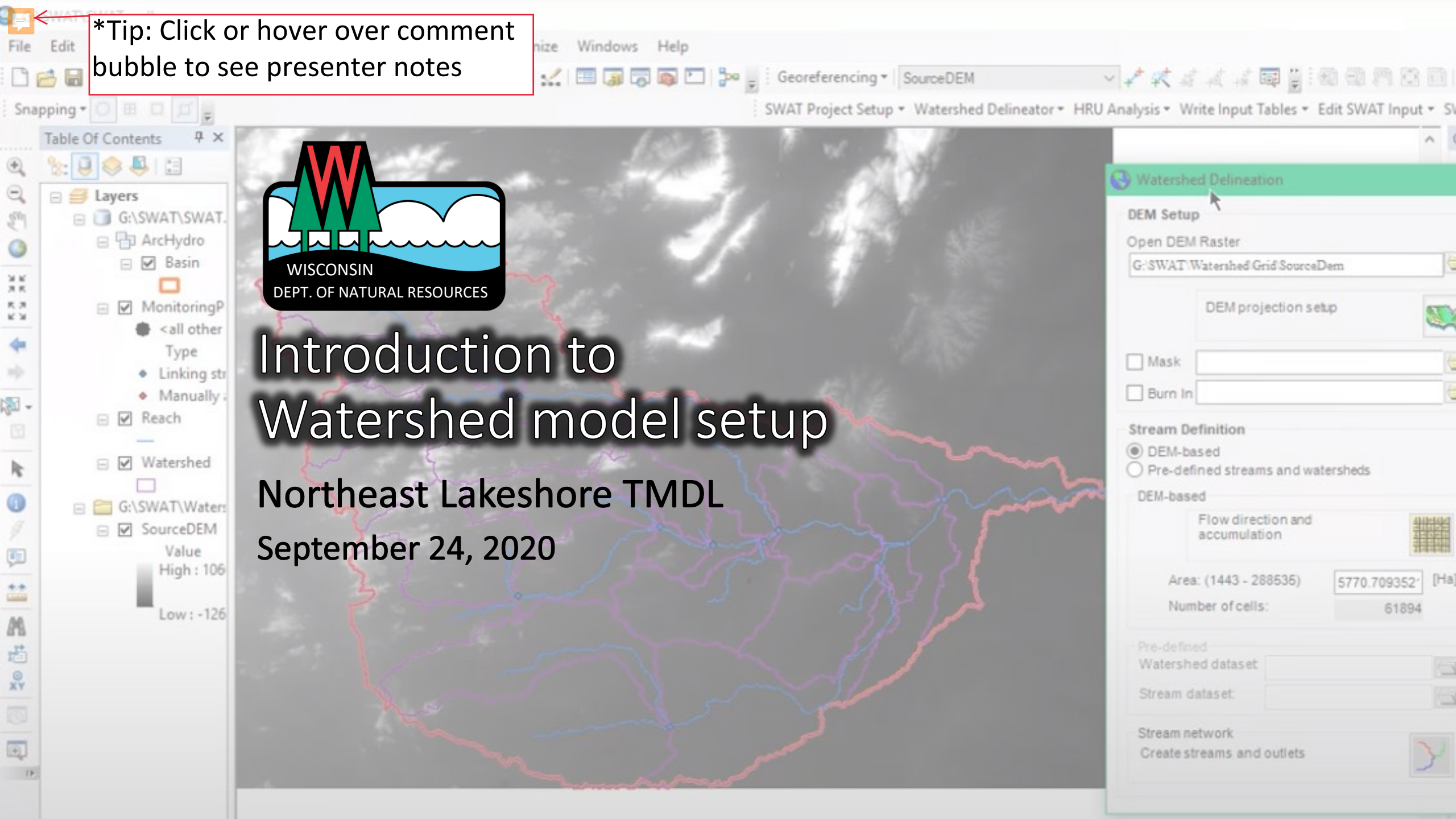
*Tip: Click or hover over comment bubble to see presenter notes



Introduction to Watershed model setup

Northeast Lakeshore TMDL

September 24, 2020

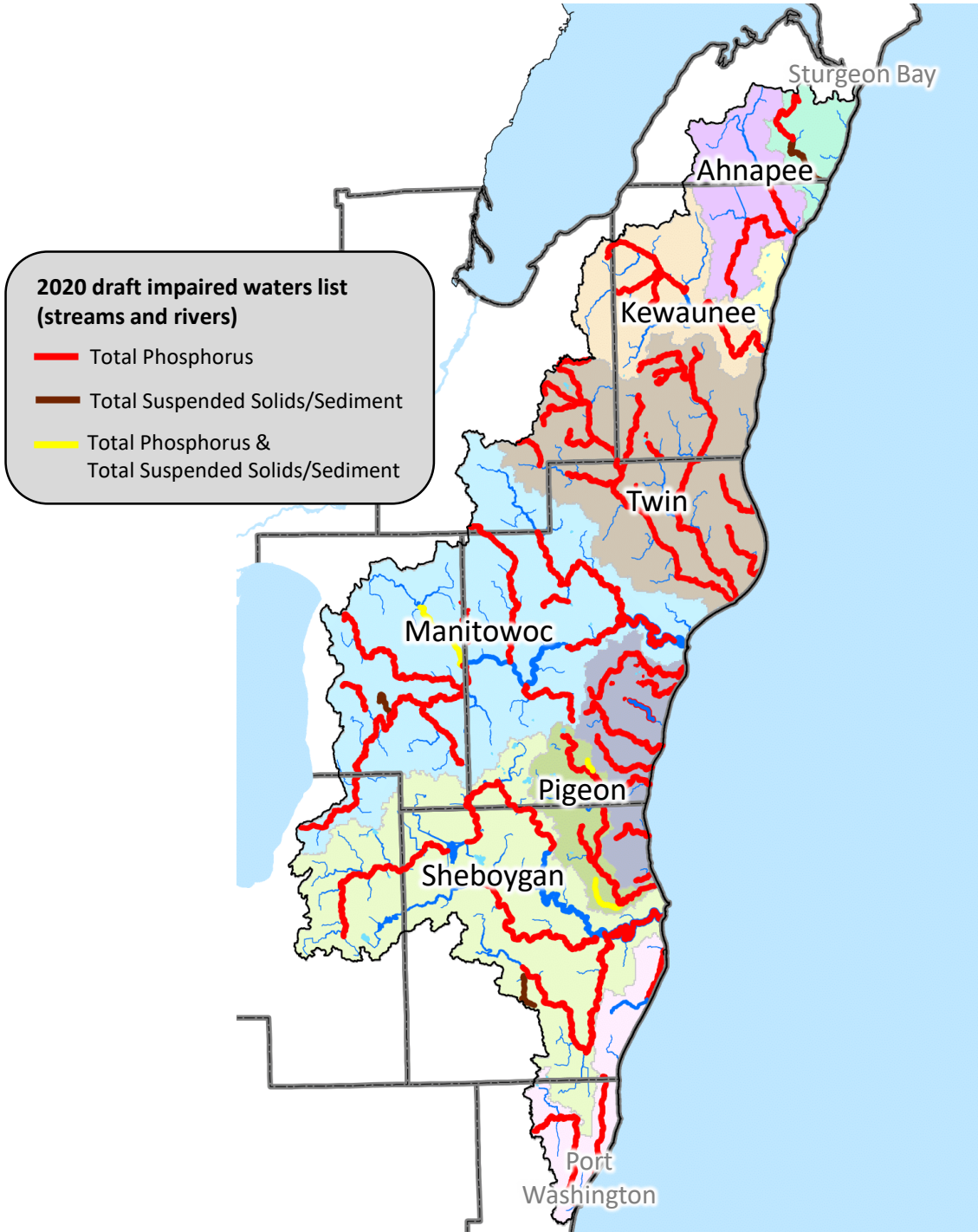
NE Lakeshore TMDL

Study area
- Cover nearly 2,000 square miles
- Includes many major river basins

Impaired waters (Draft 2020 list)
- Stream Segments
  - TP impaired: 74
  - Sediment impaired: 3
  - TP & Sediment impaired: 3
- Lakes
  - TP impaired: 13

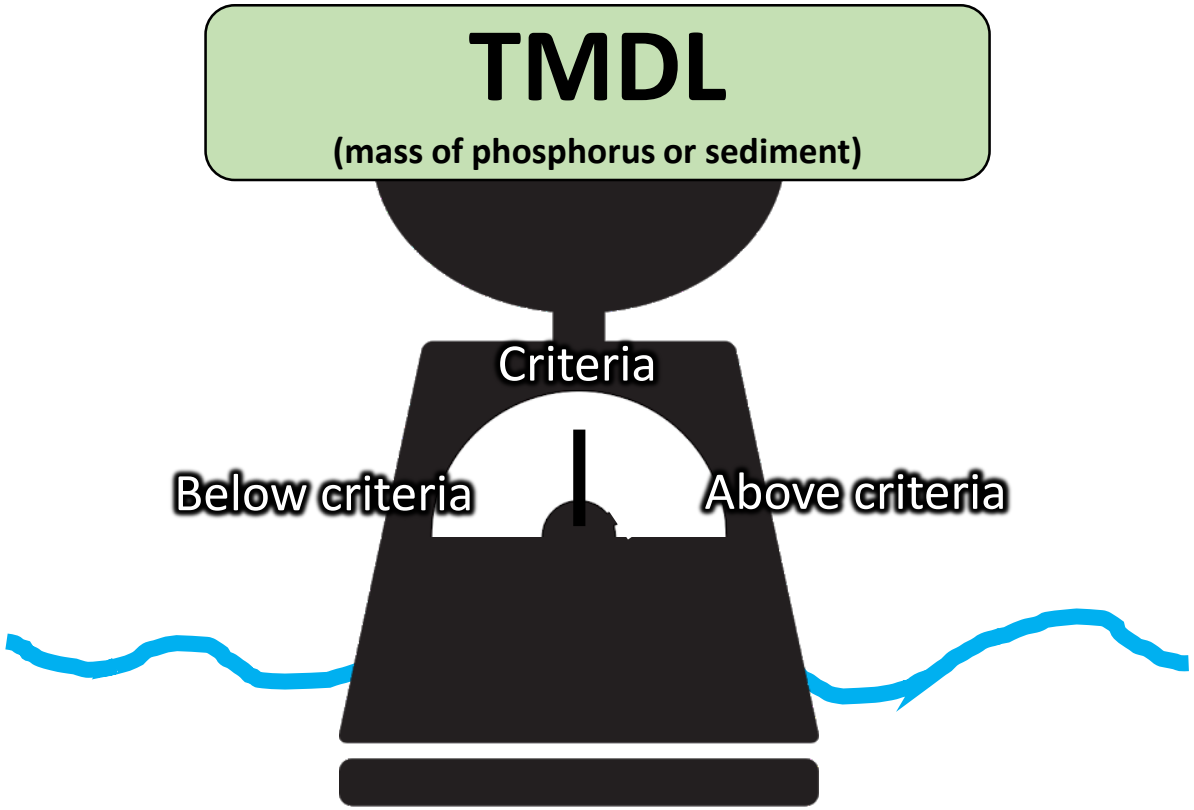
Focused on streams, rivers, and inland lakes (not Lake Michigan)

Funding from WI legislature in 2017



TMDL = Total Maximum Daily Load

The amount (or mass) of phosphorus or sediment that a waterbody can receive and still meet water quality criteria (a concentration)



NE Lakeshore TMDL development

Anticipated milestones

Stream monitoring

Watershed model contract: Nov. 2018 – May 2021

2017

WI legislature supports NE Lakeshore TMDL

2018

2019

Completed inventory of WPDES permit holders and effluent monitoring data

2020

Completed collection of agricultural management data

Completed analysis of stream monitoring data

June, webinar 1: TMDL Overview

July, webinar 2: Water quality data and impairments (3 separate presentations for each basin).

August, webinar 3: Watershed model introduction and data inputs

Today

September, webinar 4: Watershed model setup

Public comment period on model setup section of model report

2021

Stakeholder meetings/webinar. Late 2020 to early 2021

Present draft watershed modeling report, baseline load results, and allocation methods

Public comment period on model report.

Stakeholder meetings/webinar: Spring 2021

Present draft allocation results.

