Developing and Using Surface Weighted Average Concentrations (SWACs)

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Presentation Overview:

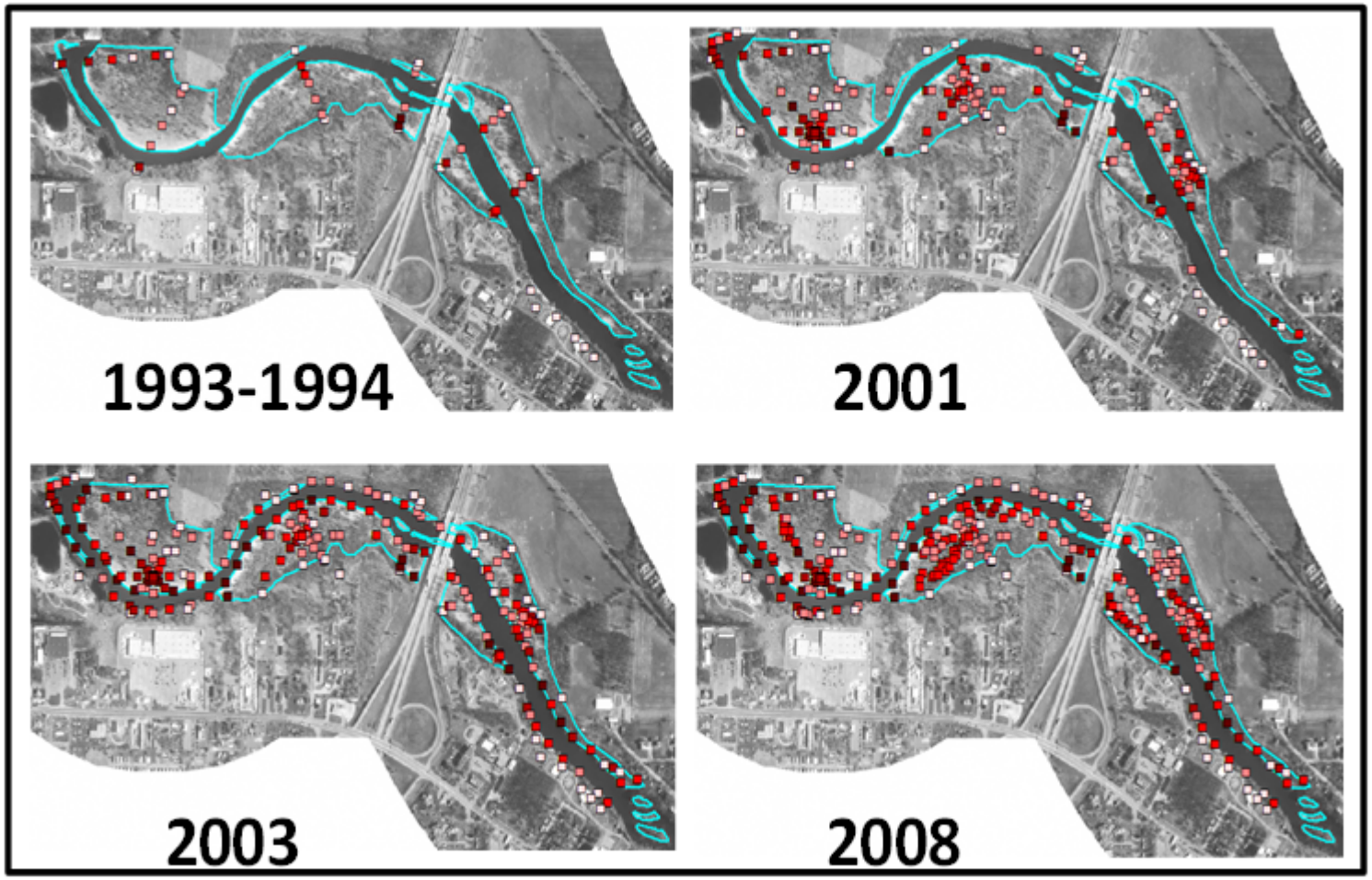
- SWAC Defined
- Rationale for Spatial Weighting
- Application for comparing remedial alternatives (SWAC vs RAL)
- Uncertainty and need for confidence limits
- Long term performance monitoring
- Problems with biased sampling programs
- Use of probability based sampling to develop unbiased SWAC estimates
- Recommendations

