

Geomorphology Update, April 2008

Geological Sciences
U. Of Delaware

Jim Pizzuto

Katie Skalak

Andrea Barbieri

Prame Narinesingh

Geography
U. Of Delaware

Michael O'Neal

Erica Rhoades

Topics

1. Fine-grained channel margin deposits
 - History of Hg accumulation
 - Rates of reworking
2. Hg concentrations in eroding banks
3. Results from 1 and 2 above can explain the “humped” distribution of Hg along the river
4. Hg concentrations in release age floodplain deposits
5. Updated computations of bank erosion and Hg loading
6. Some preliminary short term erosion rates from tripod LIDAR data

Summary of Take-Away Points

1. 75% of the Hg in fine-grained channel margin deposits dates from 1929-1950
 - probably carried downstream directly from the plant and deposited
2. Hg concentrations in eroding banks decreases exponentially from the plant downstream
 - Spatial pattern consistent with original point source from plant, 1929-1950
3. “Hump” of Hg concentration downstream may originate from:
 - Ongoing erosion of contaminated bank sediments
 - Processes that reduce Hg concentrations with transport distance
 - Supply of “clean” particulates from tributaries, etc.

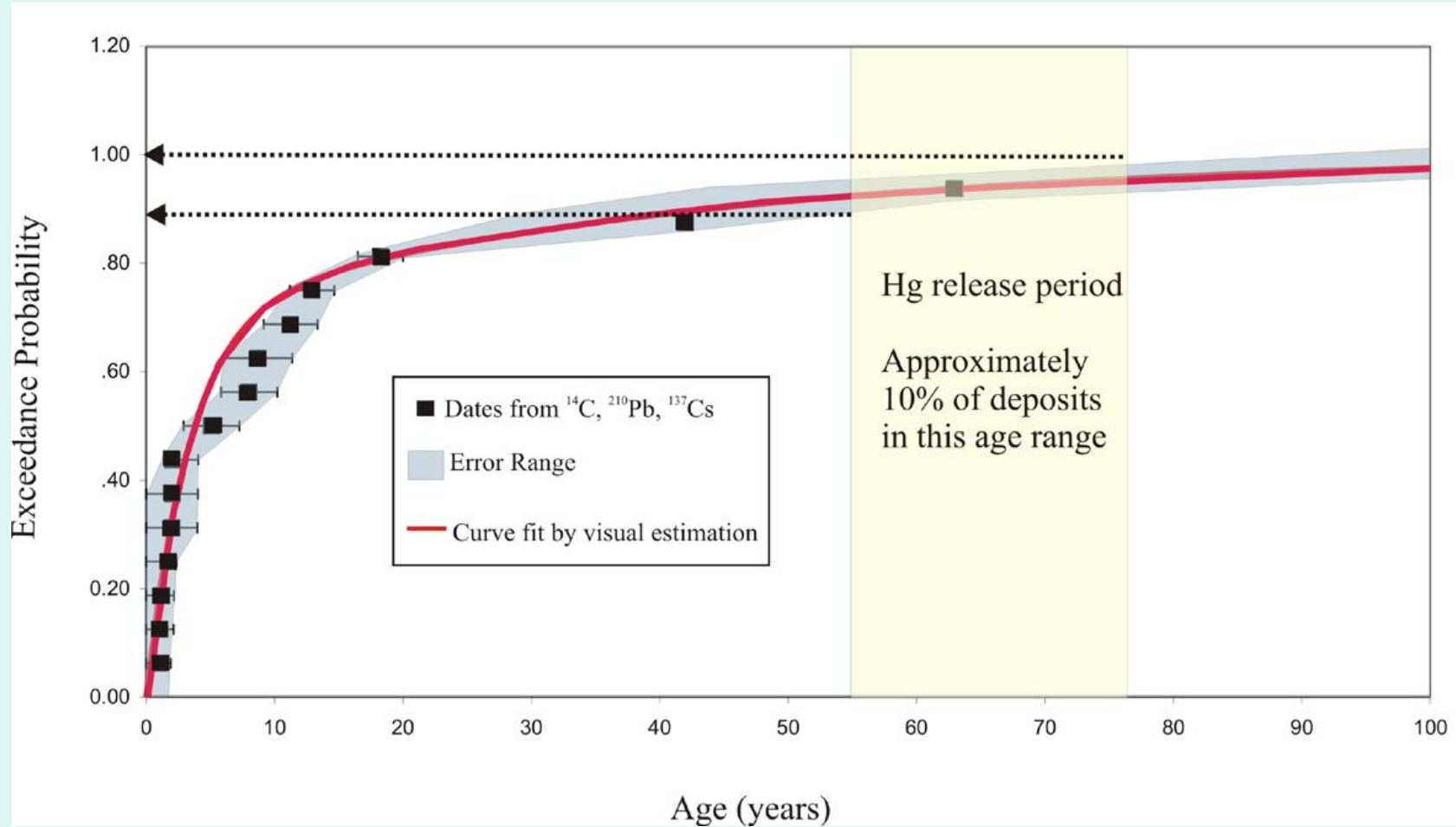
Hg Concentrations and Dynamics of Fine-Grained Channel Margin Deposits

- Update based on:
 - New data (September, 2007)
 - New interpretation
 - Consider all FGCM deposits as a single reservoir.
 - Use existing theory to interpret population of age dates and couple this with new observations of Hg concentration.

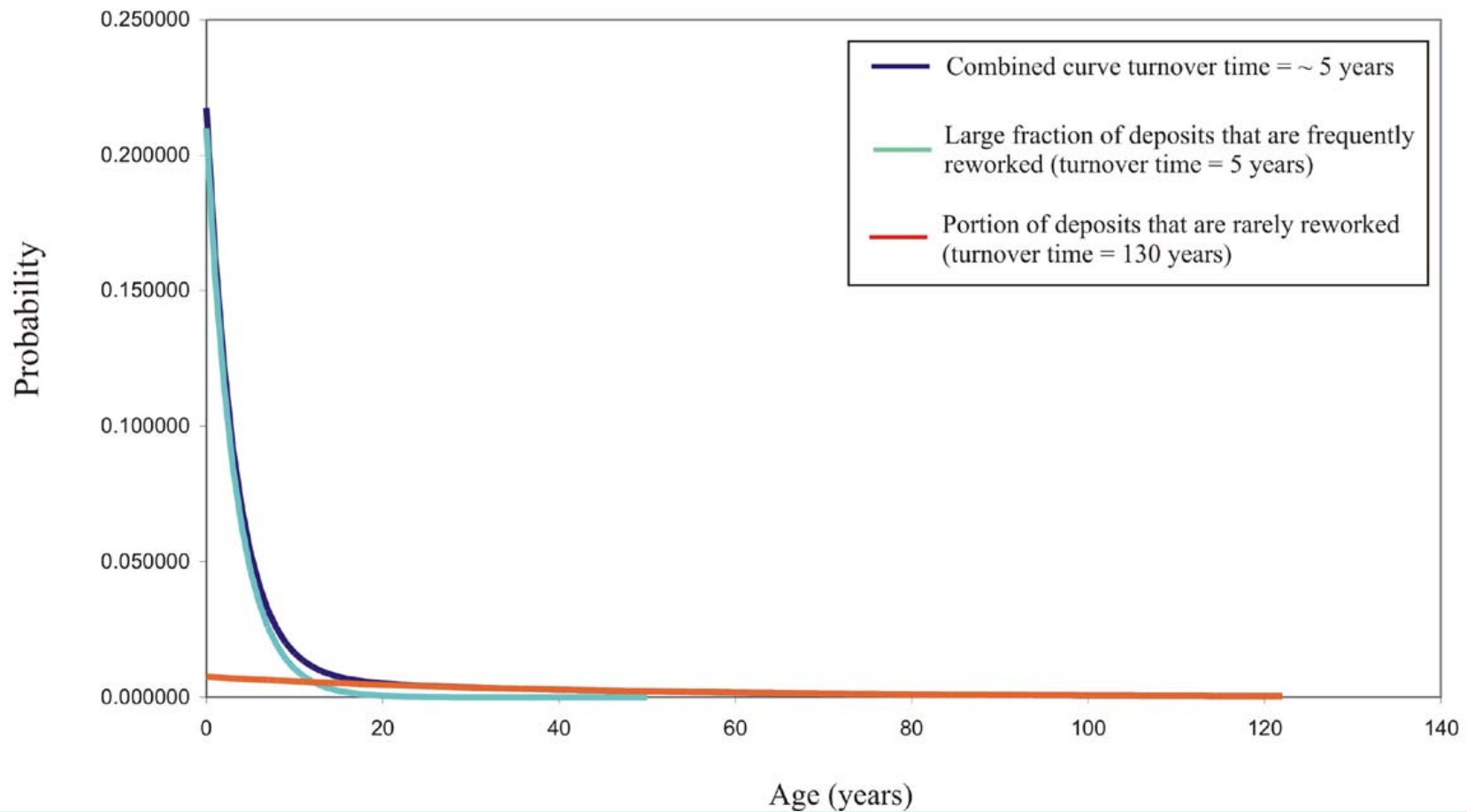
Use Cumulative Distribution of FGCM Deposit Ages To Estimate % Remaining From Period of Hg-Release (1929-1950)

