# Lower Fox River Statistical Methodology for Long Term Monitoring Plan Update

SMWG Fall Sponsor Forum

November 13, 2024 | Stephen G. Lehrke, Ph.D.

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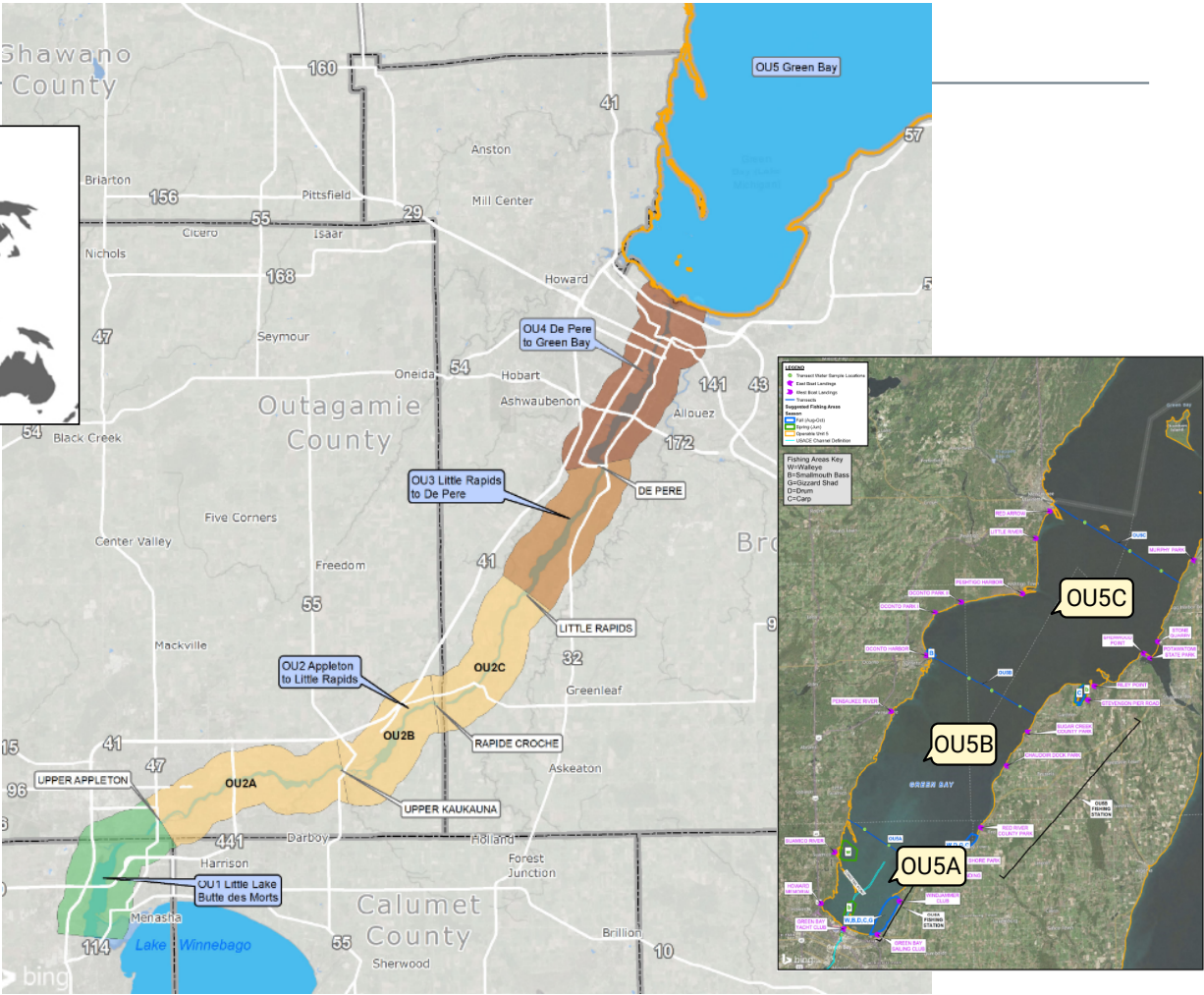Sharon Kozicki, P.G., MBA (Foth, Green Bay, WI, USA)

