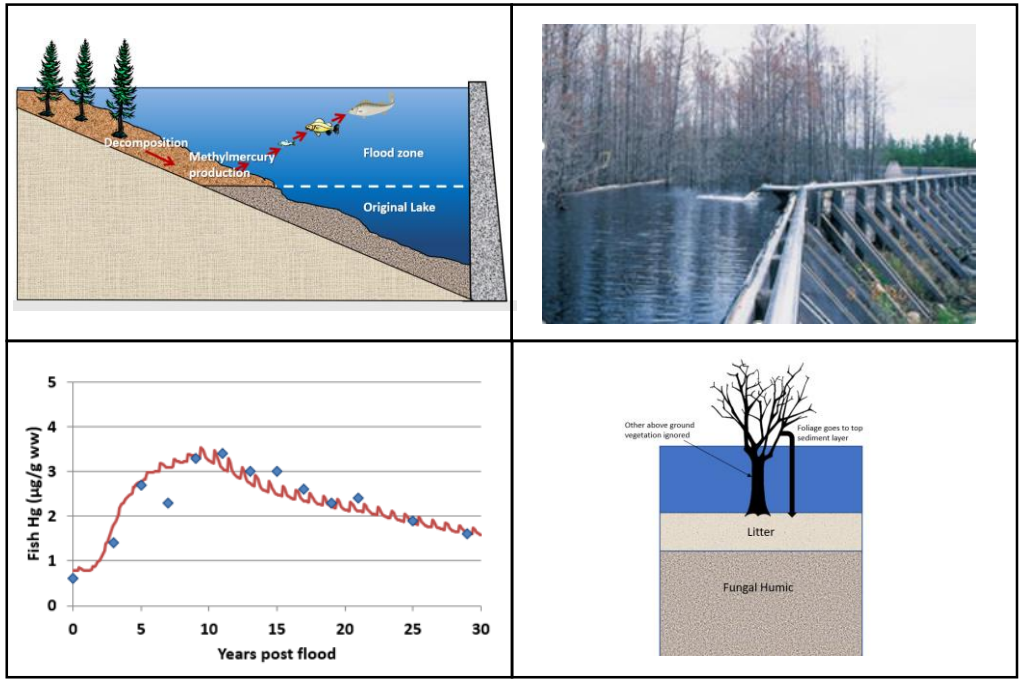
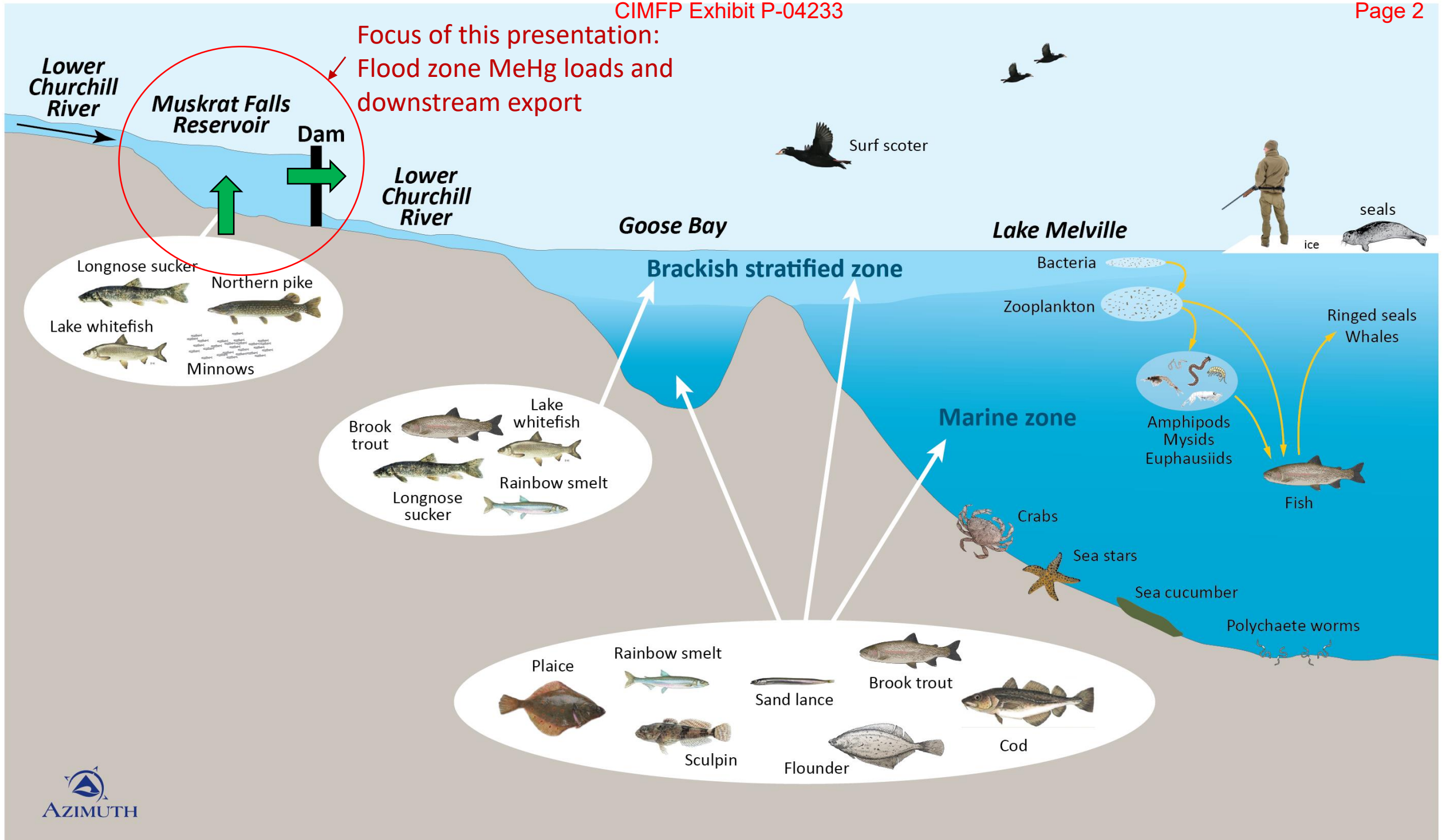
Predicted Increases in Methylmercury Concentrations in Goose Bay and Lake Melville Waters Following the Creation of Muskrat Falls Reservoir



Presented by Reed Harris
June 28, 2018


Focus of this presentation:
Flood zone MeHg loads and downstream export
Lower Churchill River
Muskrat Falls Reservoir
Dam
Lower Churchill River
Goose Bay
Lake Melville
Surf scoter
seals
ice
Brackish stratified zone
Bacteria
Zooplankton
Ringed seals
Whales
Longnose sucker
Northern pike
Lake whitefish
Minnows
Amphipods
Mysids
Euphausiids
Fish
Marine zone
Brook trout
Lake whitefish
Rainbow smelt
Longnose sucker
Crabs
Sea stars
Sea cucumber
Polychaete worms
Plaice
Rainbow smelt
Sand lance
Brook trout
Sculpin
Flounder
Cod

AZIMUTH

Field data for methylmercury in new reservoirs

Fish mercury:

- 12 reservoirs with good data (red points on figure)
- A few more reservoirs with some data (e.g. Smallwood)

Methylmercury in reservoir waters

- Only one site (FLUDEX experiment) (blue point on figure)
- No data for any full scale reservoirs

How can we use data from existing reservoirs to help predict increases in methylmercury Muskrat Falls waters?

