Predicting environmental reference conditions in streams from watershed geology

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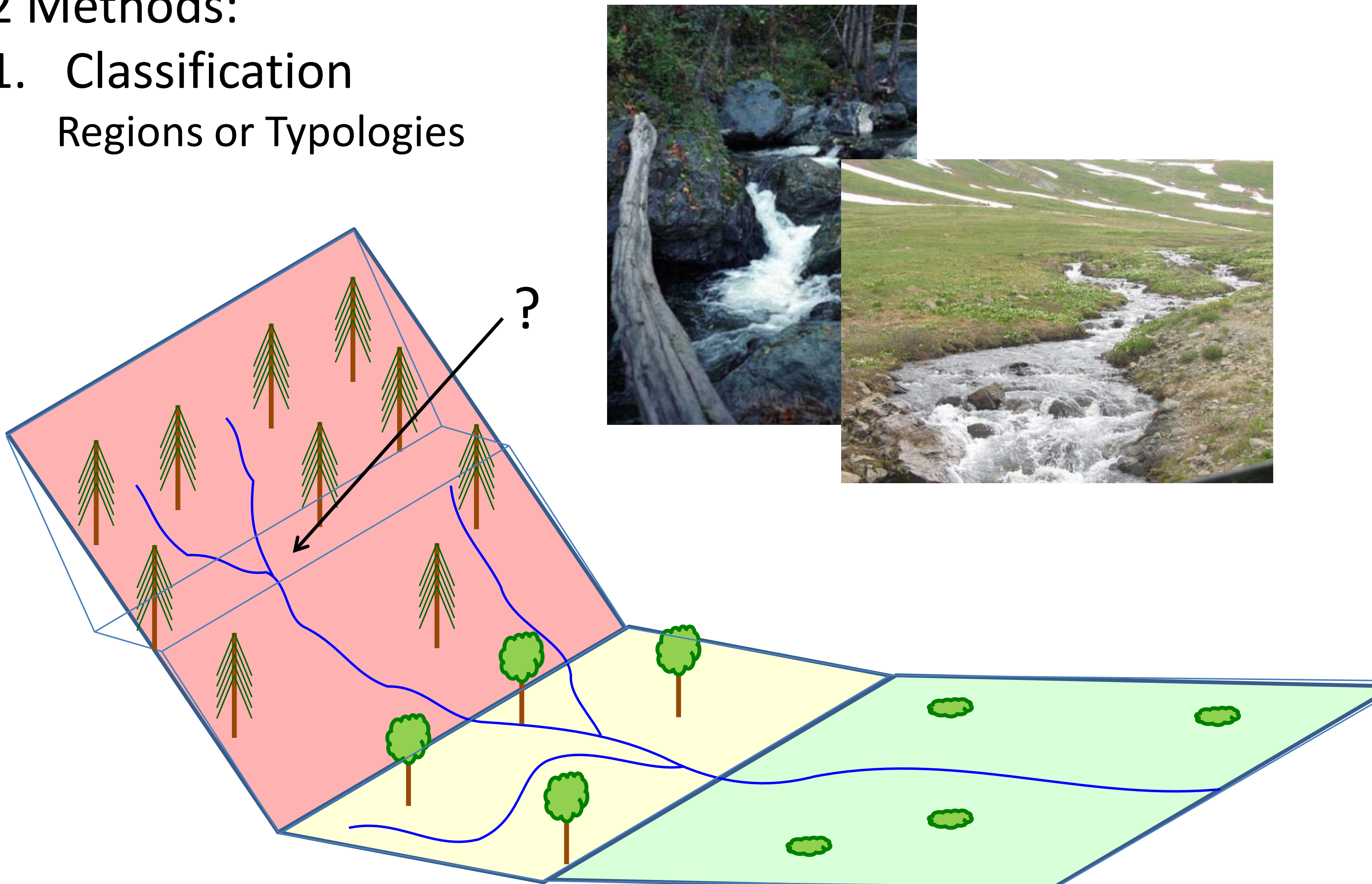
Reference Condition Problem

2 Methods:

1. Classification

   Regions or Typologies



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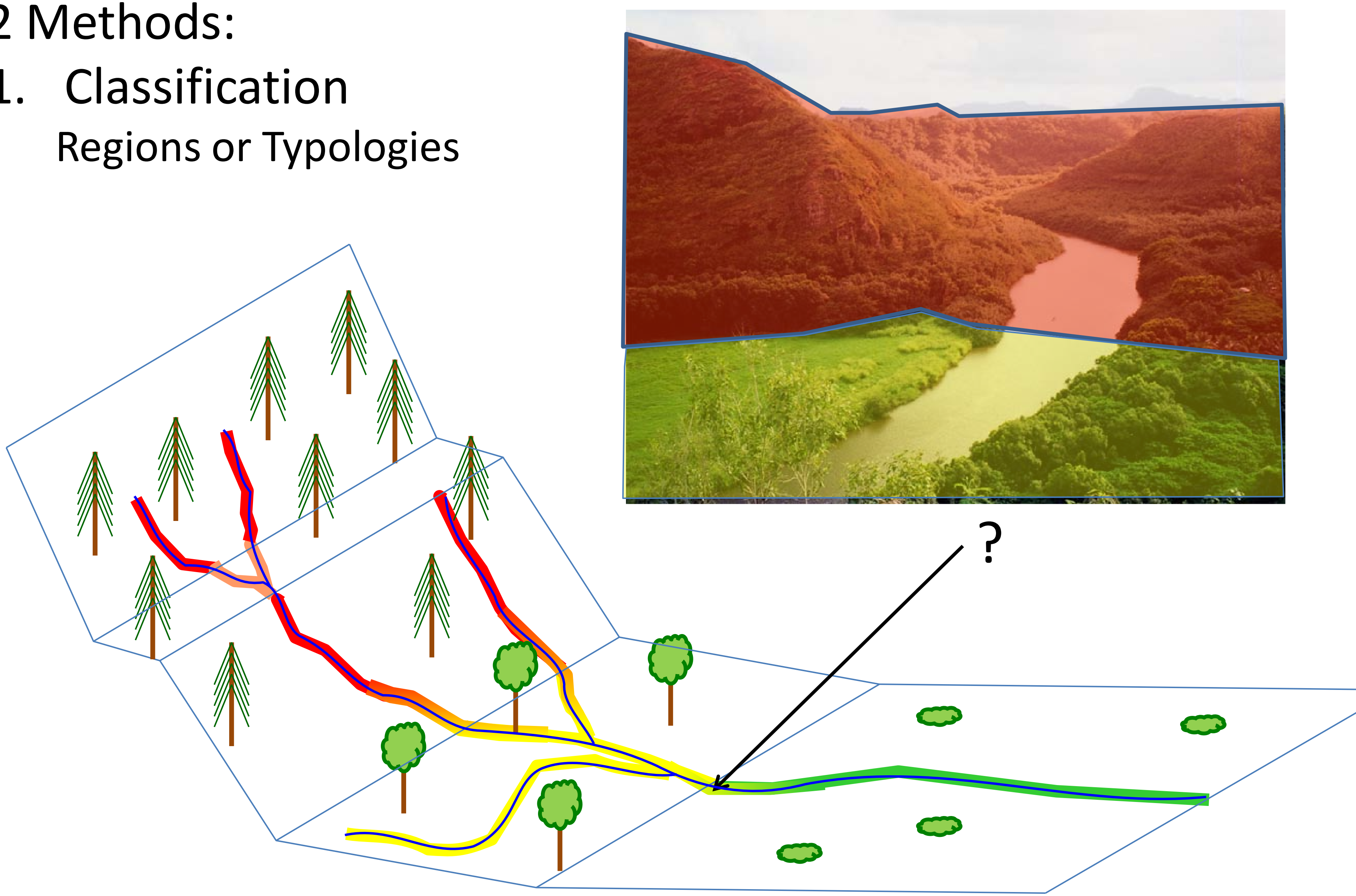

Reference Condition Problem

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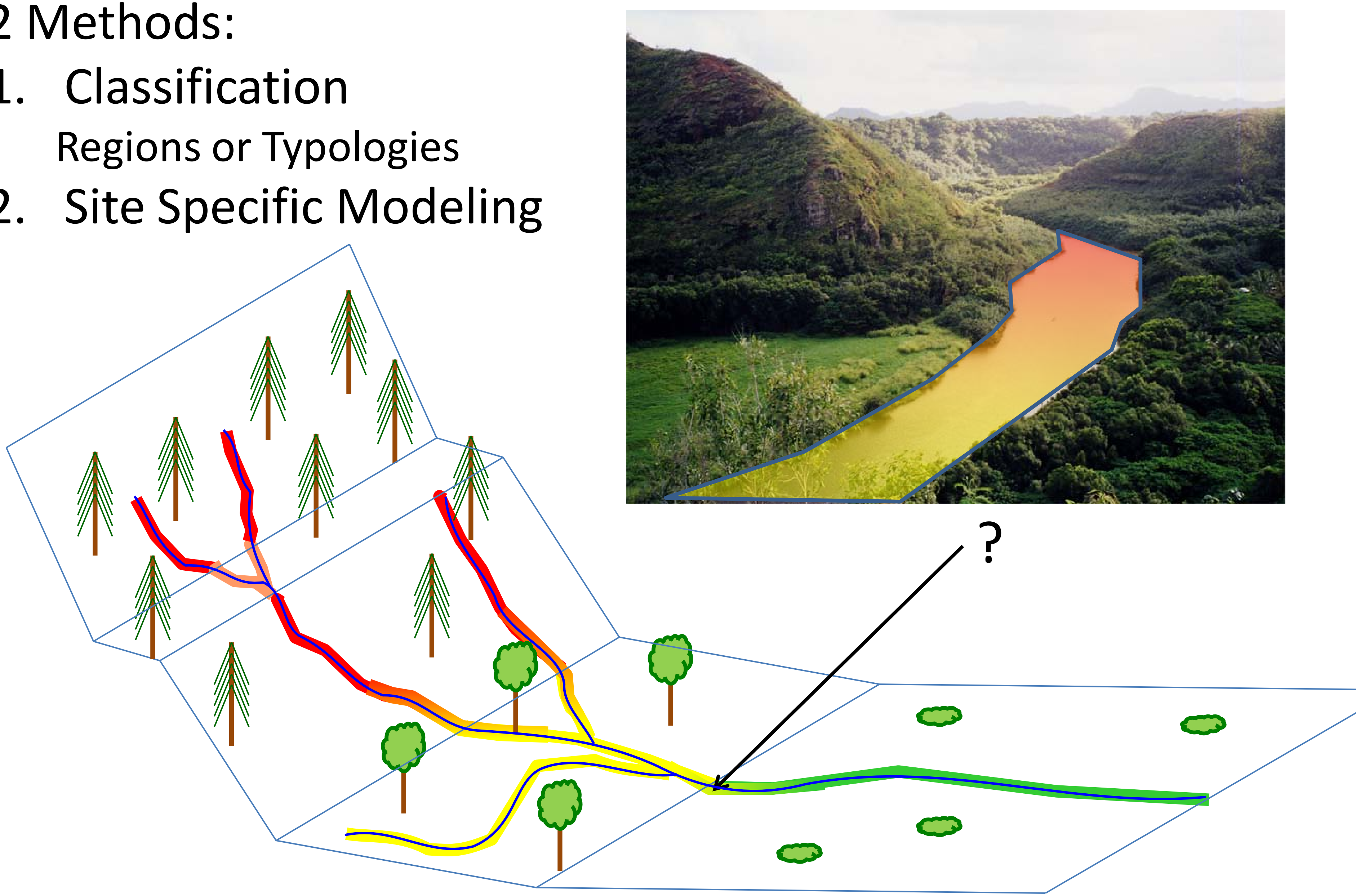
2. Site Specific Modeling