Public comment period on draft allocations

Conduct Public Hearing. Mid to late 2021

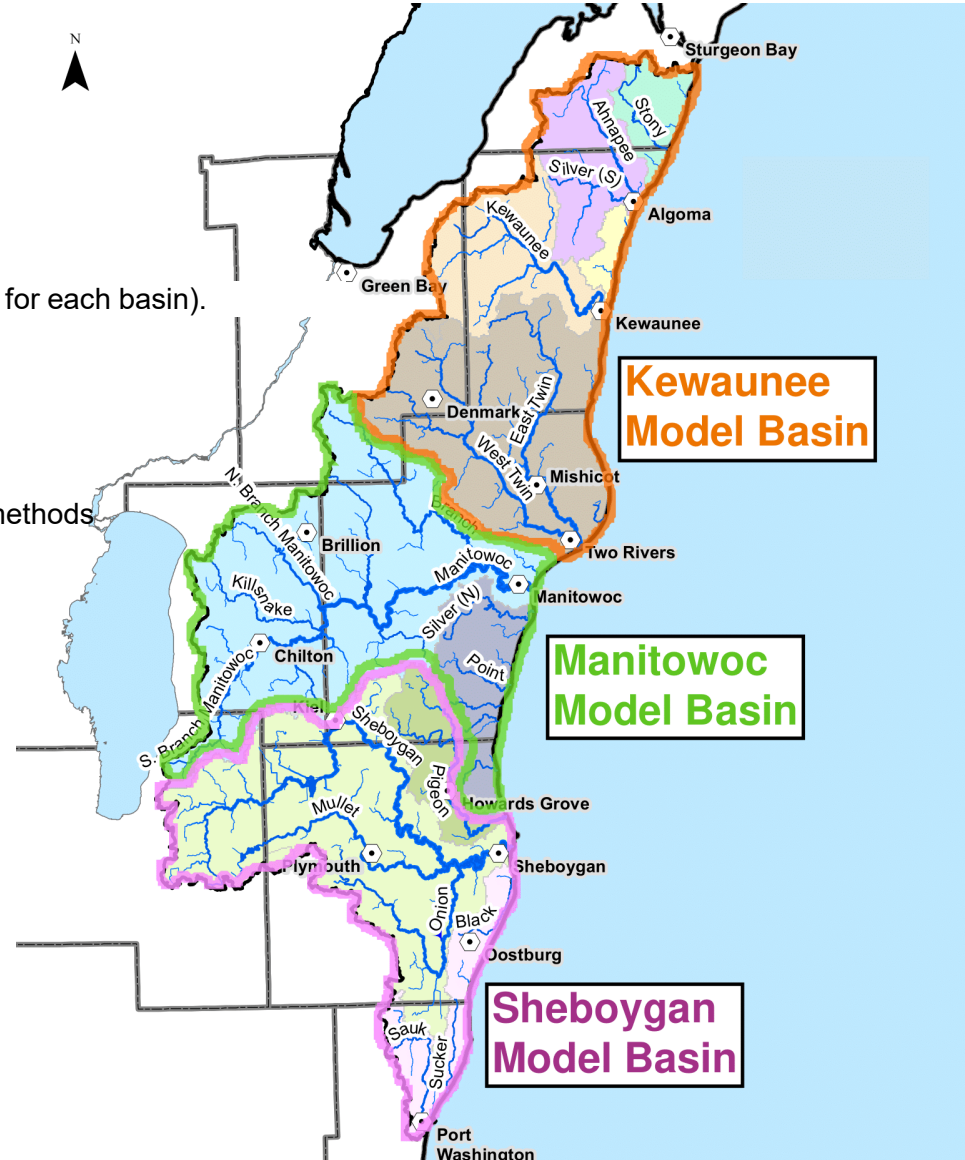
Present draft TMDL report

Public comment period on TMDL report

2022

Mid 2022: Anticipated submittal of TMDL report to EPA for approval

Anticipated start of the TMDL implementation phase



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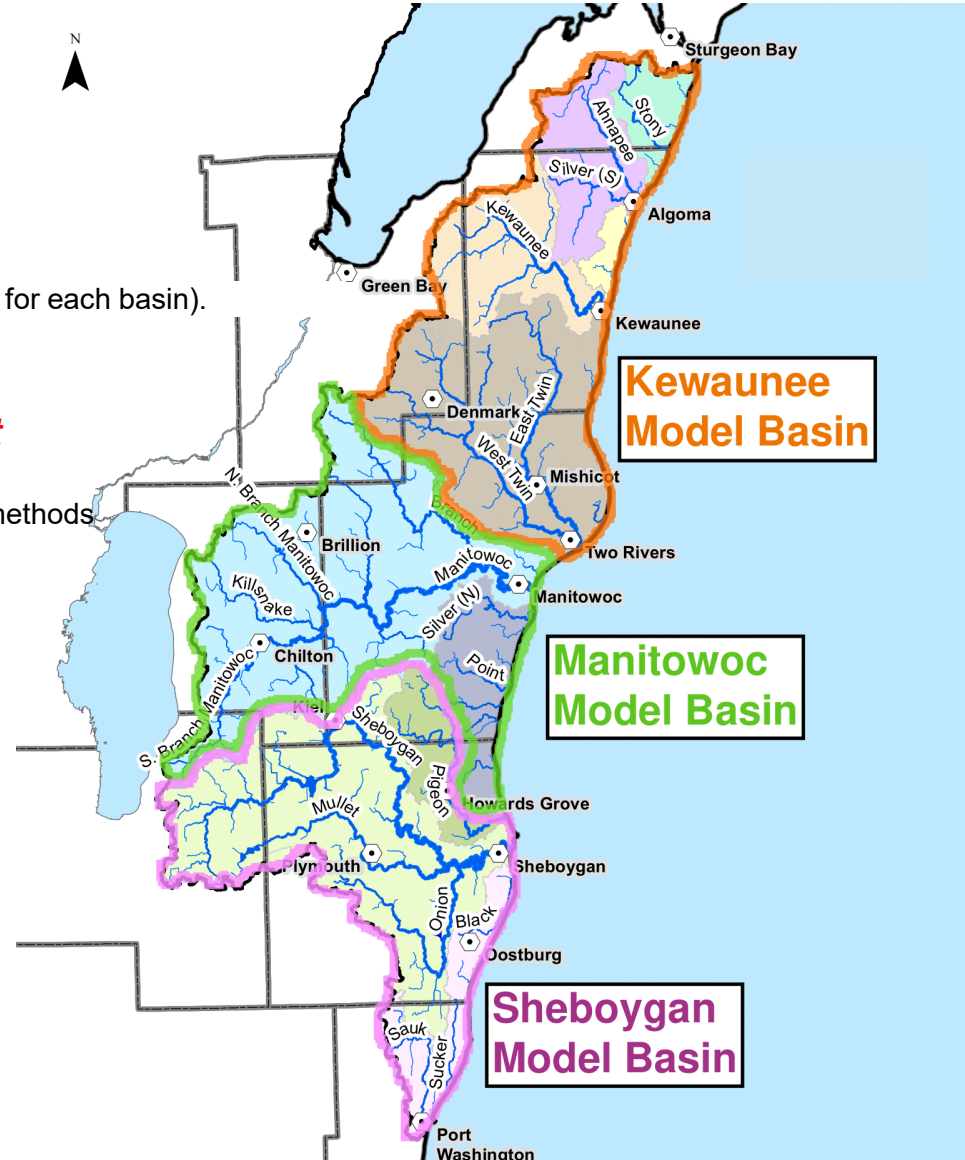

Outline of the Watershed Model Report

Prepared by The Cadmus Group through an EPA contract

Upcoming Comment Period

Accepting comments until Oct 16th

Send comments to Kim Oldenborg Kimberly.Oldenborg@Wisconsin.gov

1. **Overview**
2. **Model Setup**
   - 2.1. ArcSWAT and SWAT software
   - 2.2. Subbasin and Reach Delineation
   - 2.3 Hydrologic Response Units
     - 2.3.1. Land Cover
     - 2.3.1. Soils
     - 2.3.2. Slope
     - 2.3.4. HRU Definition
   - 2.4. Weather
     - 2.4.1. Weather Data
     - 2.4.2. Potential Evapotranspiration
   - 2.5. Point Sources
     - 2.5.1. Wastewater Treatment Facilities
     - 2.5.2. Municipal Separate Storm Systems
     - 2.5.3. CAFOs
     - 2.5.4. General Permits
   - 2.6. Soil Phosphorus
   - 2.7. Manure Application
   - 2.8. Baseflow Alpha Factor
   - 2.9. Internally Drained Areas
   - 2.10. Mannings N
   - 2.11. Subbasin Slope Length
   - 2.12 Simulation Period

Future Webinar and Comment Period (Late 2020/Early 2021)

3. **Model Calibration** (methods and results)
4. **Model Validation** (methods and results)
5. **Discussion of Model Performance**
6. **Summary of Model Results**
7. **References**

Outline of the Watershed Model Report

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Upcoming Comment Period

Webinar 3 topics

Webinar 4 topics (today)

1. **Overview**
2. **Model Setup**
   - 2.1. ArcSWAT and SWAT software
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Why is a watershed model needed?

Recall the 3 major steps in TMDL development

1

Calculate Baseline loads

What are the current pollutant loads and how much is coming from each source?

2

Determine loading capacity

What amount of pollutant can a waterbody receive?

3

Allocate load among sources

What amount of pollutant reduction is needed from each source?

Why do we need a watershed model ?

Recall the 3 major steps in TMDL development

1

Calculate Baseline loads

What are the current pollutant loads and how much is coming from each source?

Watershed model needed for Nonpoint (ag, urban, natural) loads

2

Determine loading capacity

What amount of pollutant can a waterbody receive?

3

Allocate load among sources

What amount of pollutant reduction is needed from each source?

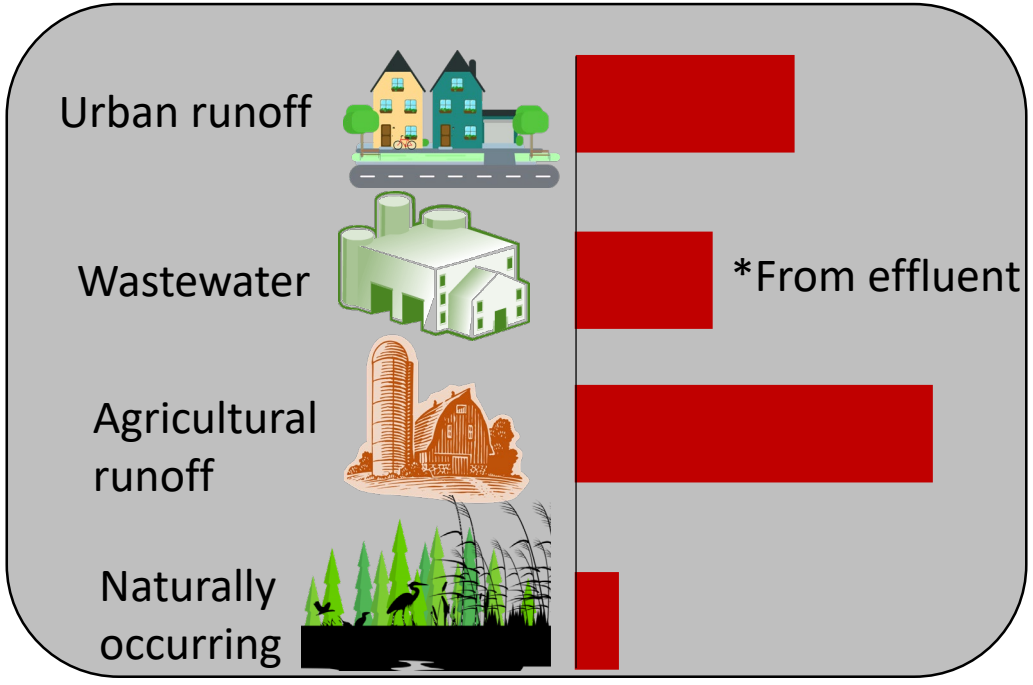
Why do we need a watershed model ?