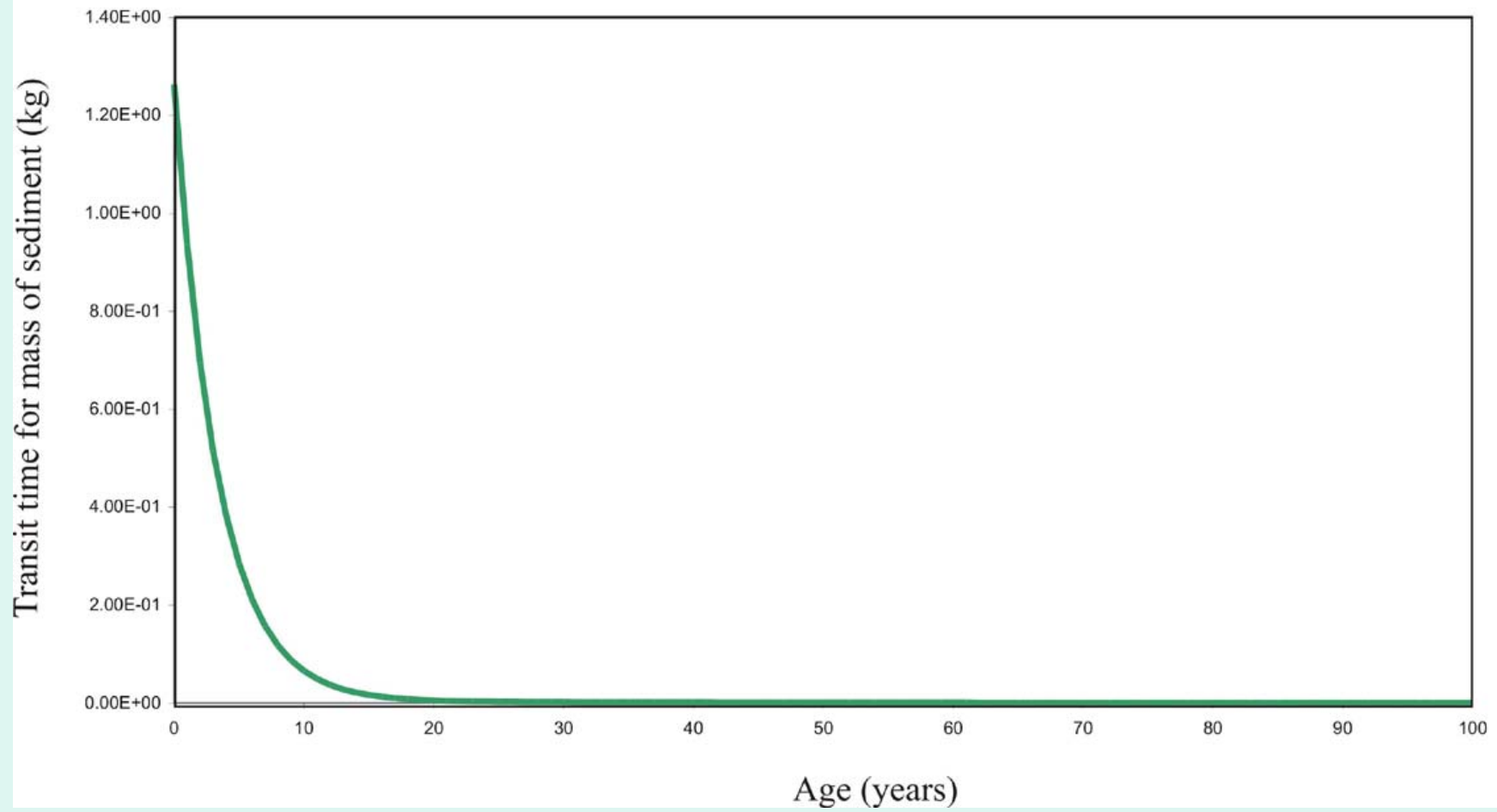
- ❖ Plot of all ages from bomb radiocarbon (11/2005), Pb-210, and Cs-137 (from past coring effort at Dooms).
- ❖ Error ranges come from radiocarbon dating.
- ❖ 15 dates total.
- ❖ Fit a curve to the data to predict what portion of FGCM deposits are from the original release period (i.e., 1929 to 1950 or 55 to 76 years from 2005).

Cumulative Distribution of Ages



Frequency Distribution of Ages Represents 2 separate populations





Age analysis using Hg concentrations in deposits

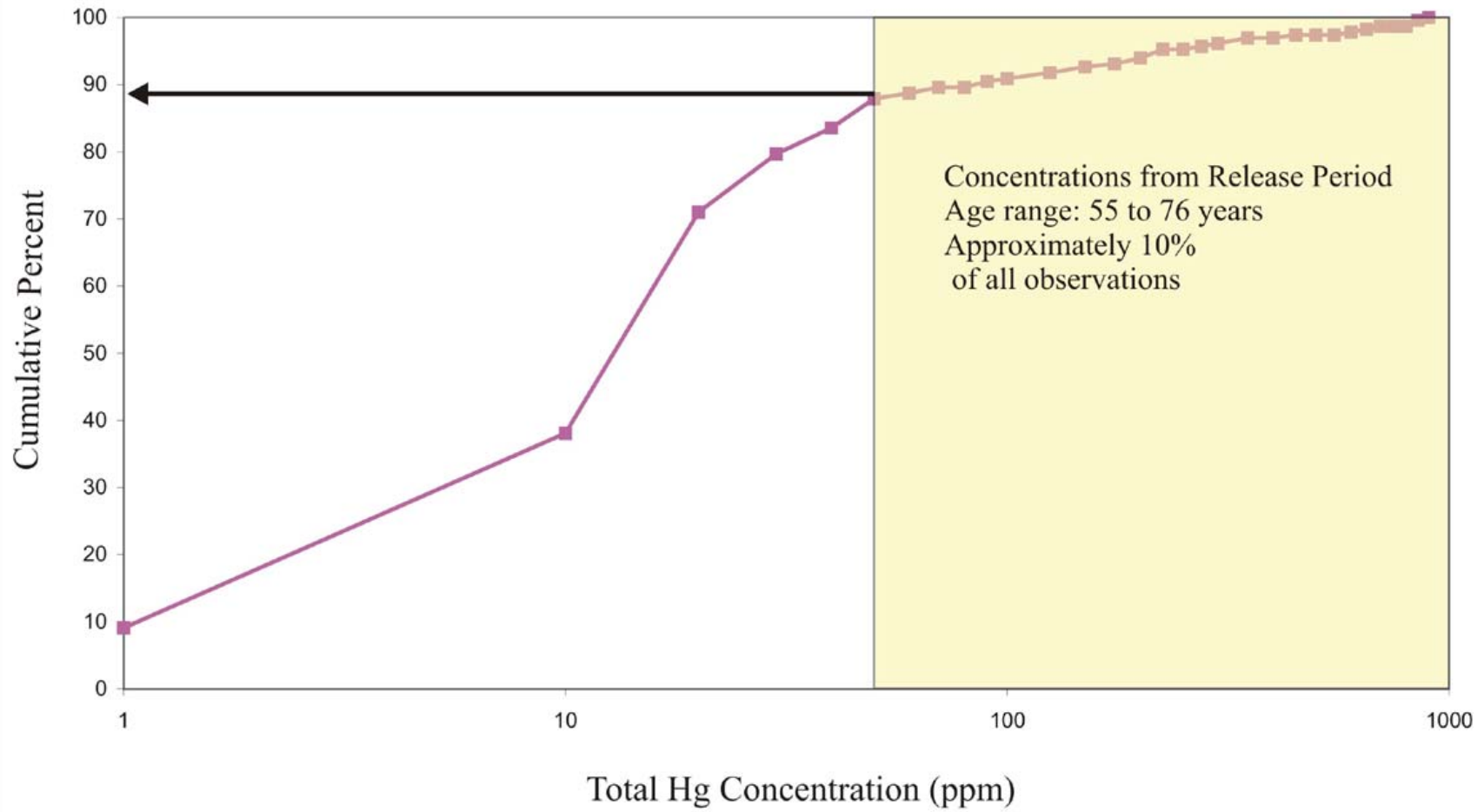
- ❖ Parallel age analysis using Hg concentration as a proxy for time.
 - Can release age Hg concentrations be determined from Hg distribution?
- ❖ Generate cumulative frequency curve and histogram of observations of Hg concentrations from all sampled FGCM deposits.
 - Concentrations binned at various intervals.

Age analysis using Hg concentrations in deposits

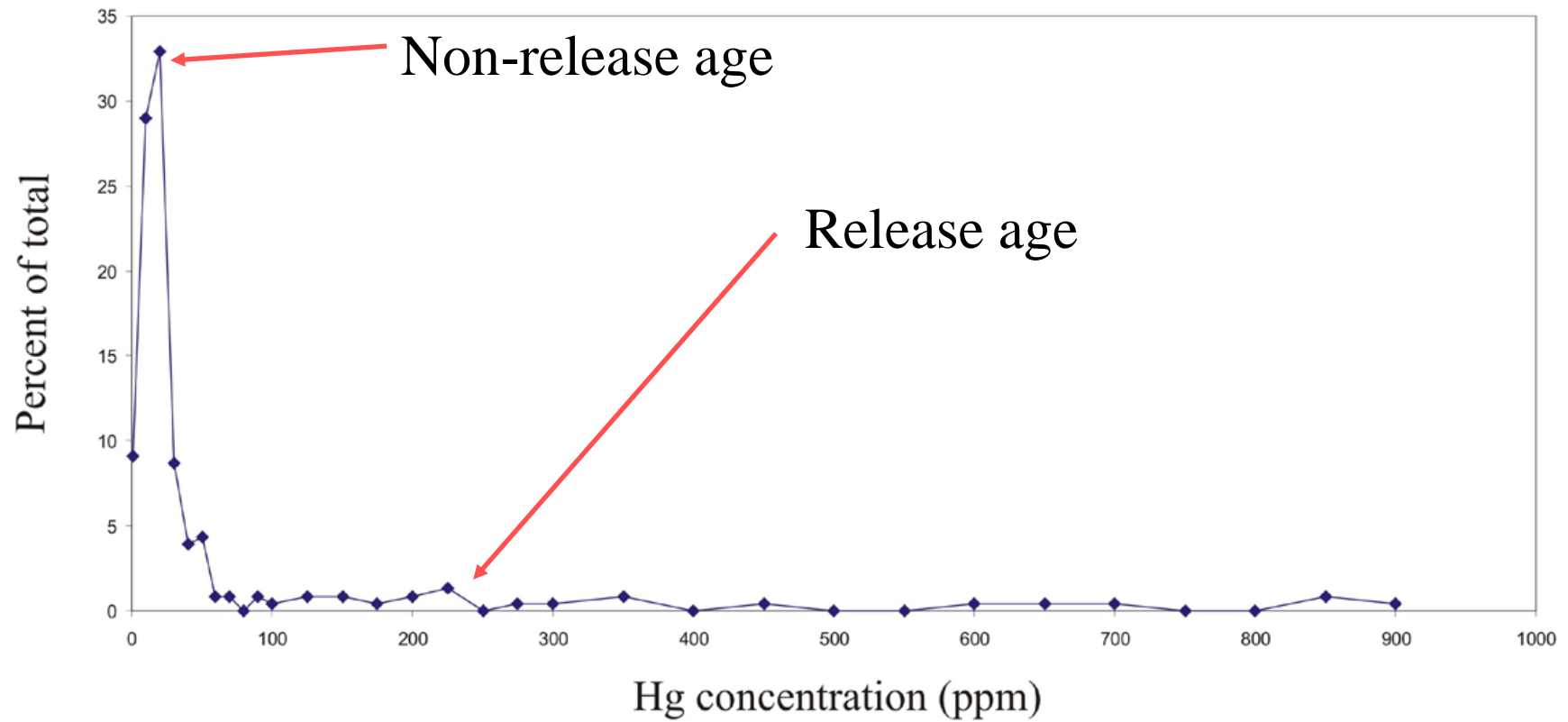
- ❖ Data suggest that there are two populations of concentrations (release period and post-release).
 - Assume that the first significant break in slope represents release age concentration (80 to 900 ppm).
 - Anything less than 80 ppm represents post-release.
- ❖ Release age sediment in FGCM deposits account for 10% of all sediment stored in deposits.