Methylmercury in reservoirs waters

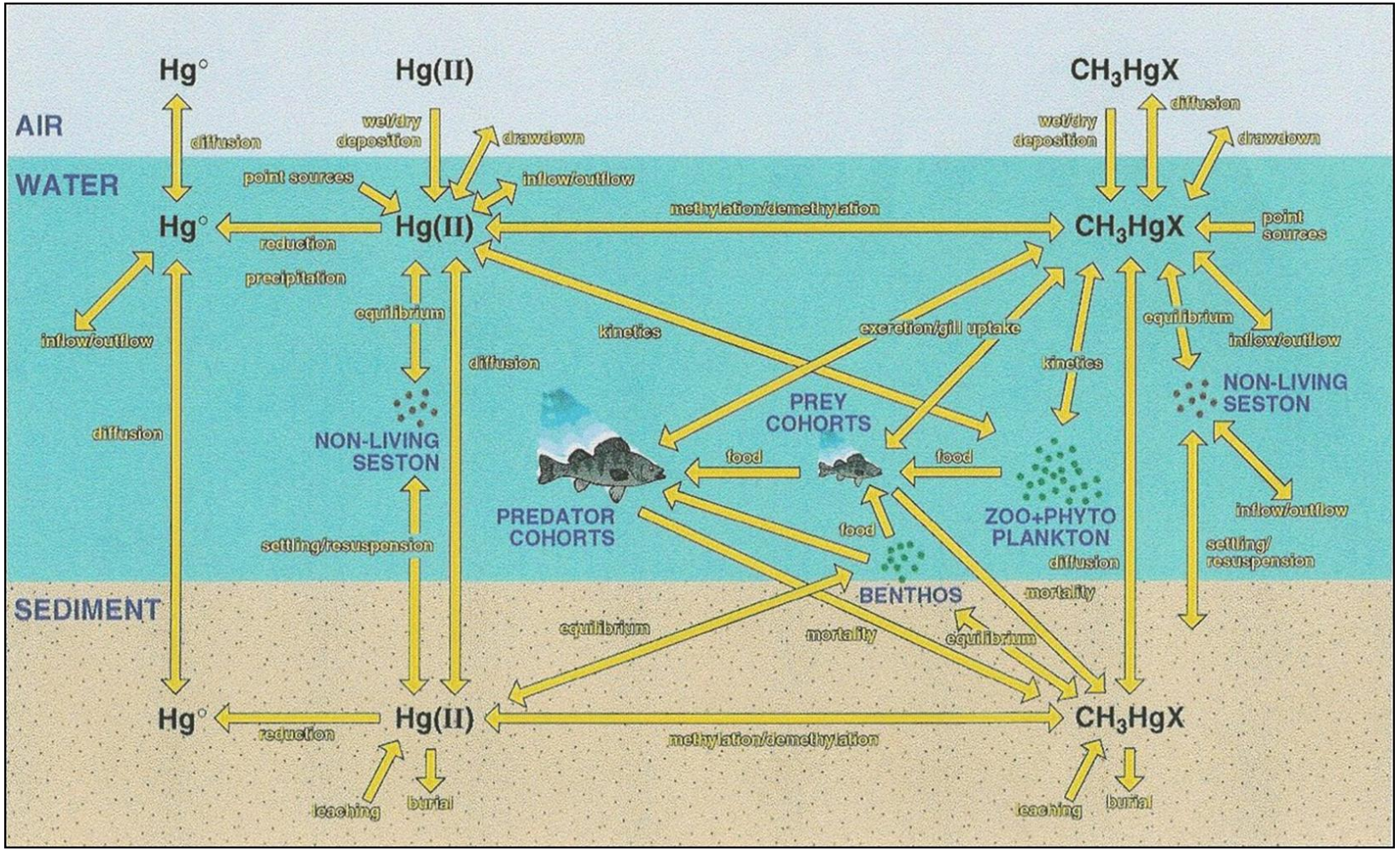
- Used the FLUDEX field estimates of downstream methylmercury export from the reservoir, per m^2 of flooding, and applied that to the Muskrat Falls Reservoir to predict downstream methylmercury export.

Fish mercury:

- Used a model to predict what methylmercury load from the flood zone would produce observed increases in fish in Robert Bourassa Reservoir in Quebec.

- Applied that load from the flood zone, per m^2, to Muskrat Falls Reservoir, to predict methylmercury in fish, and in water exported downstream.

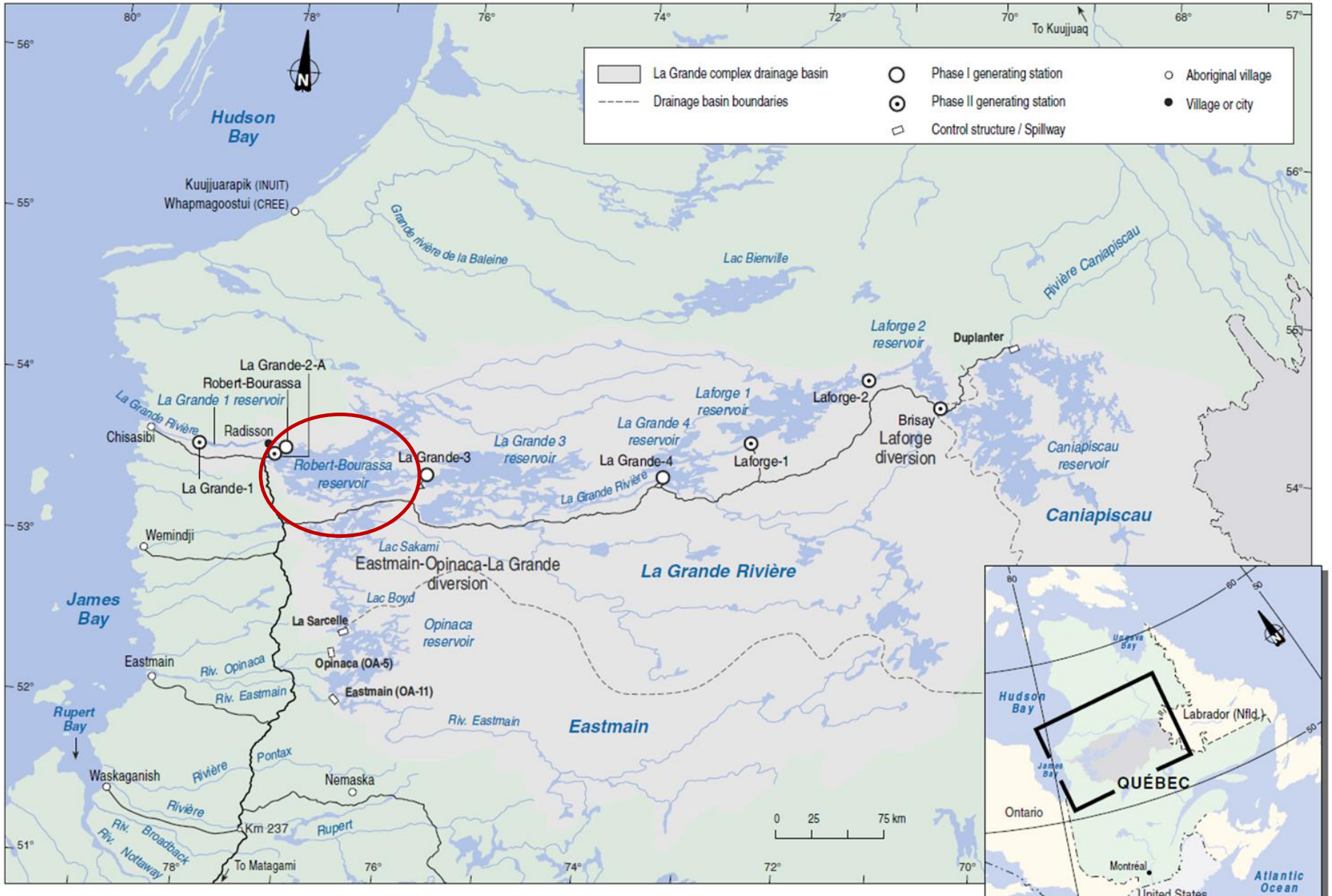
Mechanistic Reservoir Mercury Model (ResMerc)



- Three mercury forms
- Water, sediments and food web
- Flooded uplands and wetlands
- Predicts concentrations as a function of time.