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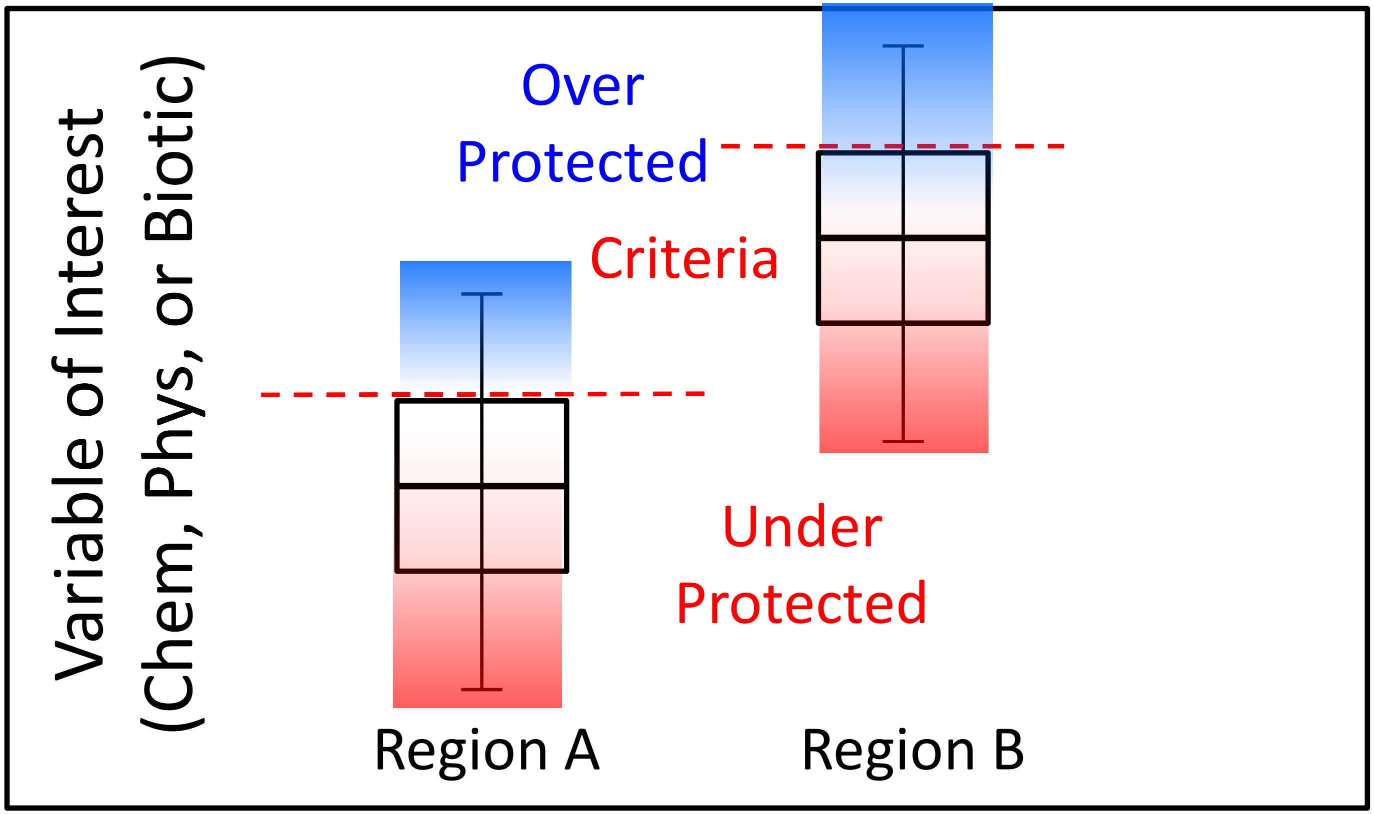
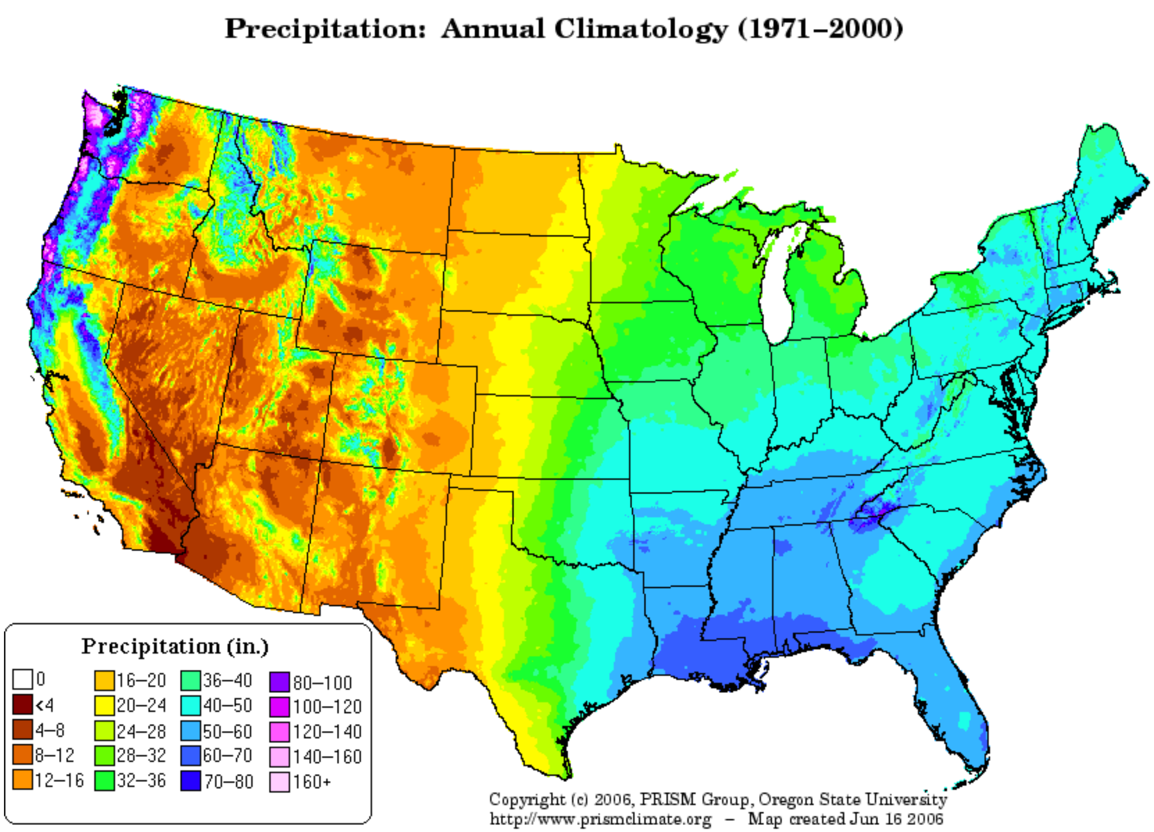


Objective: Develop models to predict water chemistry for any site in the western U.S.

1. Measure factors affecting water chemistry:
   - Weathering rate (Temp & Precipitation)
   - Amount of water/rock contact
   - Geology
2. Develop empirical models
   - Multiple Linear Regression & Random Forest
   - Predict electrical conductivity, alkalinity/ANC, total phosphorus, and total nitrogen

Measure factors affecting water chemistry:

- **Weathering rate (Temp & Precipitation)**
- Amount of water/rock contact
- Geology



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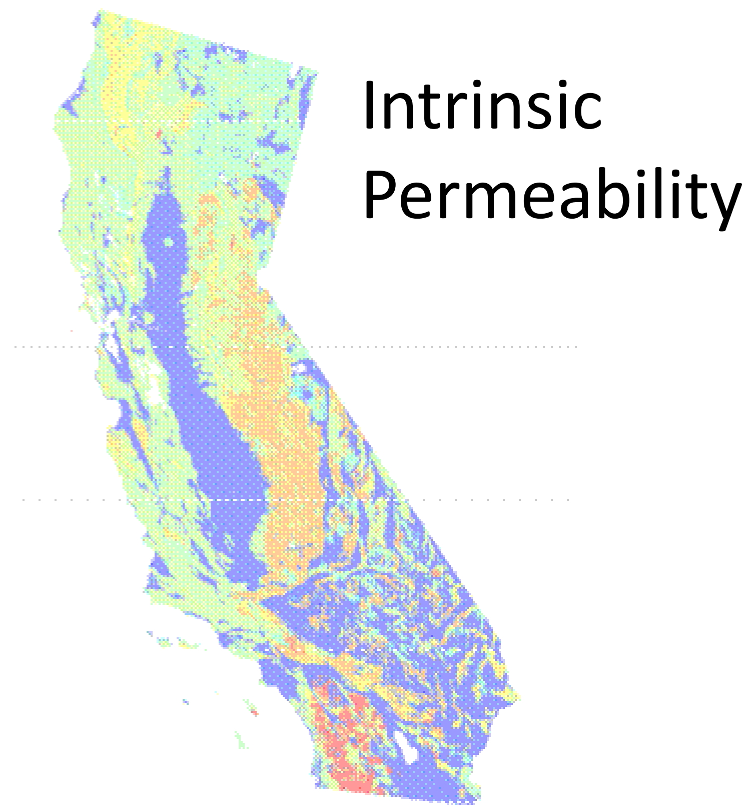

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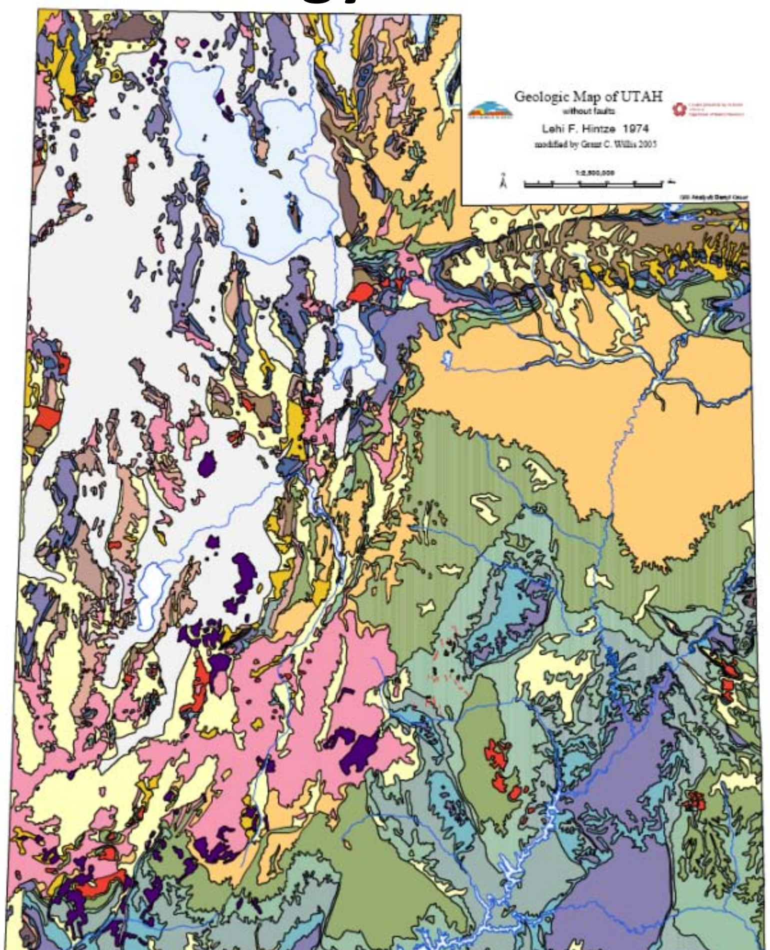
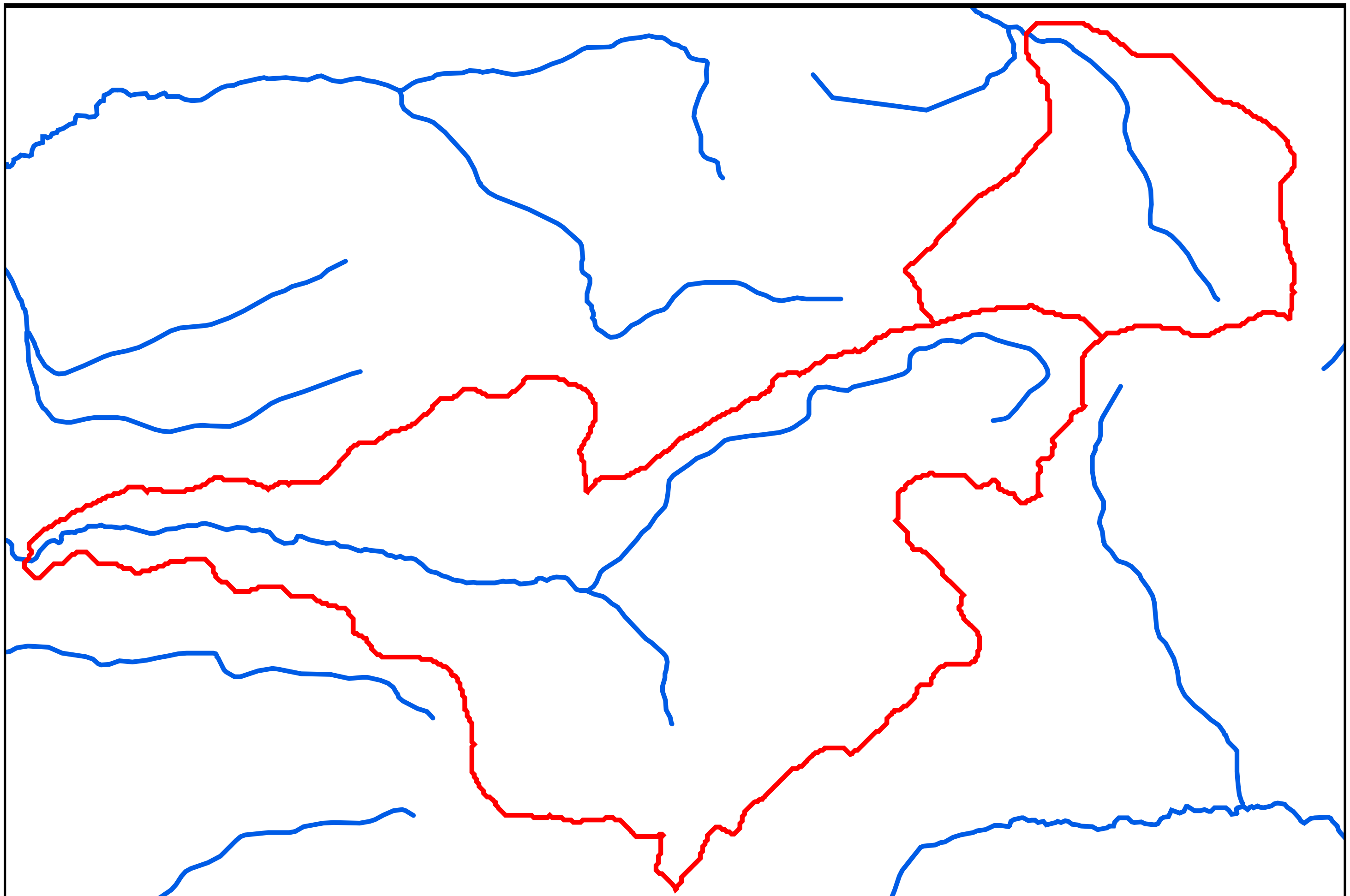


Challenges of predicting from geology:

- Categorical
- Categories not useful
- Too many categories
- Rocks often in mixtures