What is a SWAC

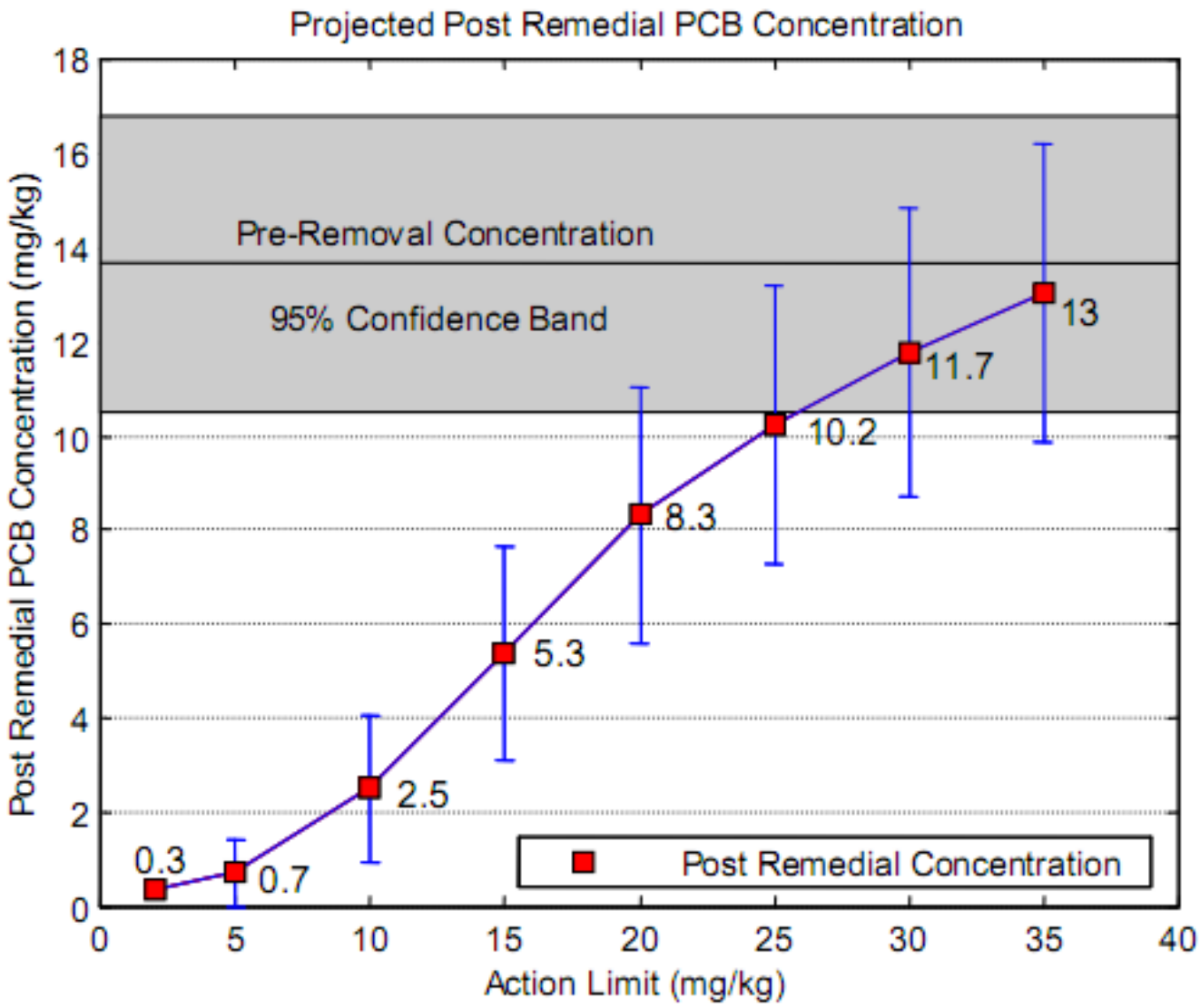
- SWAC (**Surface Weighted Average Concentration**) is a weighted average of sample data intended to estimate mean contaminant concentration over a specified spatial area.
- As an exposure point concentration (EPC) confidence limits needed
- Weights are intended to correct for spatial biases in RI/FS sampling programs.
- Weights may be derived in one of several ways.
  - Weights proportional to polygons of influence (Thiessen Polygons).
  - Averaging over a map of interpolated values
    - Natural neighbor
    - Kriging
    - Inverse distance weighting
  - Spatial stratification of site data
  - Equally weighted arithmetic average
  - Geostatistical Simulation

Why use spatial weighting?

- Sediment data evolve through many site investigations.
- Spatial weighting used to correct spatial biases in sampling.

