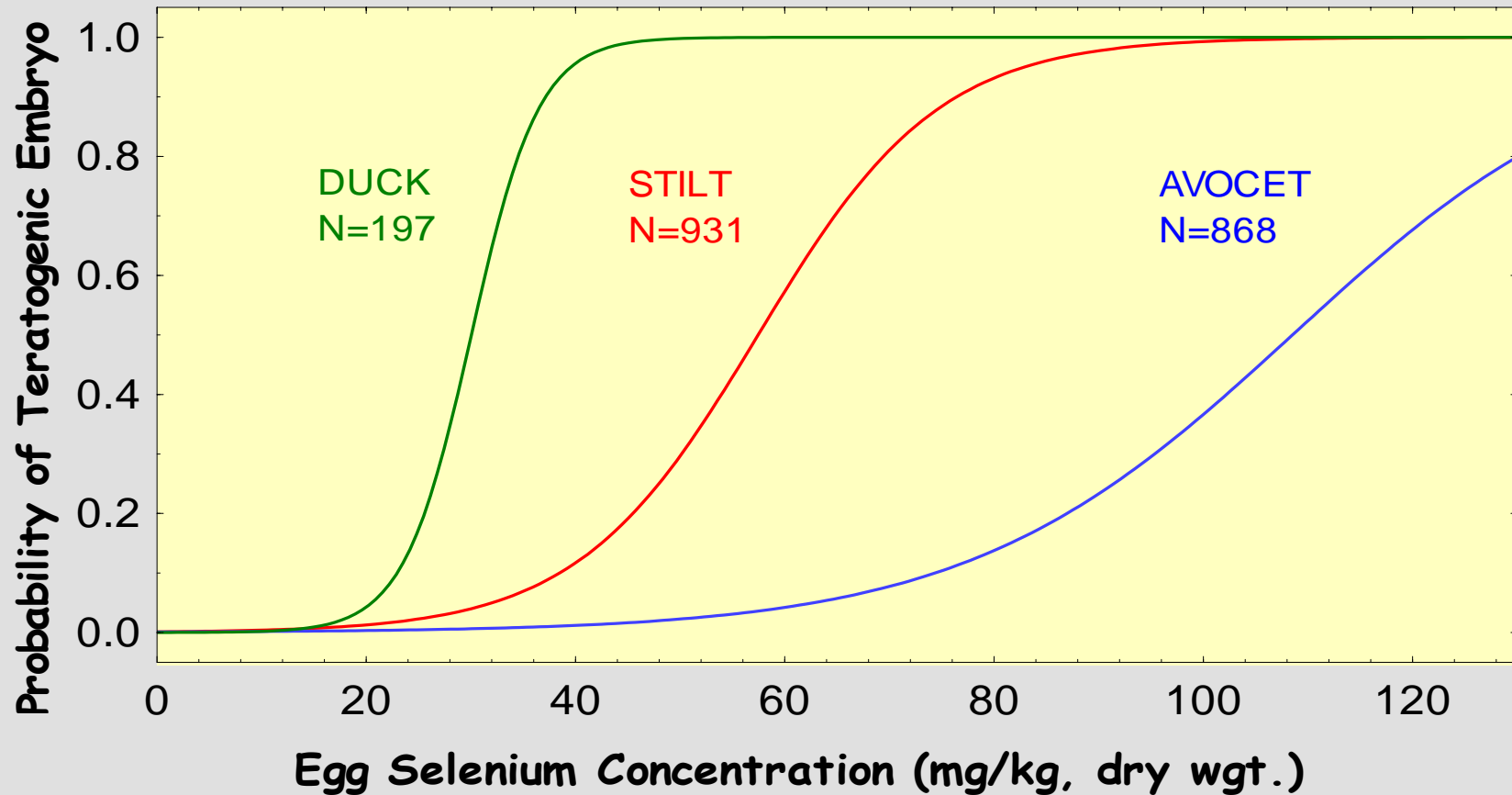


Figure 2. Mallard egg hatchability vs control as a function of selenium concentration in eggs.

April 2008

Selenium-Induced Teratogenesis in Nature

Logistic Response Curves



Logistic response curves for selenium-induced teratogenesis among black-necked stilt, American avocet, and duck eggs exposed to agricultural drainage water.

Science Panel Identified Four Projects to Meet Objective

Project 4

Projects 1 & 2

Output, bioaccumulation, and toxicological endpoints in food chain

Output to atmosphere via vapor phase

Project 3

Inputs

Is the chemistry such as that the concentration of Se in the lake is independent of input sources?