1) To provide baseline phosphorus and sediment loads in each of the 321 subbasins

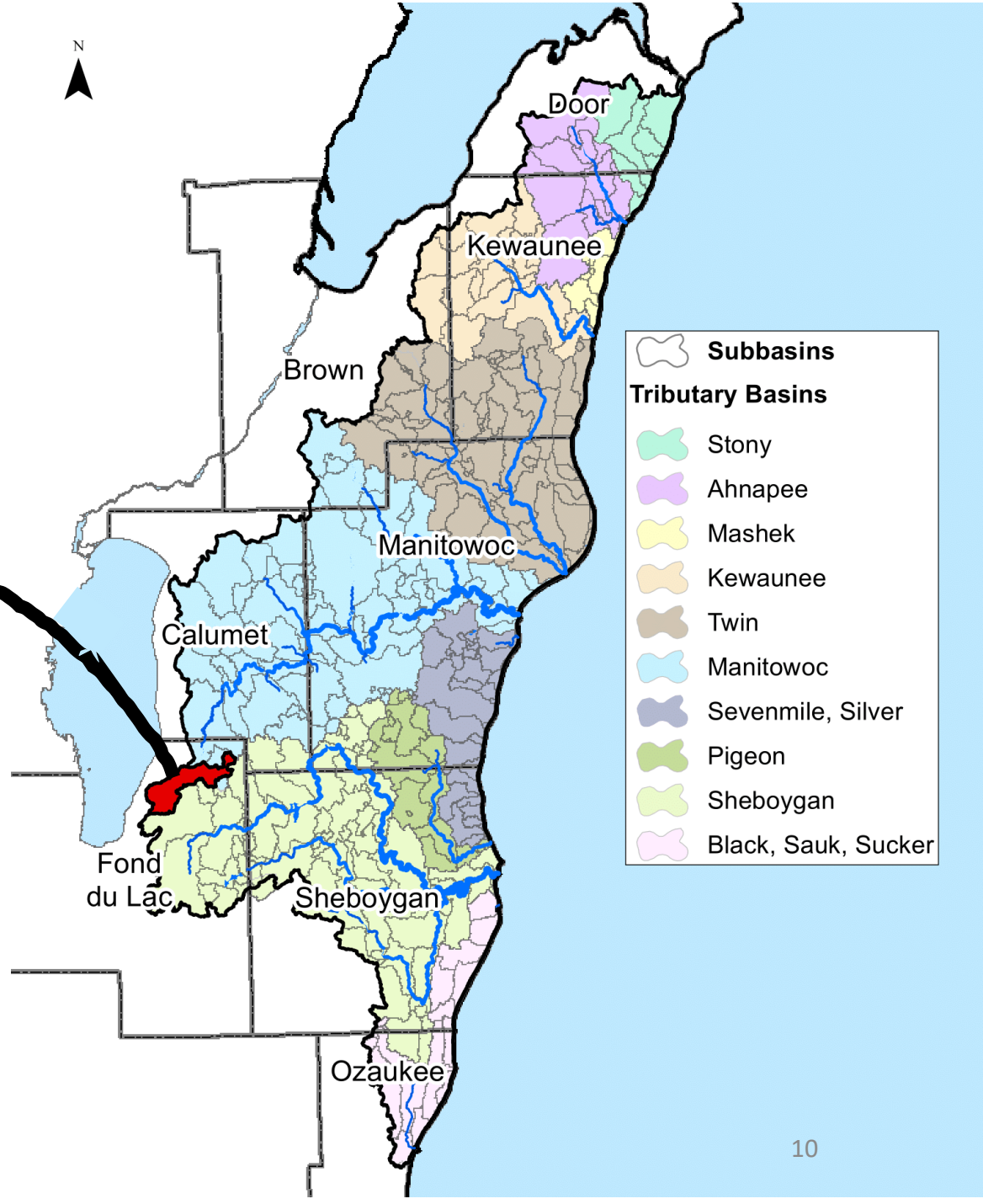
2) To provide the relative pollutant contribution from nonpoint pollutant sources in each of the 321 subbasins

Example Baseline Load

Subbasin 184



*From effluent monitoring



Watershed model development process

Webinar 3

Model inputs:

2008 – 2019 Conditions

- Climate
  Precipitation, Temp
- Agricultural Land Management
- Land Cover
- Soils
  Type and Attributes
- Topography
  Slope
- Hydrography
- Point Sources

Webinar 2

Stream flow and water chemistry monitoring data

Watershed model setup

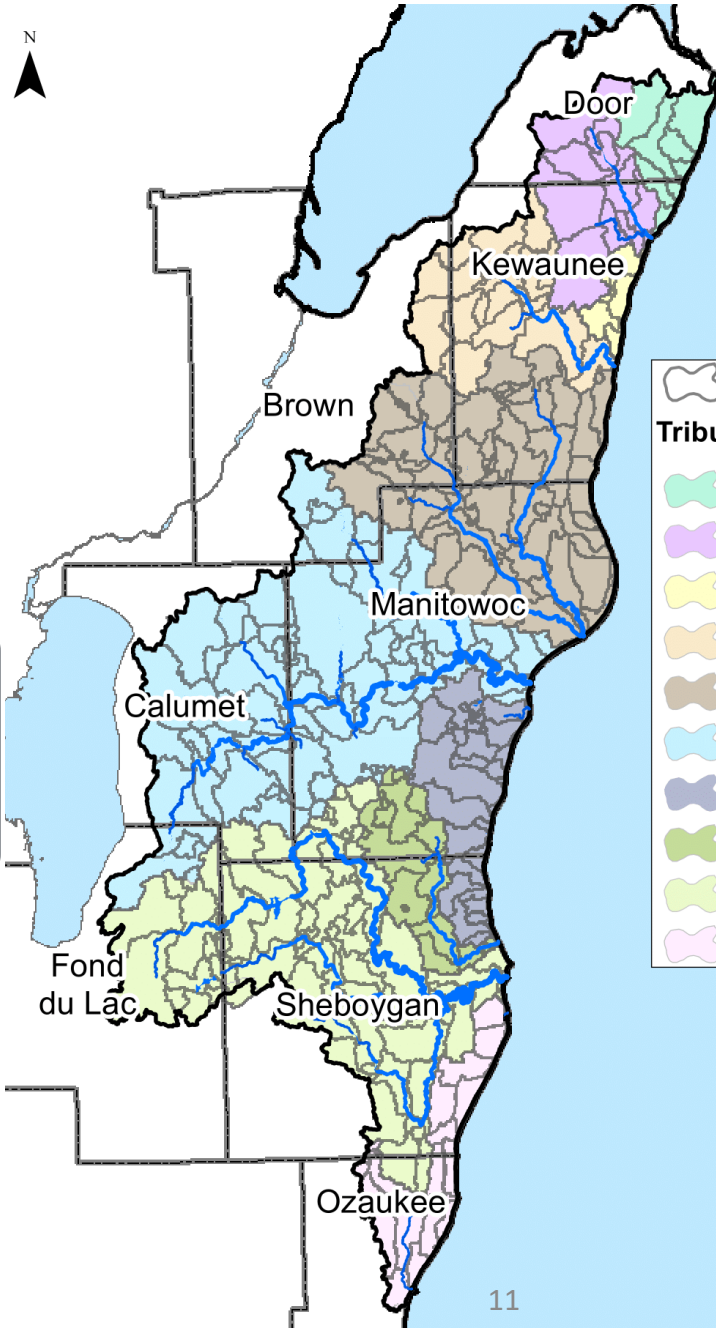
Calibrate watershed model

Model outputs:

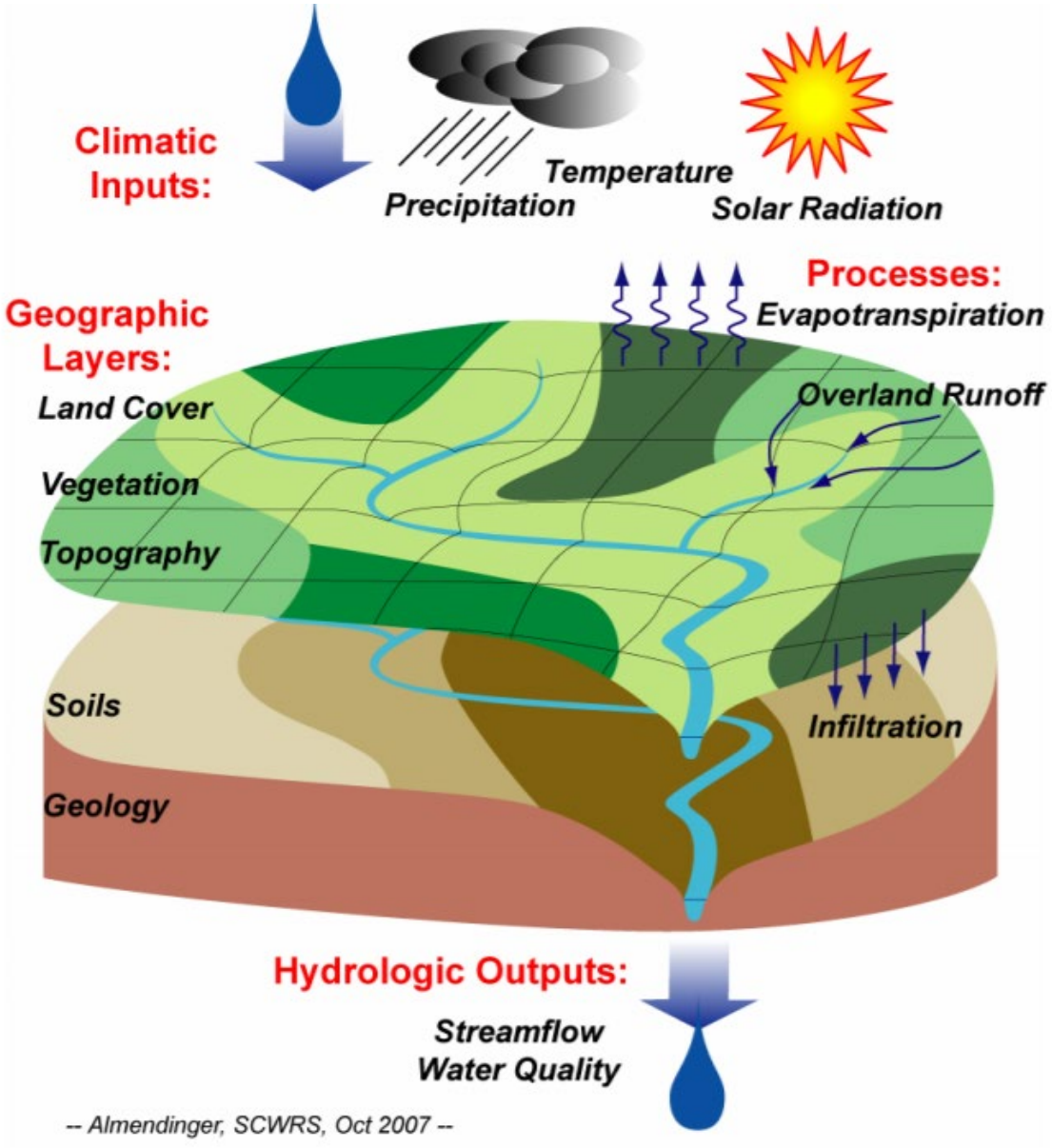
For each subbasin:
- Stream flow
- Baseline
TP & TSS loads

Webinar 4

Future meeting/webinar
Late 2020/Early 2021



Soil and Water Assessment Tool (SWAT)



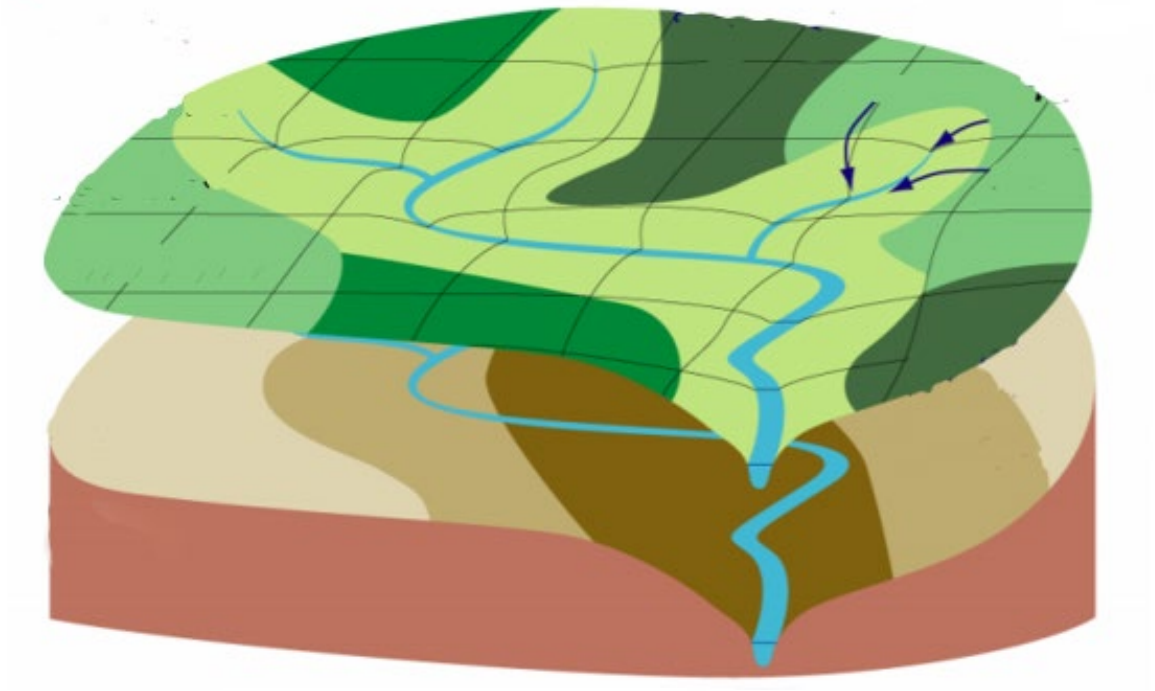
Simulates hydrologic and nutrient cycles each day, in each subbasin, based on the data inputs