Example: Predicting water chemistry from categorical geologic map



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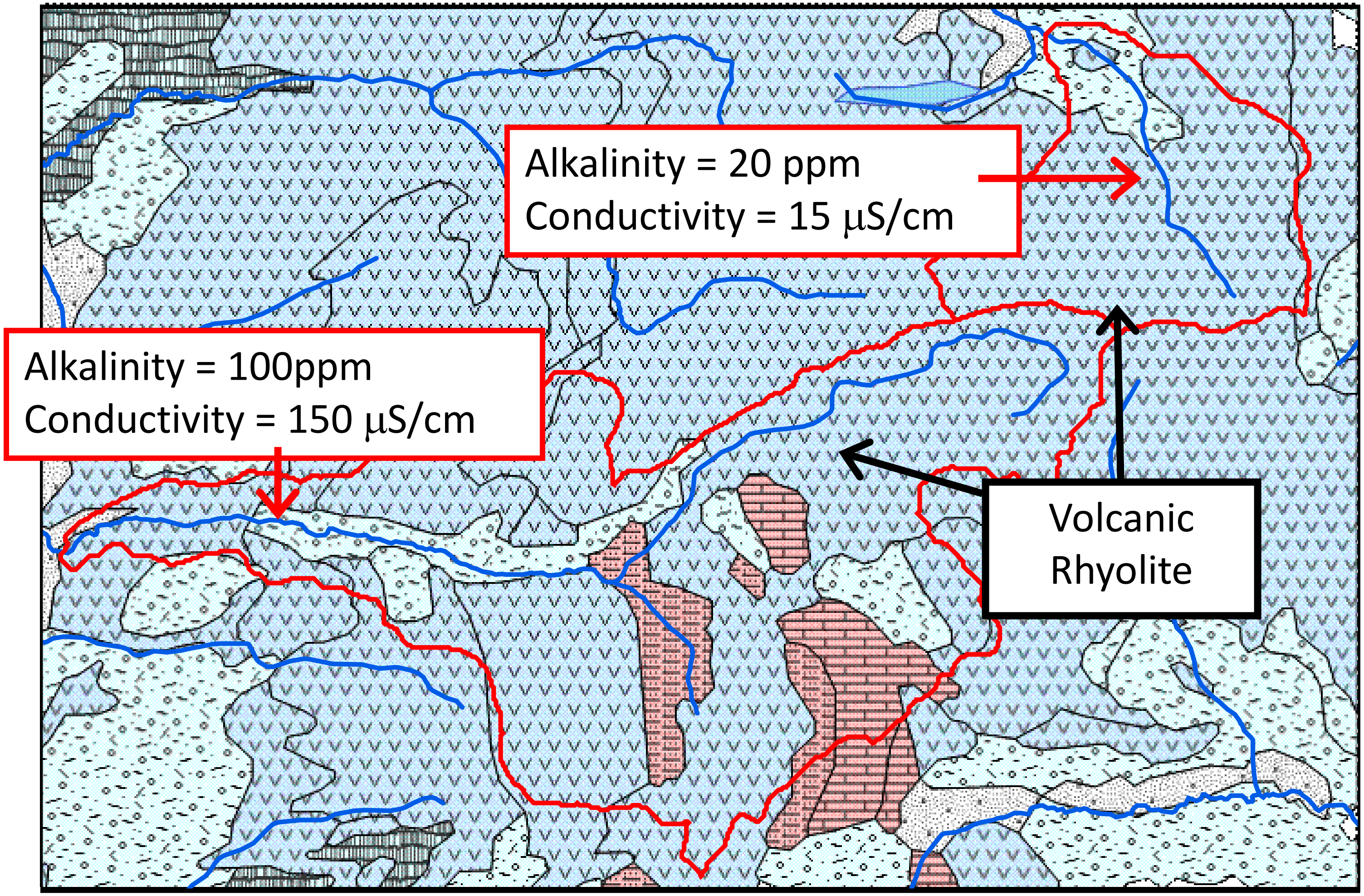
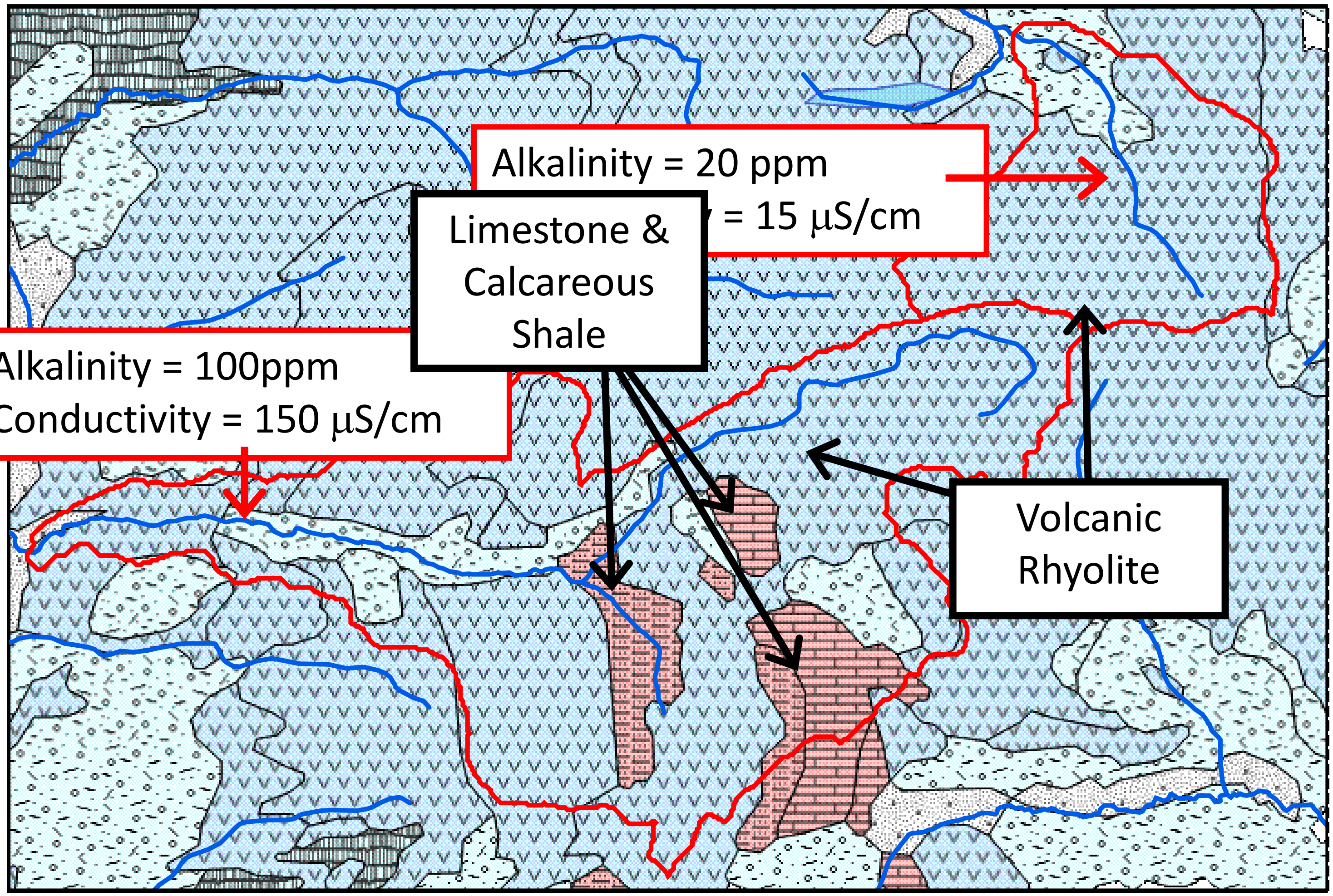


Example: Predicting water chemistry from categorical geologic map

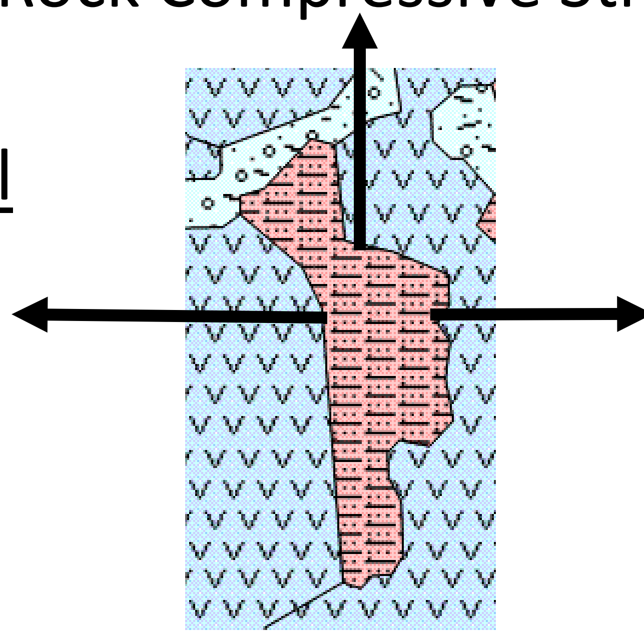


Approach

- Need to translate from geologic categories to continuous estimate of chemical and physical properties

Physical

- Intrinsic Permeability
- Rock Compressive Strength



Chemical

- % CaO
- % MgO
- (.....)

Nutrient

- P_2O_5
- Total N
- Total S

Approach

Produce separate maps of continuous gradients from categorical geologic maps

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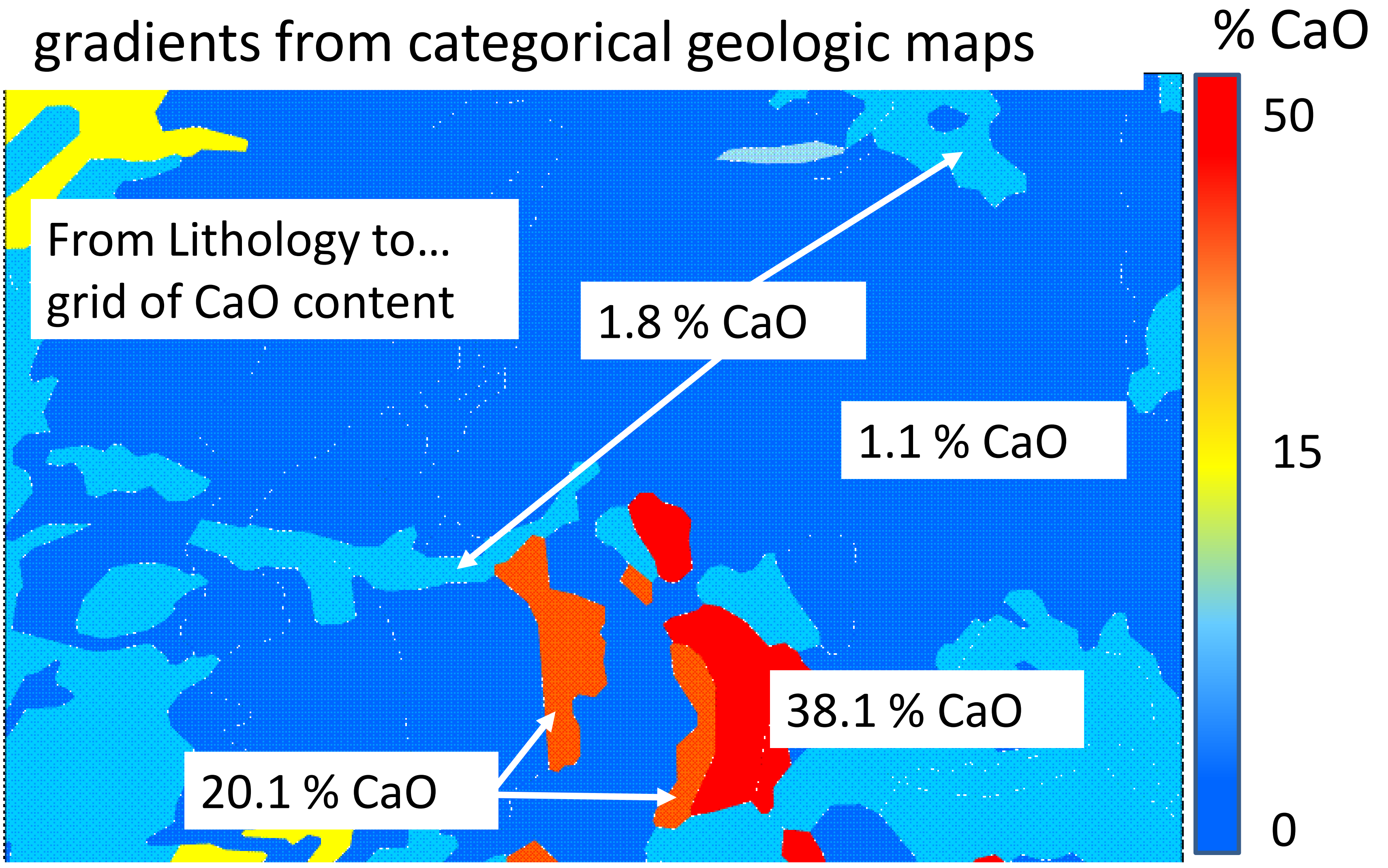