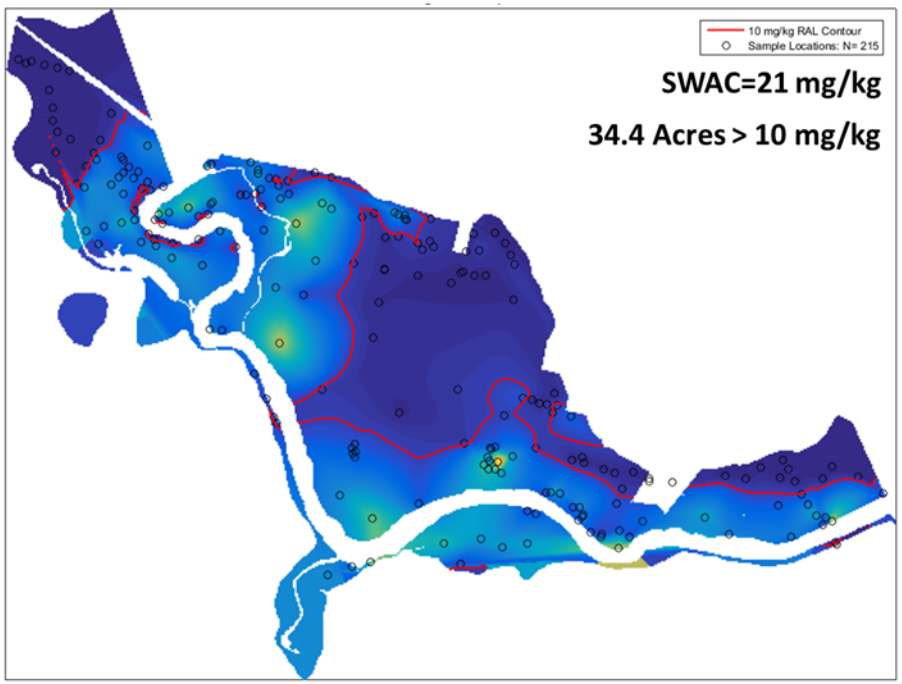


SWAC vs Remedial Action Limit Relationship

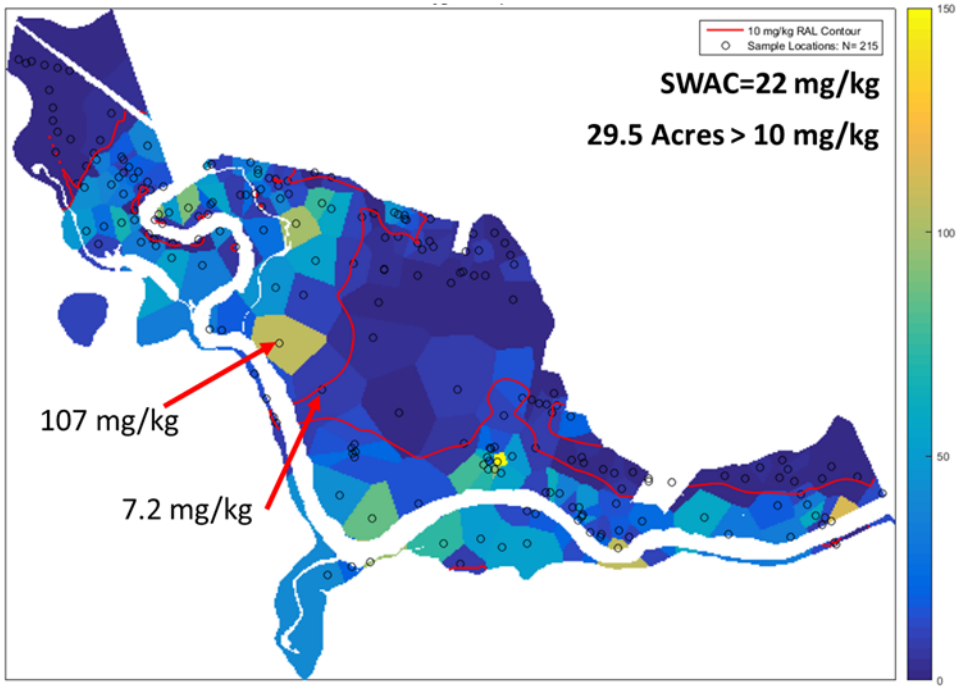


Two Common Weighting Methods

Natural Neighbor Interpolation