Modeling Units

1) Subbasin

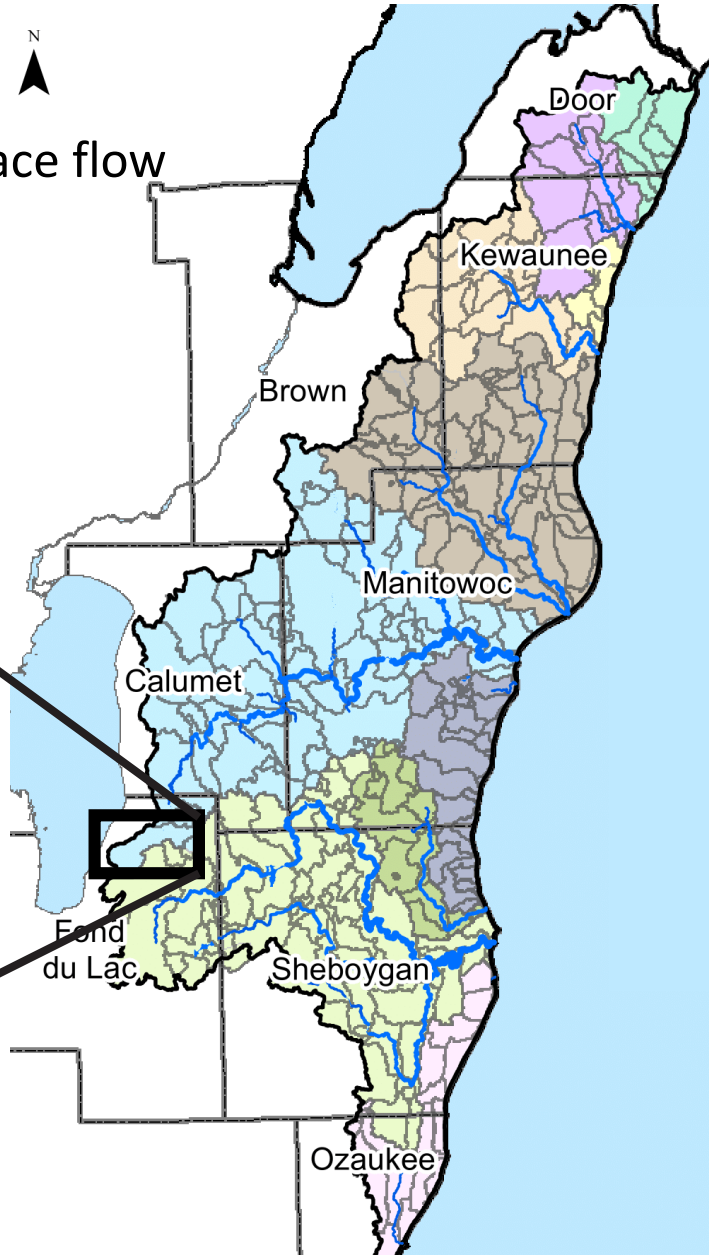
- Based on watershed boundaries
- Guide water and pollutants downstream through tributaries and subsurface flow
- Subbasin scale outputs are used for TMDL development

Subbasin:



Hydrologic Outputs:

Streamflow
Water Quality



Modeling Units

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See Webinar 3 or draft report for more detail

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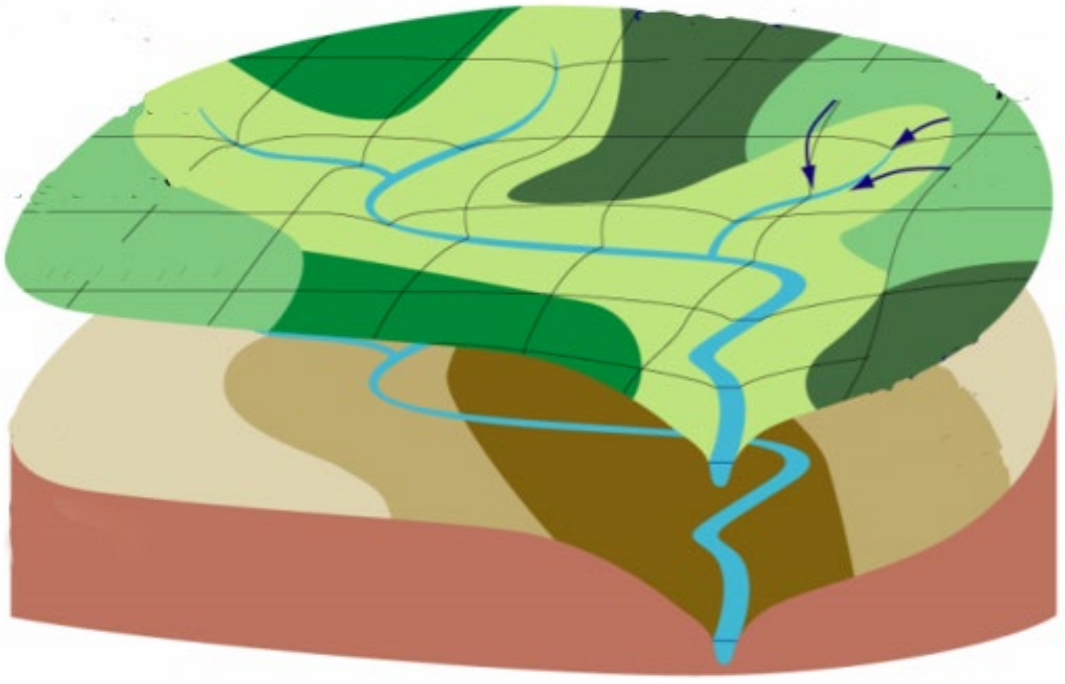

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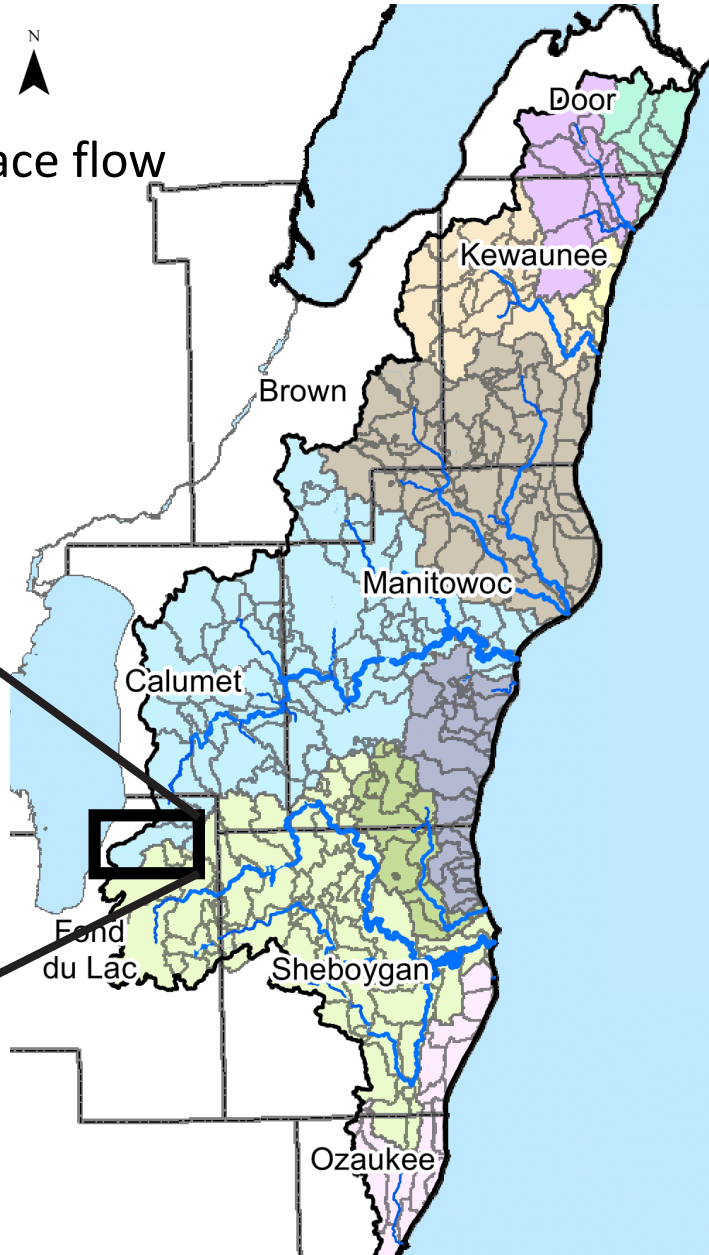

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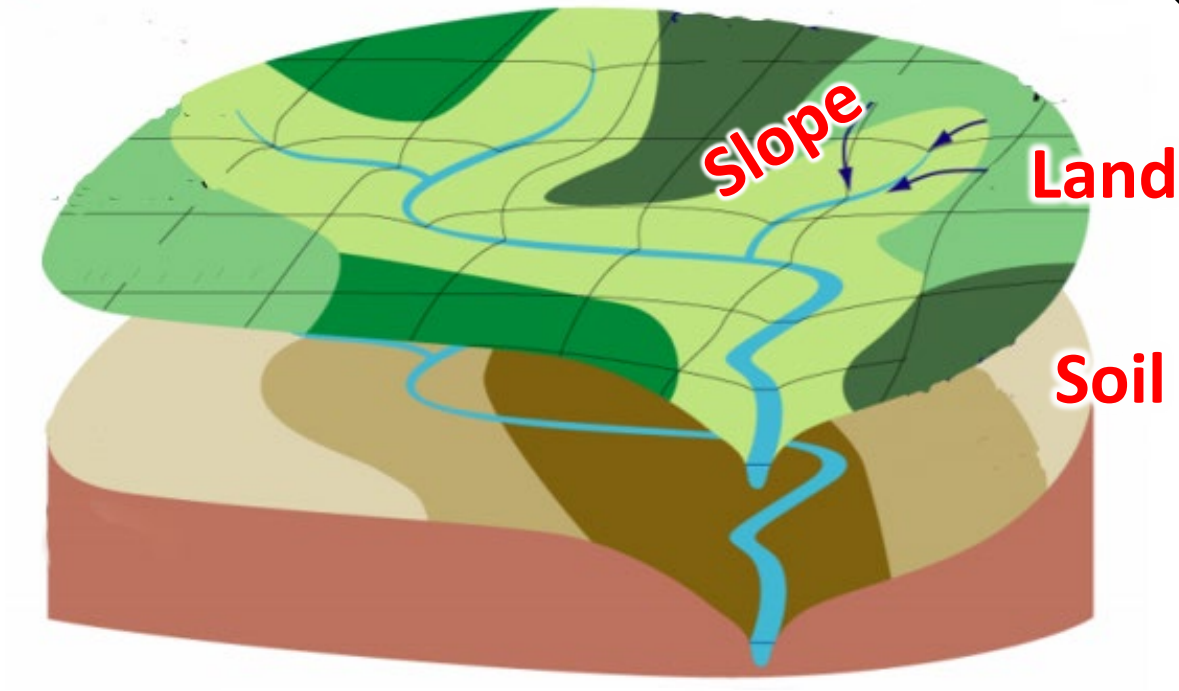

Hydrologic Outputs:

Streamflow
Water Quality

2) Hydrologic Response Units (HRUs)

Unique Combinations of
Land Use – Soil – Slope
per subbasin

Modeling Units

1) Subbasin

- Based on watershed boundaries
- Guide water and pollutants downstream through tributaries and subsurface flow
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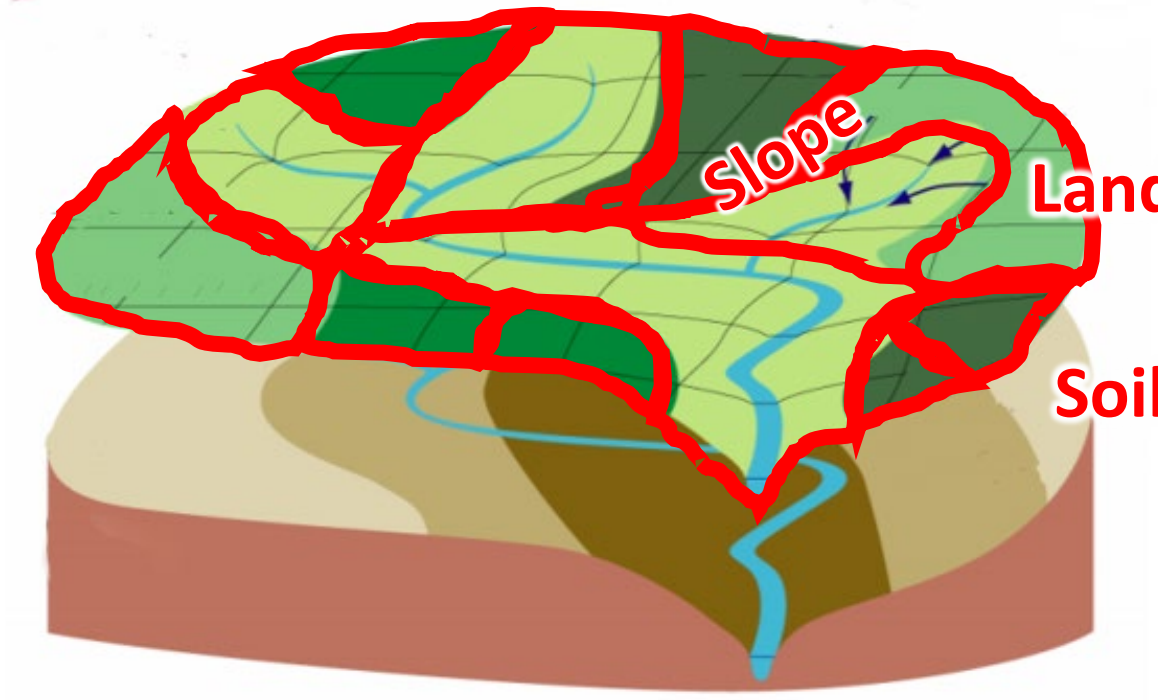
Subbasin:



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2) Hydrologic Response Units (HRUs)

- Unique Combinations of **Land Use – Soil – Slope** per subbasin
- Nested within subbasins
- Model simulates flow and pollutant runoff for each HRU

Modeling Units

1) Subbasin

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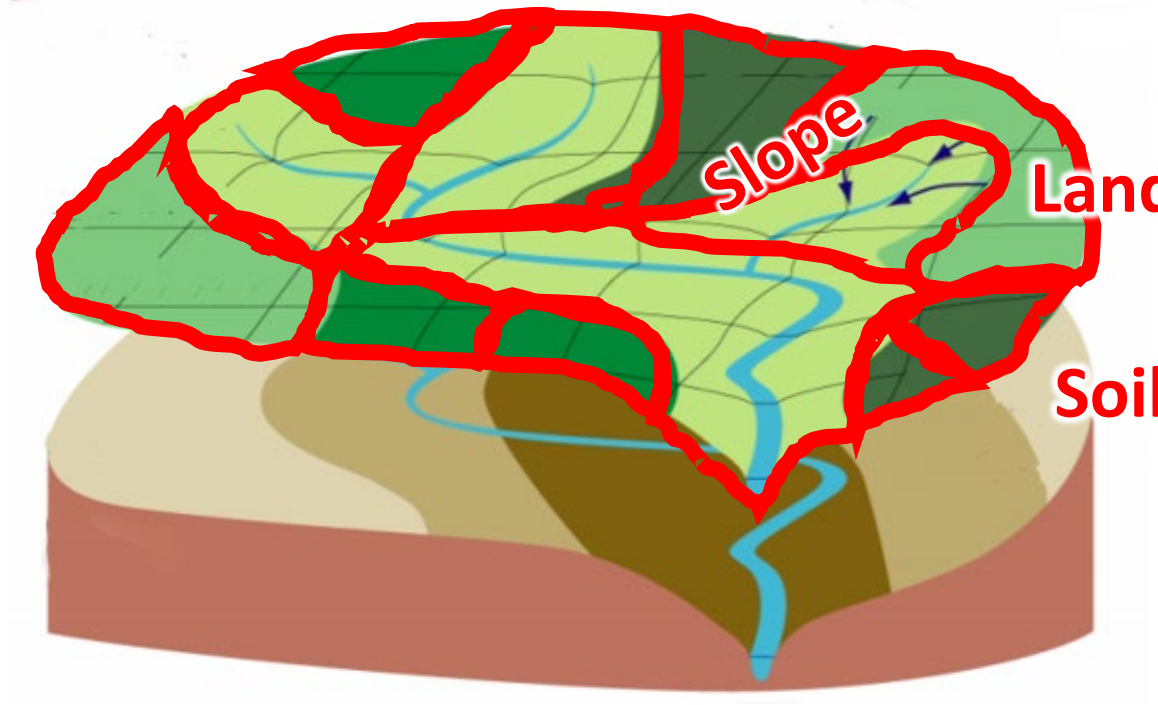

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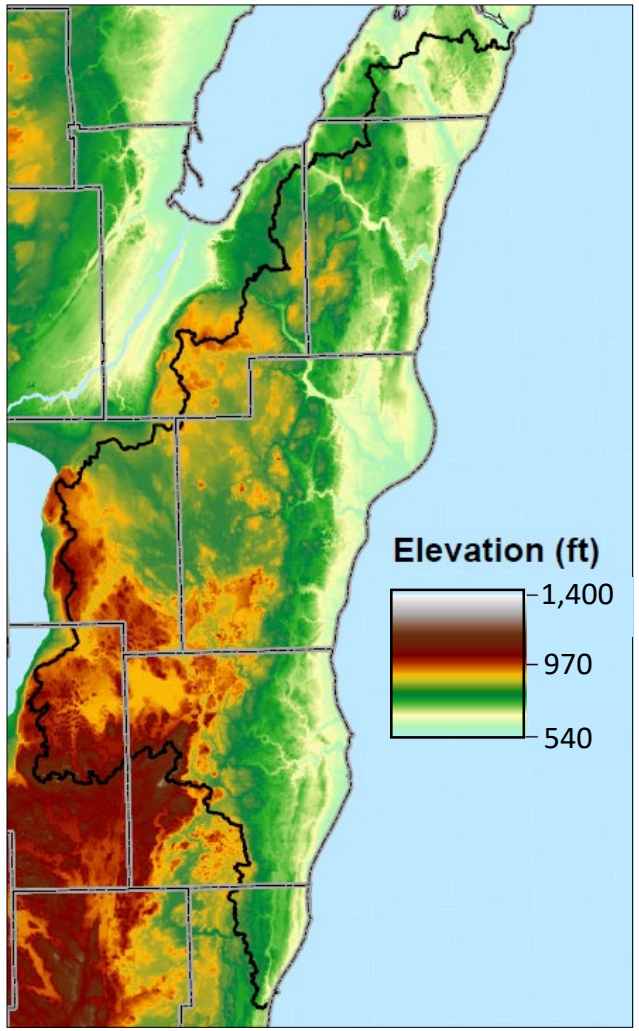
- Unique Combinations of **Land Use – Soil – Slope** per subbasin
- Nested within subbasins
- Model simulates flow and pollutant runoff for each HRU

Creating HRUs for the NE Lakeshore SWAT model

Unique combinations of slope – soil – land use – per subbasin

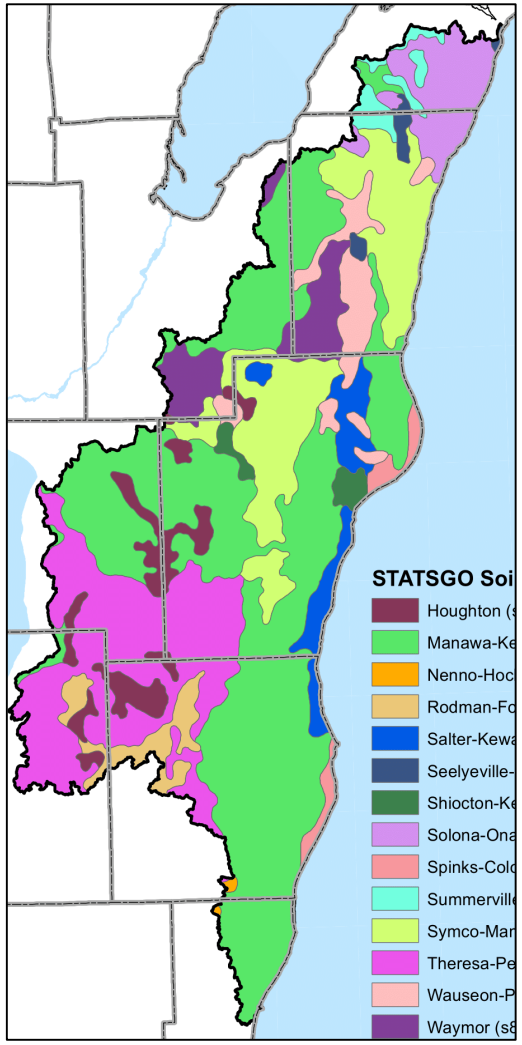
Slope

Source: DEM



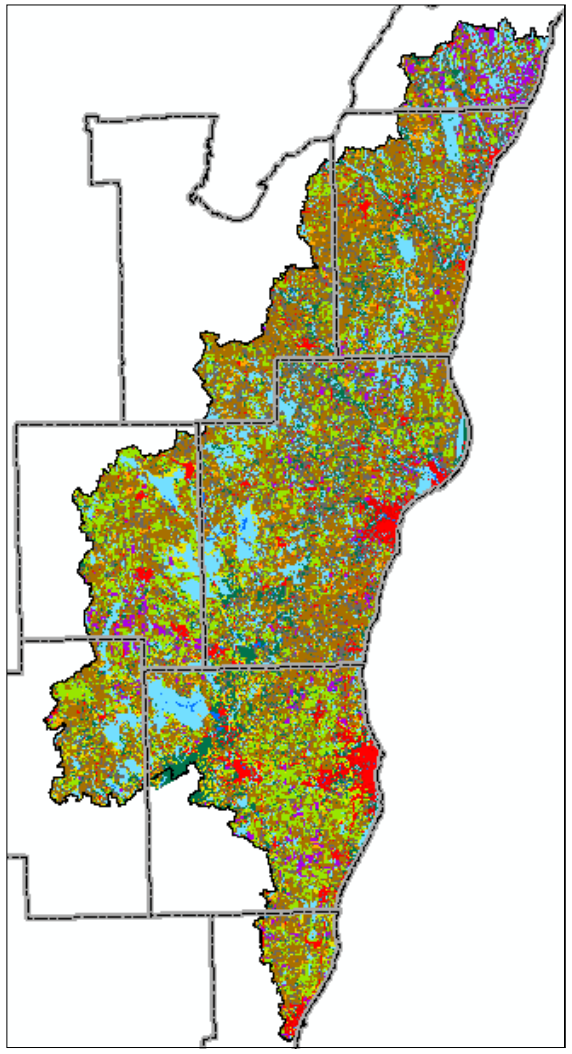
Soils

Source: SSURGO & STATSGO



Land use

Source: Wisland2 & County agricultural questionnaire survey



Dairy
- Dairy Rotation 1, Till 1
- Dairy Rotation 1, Till 2
- Dairy Rotation 1, Till 3
- Dairy Rotation 2, Till 1
- Dairy Rotation 2, Till 2
- Dairy Rotation 2, Till 3
- Dairy Rotation 3, Till 1
- Dairy Rotation 3, Till 2
- Dairy Rotation 3, Till 3

Cash Grain
- Cash Grain 1, Till 1
- Cash Grain 1, Till 2
- Cash Grain 1, Till 3
- Cash Grain 1, Till 4

Continuous Corn
- Continuous Corn, Till 1
- Continuous Corn, Till 2
- Continuous Corn, Till 3

Hay
- Continuous Hay, no till

Ag

Urban
- Urban, low intensity
- Urban, low intensity, MS4
- Urban, high intensity
- Urban high intensity, MS4