Both analyses suggest 10% is release period, 90% is post-release.

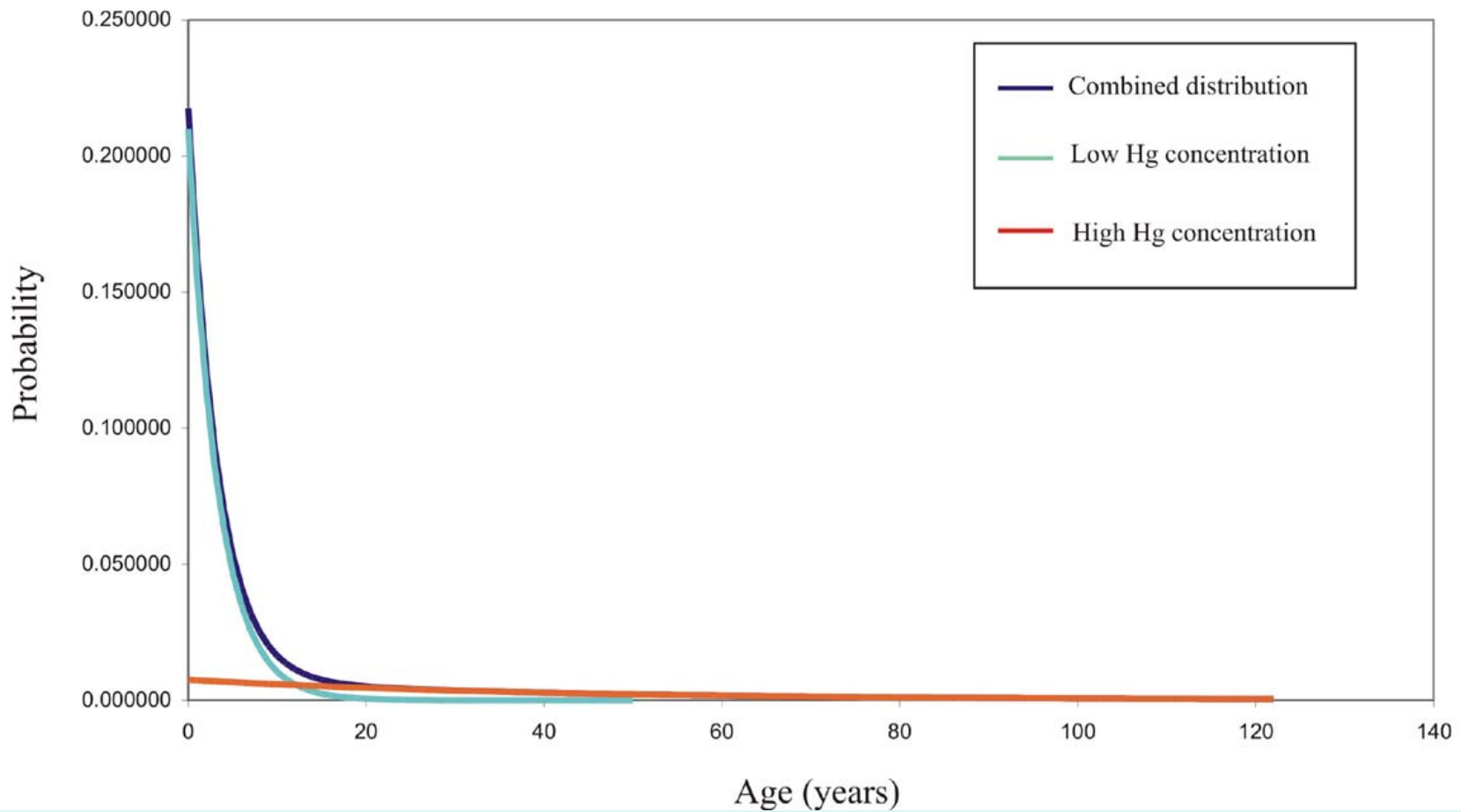
Cumulative Hg Concentration in Sampled FGCM Deposits



Hg concentration in FGCM deposits



Linking age distribution and Hg concentration



Mass of Hg in FGCM deposits From Release Period Compared to Post Release Period

- ❖ Average release concentration: 370 ppm
- ❖ Average post-release concentration: 15 ppm
- ❖ Volume in FGCM approximately 1820 m³

70 kg of Hg from release period

25 kg of Hg post-release period

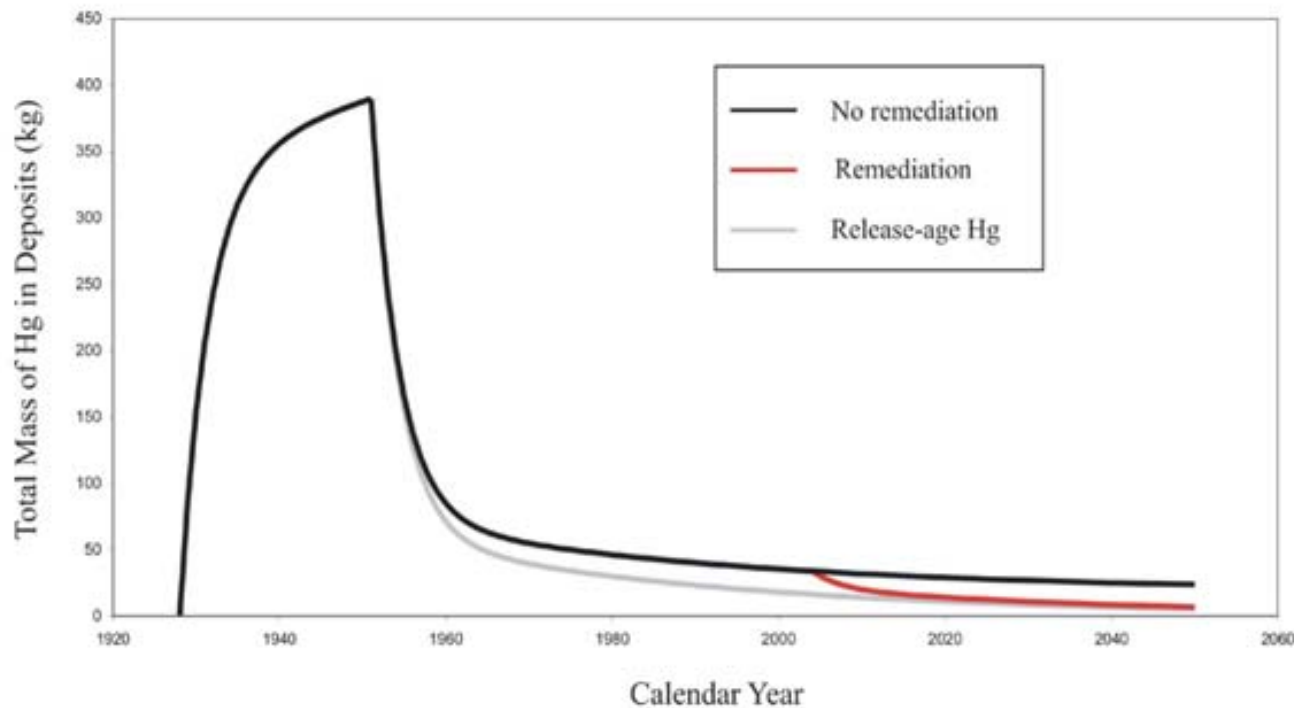
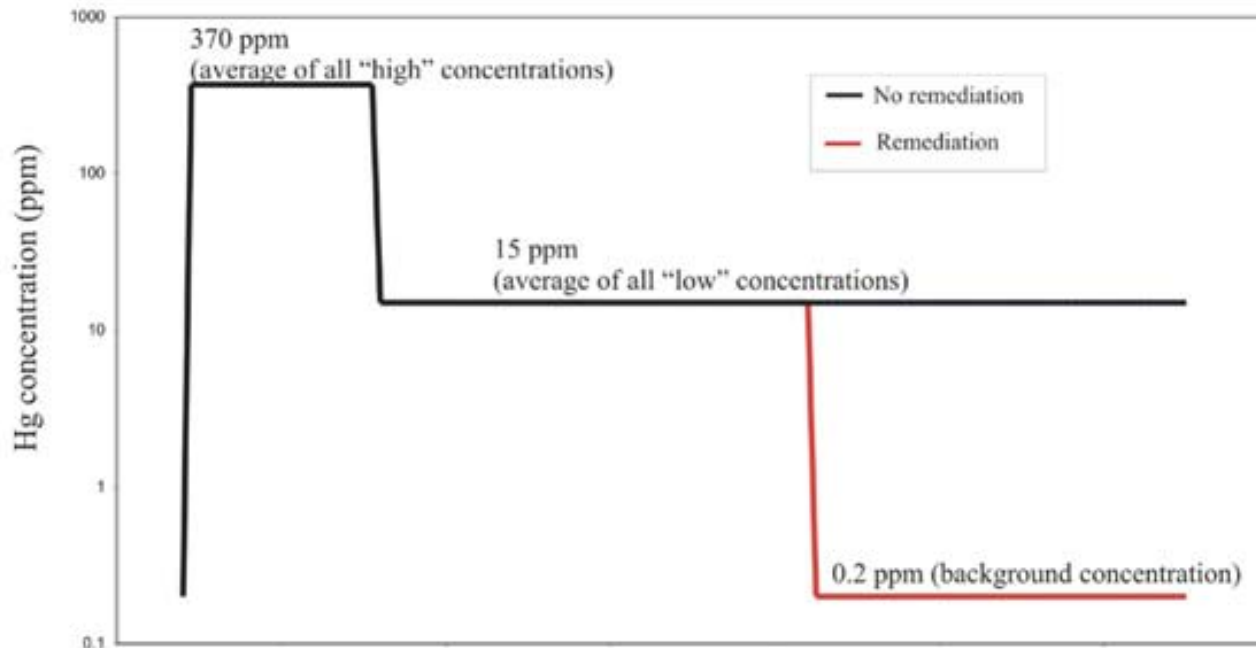
- ❖ Release age material is about 74% of total mercury mass.