Developed originally at ELA as part of FLUDEX and ELARP studies.
Used for Lower Churchill and Site C.

Robert Bourassa Reservoir



Reservoir area:
2,835 km2

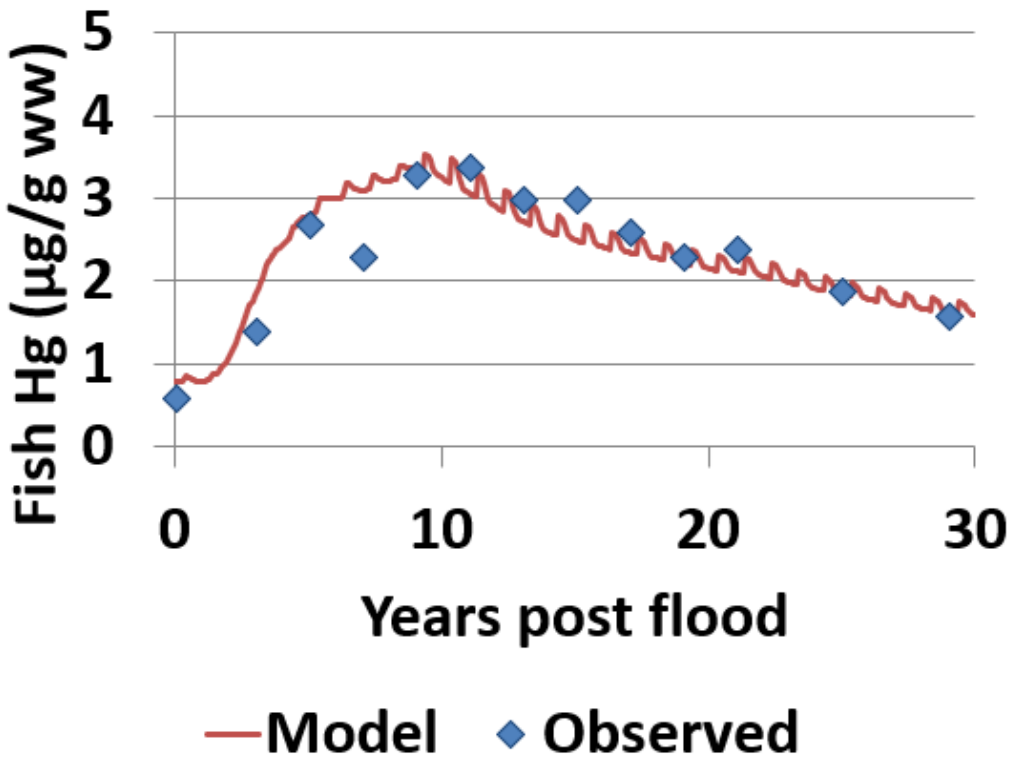
Flooded area:
2,478 km2
(87% of total area)

Water residence time:
7 months

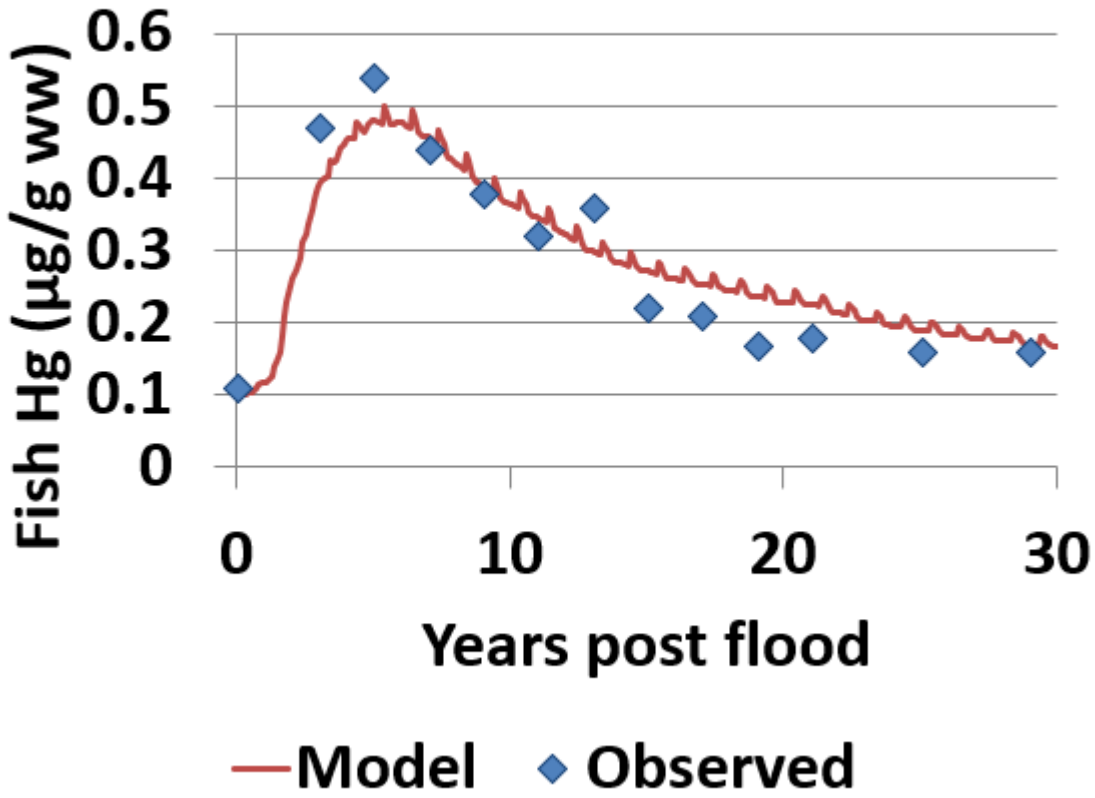
Peak mercury in adult northern pike (700mm)
3 µg/g

Calibration of ResMerc model to Robert Bourassa Reservoir

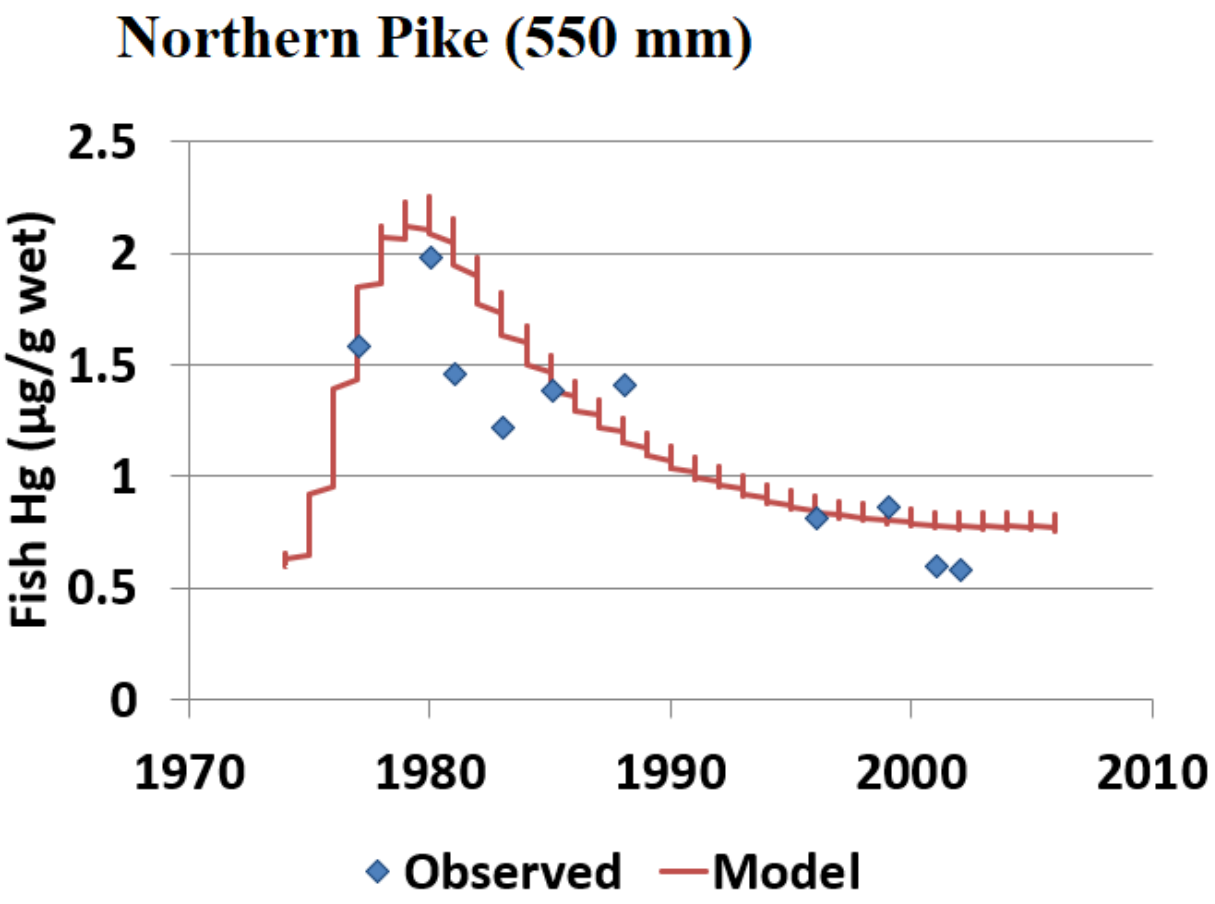
Northern Pike (700 mm)