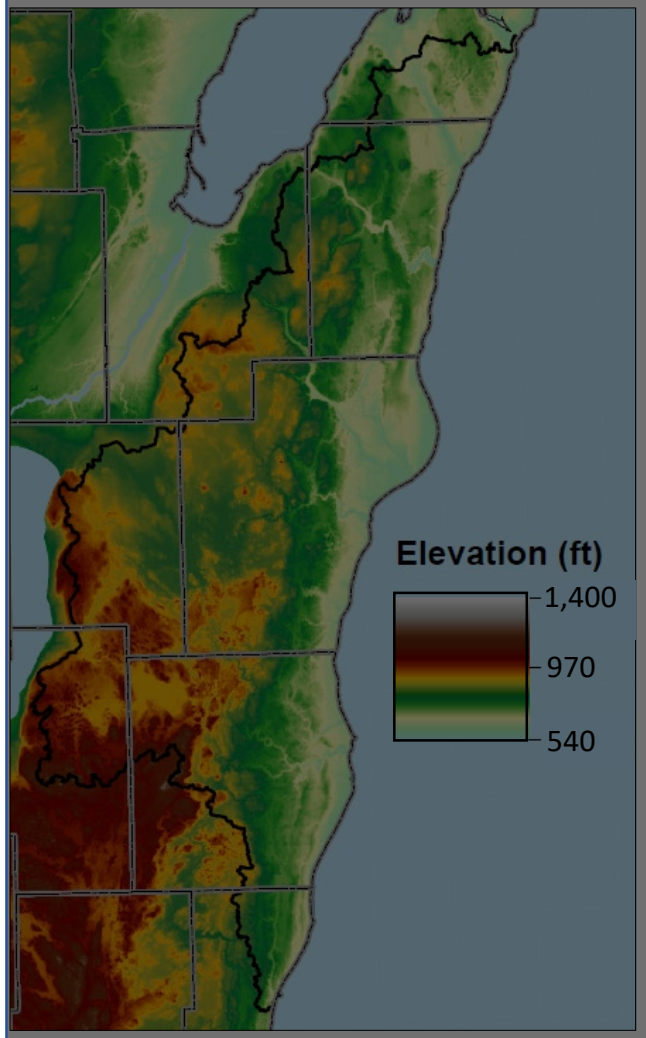
Natural
- Forest
- Wetland
- Grassland

Creating HRUs for the NE Lakeshore SWAT model

Unique combinations of slope – soil – land use – per subbasin

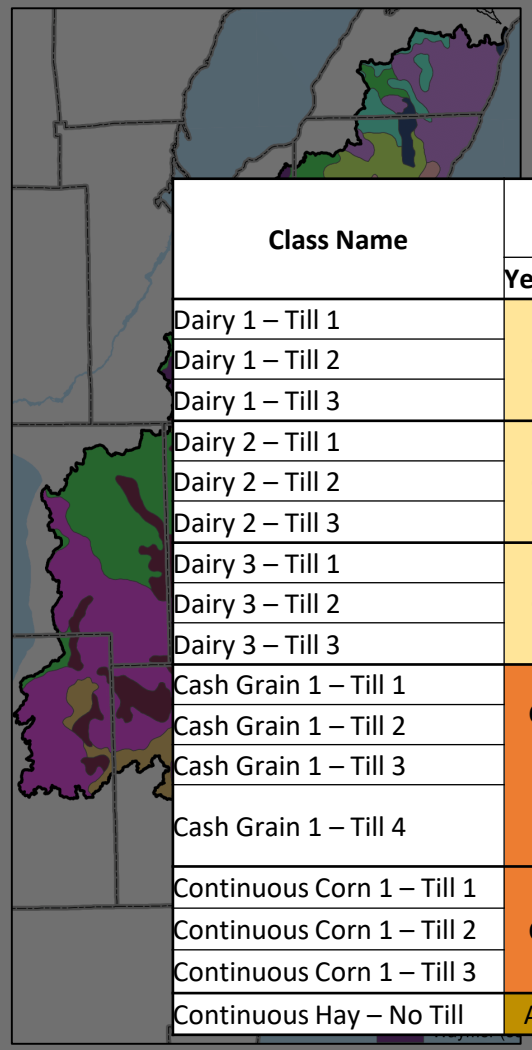
Slope

Source: DEM



Soils

Source: SSURGO & STATSGO



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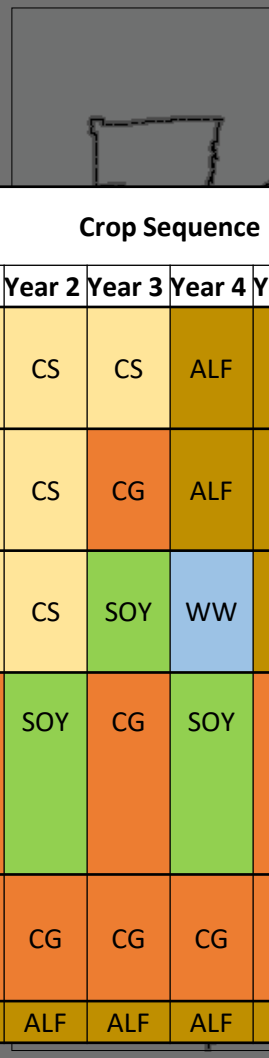

Dairy

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- Dairy Rotation 1, Till 3
- Dairy Rotation 2, Till 1
- Dairy Rotation 2, Till 2
- Dairy Rotation 2, Till 3
- Dairy Rotation 3, Till 1
- Dairy Rotation 3, Till 2
- Dairy Rotation 3, Till 3

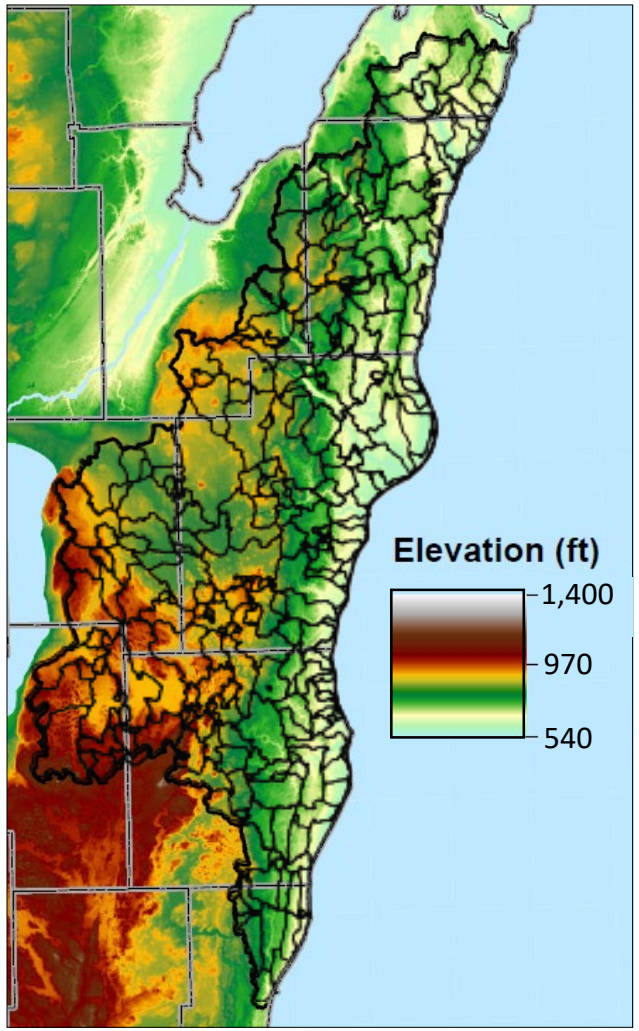
Class Name	Crop Sequence						Fall Tillage	Spring Tillage	Chemical P2O5 (lb/ac/yr)	Manure
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6				
Dairy 1 – Till 1	CS	CS	CS	ALF	ALF	ALF	*Chisel Plow	*Cultivator, 2X	**26**	**Liquid;** unique rate per subbasin
Dairy 1 – Till 2							*Disk Plow	*Cultivator		
Dairy 1 – Till 3							*None	*Vertical Till		
Dairy 2 – Till 1	CS	CS	CG	ALF	ALF	ALF	*Chisel Plow	*Cultivator, 2X		
Dairy 2 – Till 2							*Disk Plow	*Cultivator		
Dairy 2 – Till 3							*None	*Vertical Till		
Dairy 3 – Till 1	CS	CS	SOY	WW	ALF	ALF	*Chisel Plow	*Cultivator, 2X		
Dairy 3 – Till 2							*Disk Plow	*Cultivator		
Dairy 3 – Till 3							*None	*Vertical Till		
Cash Grain 1 – Till 1	CG	SOY	CG	SOY	CG	SOY	Chisel Plow	Cultivator, 2X	**48**	None
Cash Grain 1 – Till 2							Disk Plow	Cultivator		
Cash Grain 1 – Till 3							None	Vertical Till		
Cash Grain 1 – Till 4							Chisel Plow (Corn), No Till (Soybean)	Cultivator (Corn), No Till (Soybean)		
Continuous Corn 1 – Till 1	CG	CG	CG	CG	CG	CG	Chisel Plow	Cultivator, 2X	**46**	
Continuous Corn 1 – Till 2							Disk Plow	Cultivator		
Continuous Corn 1 – Till 3							None	Vertical Till		
Continuous Hay – No Till	ALF	ALF	ALF	ALF	ALF	ALF	None	None	None	

Creating HRUs for the NE Lakeshore SWAT model

Unique combinations of slope – soil – land use – per subbasin

Slope

Source: DEM



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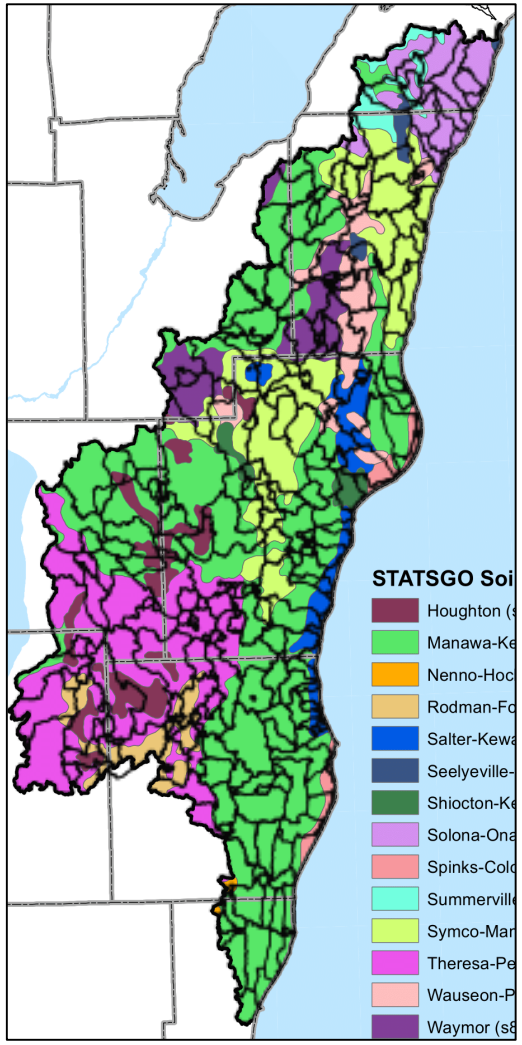
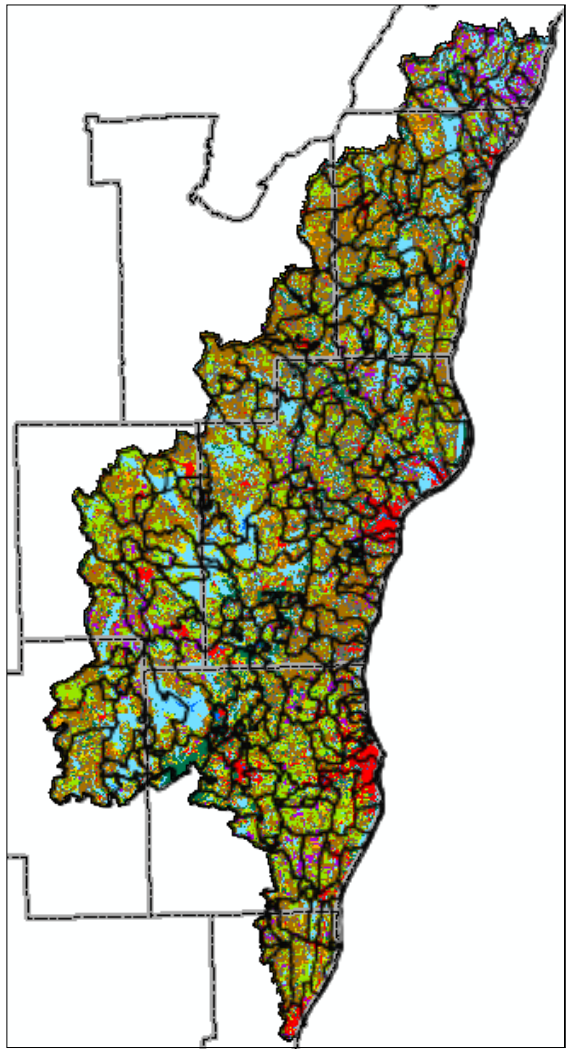