Modify the Conceptual Model!

- ❖ Most of the Hg in these deposits is NOT reworked from eroding riverbanks.
- ❖ Most of the Hg originated “directly” from the plant itself during the period of high Hg release.

Hg loading history

- ❖ We can use this theory and combine it with Hg concentration data to make predictions about Hg loading.
 - Assume steady state conditions in FGCM deposits.
 - Use average concentrations from release period and post-release period.
 - Forecast Hg removal timescales and predict remediation scenarios.



This concentration distribution can be “tweaked” so that the model output matches the existing data.

Note: Remediation does not impact the release age material in the deposits!

Hg Concentrations in Eroding Banks (Preliminary)

- Pilot bank stabilization study
- Floodplain sampling program

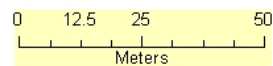
Investigations at the Bank Stabilization Pilot Project Site

Sampling Locations

Soil Profile Locations



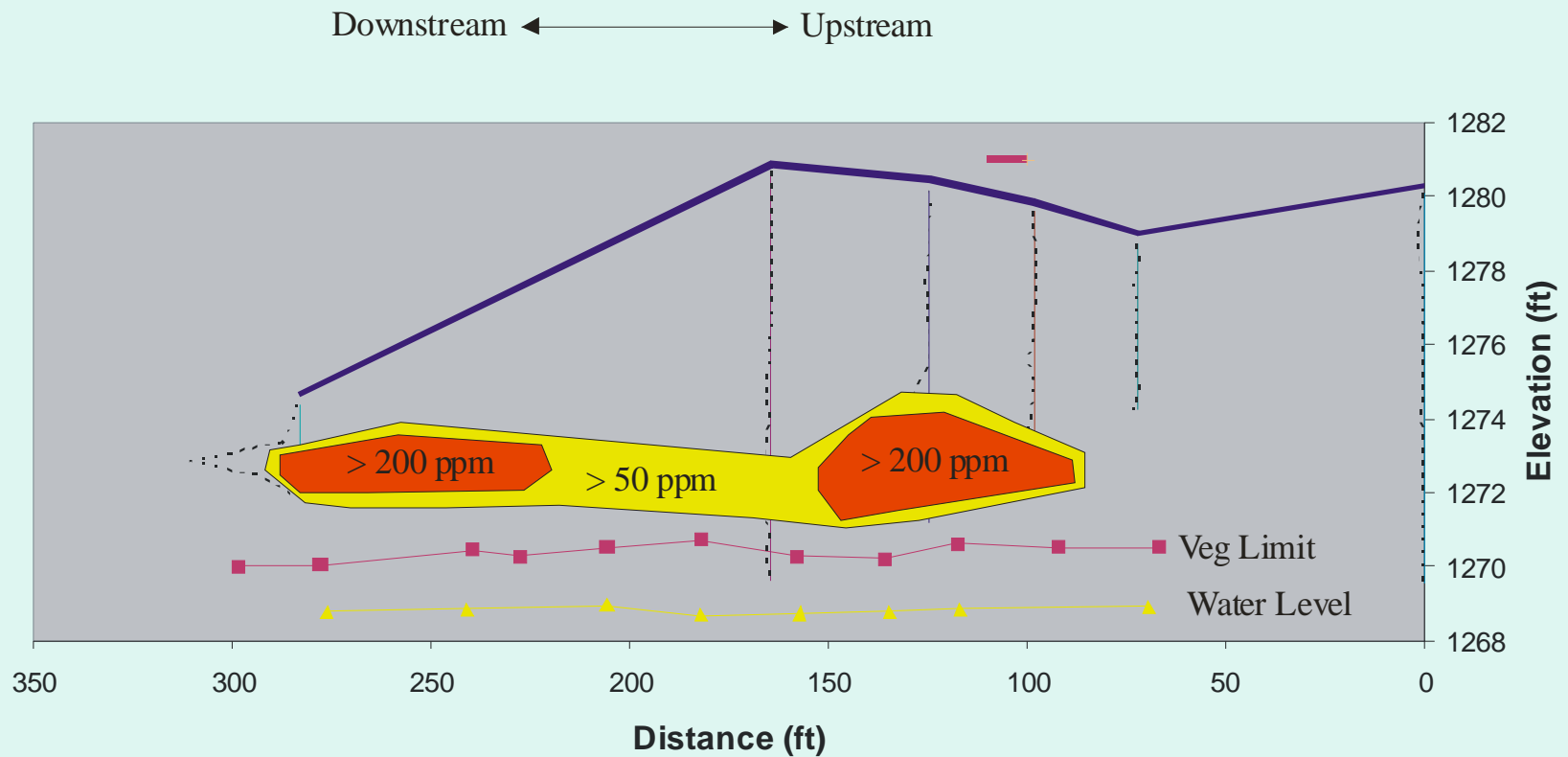
Bank profiles taken at 0.1 RRM
in Waynesboro, VA



Projected Coordinate System:
NAD_1983_StatePlane_Virginia_North_FIPS_4501
Projection: Lambert_Conformal_Conic

Date: Dec 2007

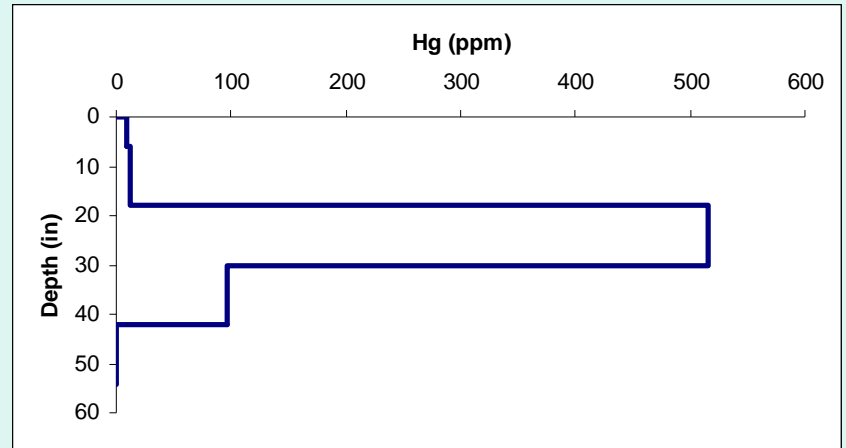
Contour Map of High Hg Concentrations



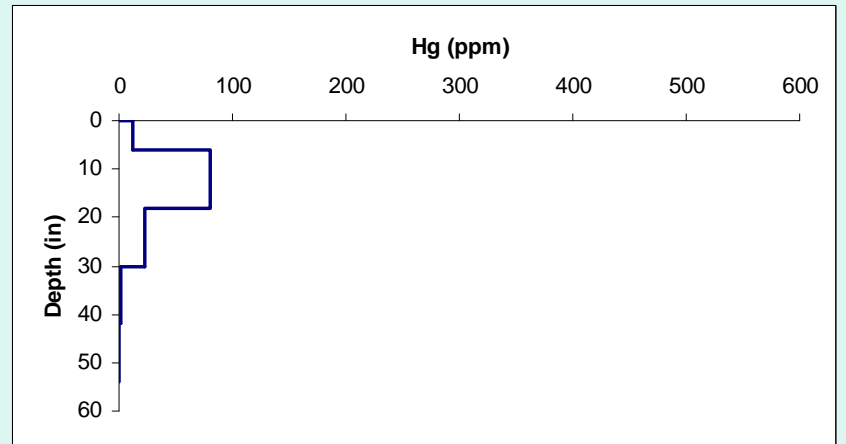
Eroding Bank Sampling – Preliminary Results

UPSTREAM

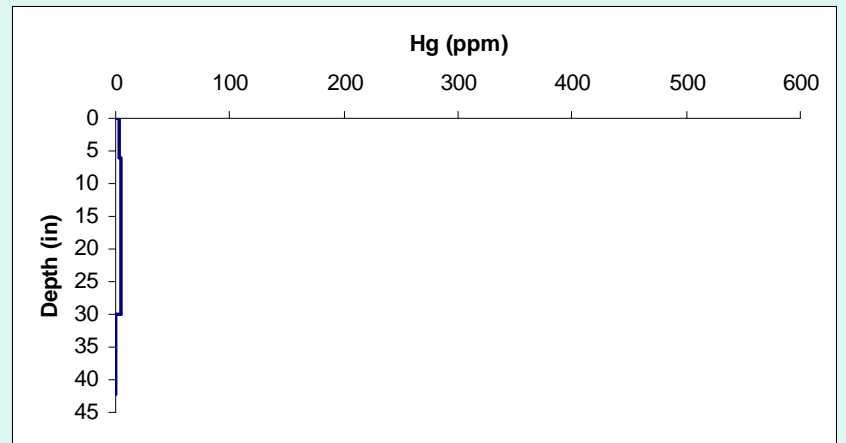
RRM 2.2 (Basic Park)



RRM 9.75 (above Crimora)