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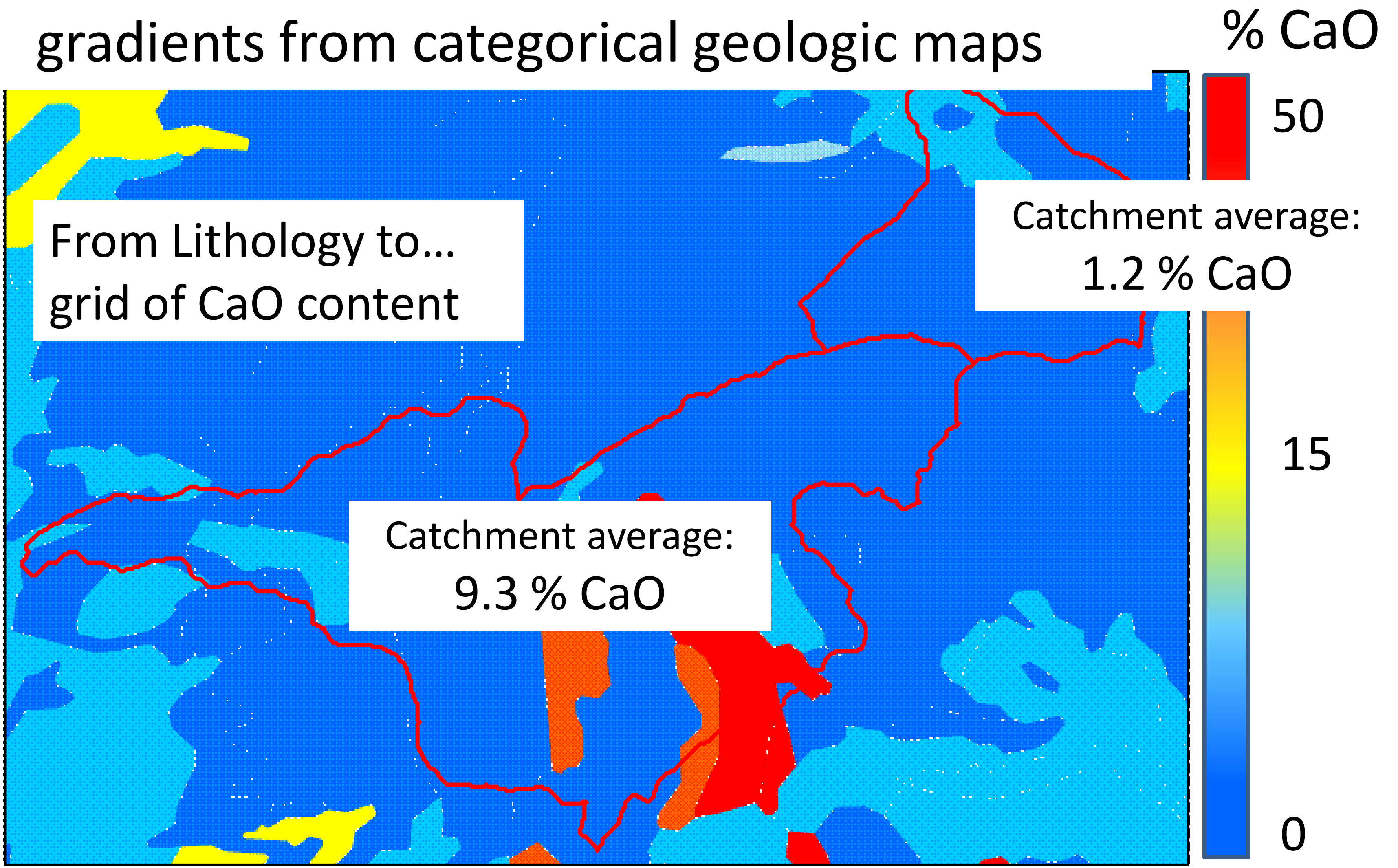
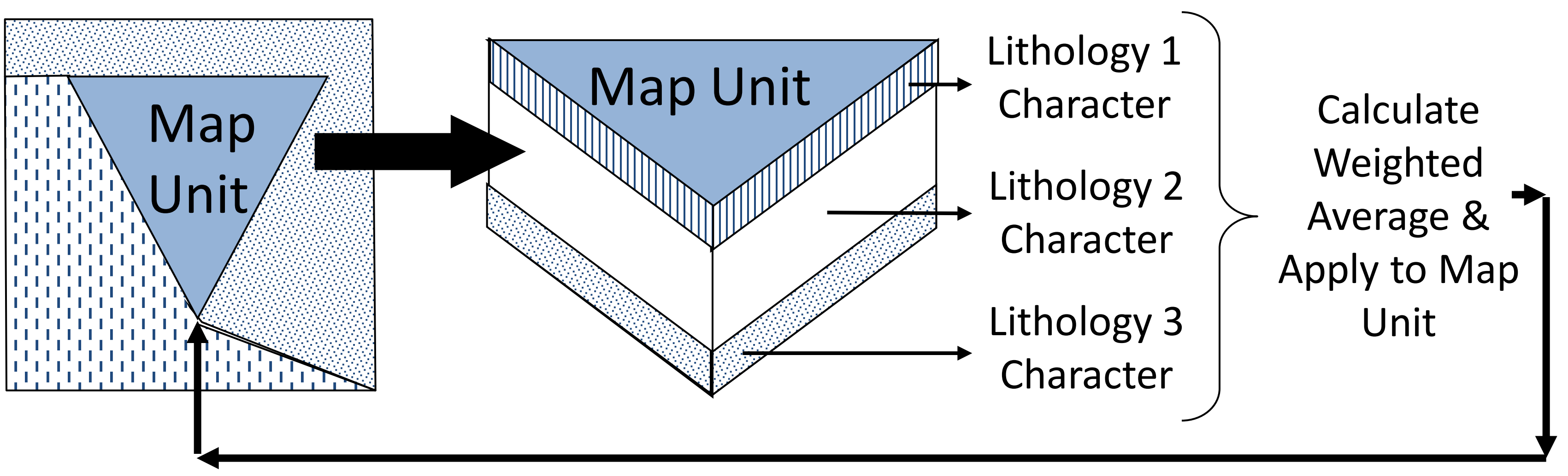


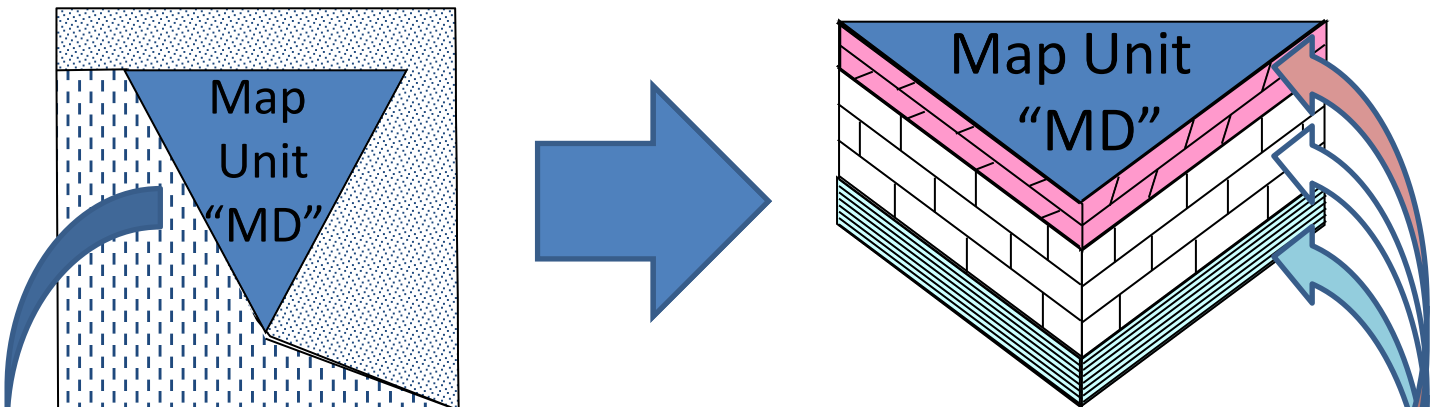
Approach

Replacing each map unit category with number representing average character of all lithologies in map unit



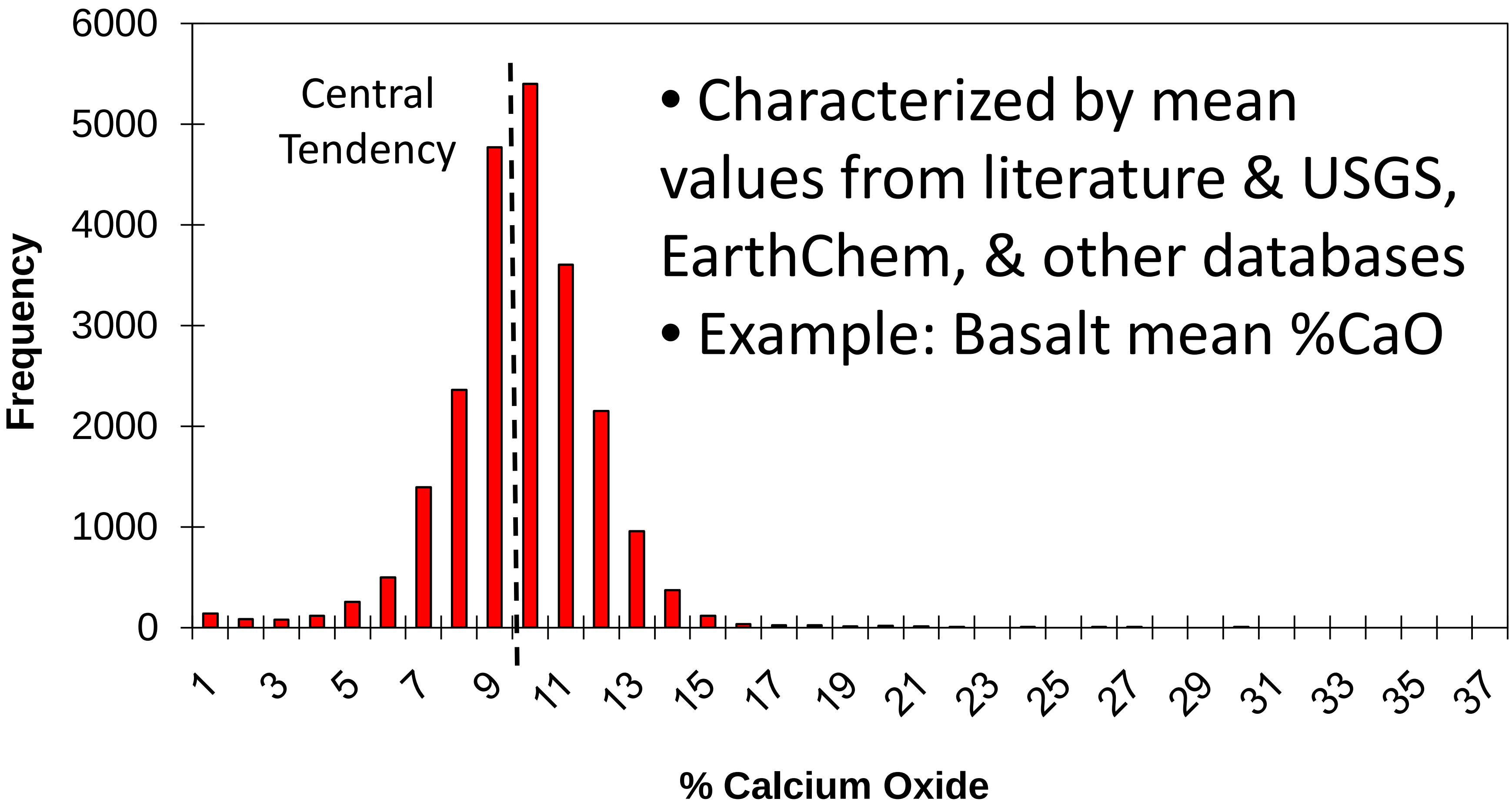
Separate lithologies by map unit

- USGS Preliminary integrated geologic map databases for the United States



LABEL	PREVELENCE	LITHOLOGY
MD	Minor	Dolostone
MD	Major	Limestone
MD	Minor	Shale

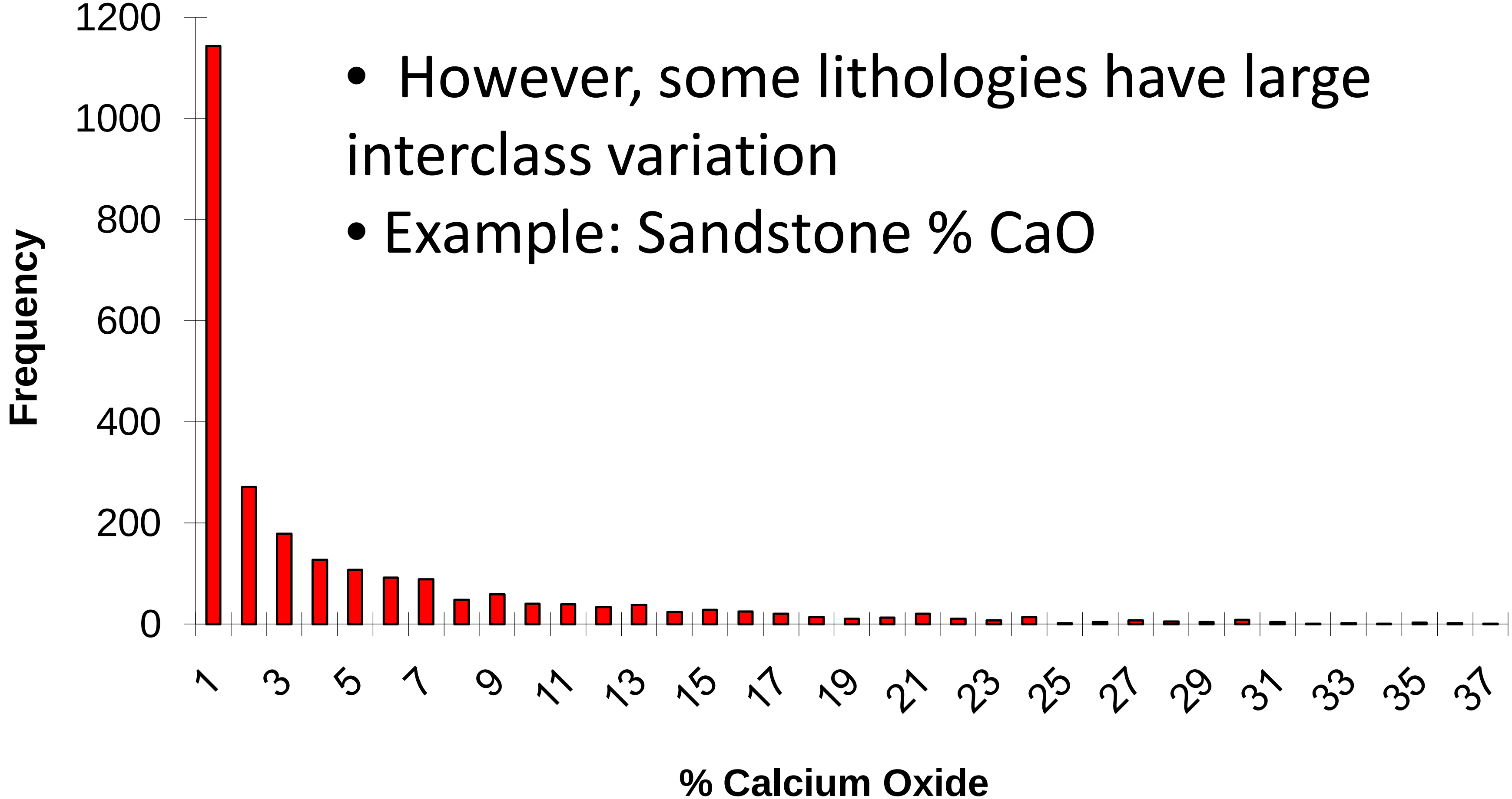
Characterize each lithology for each chemical & physical property