Land use

Source: Wisconsin2 & County agricultural questionnaire survey



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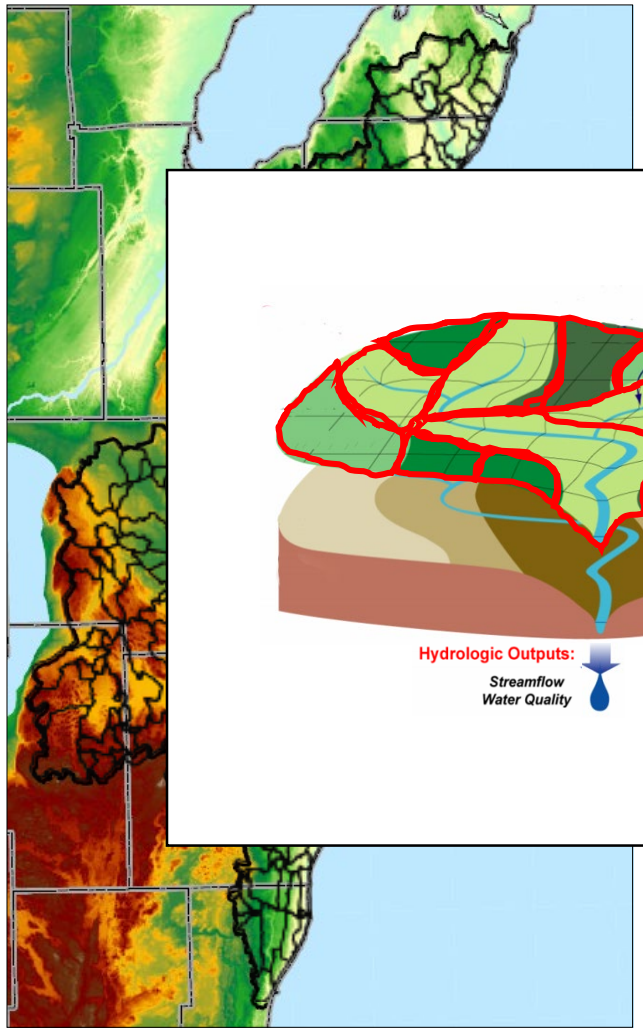
HRUs for the NE Lakeshore SWAT model

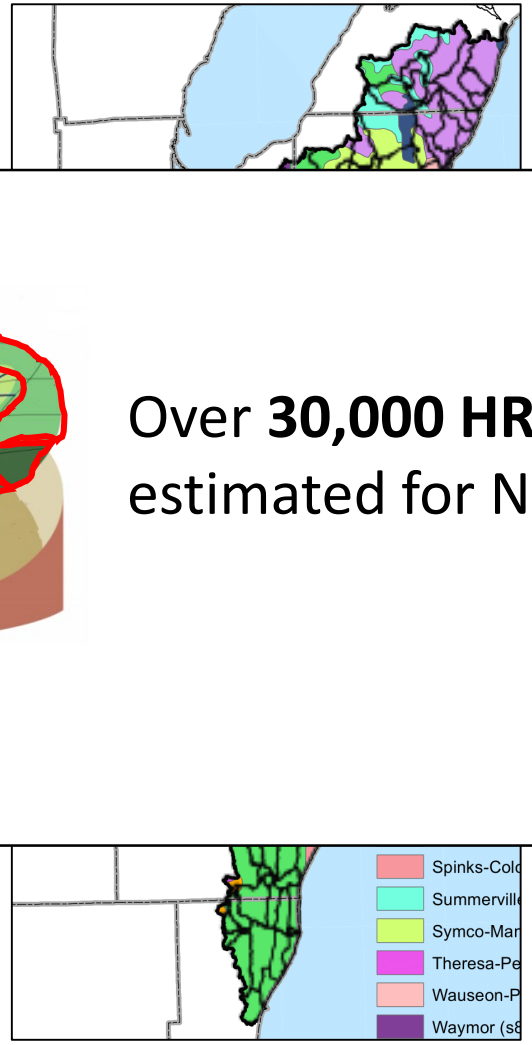
Unique combinations of slope, soil and land use **per subbasin**

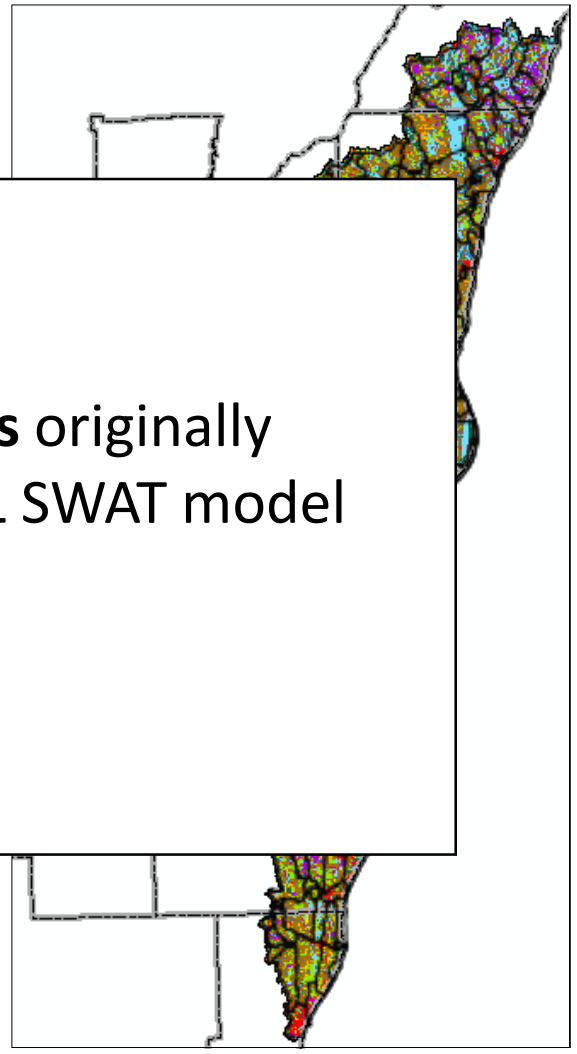
Slope
Source: DEM

Soils
Source: SSURGO & STATSGO

Land use
Source: Wiscland2 & County agricultural questionnaire survey







Over **30,000 HRUs** originally estimated for NEL SWAT model

Ag

- Dairy
  - Dairy Rotation 1, Till 1
  - Dairy Rotation 1, Till 2
  - Dairy Rotation 1, Till 3
  - Dairy Rotation 2, Till 1
  - Dairy Rotation 2, Till 2
  - Dairy Rotation 2, Till 3
  - Dairy Rotation 3, Till 1
  - Dairy Rotation 3, Till 2
  - Dairy Rotation 3, Till 3
- Cash Grain
  - Cash Grain 1, Till 1
  - Cash Grain 1, Till 2
  - Cash Grain 1, Till 3
  - Cash Grain 1, Till 4
- Continuous Corn
  - Continuous Corn, Till 1
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  - Continuous Corn, Till 3
- Hay
  - Continuous Hay, no till

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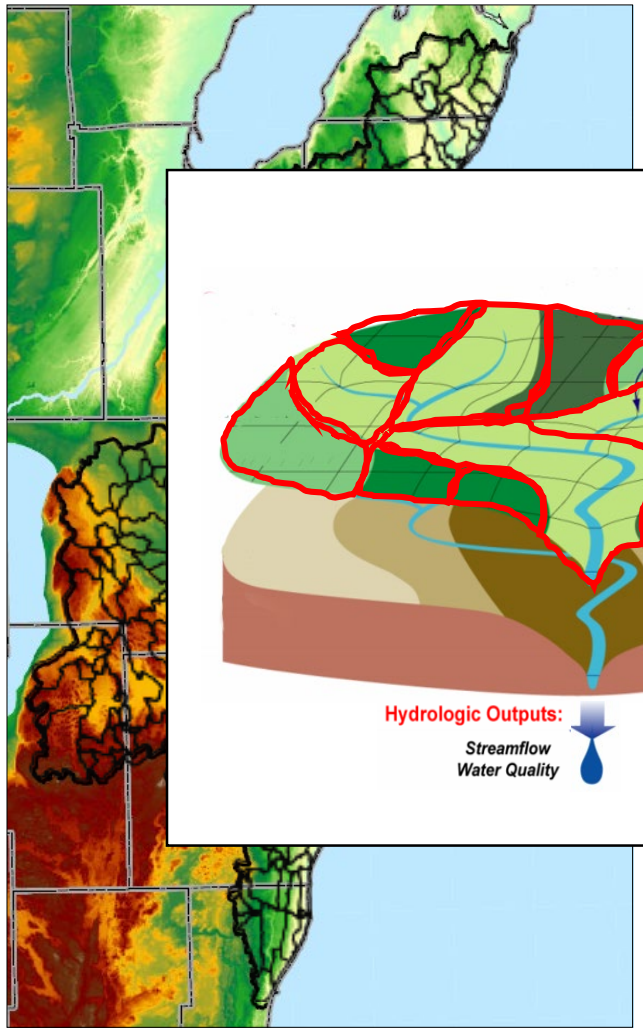
HRUs for the NE Lakeshore SWAT model

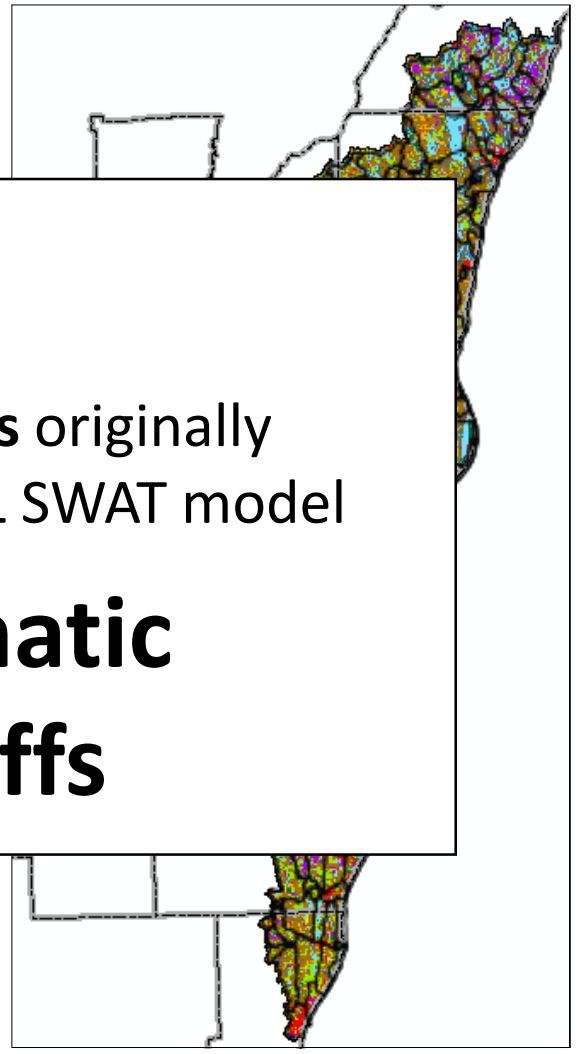
Unique combinations of slope, soil and land use **per subbasin**

Slope
Source: DEM

Soils
Source: SSURGO & STATSGO

Land use
Source: Wiscland2 & County agricultural questionnaire survey





Over **30,000 HRUs** originally estimated for NEL SWAT model

Problematic tradeoffs

- Dairy
  - Dairy Rotation 1, Till 1
  - Dairy Rotation 1, Till 2
  - Dairy Rotation 1, Till 3
  - Dairy Rotation 2, Till 1
  - Dairy Rotation 2, Till 2
  - Dairy Rotation 2, Till 3
  - Dairy Rotation 3, Till 1
  - Dairy Rotation 3, Till 2
  - Dairy Rotation 3, Till 3
- Cash Grain
  - Cash Grain 1, Till 1
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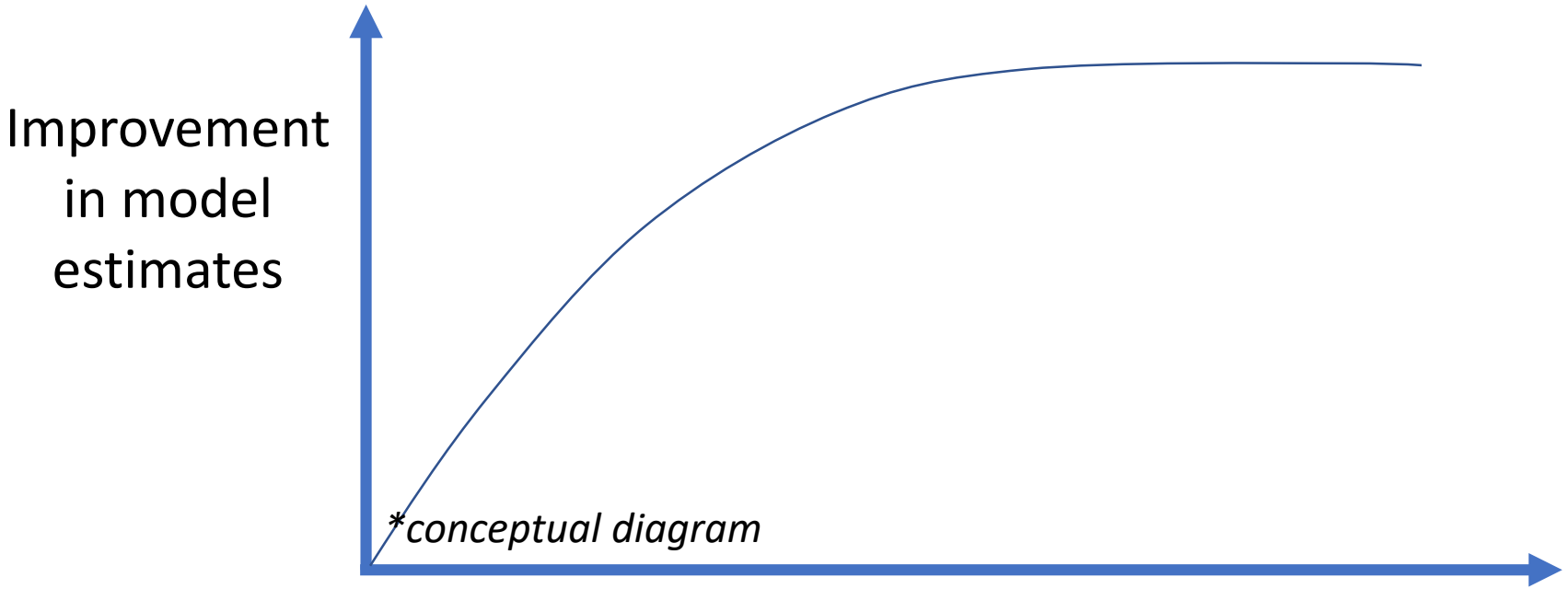
  - Cash Grain 1, Till 4
- Continuous Corn
  - Continuous Corn, Till 1
  - Continuous Corn, Till 2
  - Continuous Corn, Till 3
- Hay
  - Continuous Hay, no till