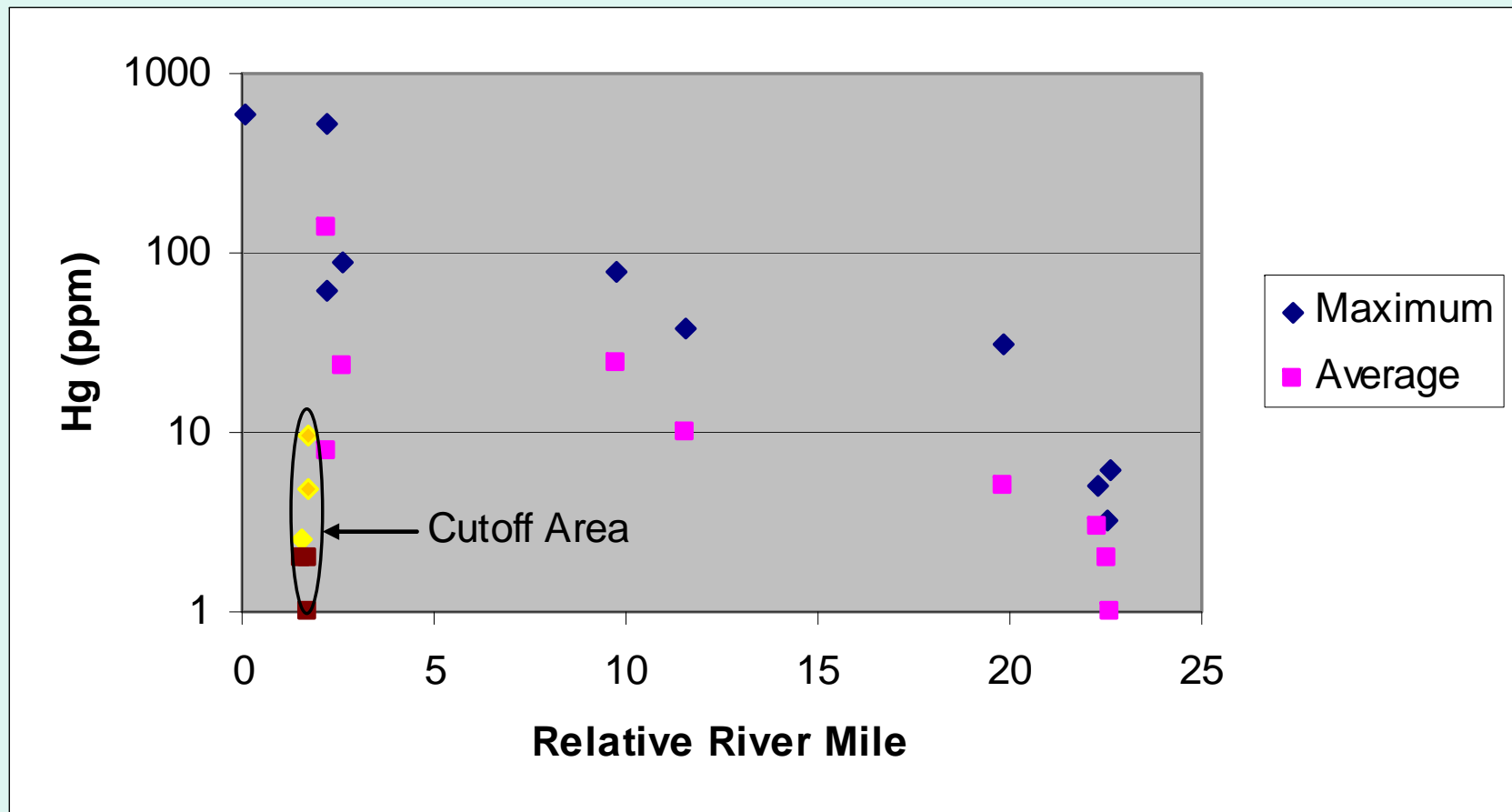


RRM 22.3 (between Grottoes and Port Republic)



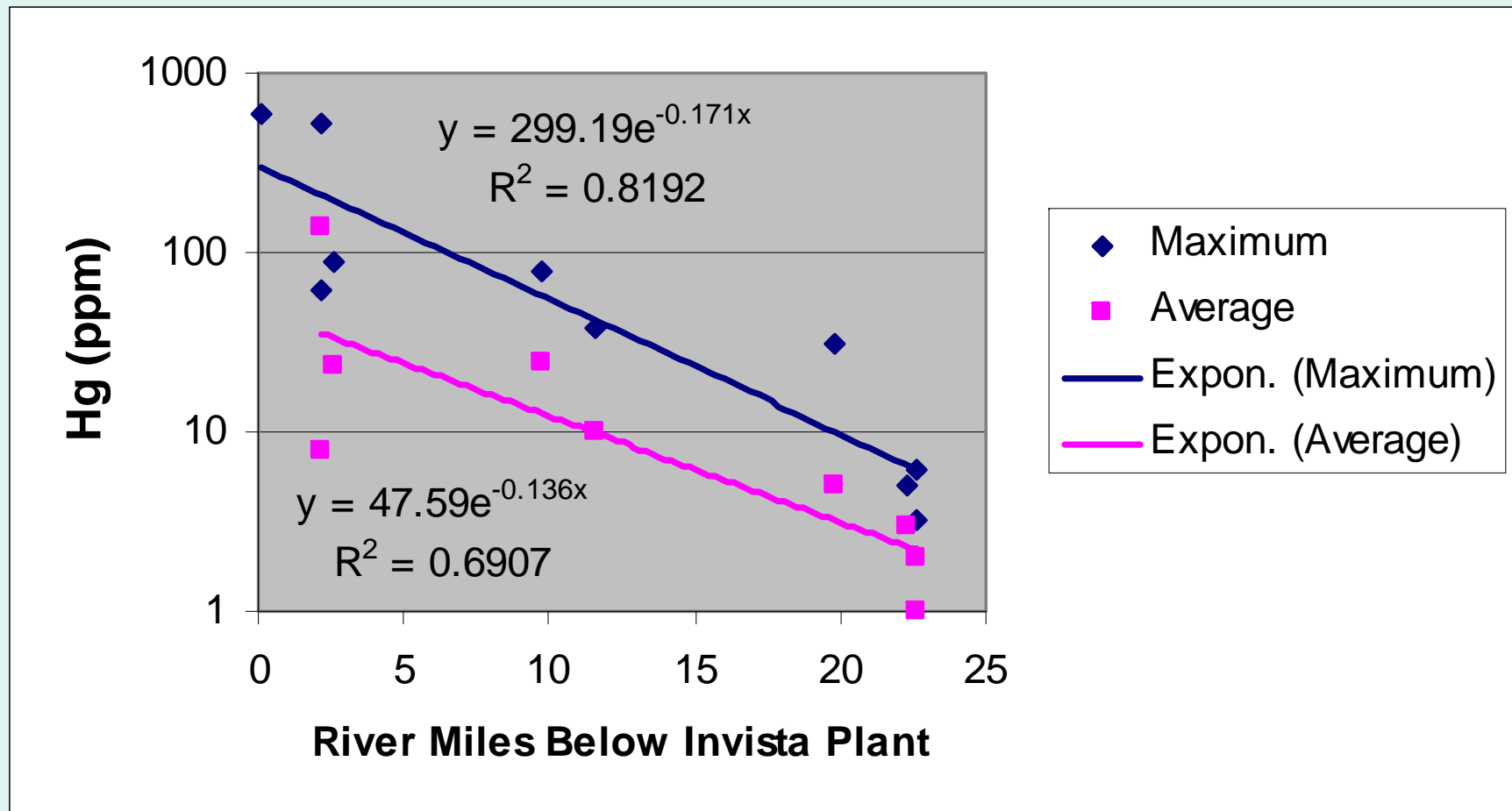
DOWNSTREAM

All Available Eroding Bank Data



Low values in cutoff area – these banks did not exist during primary release period 1929-1950!!

Eroding Bank Hg Concentrations Decrease Exponentially Downstream (more data coming)



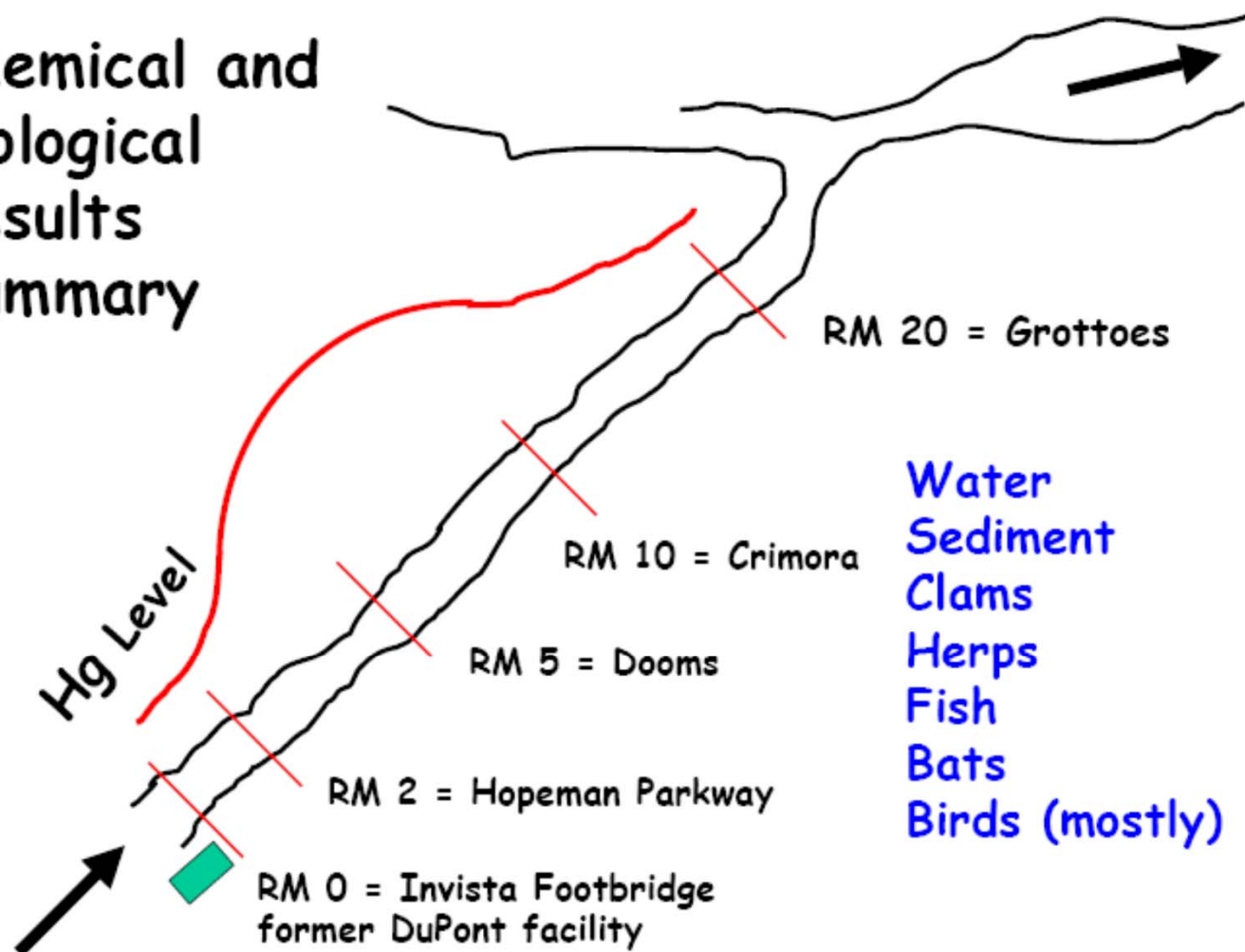
Data from cutoff area not included....