# Overview

- Summary of Project Background and Remedial Action

- Long-Term Monitoring Plan (LTMP) Scope and Objectives

- Collaborative Update to LTMP

# Summary of Project Background and Remedial Action

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# Site Location



Lower Fox River

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# Objectives of Remediation

- Address sediment RAL (1 ppm) or achieve OU SWAC goals

- Address RAOs from ROD and ROD Amendment:
  - Achieve surface water quality criteria
  - Protect humans who consume fish
  - Protect ecological receptors
  - Reduce transport of PCBs into Green Bay and Lake Michigan

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# Remedy Options Performed (2004 – 2020)

- Dredge (6.5M CY)

- Sand Cover (720 Acres)

- Engineered Cap (268 Acres)

- OU2 and OU5 - Areas of Monitored Natural Recovery (MNR)

# LTM Scope and Objectives

# FR-LTMP Monitoring Objectives

- ◆ Monitor risk reductions/progress in:

  - ▪ water and fish tissue concentrations

  - ▪ achieving human health risk goals

  - ▪ achieving ecological risk goals

  - ▪ PCB loadings to Green Bay

- ◆ Pathways:

  - ▪ Human health fish species

    - • Walleye/Smallmouth Bass

  - ▪ Ecological fish species

    - • Carp/Drum

  - ▪ Young-of-year fish species

    - • Gizzard Shad

  - ▪ Water quality

  - ▪ Sediment quality

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# LTM Collection Events

◆ LTM surface water and fish tissue monitoring activities are guided by the OU1-LTMP (2011) and the FR-LTMP (2009)

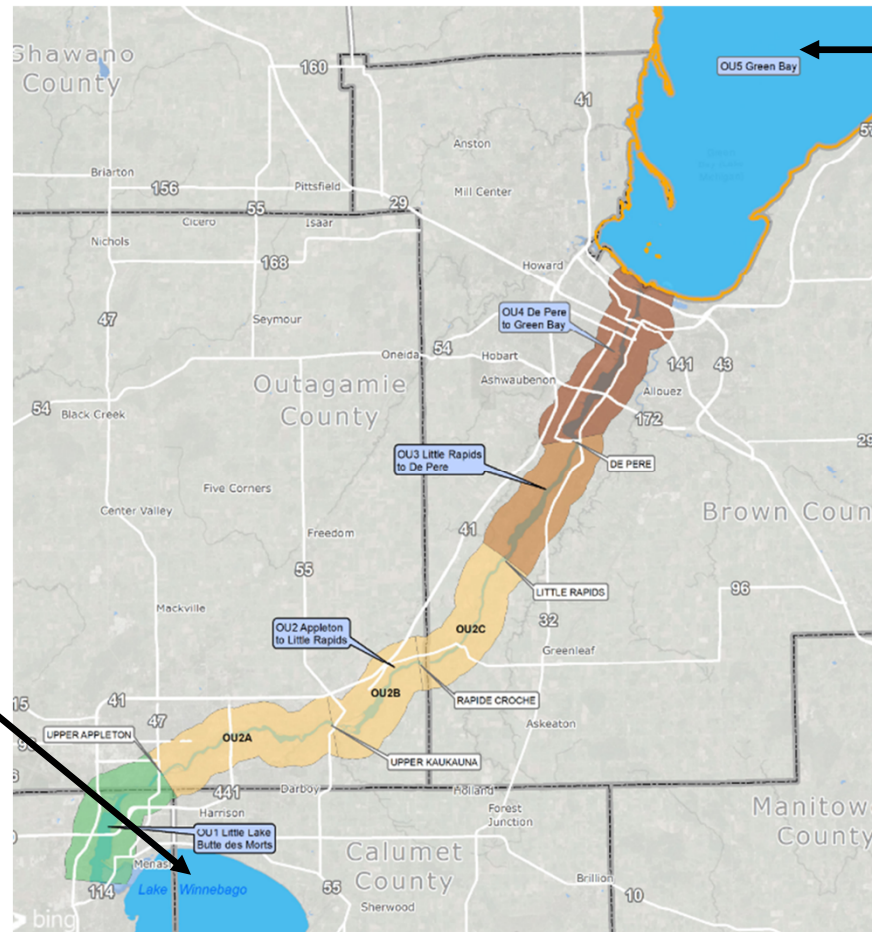|  | OU1 | OU2 | OU3 | OU4 | OU5 |
|---|---|---|---|---|---|
| Baseline (2006-07) | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2010 | ✓ |  |  |  |  |
| 2012 | ✓ | ✓ | ✓ |  |  |
| 2014 |  | ✓ | ✓ |  |  |
| 2018 | ✓ | ✓ | ✓ |  |  |
| 2021 |  |  |  | ✓ | ✓ |
| 2022 | ✓ | ✓ | ✓ | ✓ | ✓ |