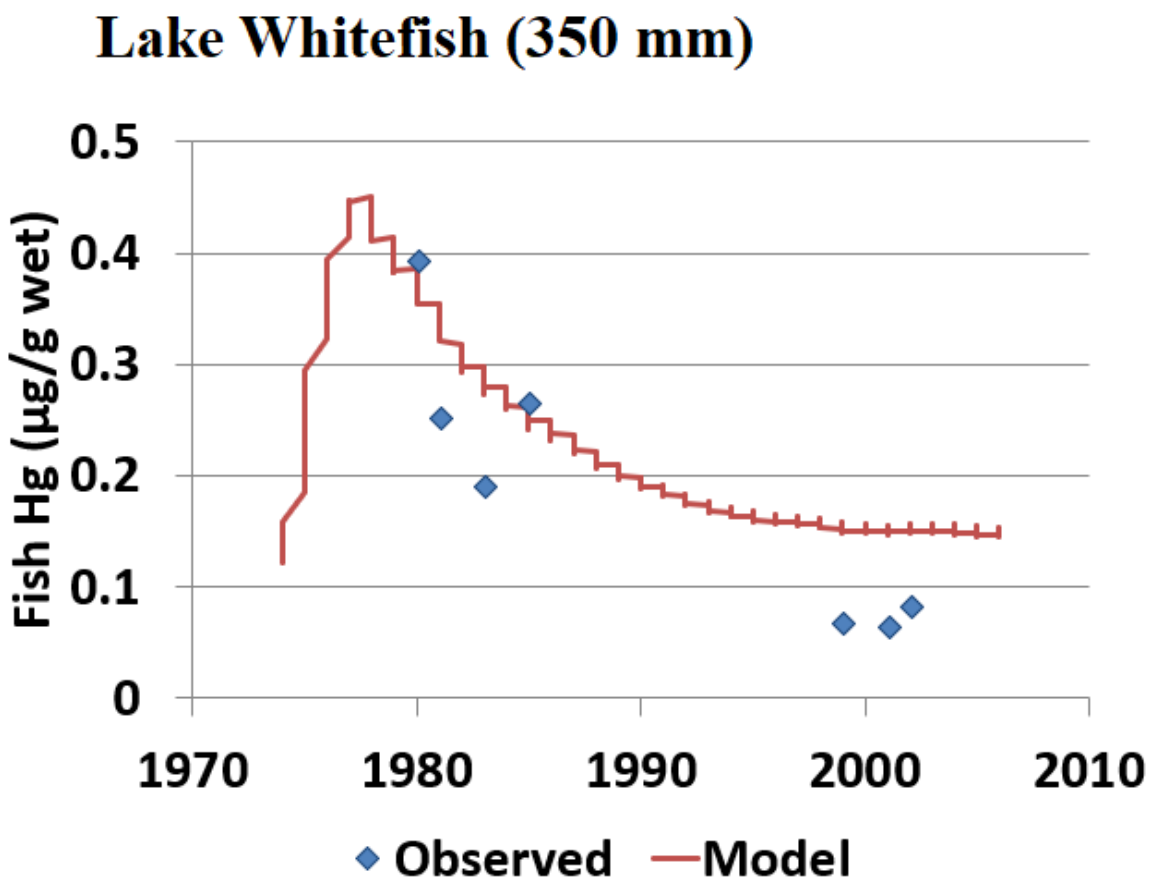


Lake whitefish (400 mm)