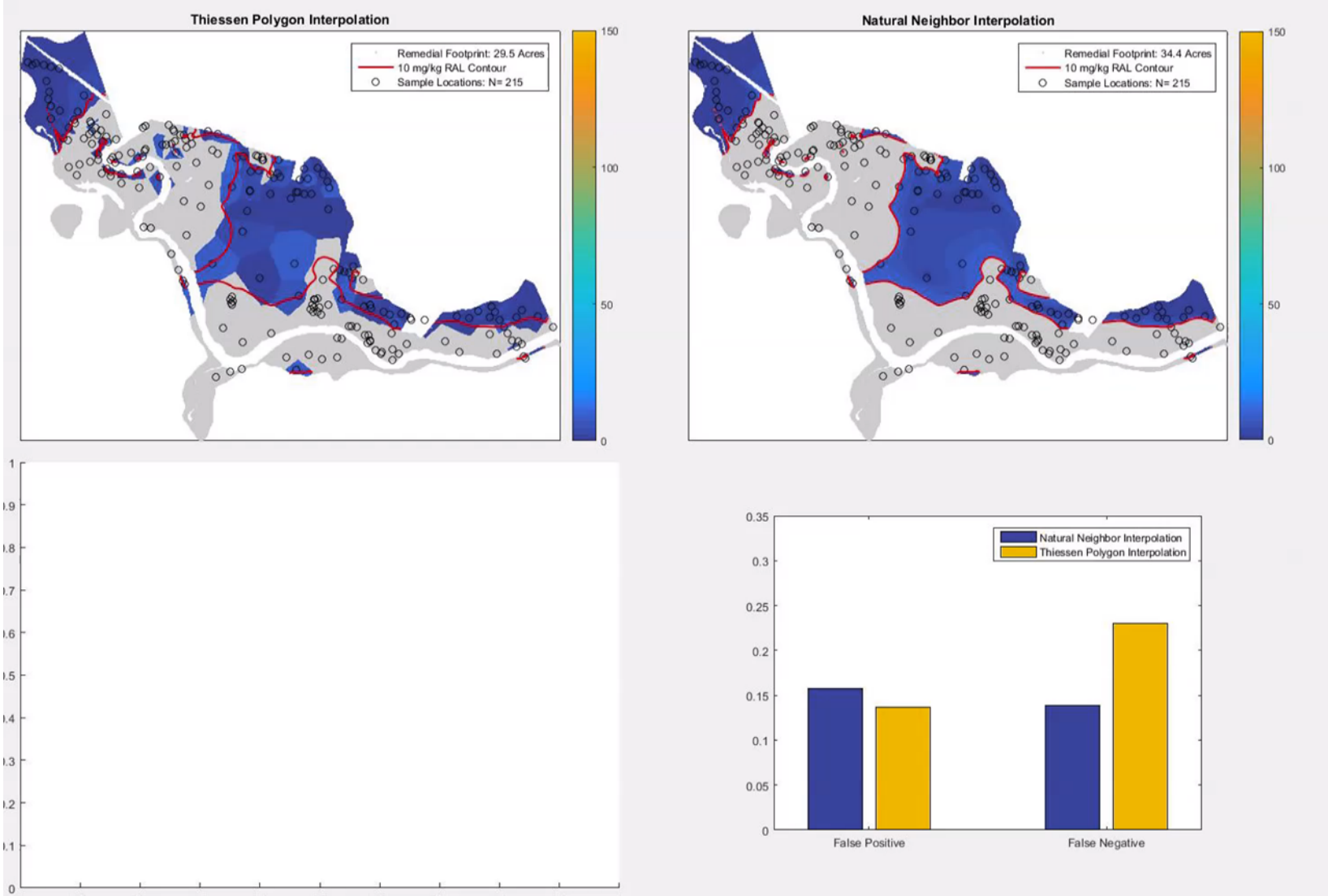


Thiessen Polygon (Areas of Influence)



SWACs are similar but areas exceeding a given threshold differ

Geostatistical simulation to evaluate spatial heterogeneity?