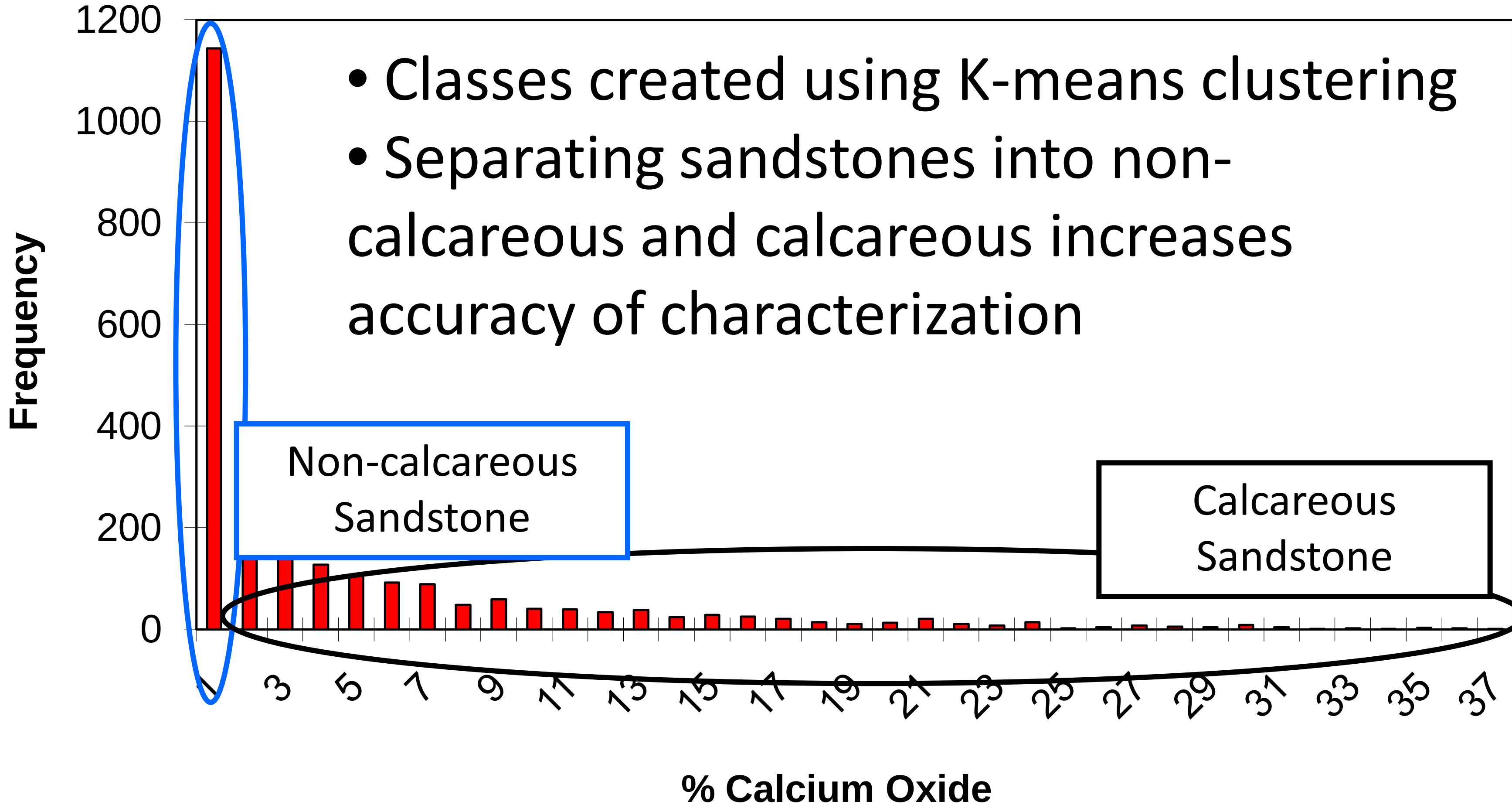
- Characterized by mean values from literature & USGS, EarthChem, & other databases
- Example: Basalt mean %CaO

Characterize each lithology for each chemical & physical property

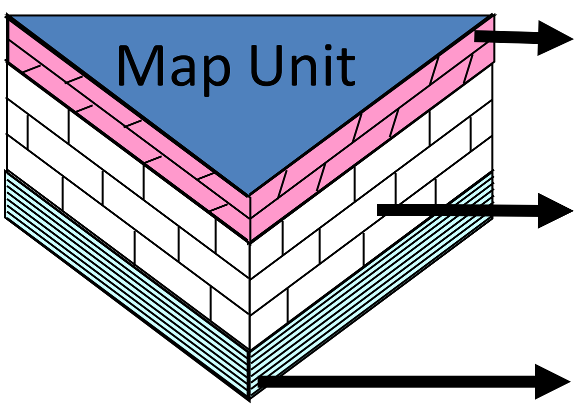
- However, some lithologies have large interclass variation
- Example: Sandstone % CaO



Characterize each lithology for each chemical & physical property



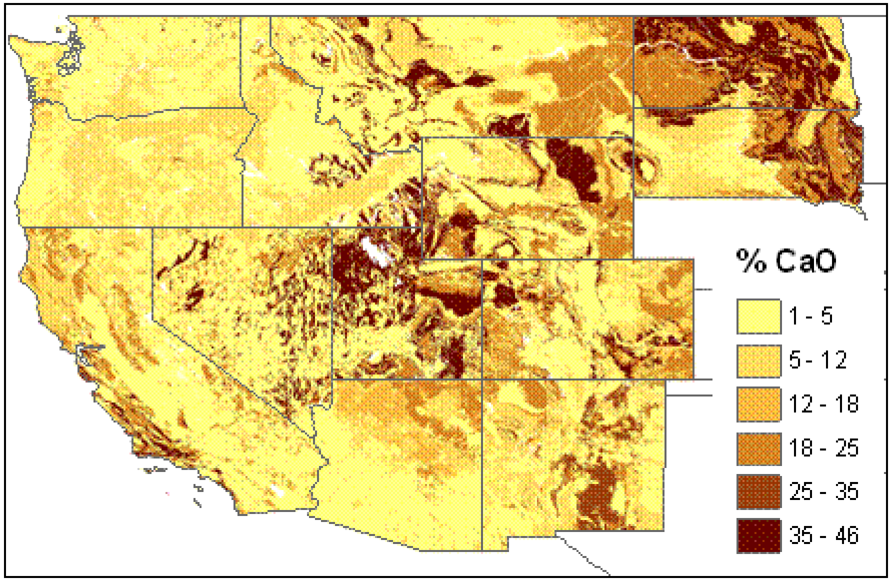
Calculate Weighted Average Map Unit Characteristic



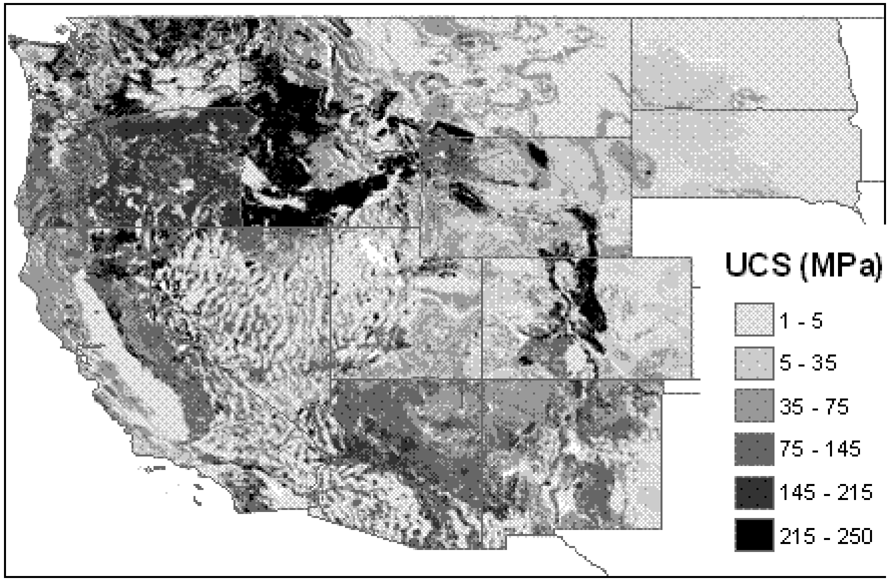
Lithology % CaO	Prevalence (Weight)	Weighted Average
Dolostone: 29.0	Minor (0.2311)	
Limestone: 46.0	Major (0.7119)	38.1 % CaO
Calcareous Shale: 23.6	Minor (0.2311)	

Create continuous maps for each characteristic by applying weighted averages

Rock Calcium Oxide Content

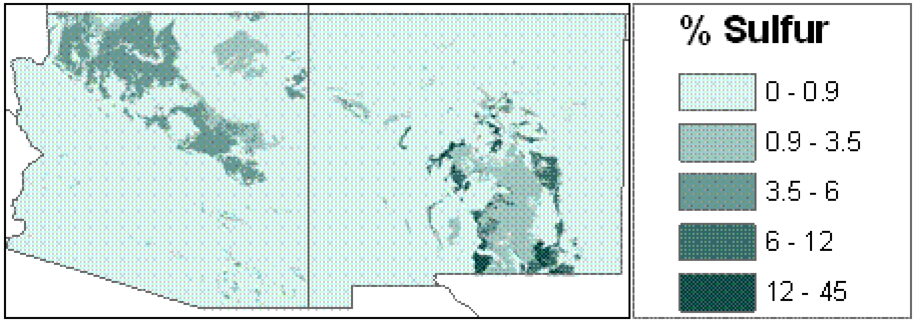


Rock Compressive Strength

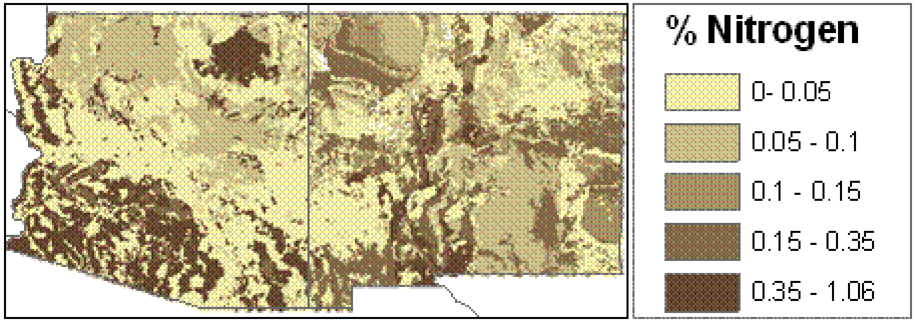


Create continuous maps for each characteristic by applying weighted averages

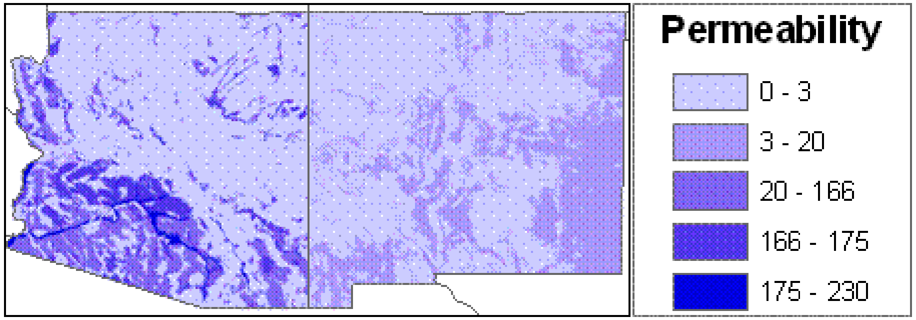
Rock Sulfur Content



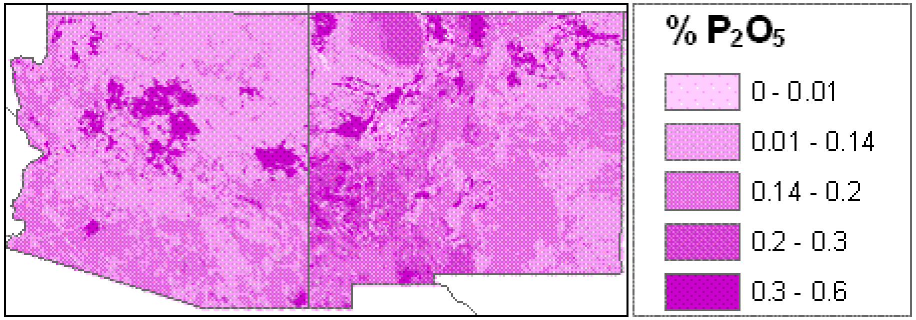
Rock Nitrogen Content



Intrinsic Permeability



Rock Phosphorus Content



Water chemistry model development

- Colorado Multiple Linear Regression Example
  - Samples collected by multiple agencies from 118 sites with minimal human impacts across Colorado
  - Developed Multiple Linear Regression models with data from 88 sites
  - Validated models with data from 30 randomly withheld sites

Water chemistry model development

- Colorado Multiple Linear Regression Example
  - Log transformed response variables to account for non-linearity
  - <u>Alkalinity Model (R^2 = 0.70):</u>

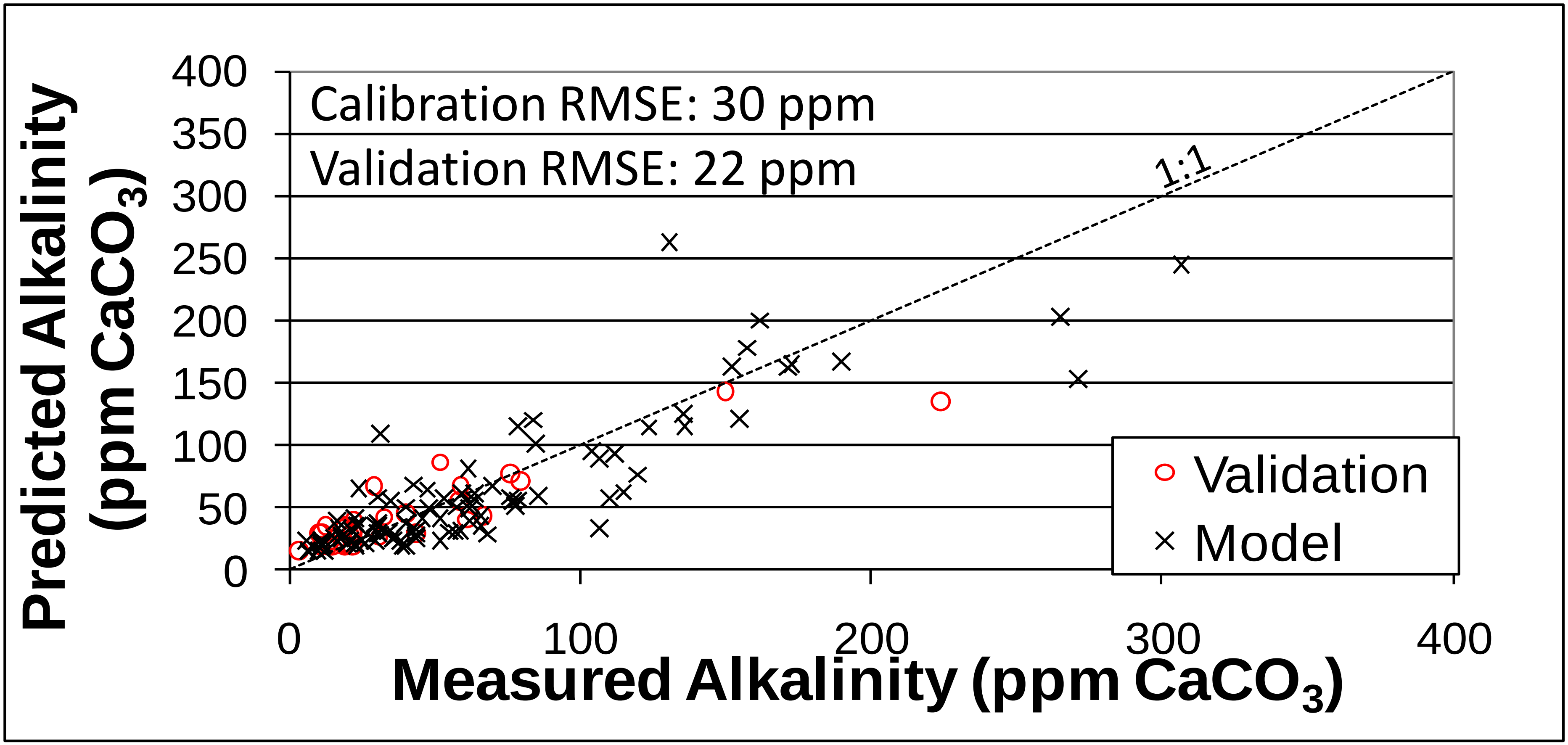
Ln(**Alkalinity**) = 0.04(**Rock %CaO**) -0.03(**Min Precip**) + 0.3(**Rock Compressive Strength**) + 0.2(**Rock %Sulfur**) - 3.3