◆ Baseline and LTM events serve to monitor progress towards achieving the RAOs

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# FR-LTMP Exit Criteria

- Achievement of the risk-reduction goals is demonstrated through exit criteria formulated under DQOs.

- Comparison to:

  - Background Concentrations

  - Risk-Based Target Concentrations

  - SWAC-Reduction Target

- Evaluation of:

  - Recovery Rate

  - Laboratory Blank Contamination Levels

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# Background Reference Data



◆ **OU5C**

  ▪ OU4, OU5A/B Surface Water

◆ **Lake Winnebago**

  ▪ OU1, OU2, OU3 Surface Water and Fish Tissue

# Weight of Evidence

◆ The FR-LTMP also provides for a WoE evaluation during each 5-year review to assess whether the preponderance of data indicates the achievement of risk-reduction goals

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# Collaborative Update to LTMP

# FR-LTMP Clarification of Exit Criteria

◆ LTMP has multiple monitoring Exit Criteria, and Agency-PRP Working Group worked collaboratively to clarify those criteria. Updated LTMP, 2021 and 2022 Reports, and upcoming Five Year Review will reflect those changes.

▪ One key criterion requiring attention addresses comparisons of site conditions to background. The remainder of this presentation focuses on the update to that criterion.

◆ Under corrective action, the presumption (null hypothesis) is that site concentrations *exceed* background.

▪ Then the burden on monitoring, to justify an exit from monitoring requirements, is to collect enough data to show that the site very likely does not exceed background.

◆ We don't expect site concentrations to be reduced below background.

▪ So how close to background is close enough to be "equivalent" to background?

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# FR-LTMP Statistical Analyses

◆ 2009 FR-LTMP Statistical Hypothesis Statements

◆ *Exit Criteria 1: Comparison to Background*

  ▪ *$H_{01}$ : Water and fish tissue contaminant concentrations are higher than reference areas.*

  ▪ *$H_{A1}$ : Water and fish tissue contaminant concentrations are less than or equivalent to reference areas.*

◆ *"Alternative Hypothesis 1 will be accepted when it can be shown that Site monitoring data from a particular OU is equivalent to background data with an appropriate level of statistical confidence."*

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# Defining Equivalence for the FR-LTMP

◆ Tests of equivalence: Are Site Data > Background Data * an Equivalence Ratio?

◆ The goal of the LTMP is to collect water and fish tissue data that will achieve:
- $\alpha$ (Type I error) = 0.1 (90% confidence)
- $\beta$ (Type II error) = 0.2 (80% percent statistical power)

◆ To develop a test with these error rates as goals, simulation may be performed.
- Hypothetical Sample Site Data are drawn, with n = sample sizes for an LTM round, from the same distribution as upstream Background Data (Lake Winnebago).
- Given a statistical test, is the hypothetical data determined to be equivalent to the background data?
- What Site and Background statistics should be compared? What sample sizes are needed?
- Specific answers depend on site data distributions and project goals.