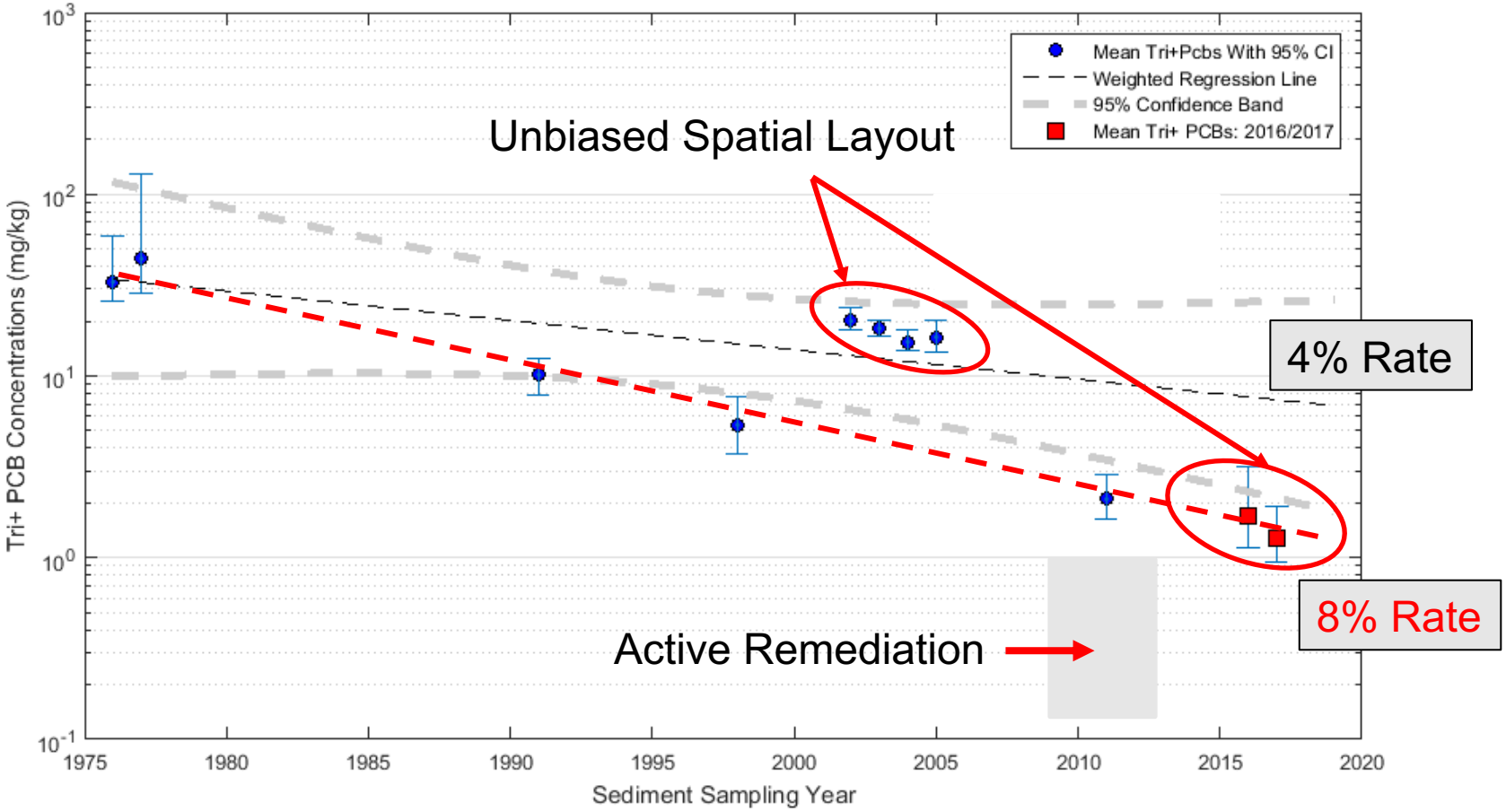


Recap

- SWAC technique evolved out of efforts to de-cluster data generated from spatially biased sampling plans.
- Particularly useful at the RI/FS stage of analysis where retrospective evaluation of the sample data is important for selecting a remedial alternative
- Choice of weighting method matters
- SWAC is a retrospective tool for integrating data from mixture of generally biased sampling programs
- Spatial weighting does not fully correct for spatially biased sampling.
- Statistical methods for bounding uncertainty are complicated

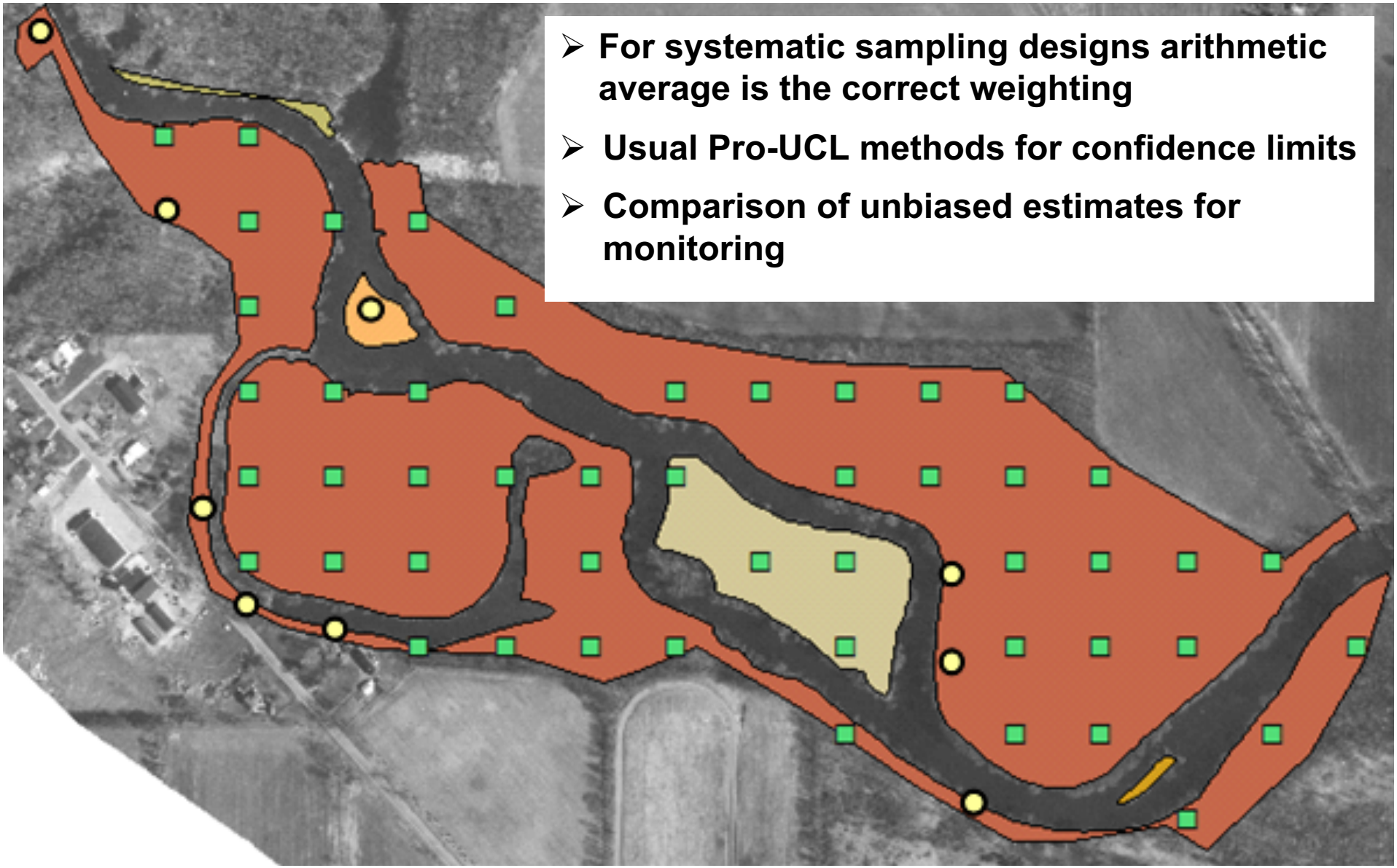
How to make reliable temporal comparisons for monitoring purposes?