Conceptual Model of Ongoing Mercury Contamination

- The plant provided the original source from 1929-1950
 - The river transported this material downstream, where it has been:
 - Deposited on the floodplain
 - Deposited on fine-grained channel margin deposits
 - Transported out of the study area
- Since 1950
 - Bank erosion provides a continuing source

THE HUMP OF MERCURY CONTAMINATION

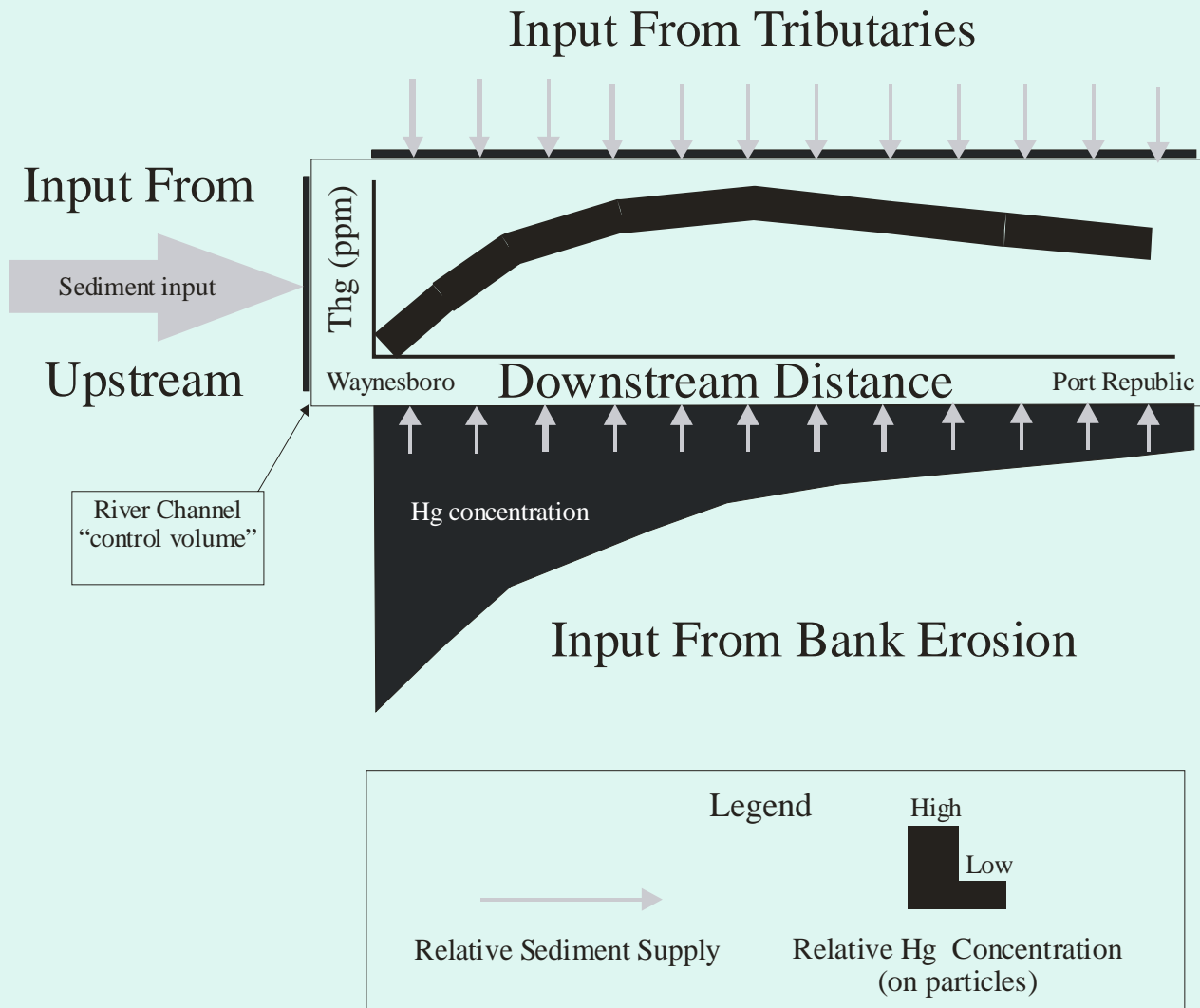
Chemical and Biological Results Summary



Explanation for the “Hump” Distribution

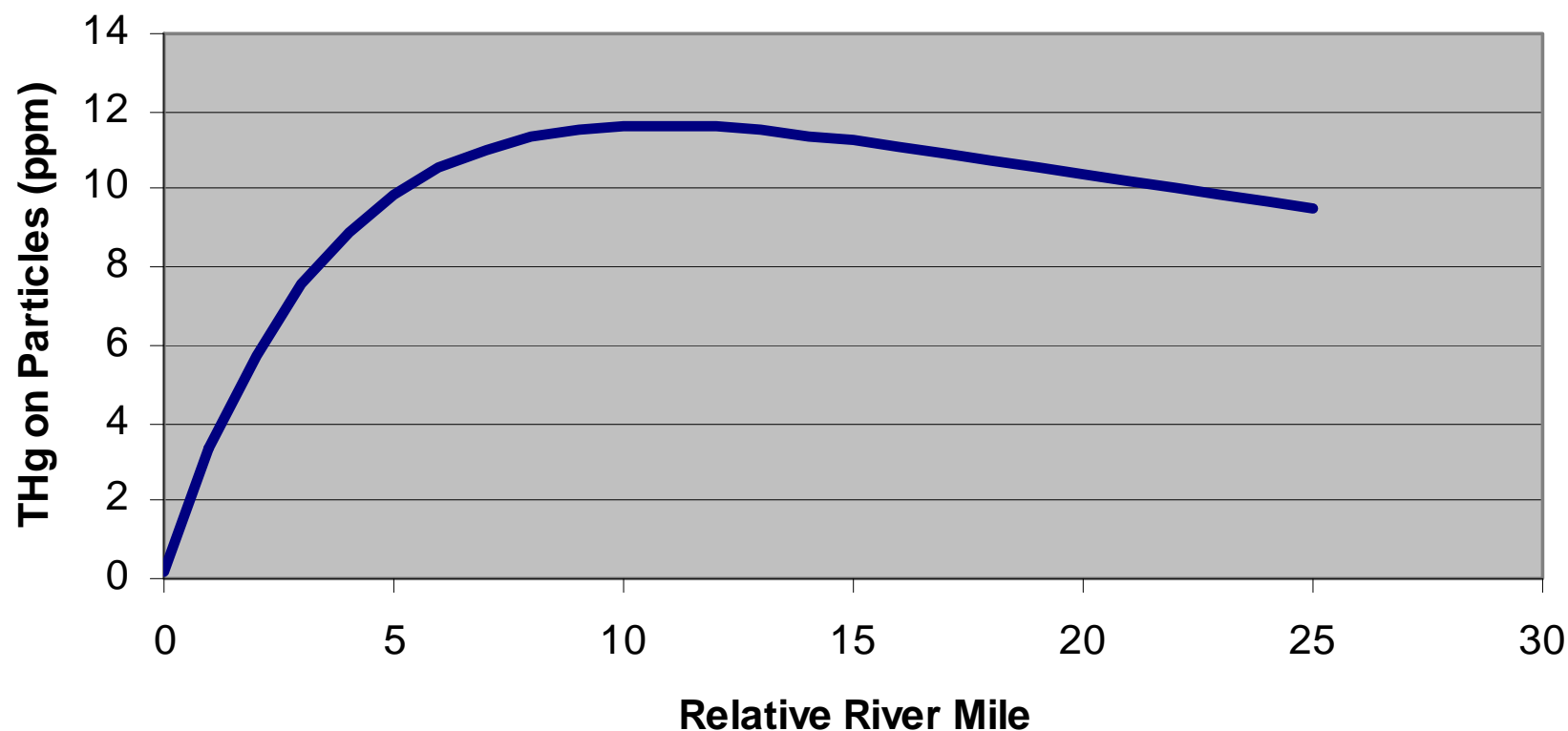
- Erosion of banks with Hg concentration that decreases exponentially downstream
- Processes that reduce particulate Hg concentrations with downstream transport
 - Dilution with clean(er) particulate material from tributaries and other sources?

Explanation for the HUMP



A “Real” Computation

(based on the sediment budget, background and bank Hg concentrations)



The “Hump” Distribution...