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# FR-LTMP Background Exit Criteria

◆ FR-LTMP: Background criteria may be defined using a 90% upper prediction limit on the mean to avoid concluding a Site is significantly more contaminated than background when in fact it is not.
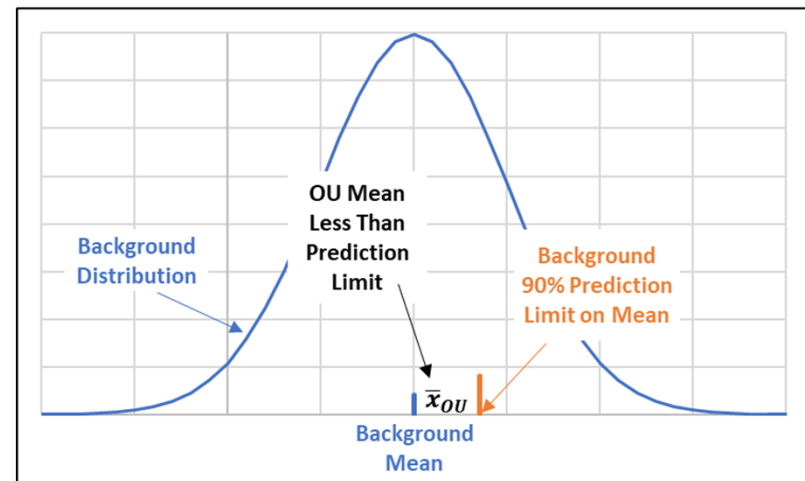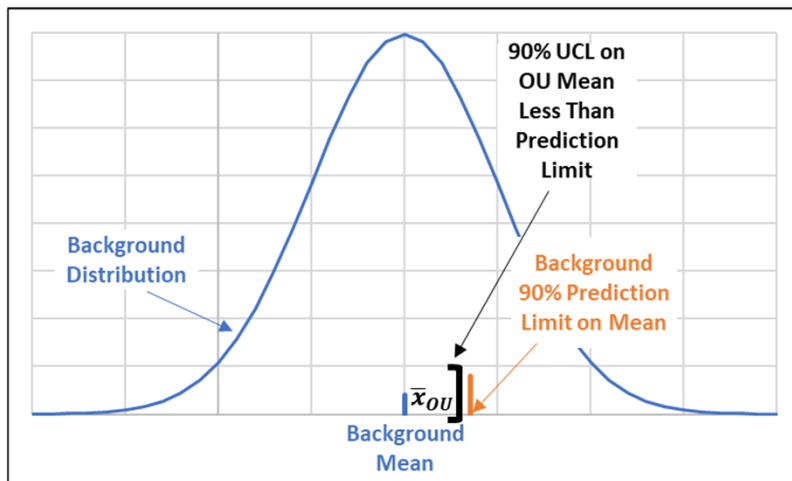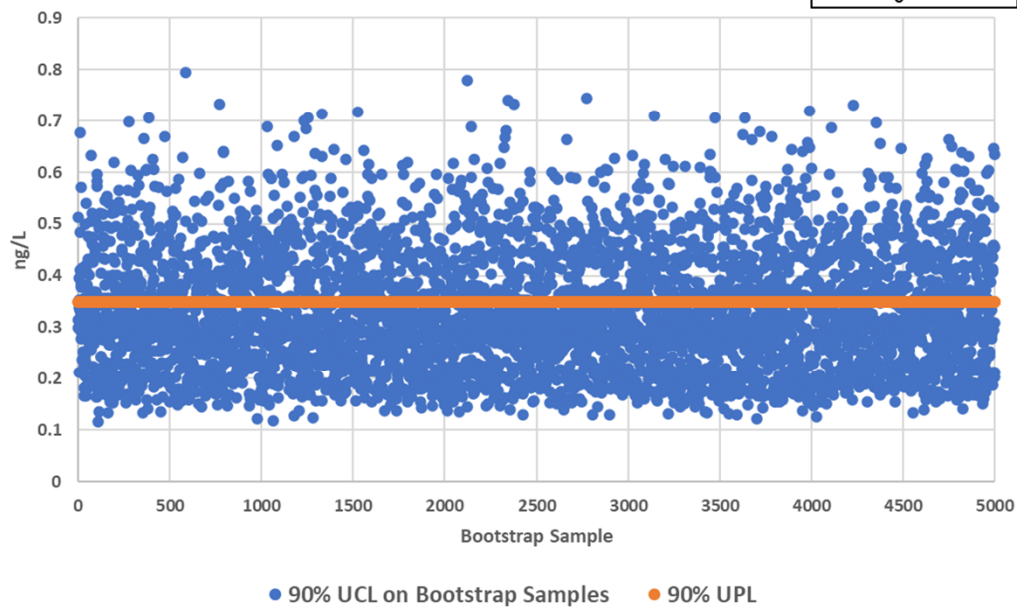
# Background Exit Criteria Simulation for Surface Water