Output to sediment via permanent burial

Project 1 – Avian Ecology

- Principal Investigators
 - Michael Conover, PhD [USU]
 - John Cavitt, PhD [Weber State]



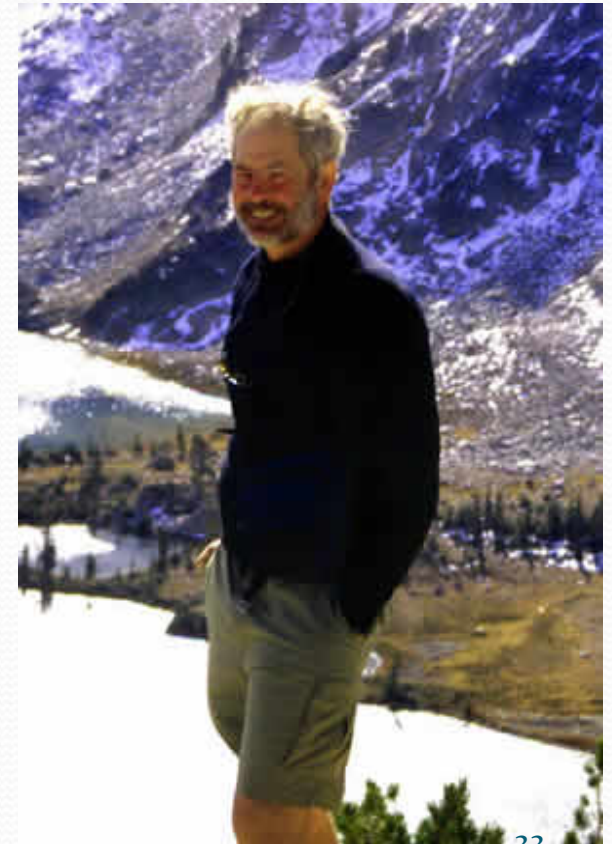
Project 1 – Avian Ecology

Project Objective

Determine Se flux from bird diet to critical end points by determining ambient selenium concentrations in water, brine shrimp, brine flies, other food items, birds and bird eggs.

Project 2 – Aquatic Ecology

- Principal Investigators
 - Wayne Wurtsbaugh, PhD [USU]
 - Brad Marden [Parliament Fisheries and the Artemia Association]



Study 2: Design and Conduct Selenium Concentrations Synoptic Surveys in the Great Salt Lake

- Survey of Se in Periphyton and Brine Shrimp from the Benthic Zone
- Survey of Selenium in Water, Seston (plankton, organic detritus and inorganic particles such as silt) , and *Artemia*



Project 3 – Selenium Loads

➤ Principal Investigators

- Dave Naftz, PhD [USGS]
- Bill Johnson, PhD [UofU]



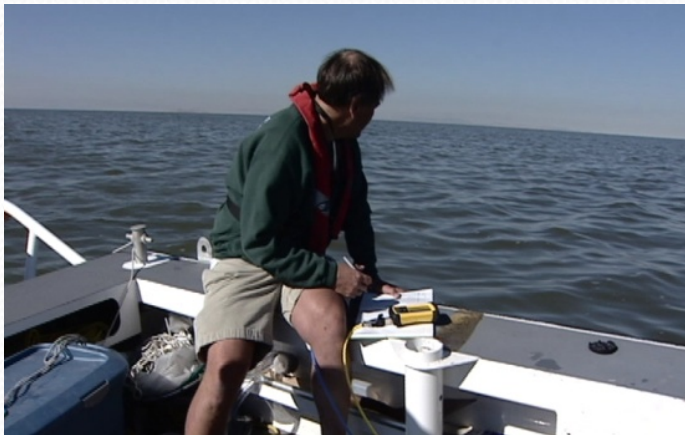
Study 3: Measurement of Selenium Loads to the Great Salt Lakes

- Install Stream Gages on all Primary Point Sources Loading to the Main Body of the GSL
- Model Daily Selenium Loadings to the GSL
- Estimate Selenium Loading to GSL from Groundwater Inputs