Temporal Change Conflated with Sampling Bias



For long Term Monitoring probability based sampling and unbiased designs are needed

A small amount of unbiased data goes a long way!

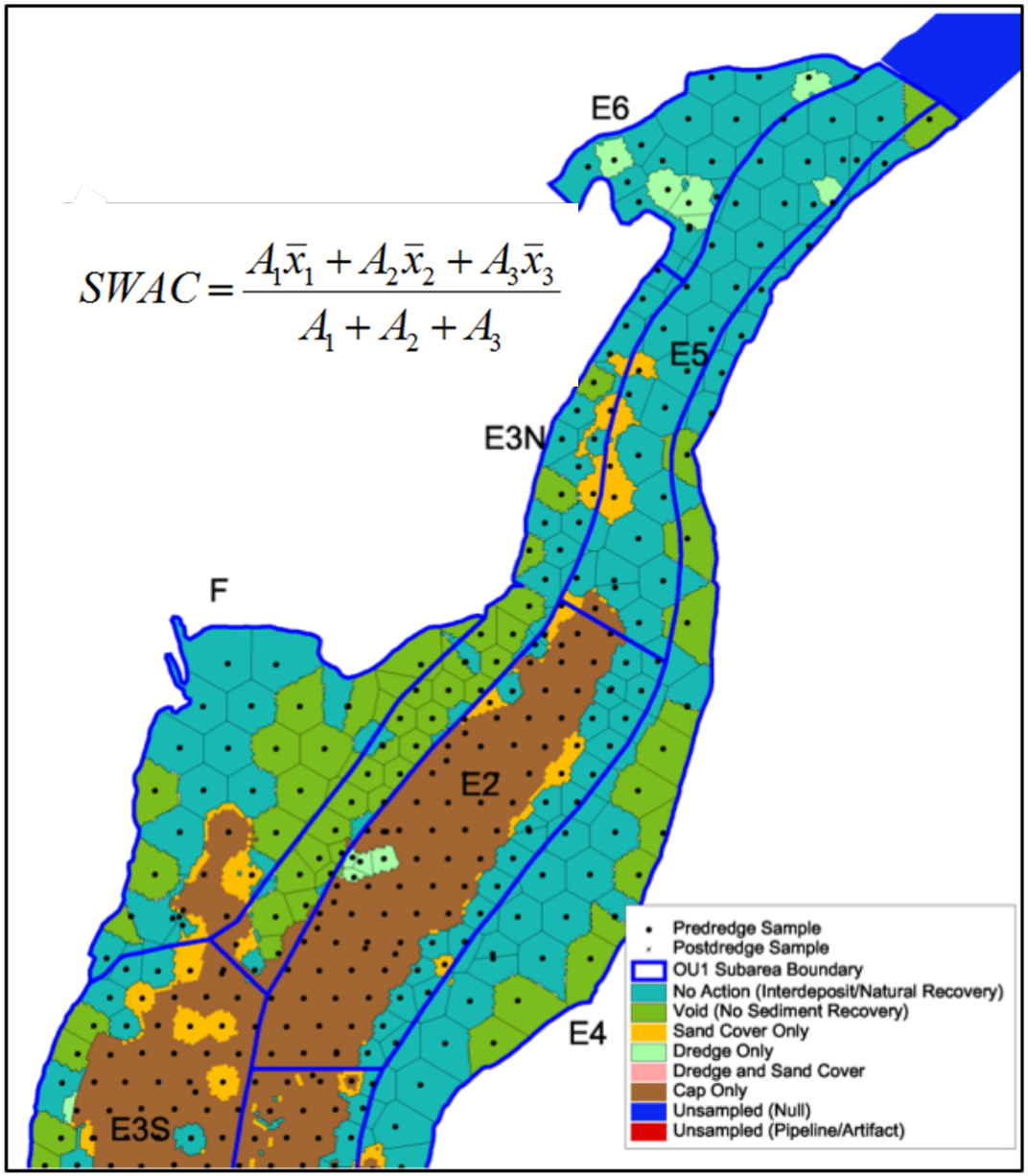


- For systematic sampling designs arithmetic average is the correct weighting
- Usual Pro-UCL methods for confidence limits
- Comparison of unbiased estimates for monitoring