  - <u>Conductivity Model (R^2 = 0.76):</u>

Ln(**Conductivity**) = 0.05(**Rock %CaO**) -0.3(**Min Precip**) + 0.2(**Rock Compressive Strength**) + 0.3(**Rock %Sulfur**) +.01(**Max Air Temp**) -3.0

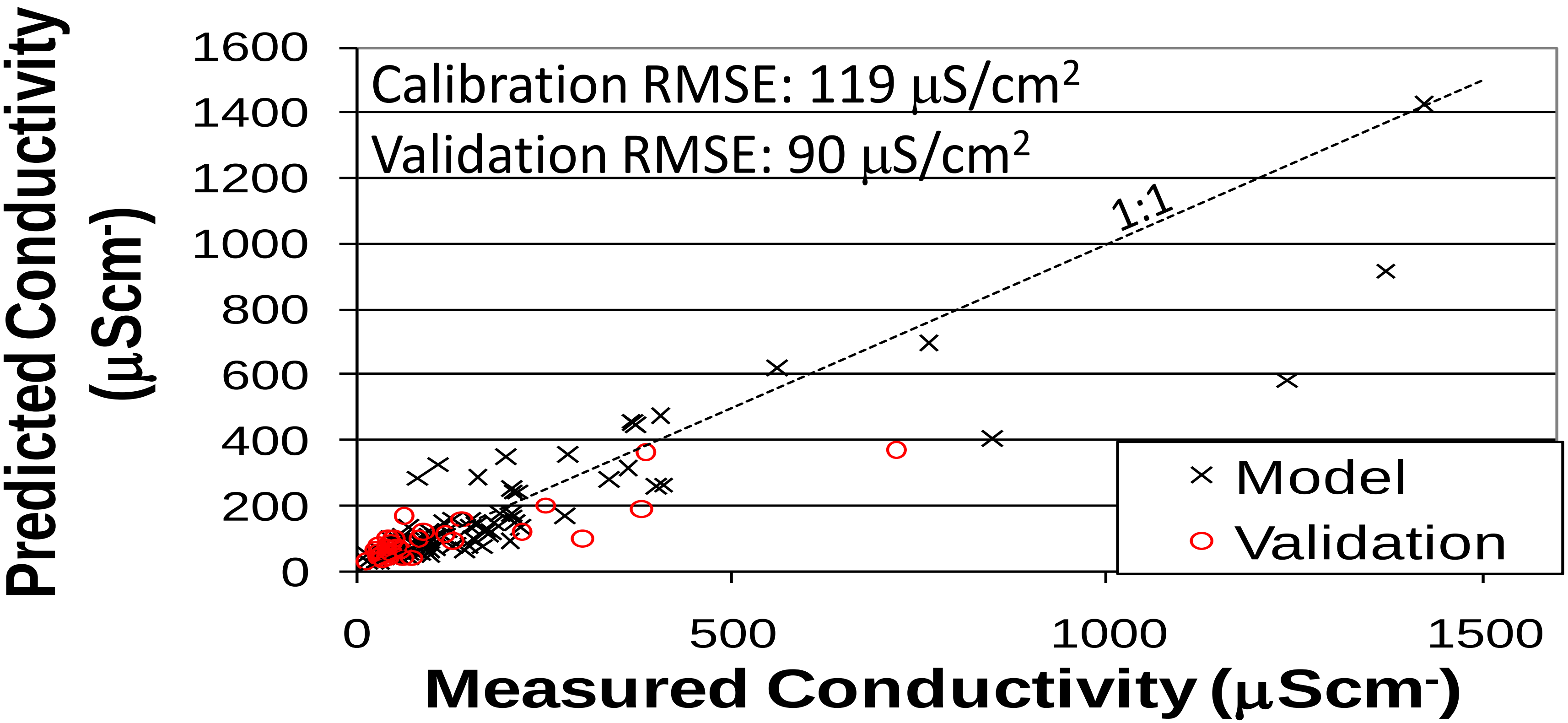
Water chemistry model development

Colorado Alkalinity Model Results



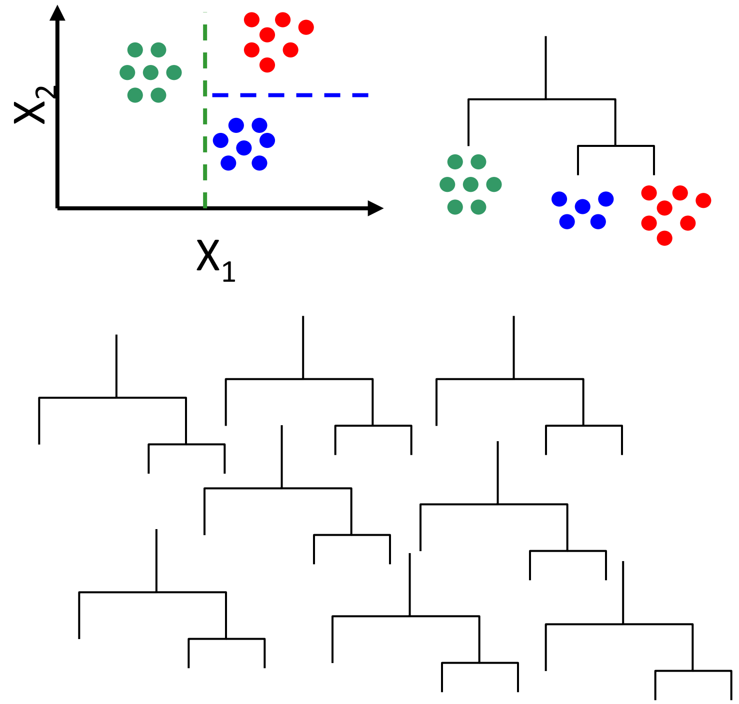
Water chemistry model development

Colorado Conductivity Model Results



Water chemistry model development

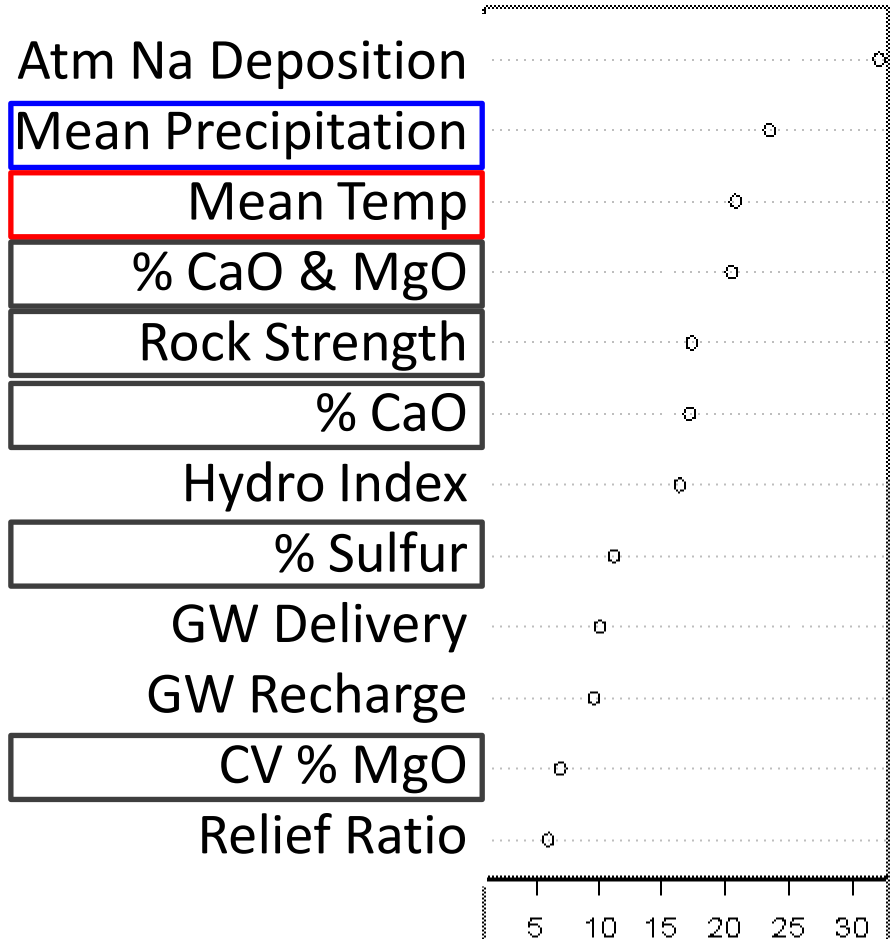
- California Random Forest Example
  - Samples collected by multiple agencies from 402 sites with minimal human impacts across California
  - Random Forest:
- Partitions the data to create tree
- Creates multiple trees via boot strapping
- Predicts outcomes by averaging across trees
  - Does not overfit
  - Effectively models non-linear data
  - Incorporates interactions



Water chemistry model development

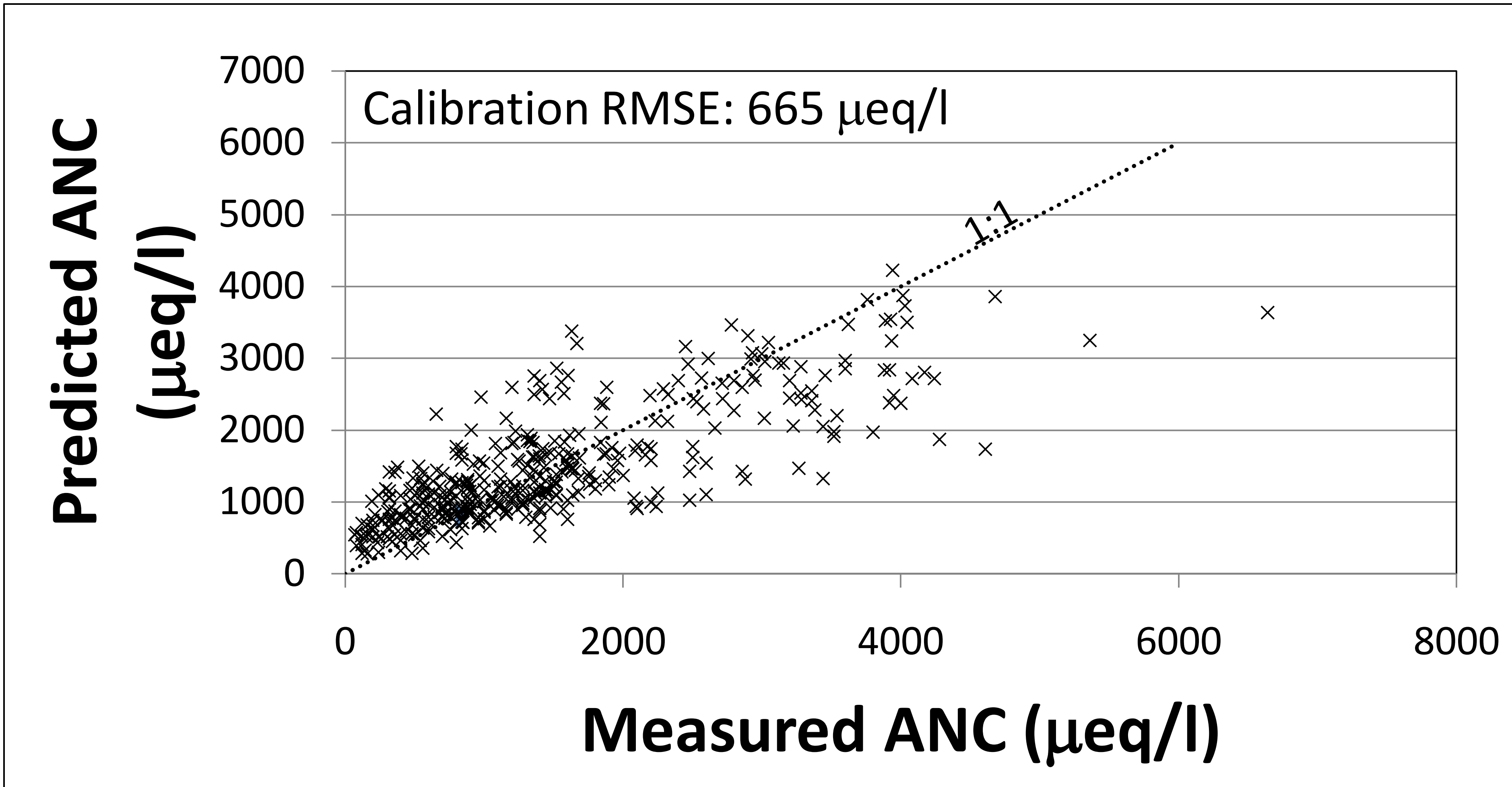
Variable Importance by Mean Decrease in % Accuracy