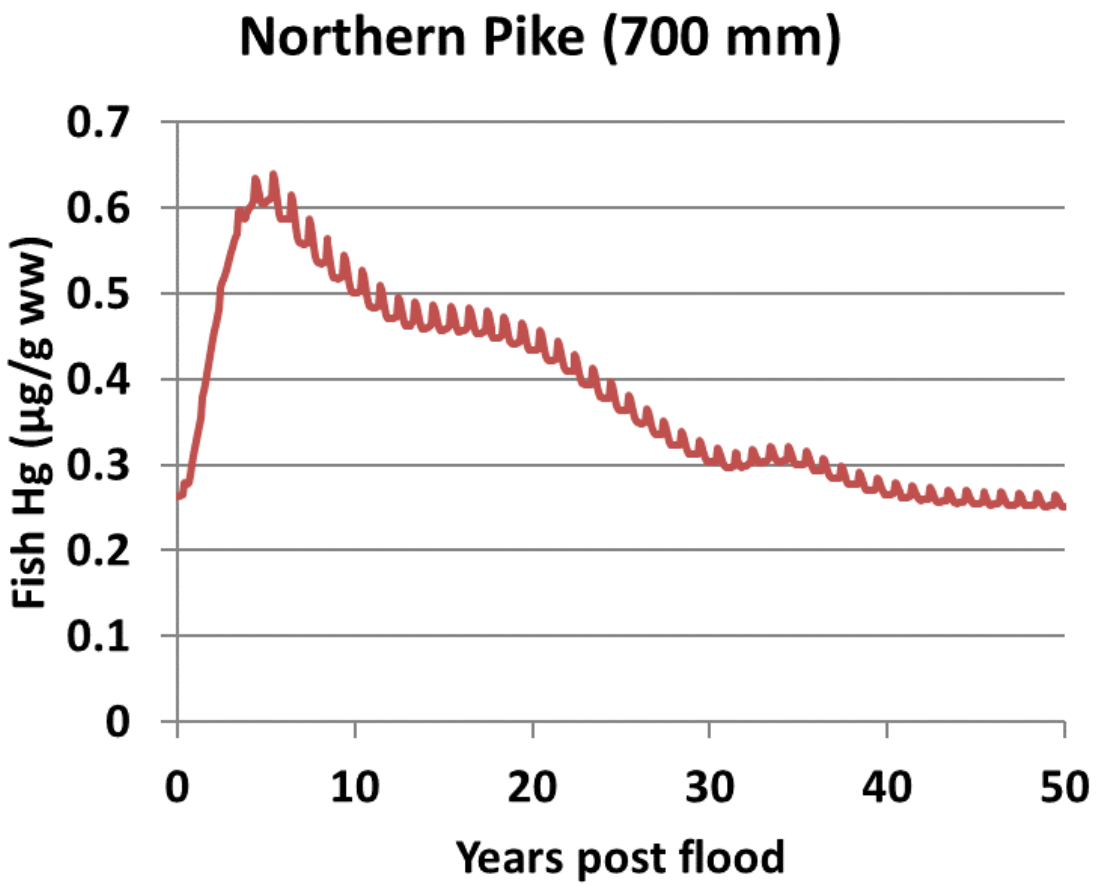


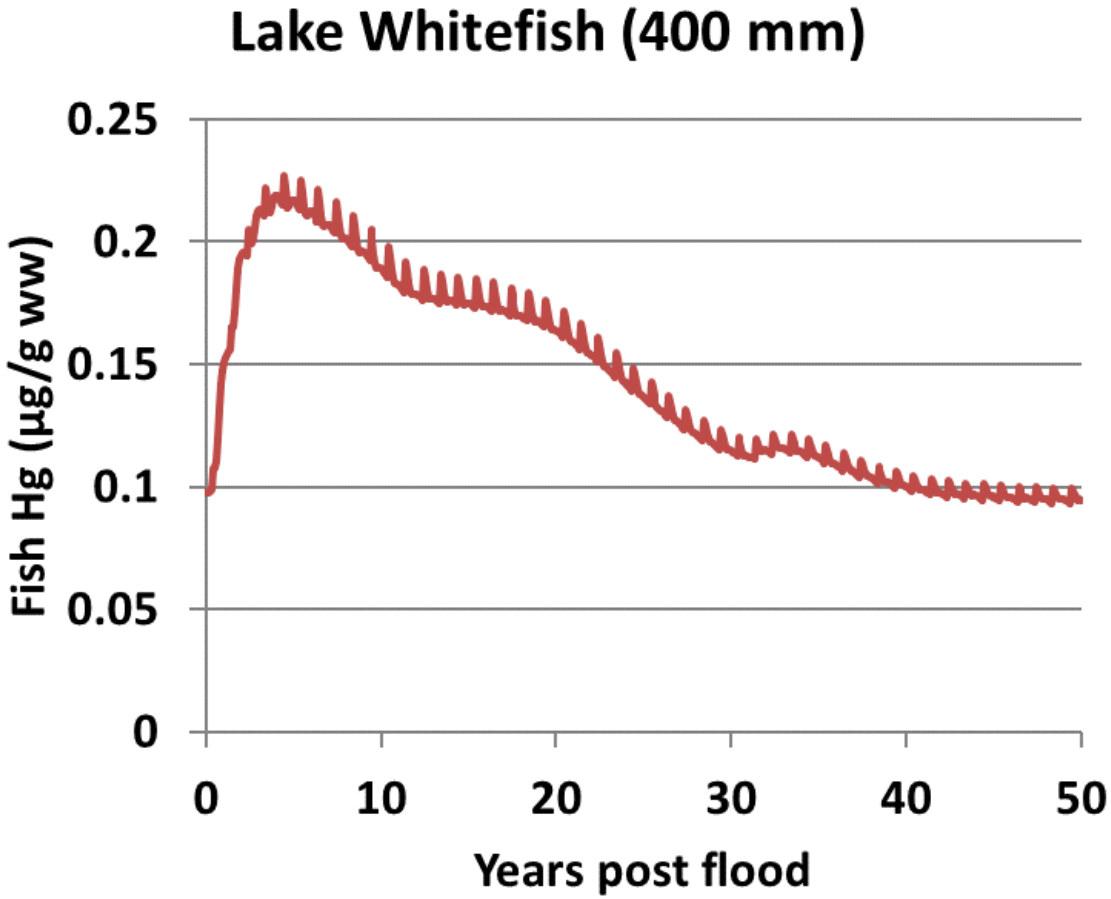
Application of calibrated model to Notigi Reservoir, Manitoba





Predicted Mercury in Muskrat Falls Reservoir Fish (using flood zone loading rates from R. Bourassa)





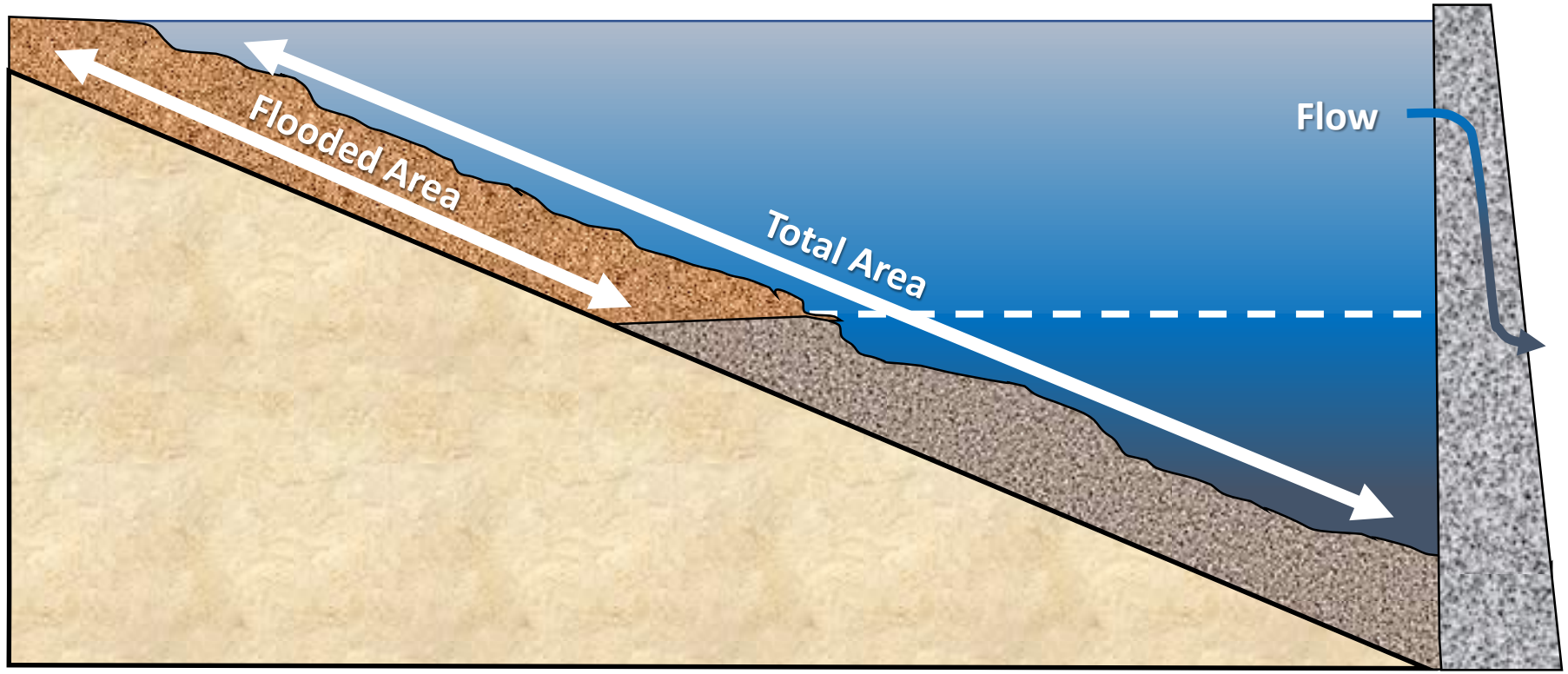
These base case runs resulted in peak concentrations ~2.4X baseline. Additional runs with different assumptions resulted in increases up to ~3X baseline

Regression model also used to predict peak increases in fish mercury levels in new reservoirs