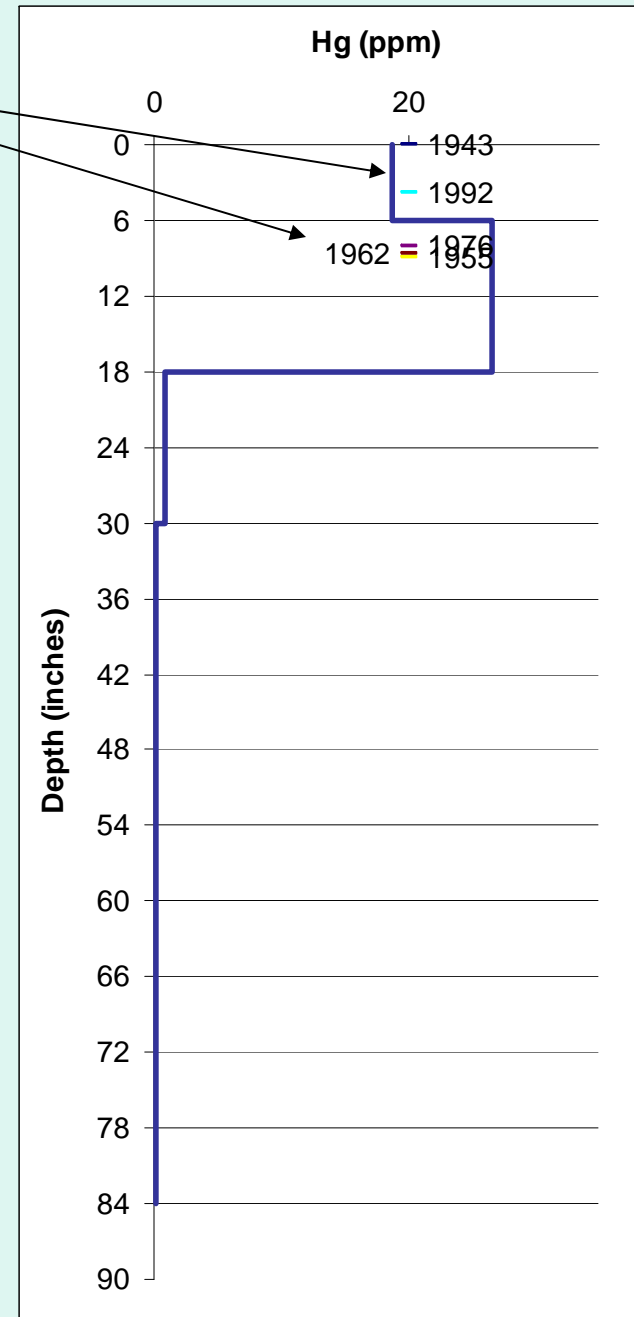
- Physical processes create a “hump” distribution of Hg stored in sedimentary deposits
- Biological and chemical processes move this Hg up the food chain
 - This creates the “Hump” distribution in fish, herps, birds, clams, and so on

Preliminary Results of Floodplain Sampling

- The search for thick deposits dating from 1929-1950 that are preserved
 - By lateral migration of the river channel
 - Behind mill dams

Dated horizons –
accumulation over
roots of trees nearby

Typical floodplain Hg
profile ~ 18 inches of
accumulation since 1929
(this core was taken on
the floodplain behind
Dooms Dam)



Preliminary Assessment

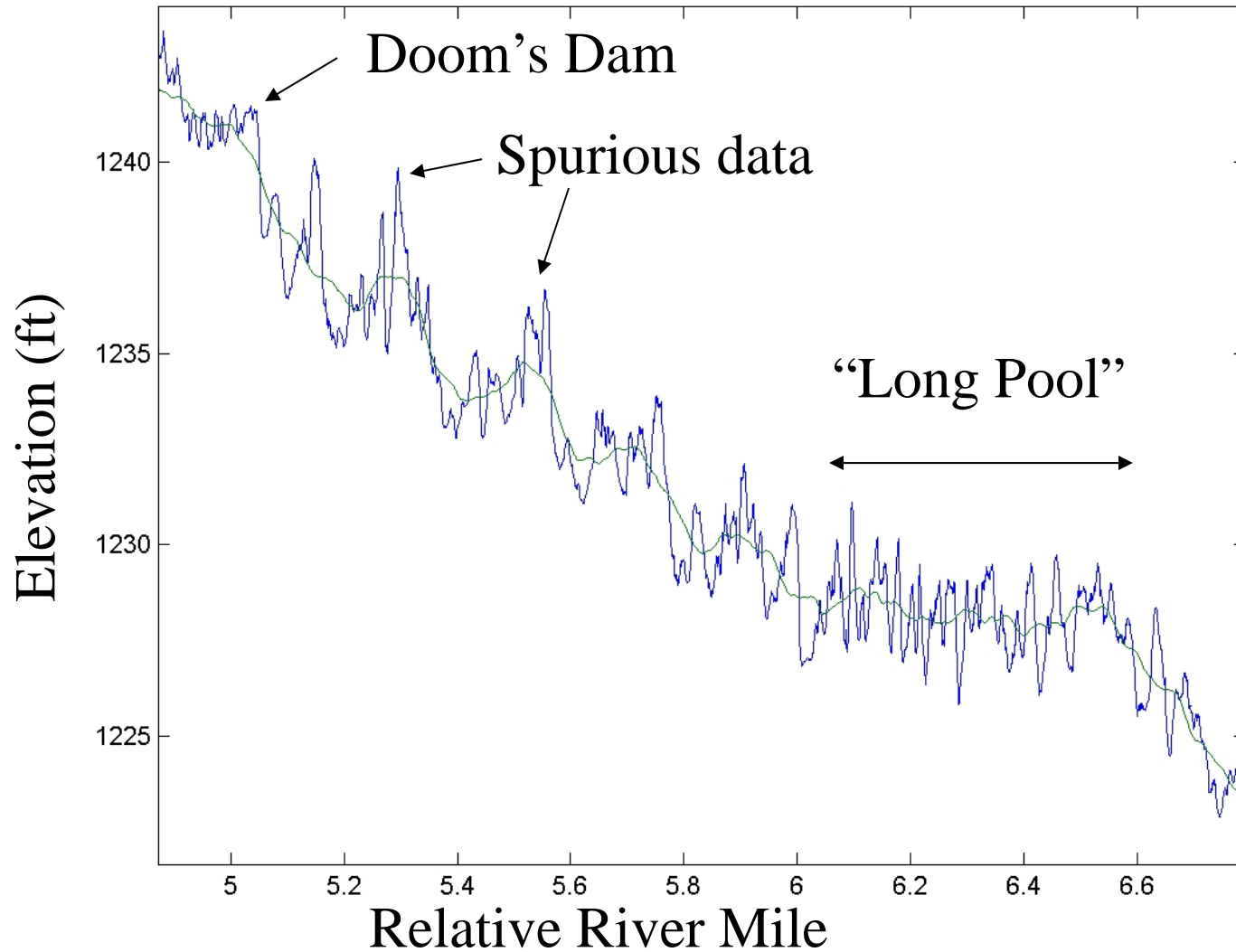
- Unlikely to find thick Hg Release Age Deposits!!
- But analyses from most deposits have not been received as yet.

Ongoing Analyses (by Michael O'Neal and Erica Rhoades)

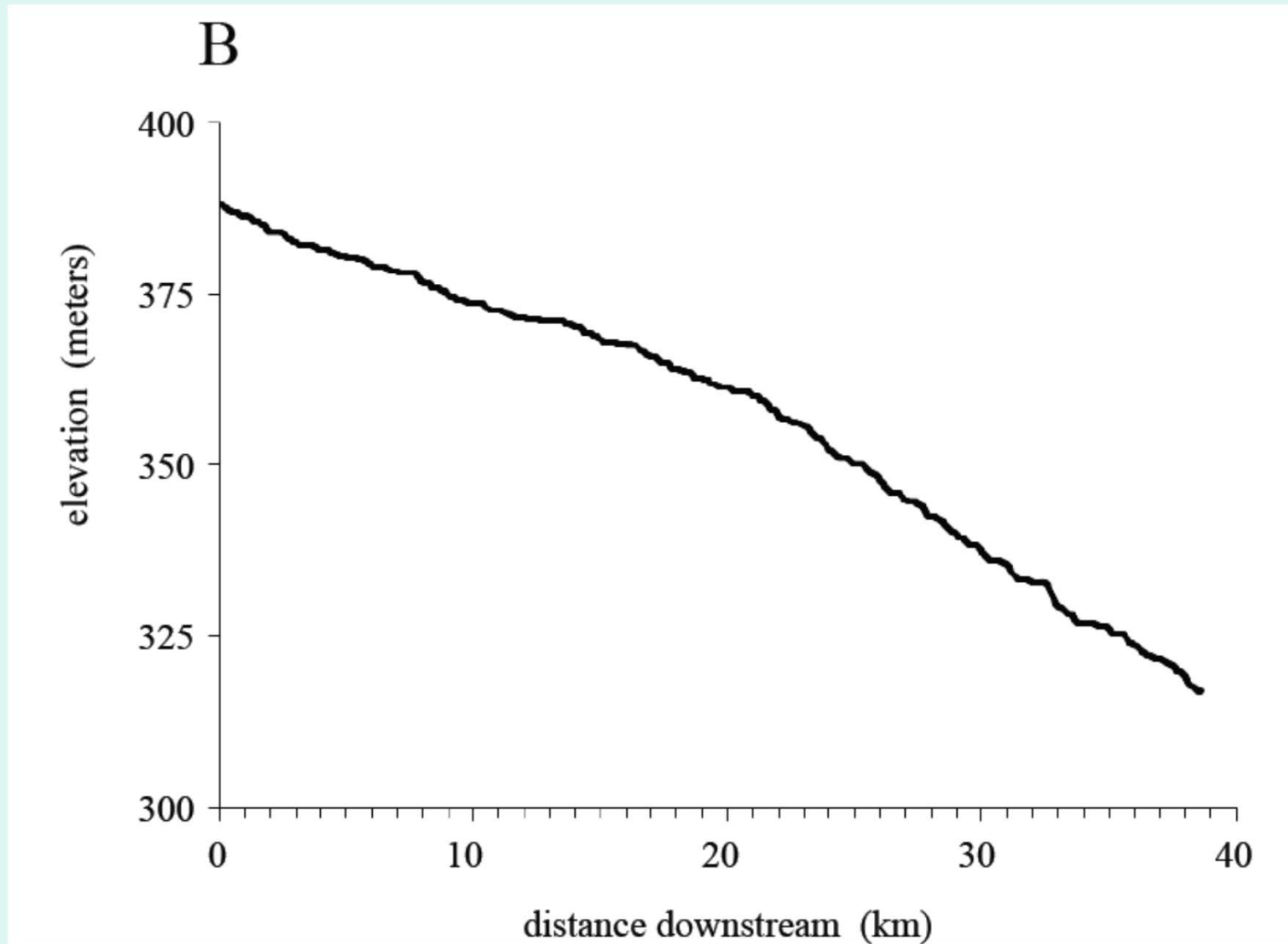
– Improved Topography From Aerial Lidar

- Extract elevation data near the channel from aerial lidar
 - Floodplain surface
 - “Water” surface
- These data provide local bank height estimates for 1937-2005 bank erosion polygons
- Resulting estimates are ~20% higher than previously estimated in Pizzuto et al. 2006 report