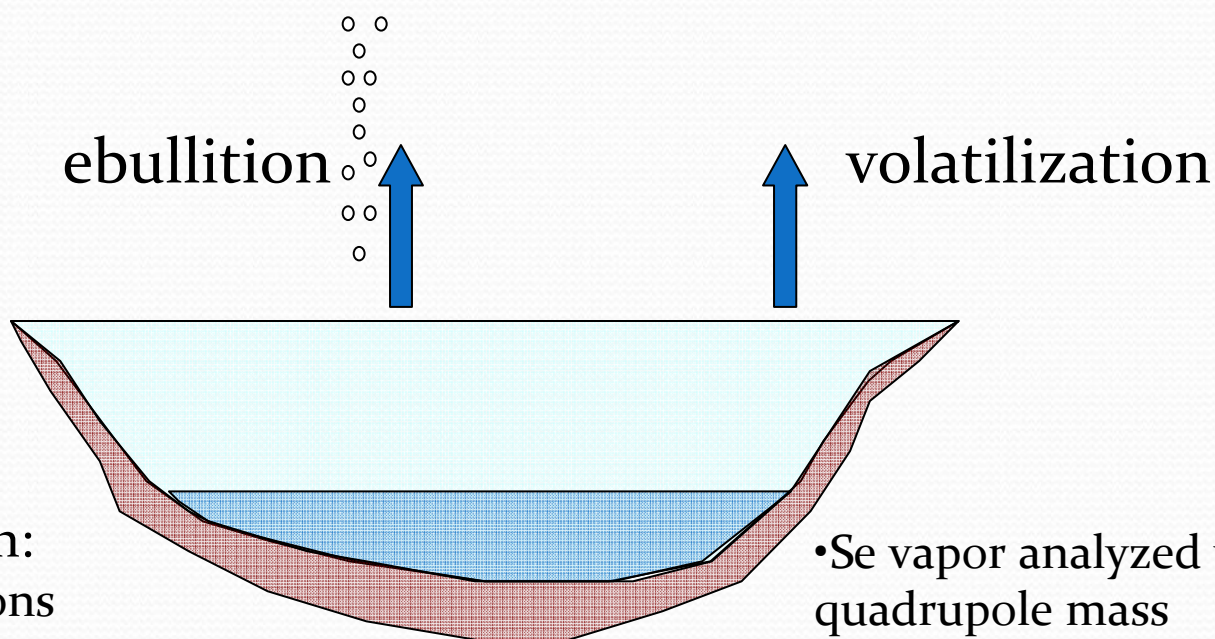
Project 4 – Se in Vapor/Sediment

- Principal Investigators
 - Bill Johnson, PhD [UofU]
 - Dave Naftz, PhD [USGS]



Project 4 – Se in Vapor/Sediment

Task 1. Vapor Selenium Flux



Ebullition:

- 20 locations
- 5 depths
- Semi-monthly
- Boat-mounted total dissolved gas probes
- Vapor collection via floating flux chamber

- Se vapor analyzed via quadrupole mass spectrometry
- Sediment grab samples for total organic carbon and total Se

Using a Mathematical Model to Predict Bioaccumulation

- Mathematically define the pathway of selenium with “transfer factors” to the next level of the food web.
 - Water →
 - Algae →
 - Brine Shrimp & Brine Flies →
 - Bird Egg (Critical Endpoint)
- Predict the concentration of Se in the egg
- Compare the egg concentration to the tissue-based standard



Brine Shrimp

Using a Mathematical Model to Predict Bioaccumulation

If the water in GSL were at “x” ug/L what does the model predict the concentration of selenium would be in the egg?