Three factors

- **Flooded Area**
- **Total Area**
- **Mean annual flow**

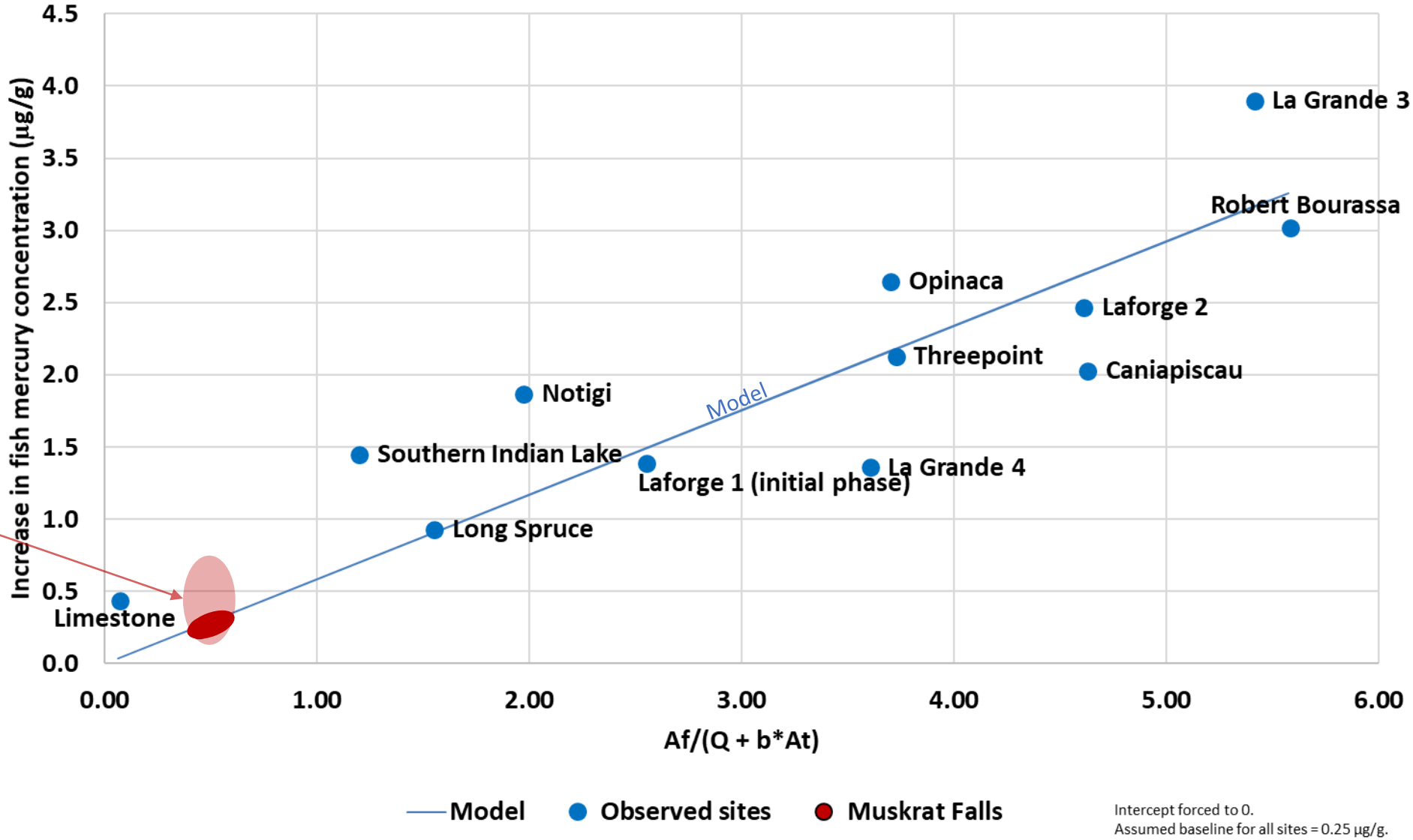
Advantage: Based on data from 12 reservoirs.
Limitation: Lower Churchill baseline mercury levels outside (lower) than the range for sites used to develop model.



Predicted and observed mercury increases in 700 mm Northern Pike

Predicted increases must be added to baseline to estimate overall peak concentration

Shaded red area outlines range of results for different assumptions

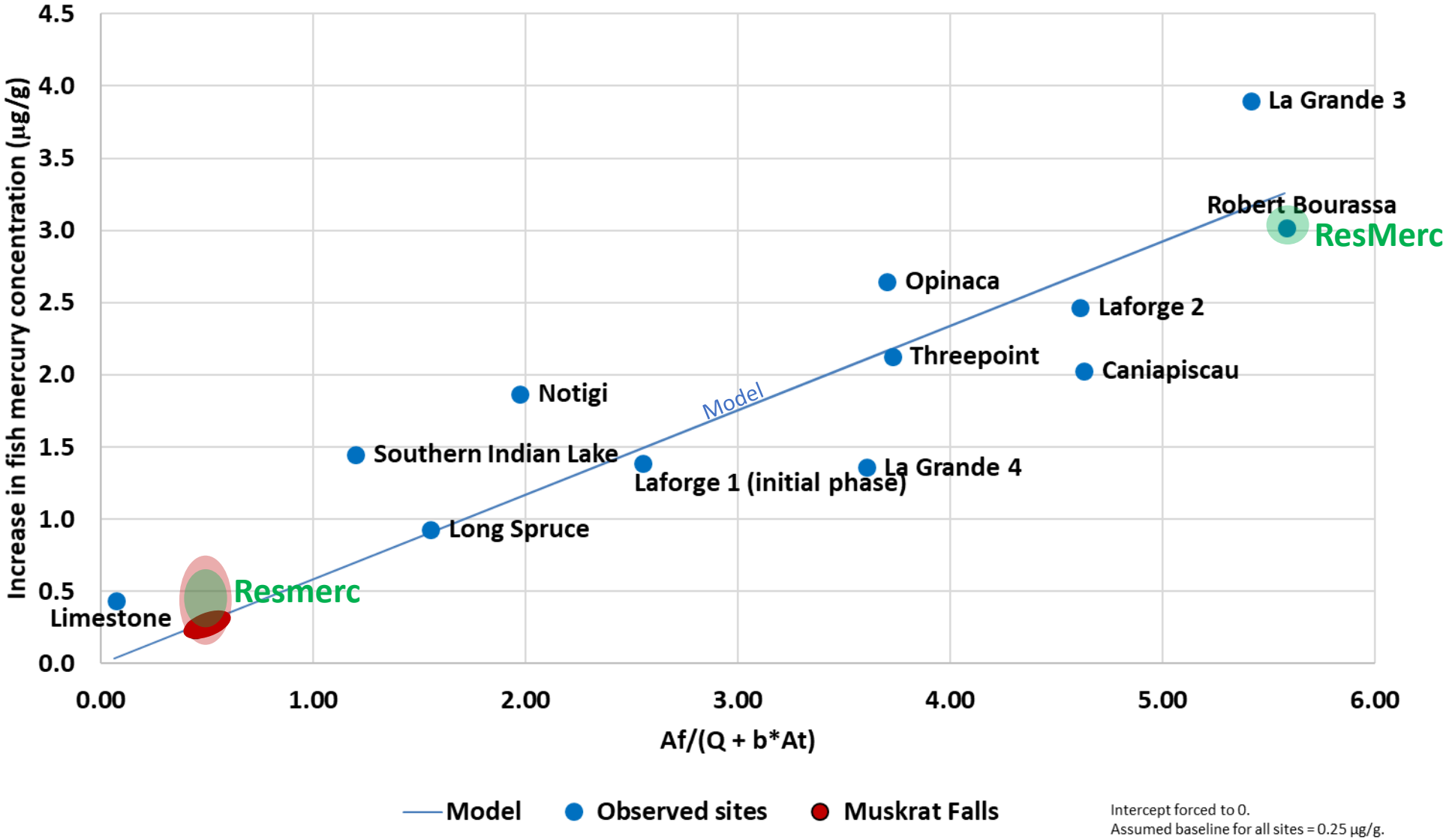


Intercept forced to 0.
Assumed baseline for all sites = 0.25 µg/g.