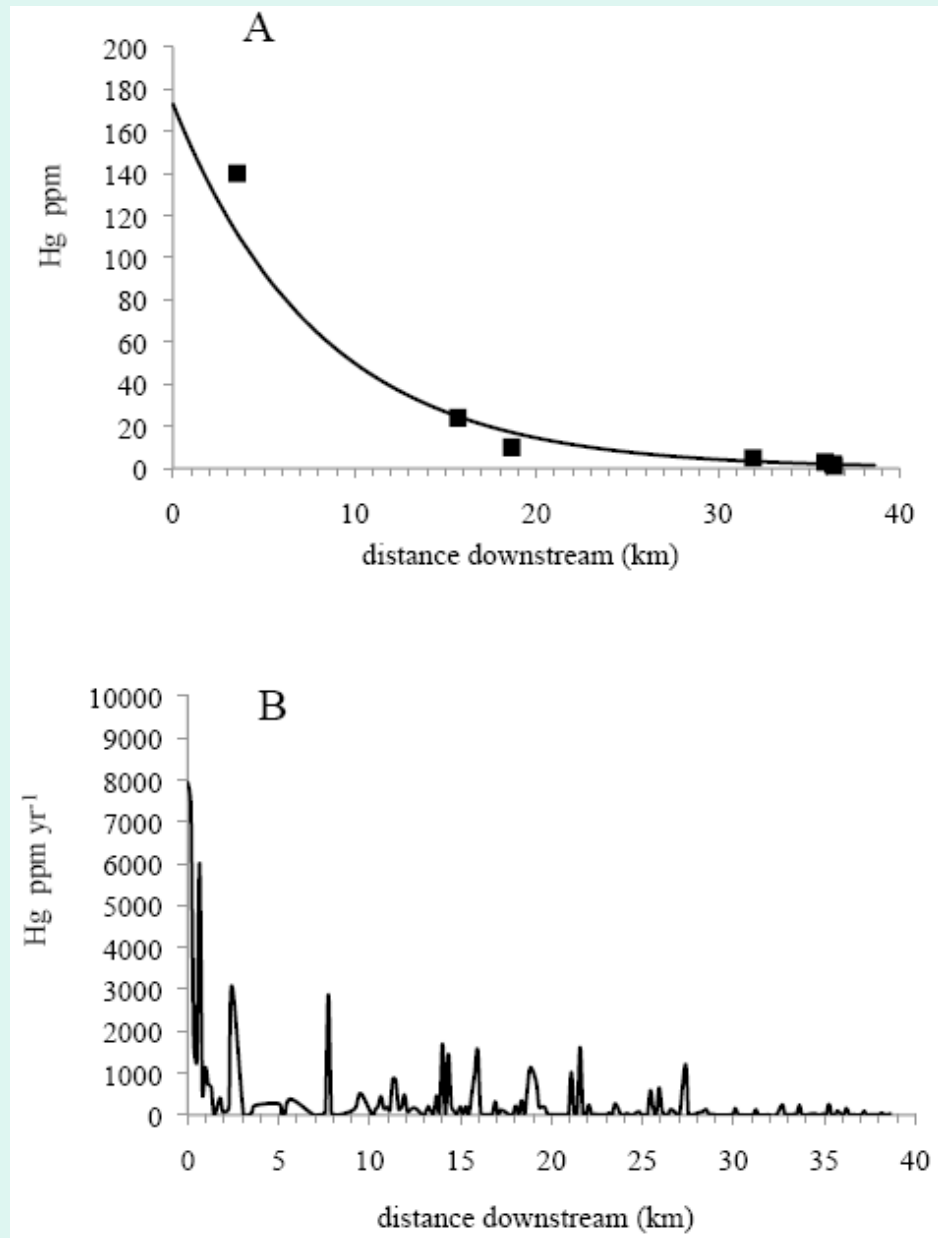
Section of New Longitudinal Profile (better filtered version available)



Improved “Smoothed” Version



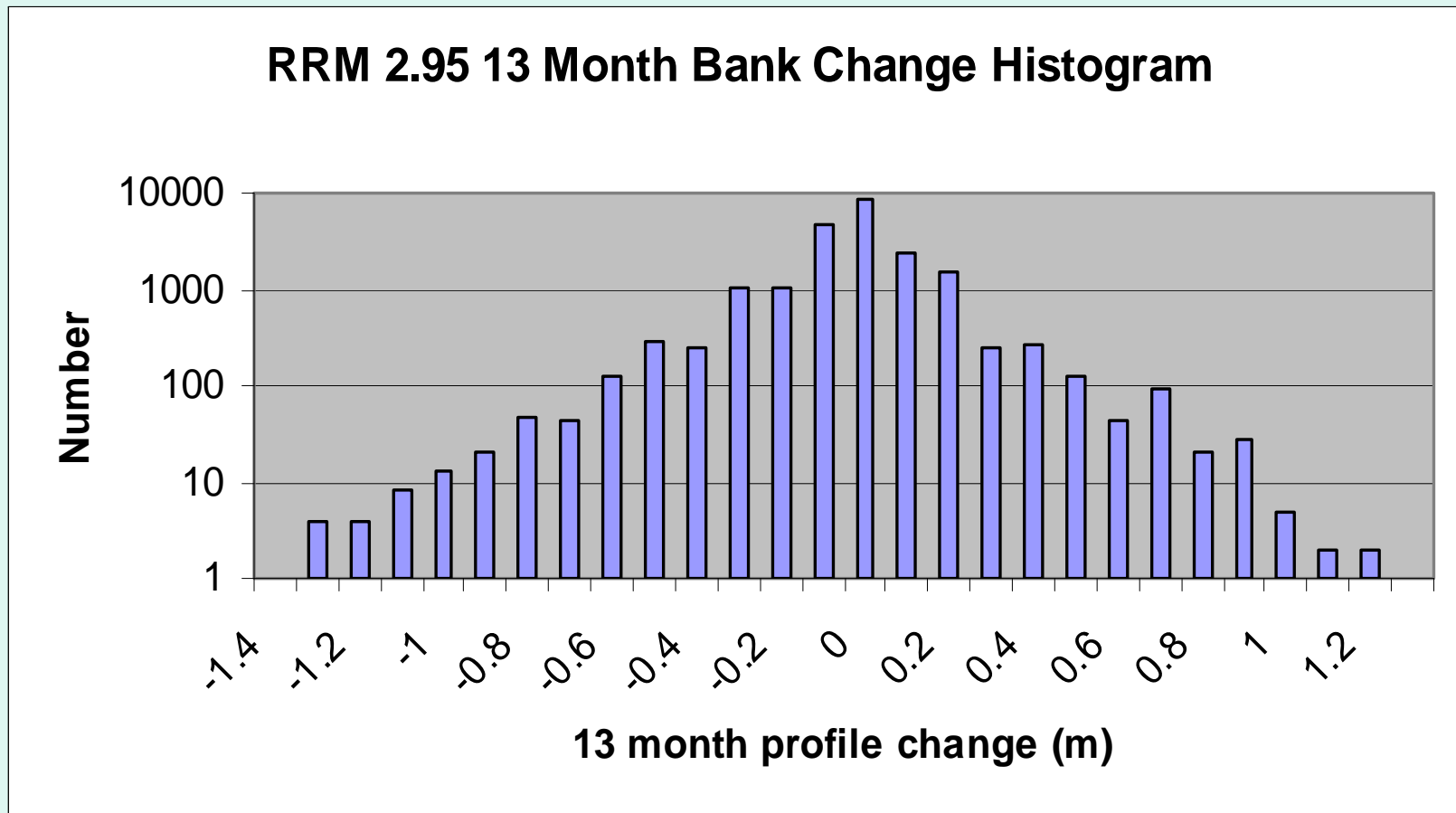
Improved Hg Loading From Bank Erosion (Preliminary)



Quantitative Analysis of Lidar Bank Surveys

- Preliminary analysis – RRM 2.95

RRM 2.95 - Histogram of Changes From Tripod Lidar (0.05 x0.05 m resolution)



Sign convention – Negative = erosion, positive = deposition

RRM 2.95

- Bank erosion rate 1937-2005 – ZERO m
- Statistics for 13 month erosion rate from tripod mounted lidar:

RRM 2.95 13-Month Bank Changes From Tripod-Mounted Lidar

Spatial Intervals - 0.05x0.05 m

Descriptive Statistics	
Mean change (m)	-0.064
Median change (m)	-0.063
Maximum change (m)	1.313
Minimum change (m)	-1.375
Standard deviation (m)	0.186
Cumulative total change (m ³)	-3.309

Contemporary Erosion Rates Monthly – Annual Timescales

- These will be much higher than 1937-2005 bank erosion rates

Summary of Take-Away Points

1. 75% of the Hg in fine-grained channel margin deposits dates from 1929-1950
 - probably carried downstream directly from the plant and deposited
2. Hg concentrations in eroding banks decreases exponentially from the plant downstream
 - Spatial pattern consistent with original point source from plant, 1929-1950
3. “Hump” of Hg concentration downstream may originate from:
 - Ongoing erosion of contaminated bank sediments
 - Processes that reduce Hg concentrations with transport distance
 - Supply of “clean” particulates from tributaries, etc.