Water: ug/L (ppb)	Bird Egg: mg/kg (ppm)
0.60	2.53
1.0	4.32
2.0	8.80
3.0	13.3

ppb = parts per billion ppm = parts per million



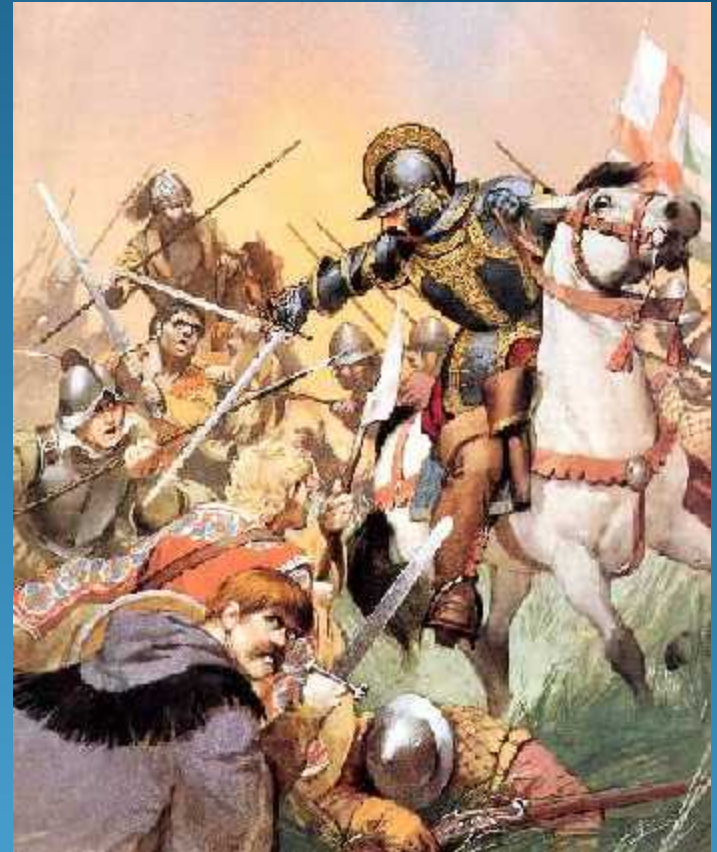
Black-Necked Stilt

Project Costs

Project 1	\$312,900
Project 2	\$163,300
Project 3	\$213,600
Project 4	\$347,000
Program Support	\$198,700
Undefined Support for '07/'08 \$106,200	
Subtotal	\$1,341,700
<i>USGS Matching Funds</i>	<i>\$124,000</i>
Additional Cost [Science Panel]	\$1,000,000
Total Costs	~ \$2,650,000

With the Studies completed, the Science Panel was in a position to recommend a Standard.

Let the deliberations begin



Utah Division of Water Quality
May 2008

Protecting the Beneficial Use:

- (1) Should a standard be developed to protect the individual, or
- (2) Should a standard be developed to protect the population?

- Protecting the Individual

- No Effect Concentration: NEC
 - Position of US Fish & Wildlife Service [USFWS]
 - Migratory Bird Act & Endangered Species Act



- Protecting the Population

- Effective Concentration: EC
 - Position of US Environmental Protection Agency [EPA]
 - Clean Water Act
 - Utah Water Quality Standards
 - Enforcement



Protecting the Individual



- NEC: No Effect Concentration
 - Greatest concentration or amount of a substance, found by experiment, observation, or statistical regression that causes no alteration of morphology, functional capacity, growth, development or life span of target organism.
 - Position of the US Fish and Wildlife Service
 - **Protect the individual bird**
 - FWS to Consult with EPA in development of water quality standards



Protecting the Population

- Effect Concentration “EC”
 - Concentration or amount of a substance, found by experiment or observation, that causes an allowable alteration of morphology, functional capacity, growth, development or life span of target organisms distinguishable from those observed in normal (control) organisms of the same species and strain under the same defined conditions of exposure.
 - Position of the US Environmental Protection Agency [EPA]
 - **Protect the Population**
 - EC₂₀ used on previous WQ Standards nationwide
 - EC₁₀ used on Great Lakes Initiative [rich data source]
Data Rich and Tissue Based Standard
 - Under Clean Water Act responsible for development of water quality standards



Sooty Shearwaters, Colac Bay, New Zealand, copyright Duncan Poyser



What is the Science Panel Recommendation to the Steering Committee for the Standard?

- Matrix: Bird Egg
- Frequency: Nesting season
- Measured as: Geometric Mean
- Range:
 - The Panel: 6.4 – 16.5 mg/kg (ppm)
 - As Individual Panel Members:
 - 5 mg/kg 1 Panel Member
 - 10.4 mg/kg 1 Panel Member
 - 12 – 13 mg/kg 6 Panel Members
- Assessment Methodology
 - Monitor and Evaluate the Status of Bird Eggs and the Ecosystem
 - Act with more aggressive monitoring and initiate DWQ action when the concentration of Se in the eggs increase.



American Avocet

Water Quality Board Presentations

- The Steering Committee could not come to a majority consensus (3/4) on a recommended standard
- The three positions will be presented to the Board
 - 5 mg/kg
 - 10.4 mg/kg
 - 12.5 mg/kg
- Staff is not making a position to the Board
- Board is now invited to deliberate and develop the standard.

Water Quality Board Meeting

June 20, 2008

- 12.5 mg/kg was chosen as the Standard
 - Tissue based
 - Shorebird egg
 - Dry weight
 - Over the nesting season
- Assessment / Monitoring Strategy
 - Included as a part of the standard