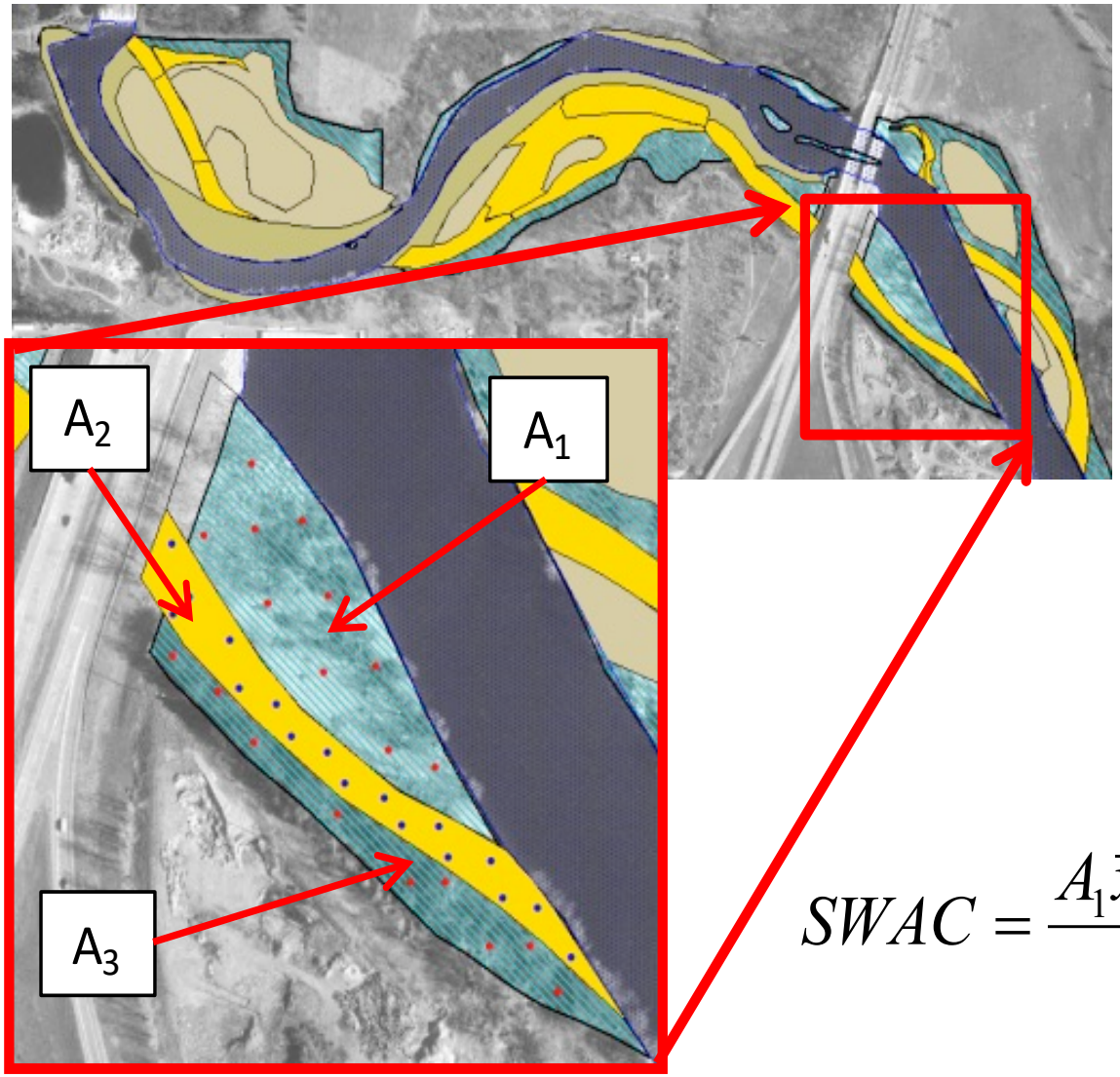
Stratification To "Bias" Probability Based Sampling

- Regular triangular grids within administrative strata
- Greater sampling density within areas of greater interests for remediation
- Overall averages obtained by area weighting stratum specific arithmetic averages.
- Confidence limits based on bootstrap resampling or standard stratified sampling equations