# Surface Water Simulation with Confirmation Event

- When incorporating a second confirmation event, the $H_0$ false acceptance rates increase from 38% to 61% for the UCL to UPL comparison, and from 9% to 17% for the sample average to UPL comparison.
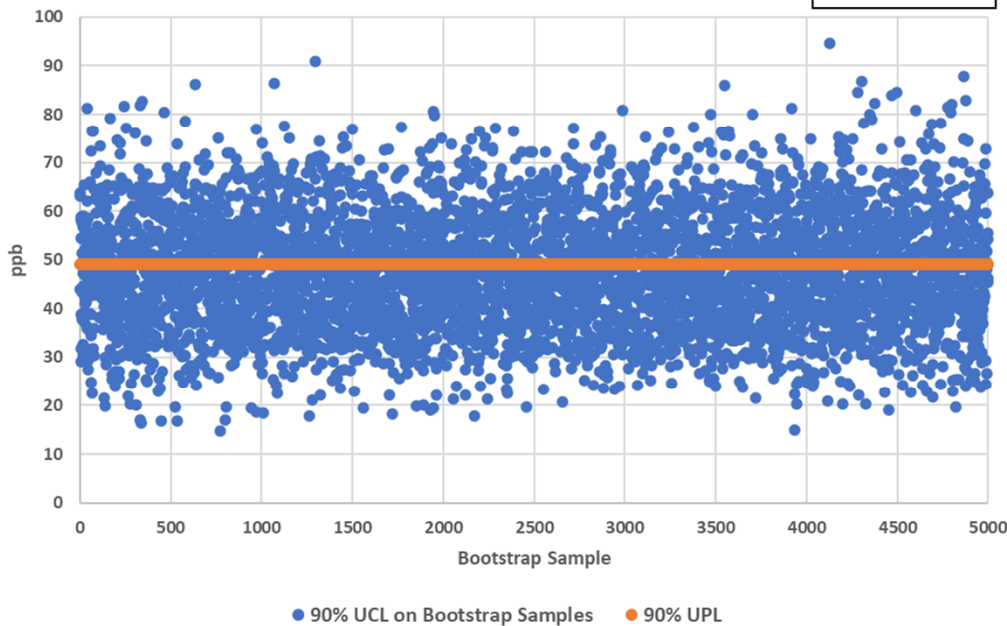


Observed False Acceptance of $H_0$ Rates
LW Water - All Baseline and LTM Data
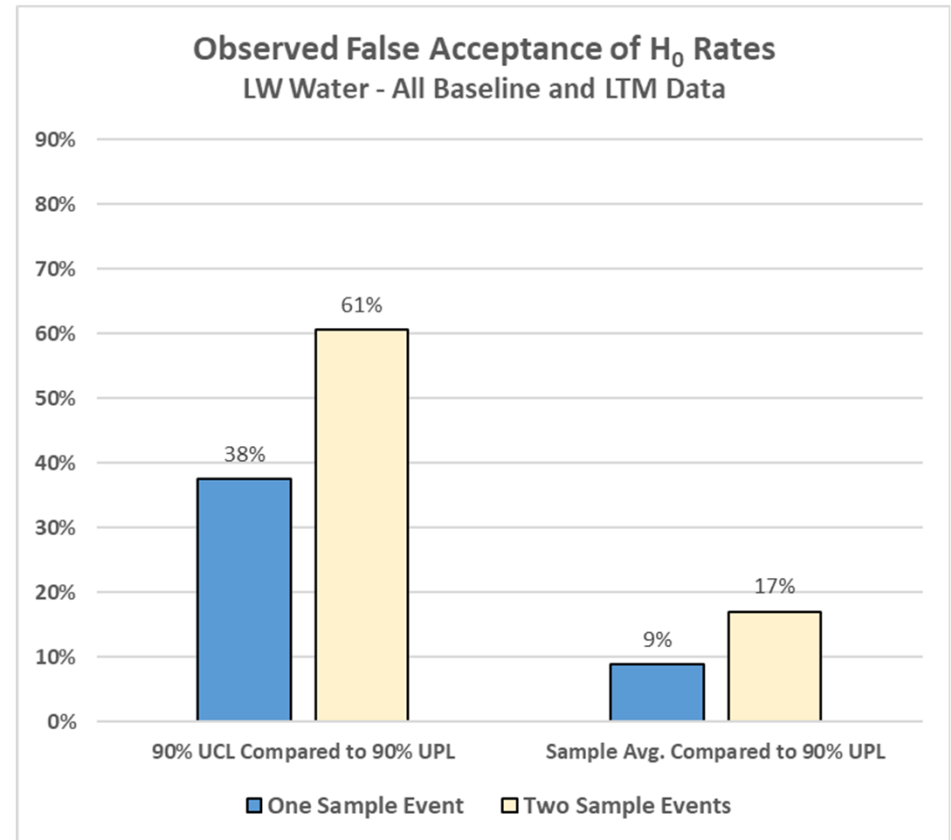
# Background Exit Criteria Simulation for Walleye