Af = flooded area, Q = mean annual flow, At = total area, b = constant

ResMerc also predicts much lower increases in fish Hg when flood zone loads from R. Bourassa were applied to Muskrat Falls…

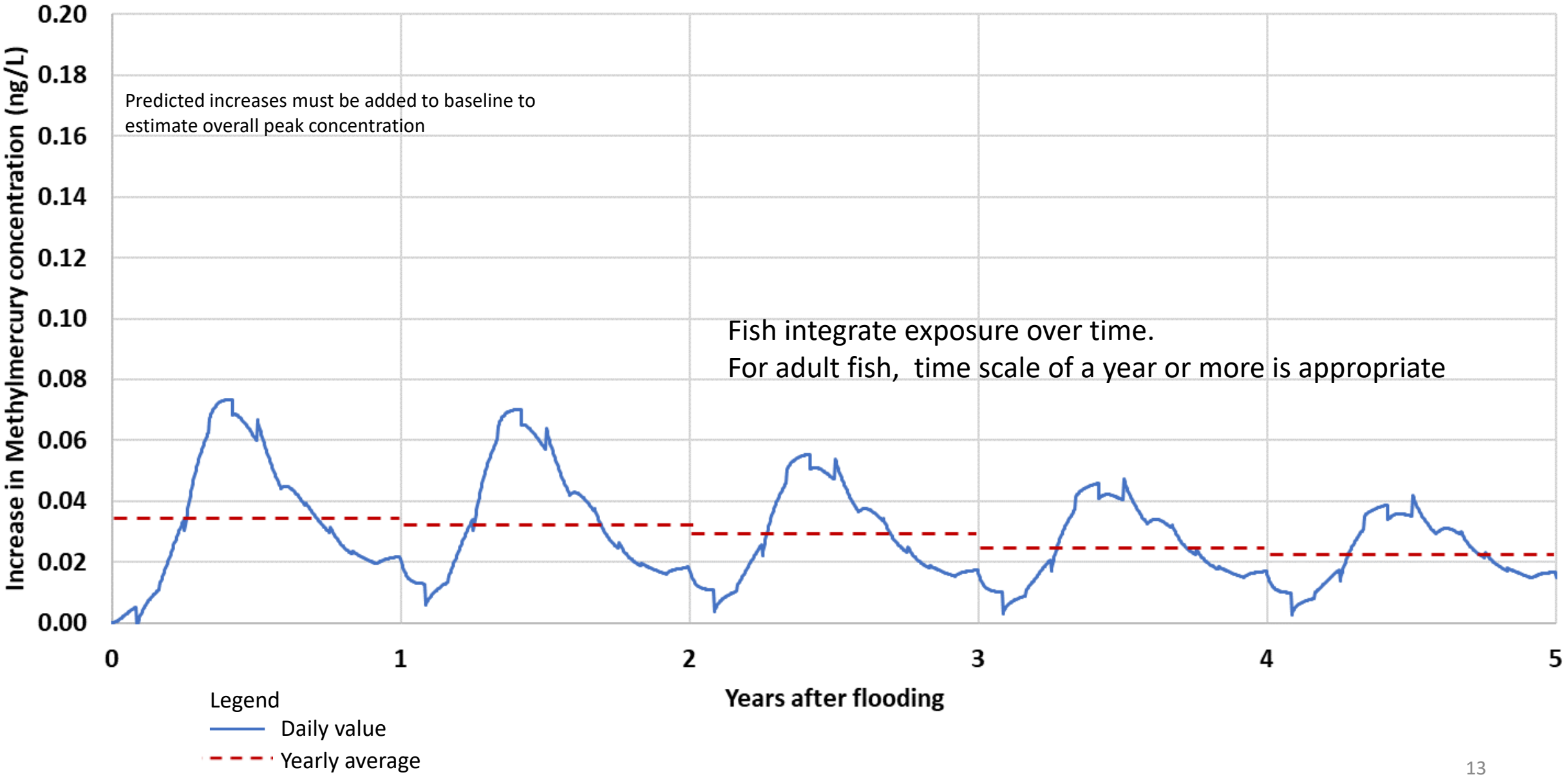
Predicted increases must be added to baseline to estimate overall peak concentration



Intercept forced to 0.
Assumed baseline for all sites = 0.25 µg/g.

Af = flooded area, Q = mean annual flow, At = total area, b = constant
Shaded red area outlines range of results for different assumptions

Predicted Increase in Methylmercury Concentrations Exported from Muskrat Falls Reservoir (ResMerc Model)

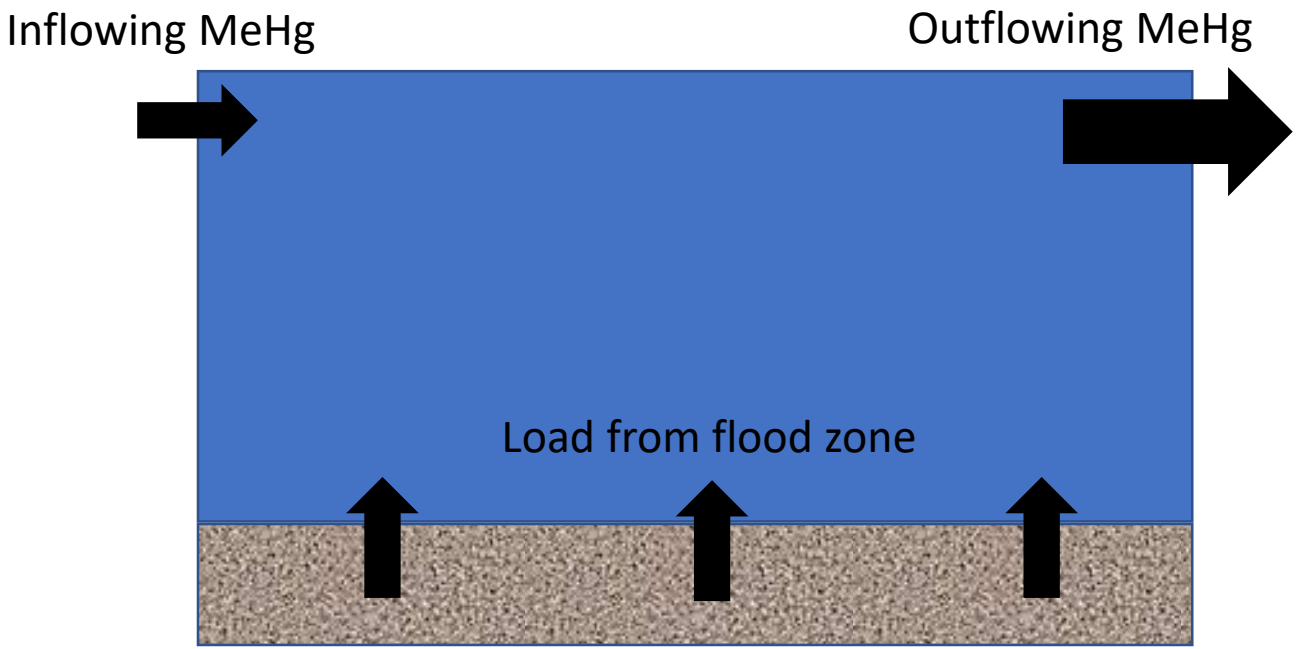


FLUDEX Experiment

- 3 upland forests were flooded (different carbon content)
- Experimental Lakes Area on the Canadian Shield
- Studied mercury and greenhouse gases
- 5 year duration (1999-2003)
- Flooded from ~ June-October each year, then drained.