$$SWAC = \frac{A_1\bar{x}_1 + A_2\bar{x}_2 + A_3\bar{x}_3}{A_1 + A_2 + A_3}$$



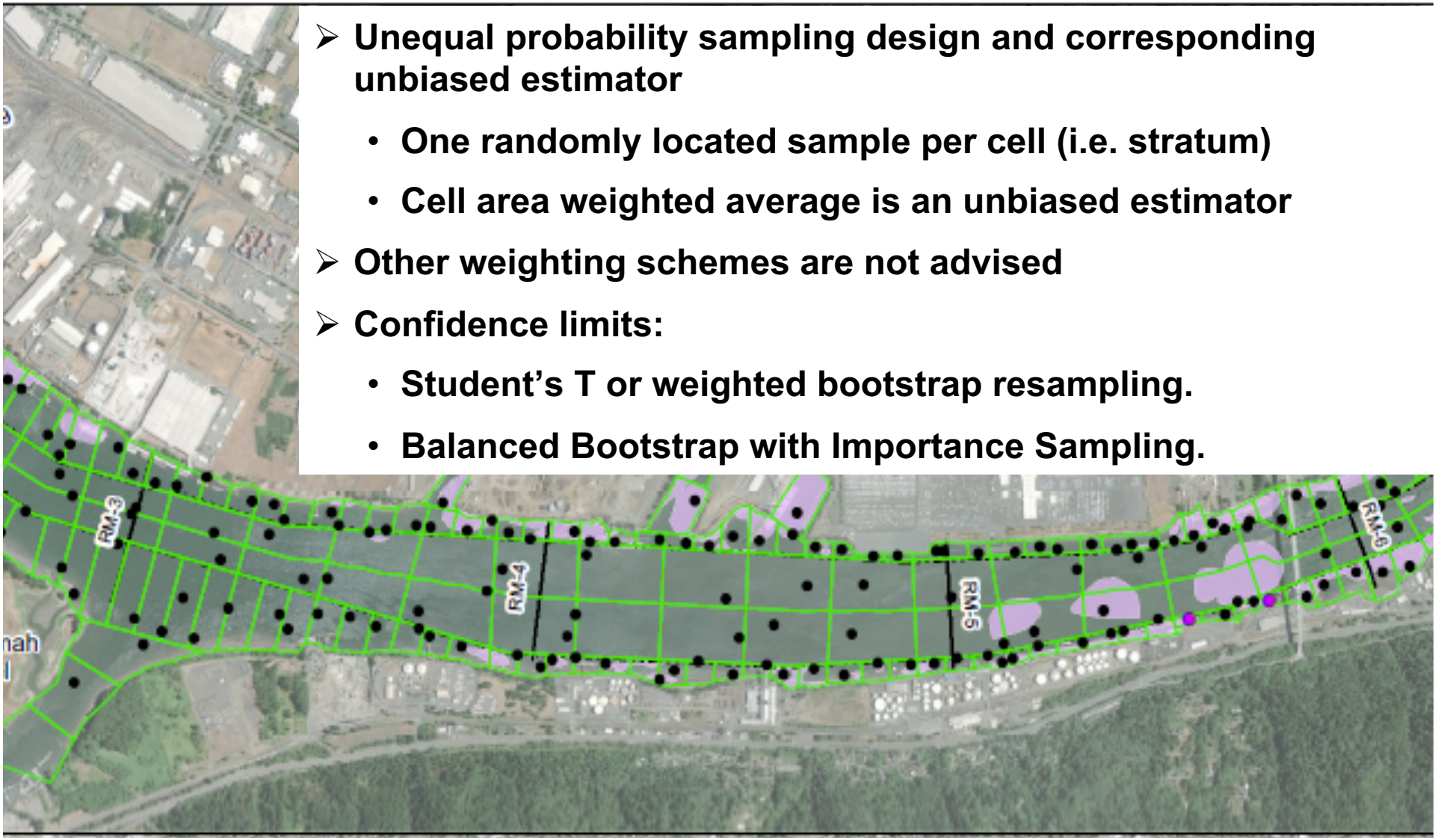
Systematic Sampling Within Geomorphic Stratification



$$SWAC = \frac{A_1\bar{x}_1 + A_2\bar{x}_2 + A_3\bar{x}_3}{A_1 + A_2 + A_3}$$

Stratified Sample with One Sample Per Stratum

- **Unequal probability sampling design and corresponding unbiased estimator**
  - **One randomly located sample per cell (i.e. stratum)**
  - **Cell area weighted average is an unbiased estimator**
- **Other weighting schemes are not advised**
- **Confidence limits:**
  - **Student's T or weighted bootstrap resampling.**
  - **Balanced Bootstrap with Importance Sampling.**



SWAC Monitoring Recommendations

- A portion of samples should be collected using a probability based sampling design.
- SWAC estimation based solely on probability based data for trend evaluation
- Re-occupy sites or not
  - Theoretically higher power obtained by re-occupying locations
  - In practice heterogeneity over small spatial scales may nullify gain in precision from re-occupying sites
  - Drawing new unbiased sample each time step provides better spatial coverage as time progresses
- Complex site conceptual models can be accommodated through careful stratification of the sampling design
- Comparisons based on differing sampling designs are valid provided each estimation procedure is unbiased to the corresponding sampling design

SWAC Monitoring Recommendations (continued)

- Estimating trends in sediment concentration is a prospective endeavor
- Plan for these studies developing unbiased sampling plans early
- The unbiased data can be used in the RI/FS evaluations,
- Temporal comparisons based on mixtures of biased and unbiased data are generally unreliable