# Walleye Simulation with Confirmation Event

- ◆ When incorporating a second confirmation event for walleye, the $H_0$ false acceptance rates increase from 44% to 68% for the UCL to UPL comparison, and from 9% to 17% for the sample average to UPL comparison.



Observed False Acceptance of $H_0$ Rates
LW Walleye - All Baseline and LTM Data
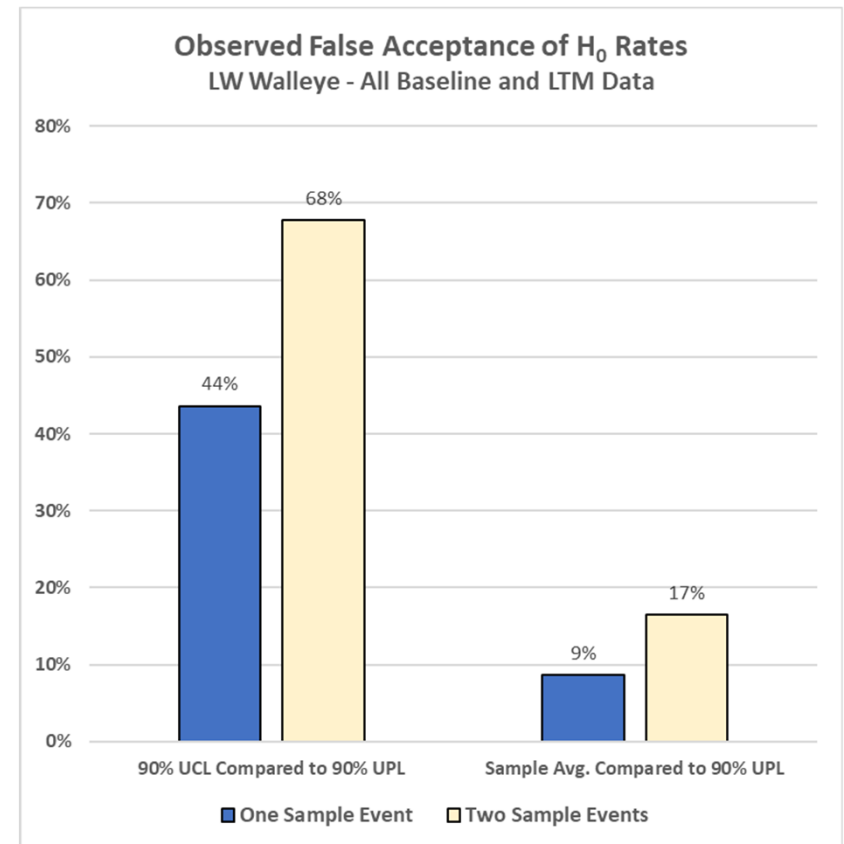
# Covariate Data

- ◆ Additional consideration - covariate data

  - ▪ Factors of interest can be more readily assessed when covariate noise is reduced