ANC Model (R^2=0.62)



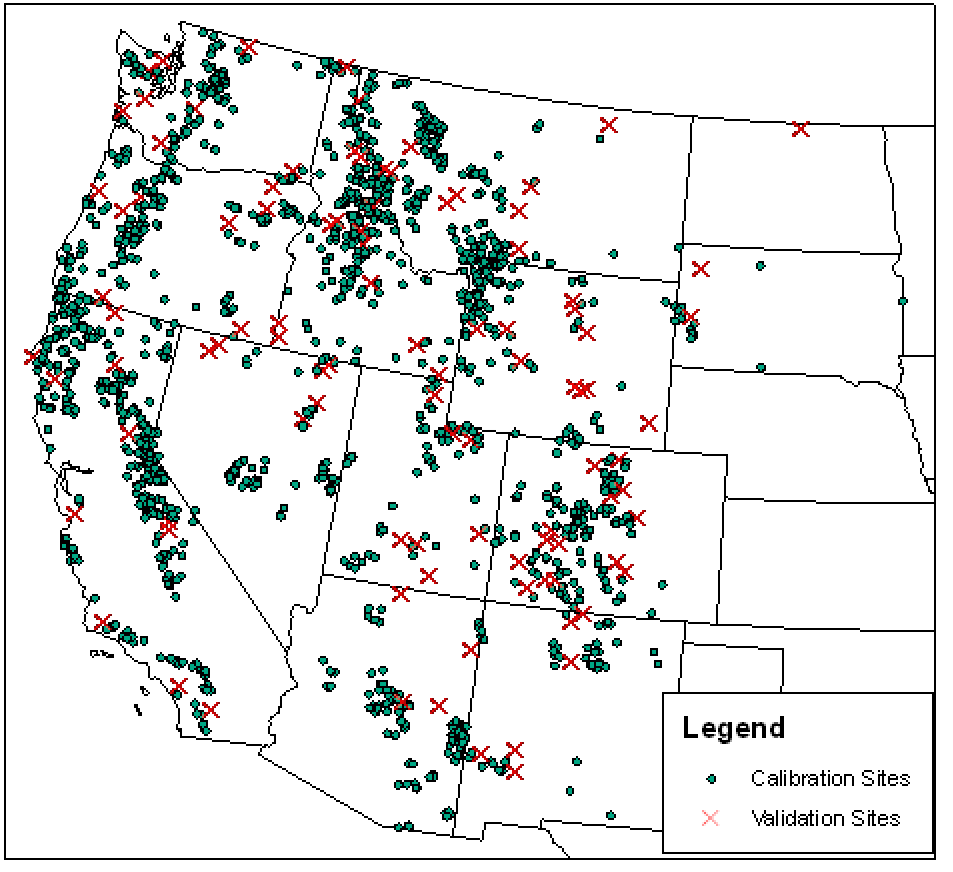
Water chemistry model development

California ANC Model Results



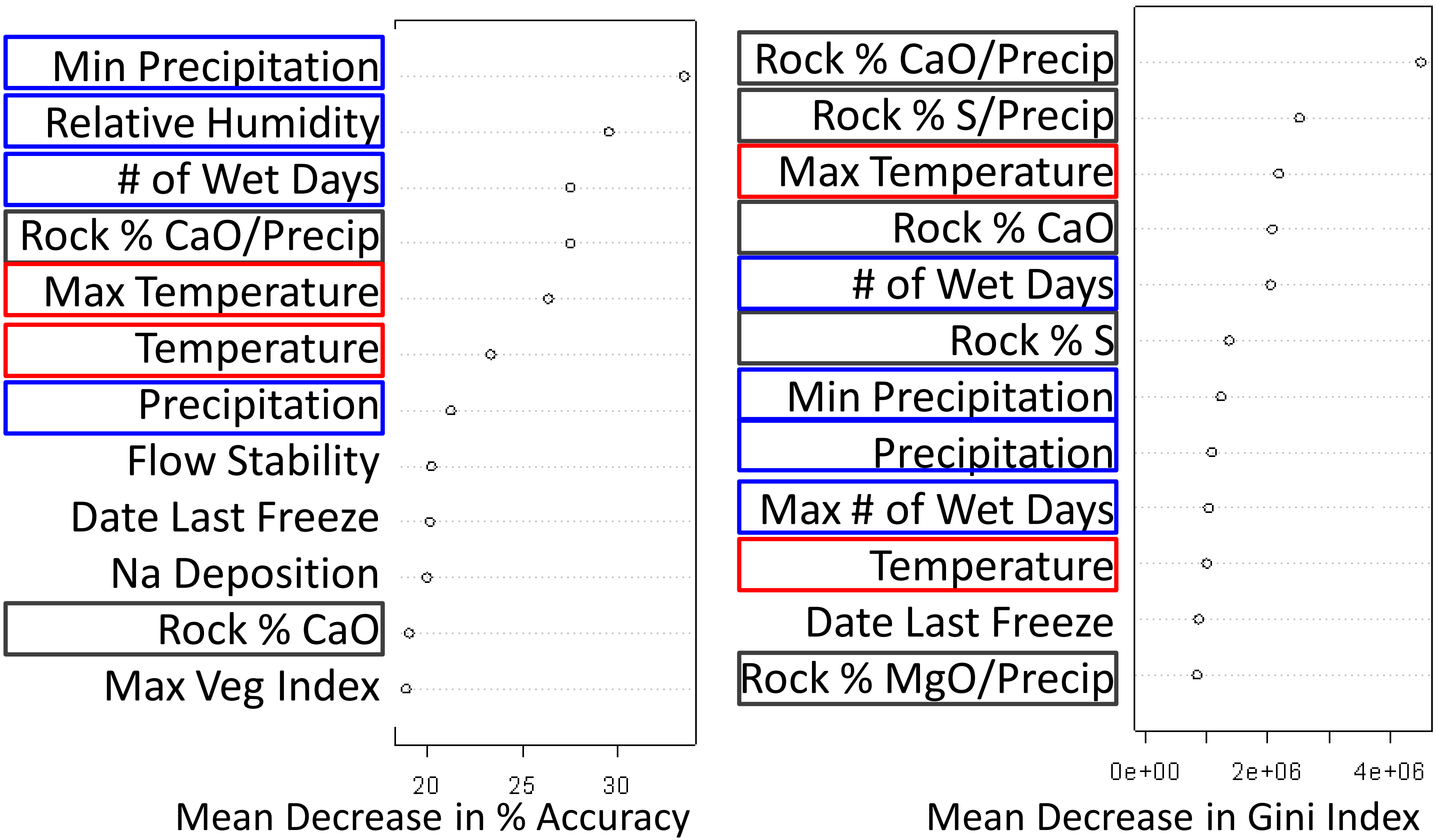
Water chemistry model development

- Currently Developing Models for Western U.S.
  - 1559 samples
  - Collected by multiple agencies
  - Sites with minimal human impacts
  - Randomly selected 100 independent sites for validation