FLUDEX

Field estimated export = Outflow flux – Inflow flux

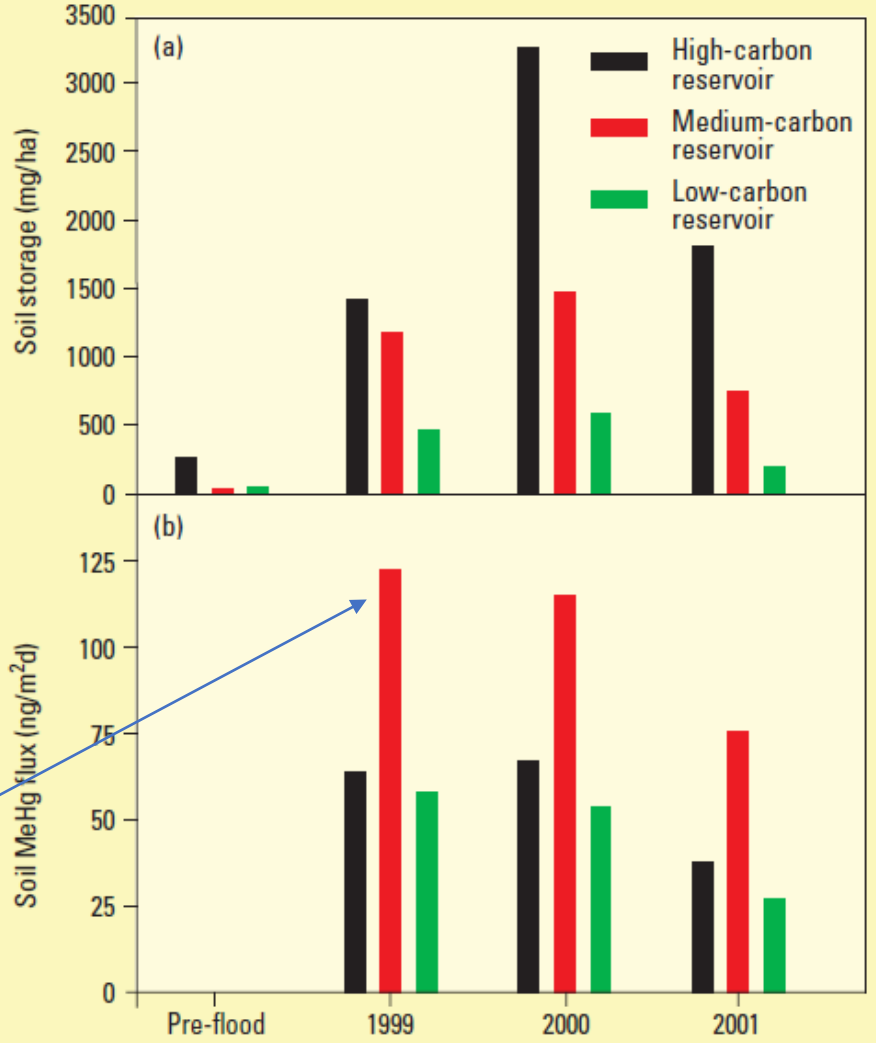


We used results from the medium carbon site, which produced the greatest increases.

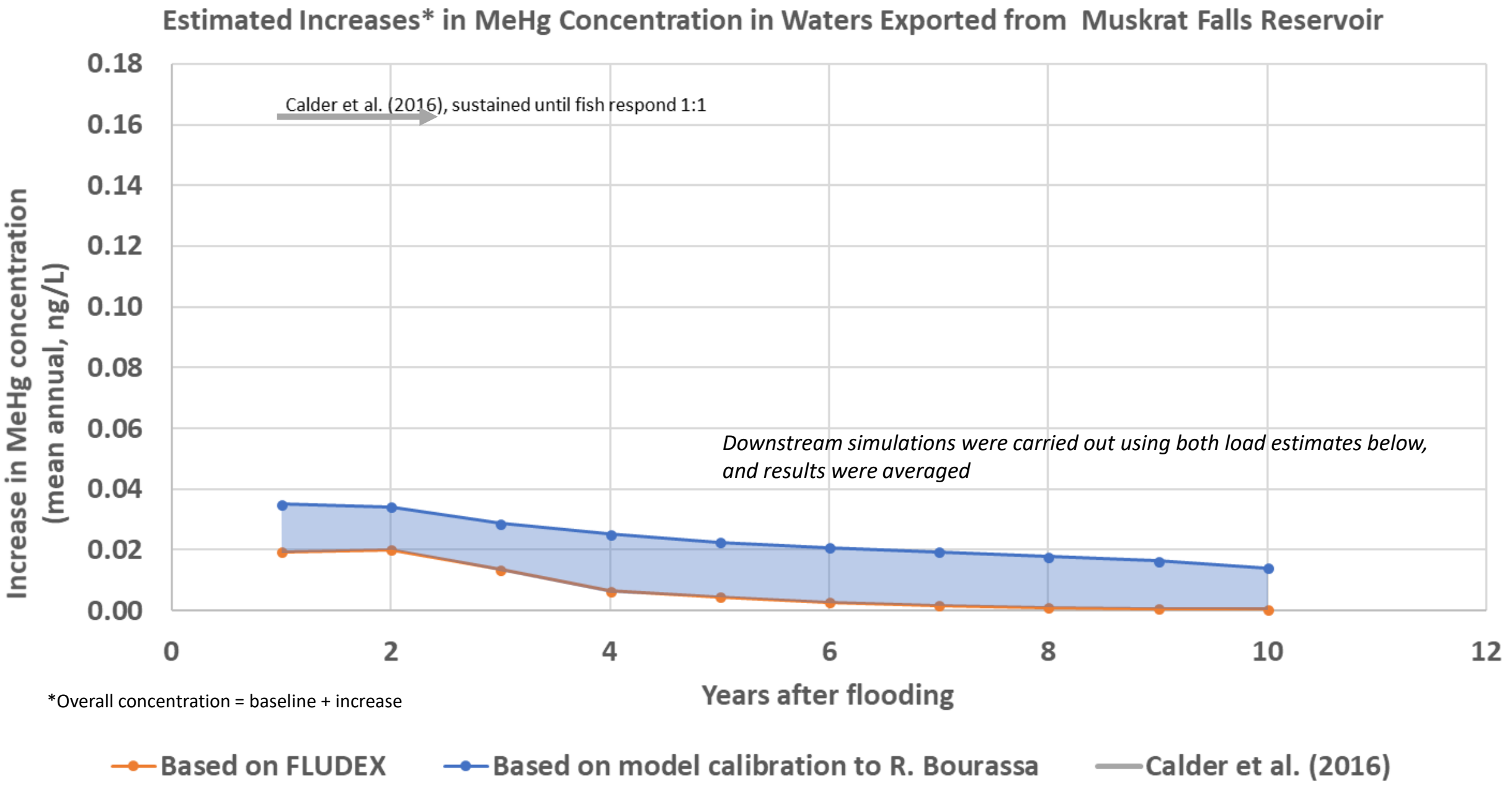
FIGURE 3

Methylmercury burdens and fluxes

(a) Soil storage in the FLUDEX reservoirs increased dramatically after flooding. (b) Fluxes out of flooded soils, calculated as net MeHg production of each FLUDEX reservoir, were highest in the medium-carbon reservoir.



Bodaly et al (2004)


Estimated Increases* in MeHg Concentration in Waters Exported from Muskrat Falls Reservoir
Calder et al. (2016), sustained until fish respond 1:1
Downstream simulations were carried out using both load estimates below, and results were averaged
Increase in MeHg concentration (mean annual, ng/L)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
2
4
6
8
10
12
Years after flooding
*Overall concentration = baseline + increase
Based on FLUDEX
Based on model calibration to R. Bourassa
Calder et al. (2016)

Summary

Fish Mercury in Muskrat Falls Reservoir:

- Two models used to predict increases in fish mercury concentrations in Muskrat Falls Reservoir.
- Both models predict adult fish will increase about 2.5-3X in the reservoir, ~0.6-0.8 ppm in 700mm Northern Pike.

Methylmercury Export:

- Lack of data for MeHg in water from full-scale reservoirs or downstream (issue for all models).
- Used two approaches to make use of data for MeHg in water from FLUDEX, and fish Hg data from existing reservoirs to "back-estimate" MeHg in water, providing a range for downstream export from Muskrat Falls Reservoir.
- Predicted *increase* in concentrations exported downstream reached a peak of 0.02 to 0.035 ng/L (1 yr avg).
- Overall peak concentration (baseline + increase) roughly 2-3X baseline, 0.04 to 0.055 ng/L (1 yr avg).
- Flow dilution predicted to be an important moderating factor.
- The predicted increases in methylmercury concentrations exported from the reservoir are lower than the Calder et al. (2016) analysis.