### Water

- ➢ TOC
- ➢ TSS
- ➢ Temperature
- ➢ Turbidity
- ➢ Flow Rate

### Fish Tissue

- ➢ Fish Length
- ➢ Fish Weight
- ➢ Percent Lipids

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# Regression Model for Background Comparison
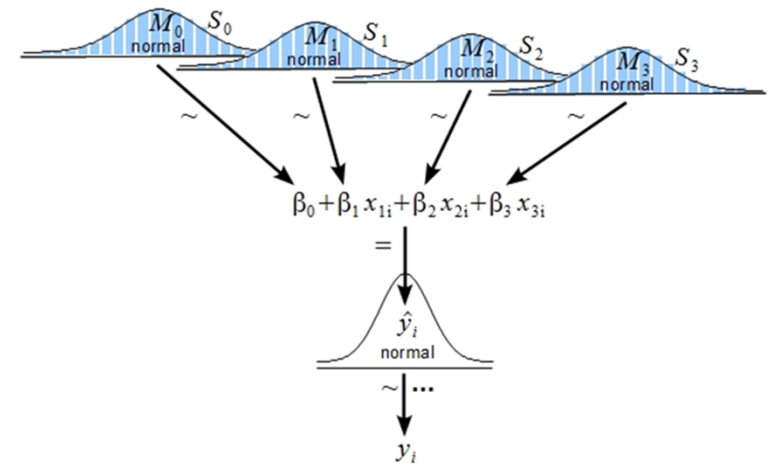
◆ Covariate variation may be addressed through multivariate regression

$Ln(PCB) = \beta_0 + \beta_1(Site) + \beta_2(Covariate_1) + \beta_3(Covariate_2) + \ldots + e$

$Site$ = "0" for background and "1" for OU data

◆ The above regression equation may be rearranged as:

$e^{\beta_1} = \dfrac{PCB_{|Site=1}}{PCB_{|Site=0}} \sim \dfrac{\mu_{OU}}{\mu_{Background}}$

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# Regression Model Hypothesis Testing

◆ The regression approach can therefore be formulated as a test of equivalence: Are Site Data > Background Data * an Equivalence Ratio?

◆ The regression approach allows testing the ratio of the OU mean to the Background mean:

$$H_1 0: \quad \frac{\mu_{OU}}{\mu_{Background}} \geq Equivalence\ Ratio$$

$$H_1 A: \quad \frac{\mu_{OU}}{\mu_{Background}} < Equivalence\ Ratio$$

◆ The logarithmic regression model approach was utilized in previous LTM reports, but without an agreed equivalence ratio

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# Regression Model Equivalence Ratio

- The goal of the LTMP is to collect water and fish tissue data that will achieve:
  - $\alpha$ (Type I error) = 0.1 (90% confidence)
  - $\beta$ (Type II error) = 0.2 (80% percent statistical power)

- Simulation modeling was performed of the background walleye data to determine an equivalence ratio that would meet the 20% Type II error goal.

- Equivalence ratio = 1.3

| | Ratio of 90% UPL to Sample Mean for Lake Winnebago Baseline Through 2018 LTM Data |
|---|---|
| Carp | 1.5 |
| Drum | 1.3 |
| Gizzard Shad | 1.3 |
| Smallmouth Bass | 1.4 |
| Walleye | 1.3 |
| Surface Water | 1.4 |

- 1.3 also generally matches the ratio observed between the background sample mean and UPL for the historical surface water and fish tissue data of all species

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# Conclusion

- Using the multivariate regression model approach to stabilize the data, along with a 90% UCL on the ratio of the Site to Background geometric mean, meets the LTMP Type I error goal of 10% and Type II error goal of 20%.

- The equivalence ratio of 1.3 was found to be a value that provides for a comparison that does not require OU Site data to achieve concentrations better than background in order to meet exit criteria.

- The 1.3 equivalence ratio was applied to surface water and all fish tissue species in the LTMP update.

- The regression method also continues to be used in the LTMP update for the Exit Criteria 3 comparison to SWAC-reduction target.

- Collaboration between the Responsible Parties and Agency/Oversight Team resulted in identification of potential issues with proposed statistical comparisons and led to innovative solutions.

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