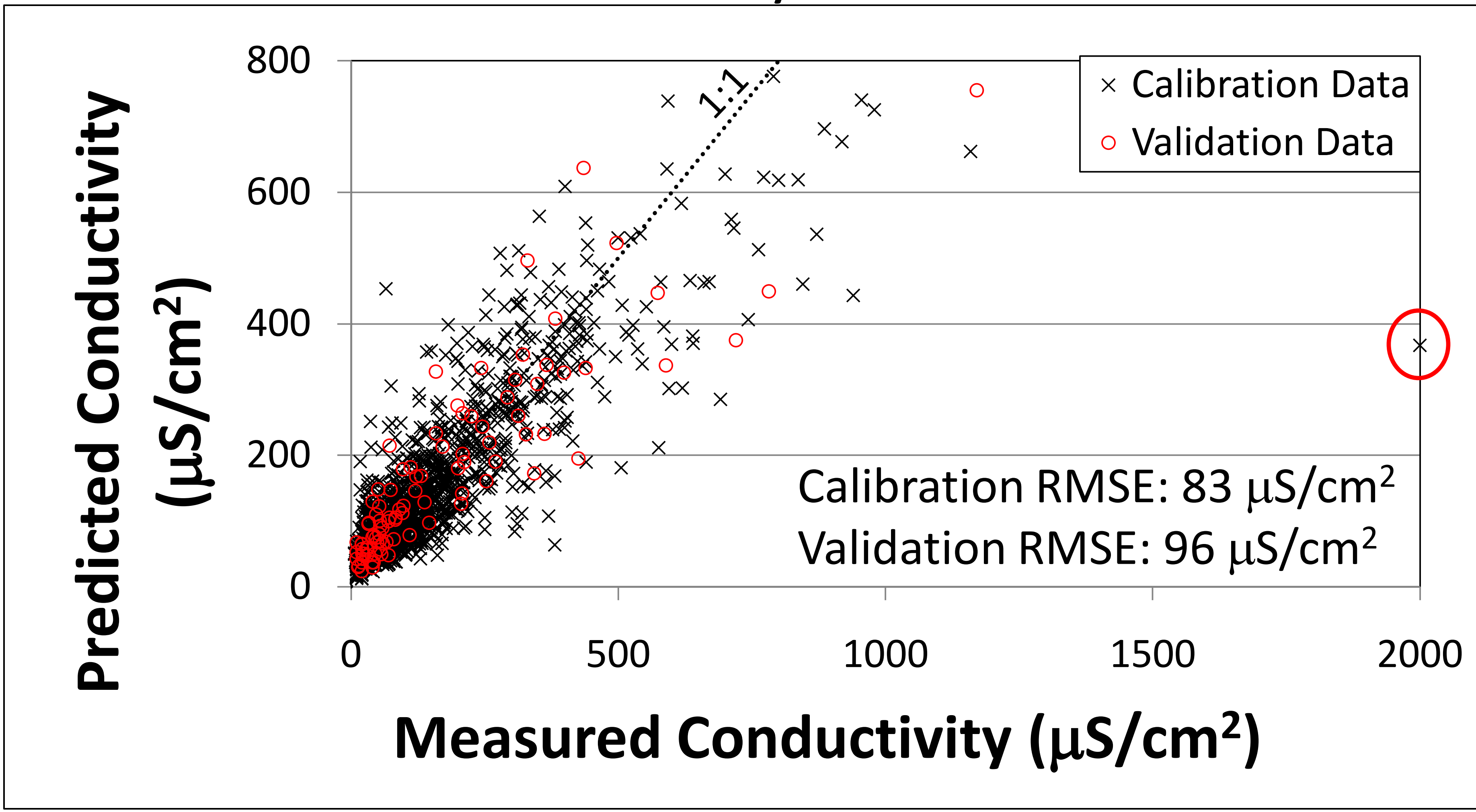
Water chemistry model development

Conductivity Model (R^2=0.71) Variable Importance



Water chemistry model development

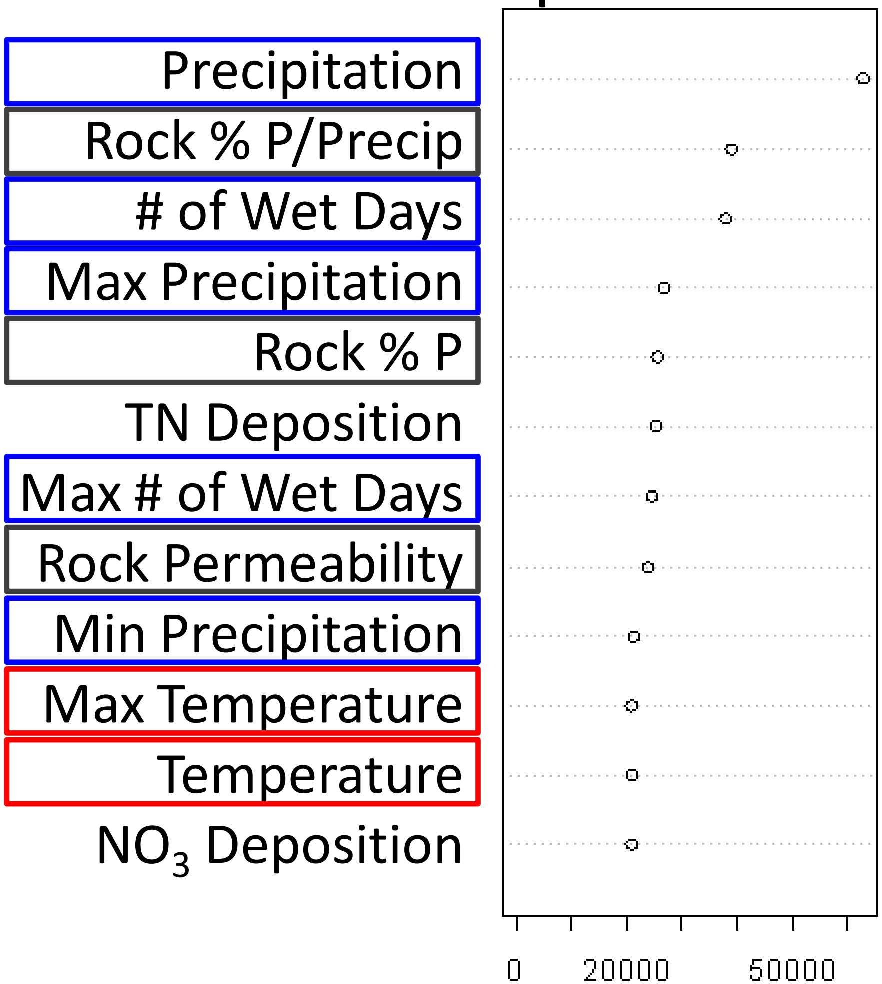
Western U.S. Conductivity Model Results



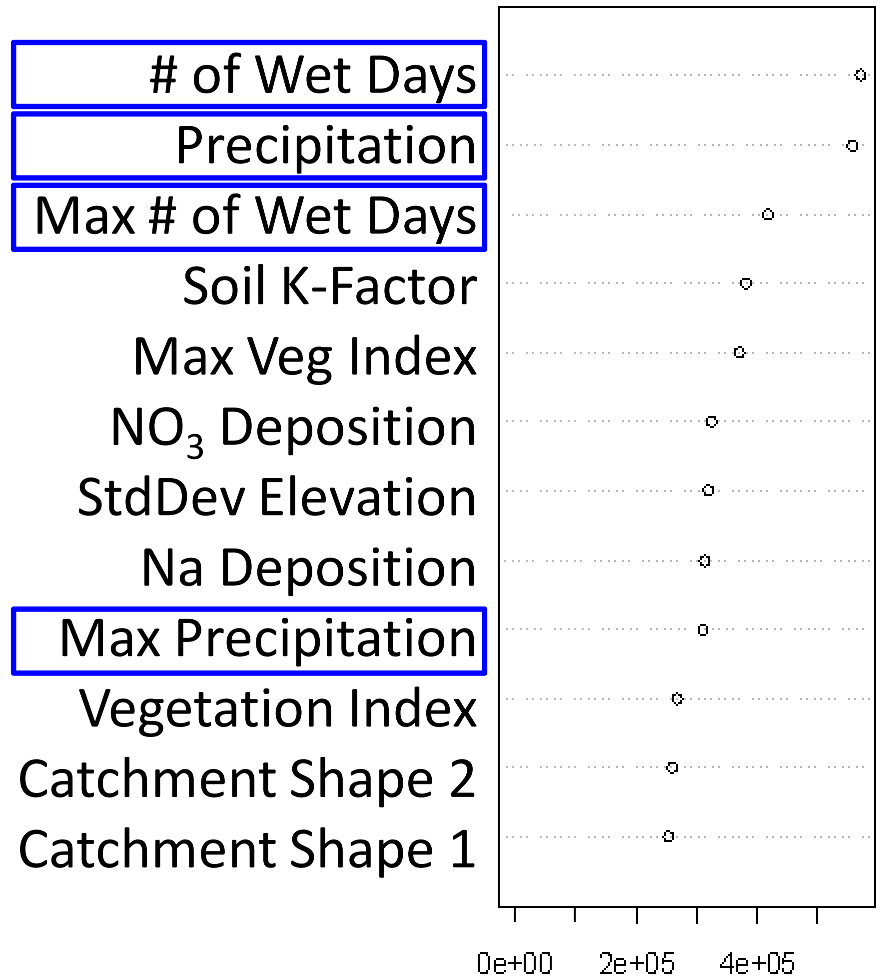
Water chemistry model development

Nutrient Model Variable Importance

Total Phosphorus

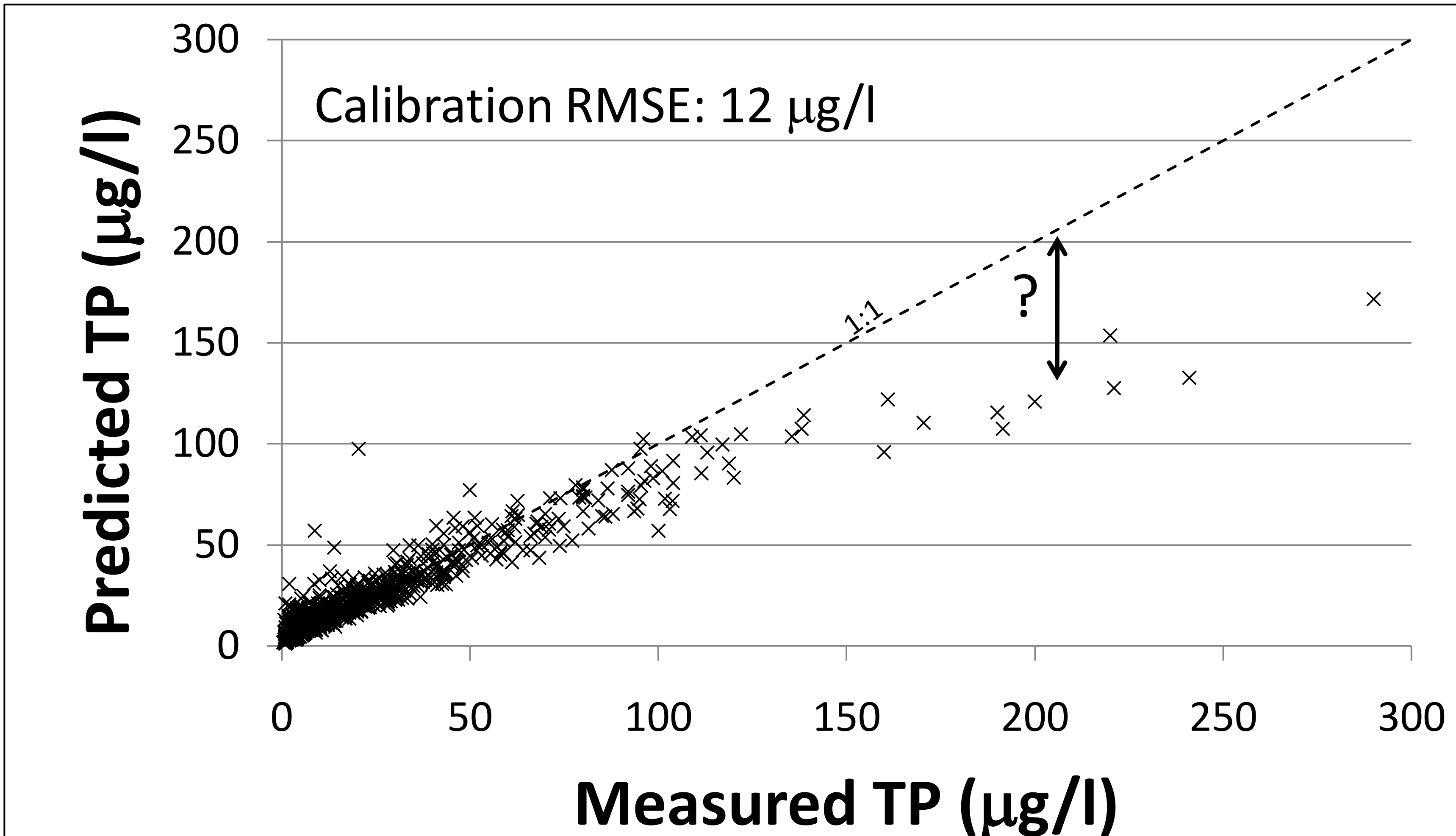


Total Nitrogen



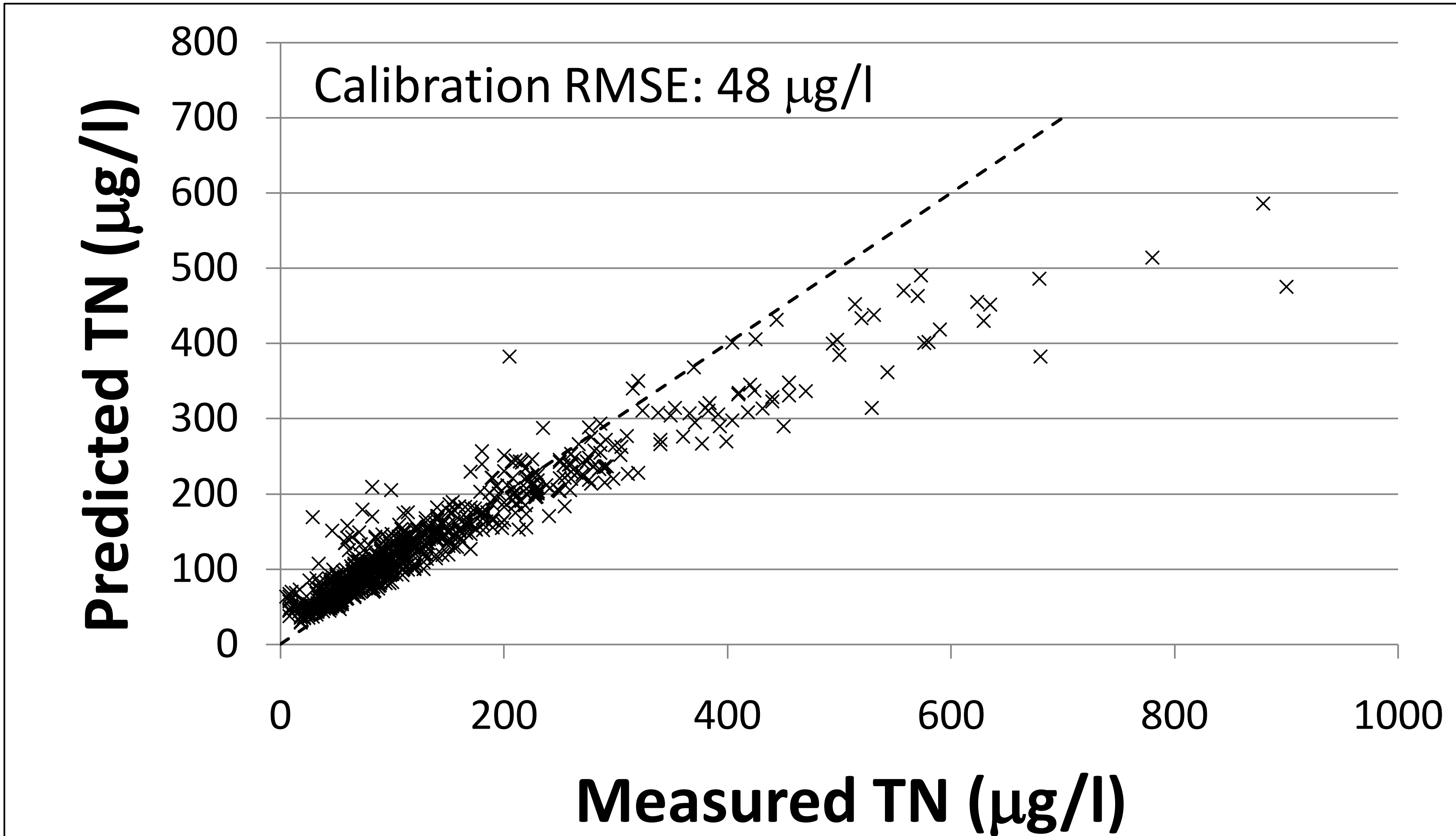
Water chemistry model development

Western U.S. Total Phosphorus Model Results



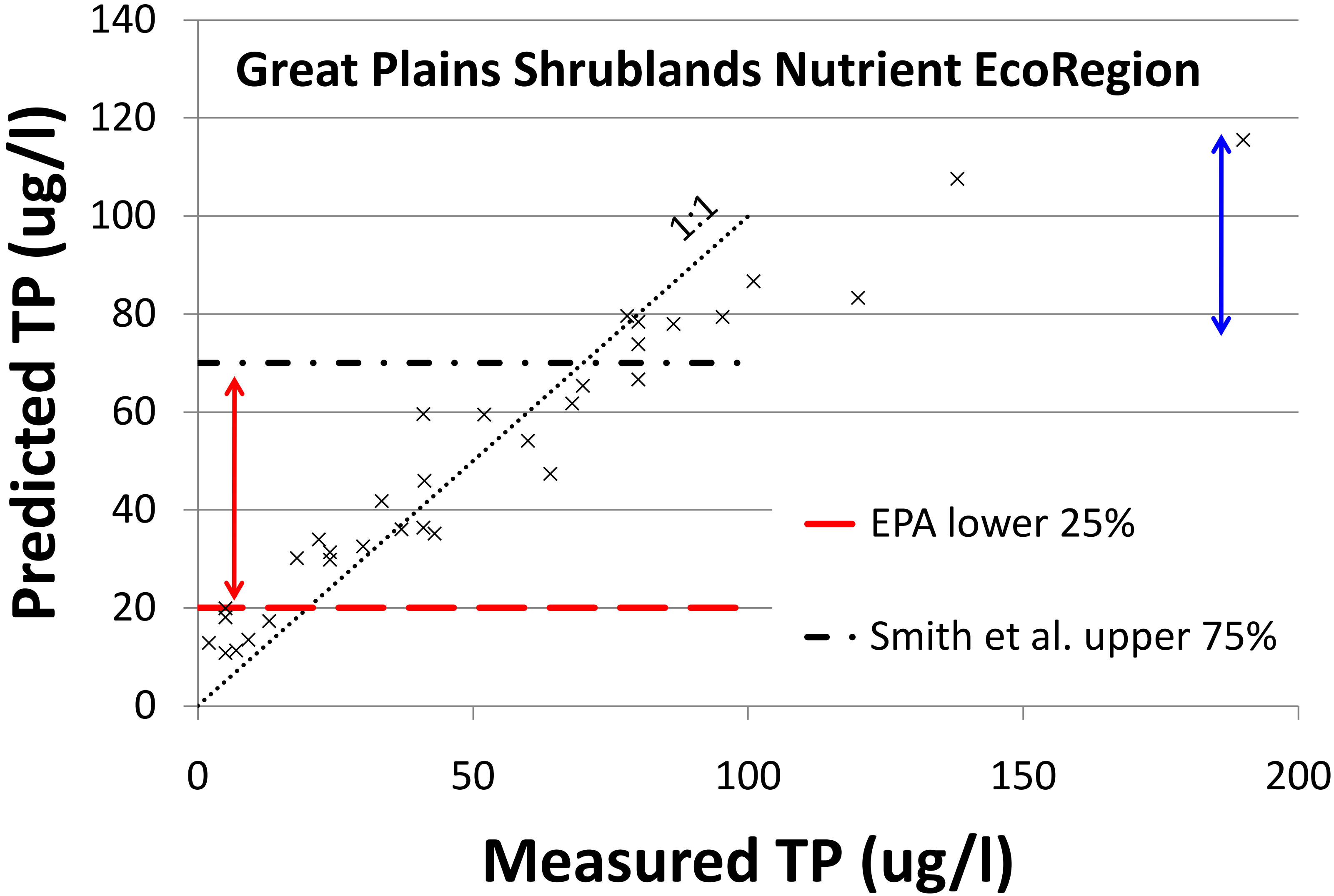
Water chemistry model development

Western U.S. Total Nitrogen Model Results



Conclusions

- We can effectively predict water chemistry at either state-wide or west-wide scales
- Site level predictions of water chemistry should allow for:
  - Improved biological predictive models
  - Establishment of more robust water chemistry and nutrient criteria



Great Plains Shrublands Nutrient EcoRegion
Predicted TP (ug/l)
Measured TP (ug/l)
0
20
40
60
80
100
120
140
0
50
100
150
200
1:1
EPA lower 25%
Smith et al. upper 75%

Questions?