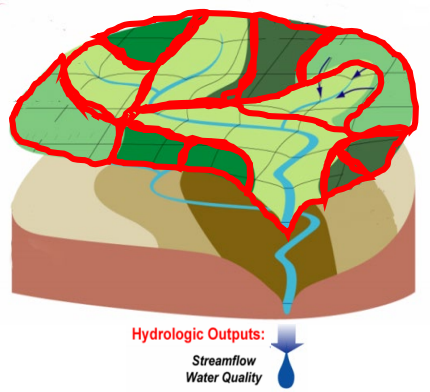
Ag

- Urban
  - Urban, low intensity
  - Urban, low intensity, MS4
  - Urban, high intensity
  - Urban high intensity, MS4
- Natural
  - Forest
  - Wetland
  - Grassland

Balance HRUs to reduce tradeoffs

After a certain number of HRUs, the additional HRU details do not significantly improve the the model's estimates





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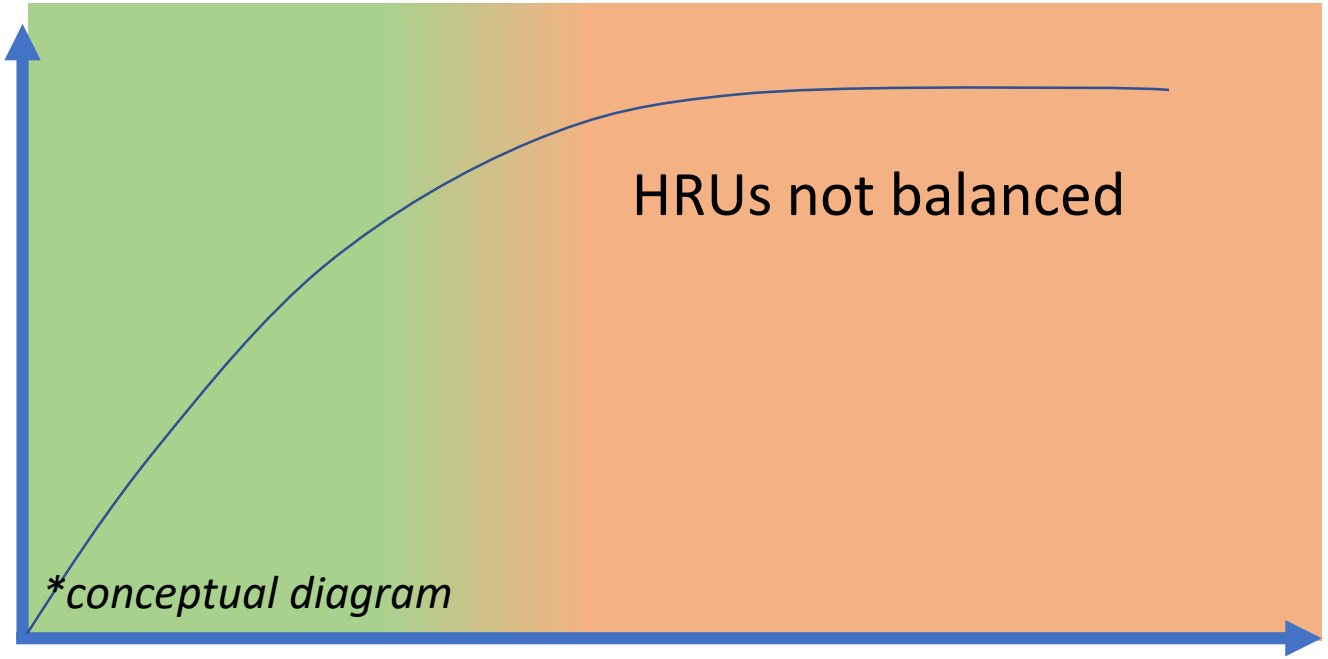
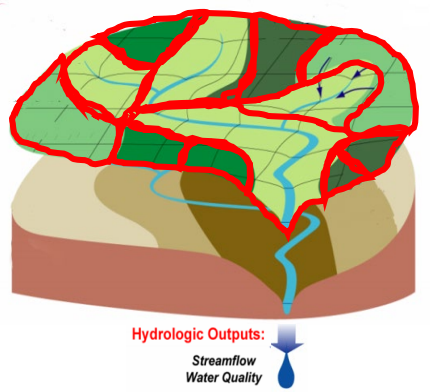
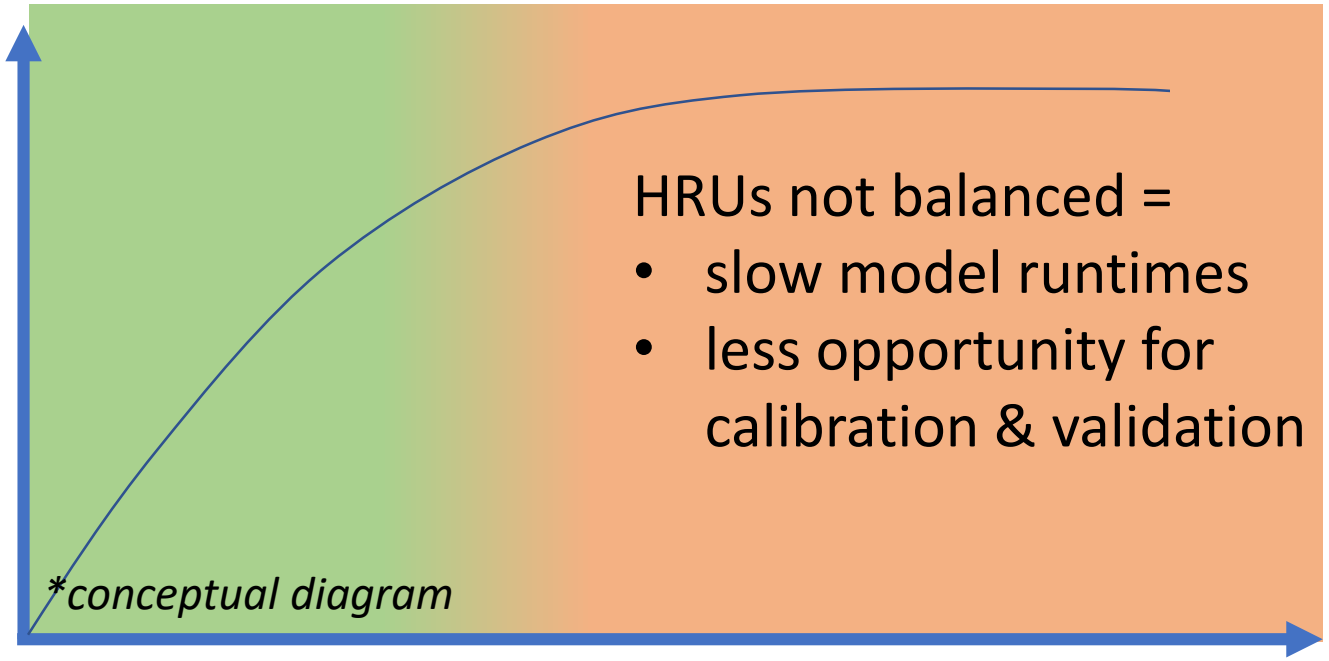




Balance HRUs to reduce tradeoffs

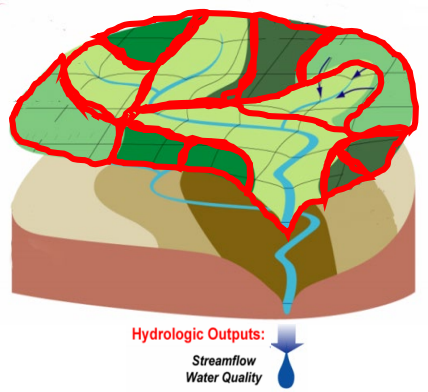
After a certain number of HRUs, the additional HRU details do not significantly improve the the model's estimates

Improvement in model estimates



Number of HRUs

(unique land use – soil – slope combinations per subbasin)



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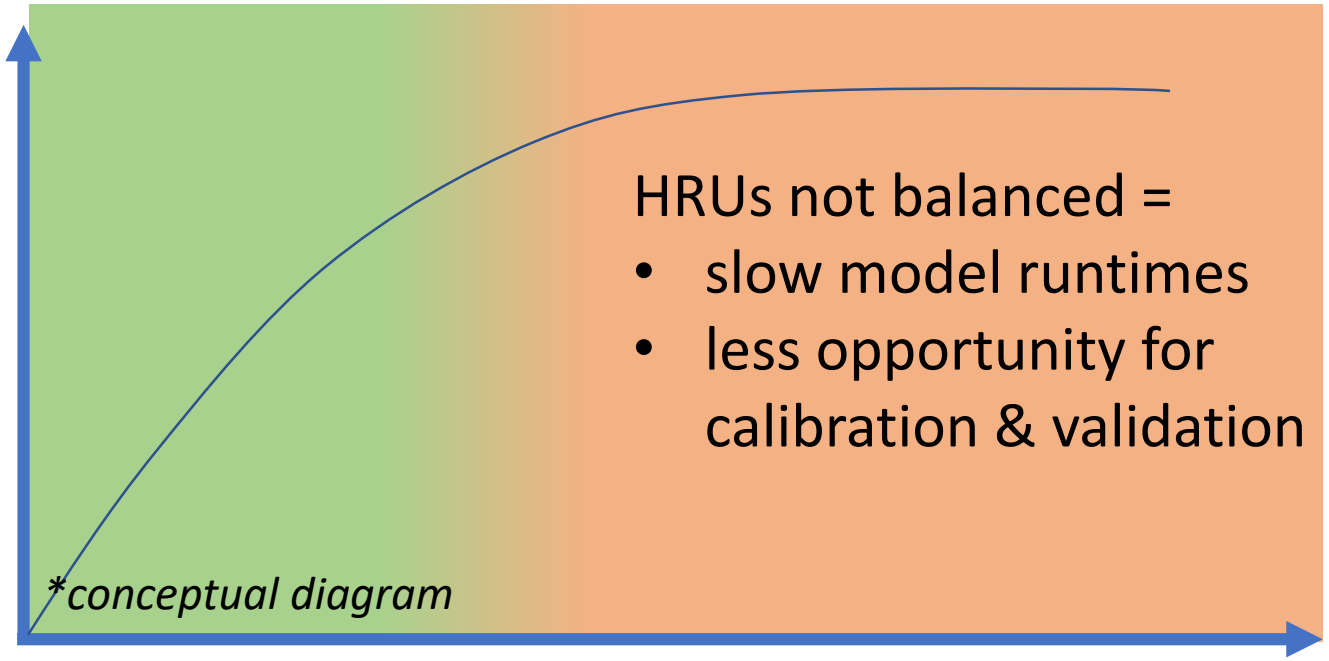
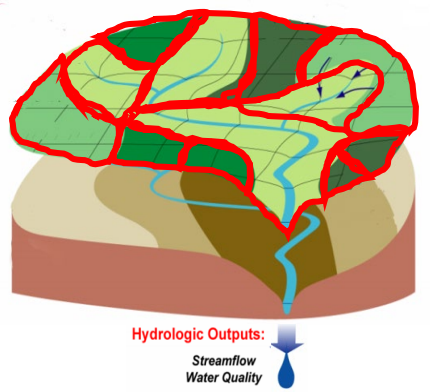


Number of HRUs

(unique land use – soil – slope combinations per subbasin)

calibration and validation

- A key step for improving model estimates
- Involves adjusting model parameters to better match model outputs with real-world stream monitoring data



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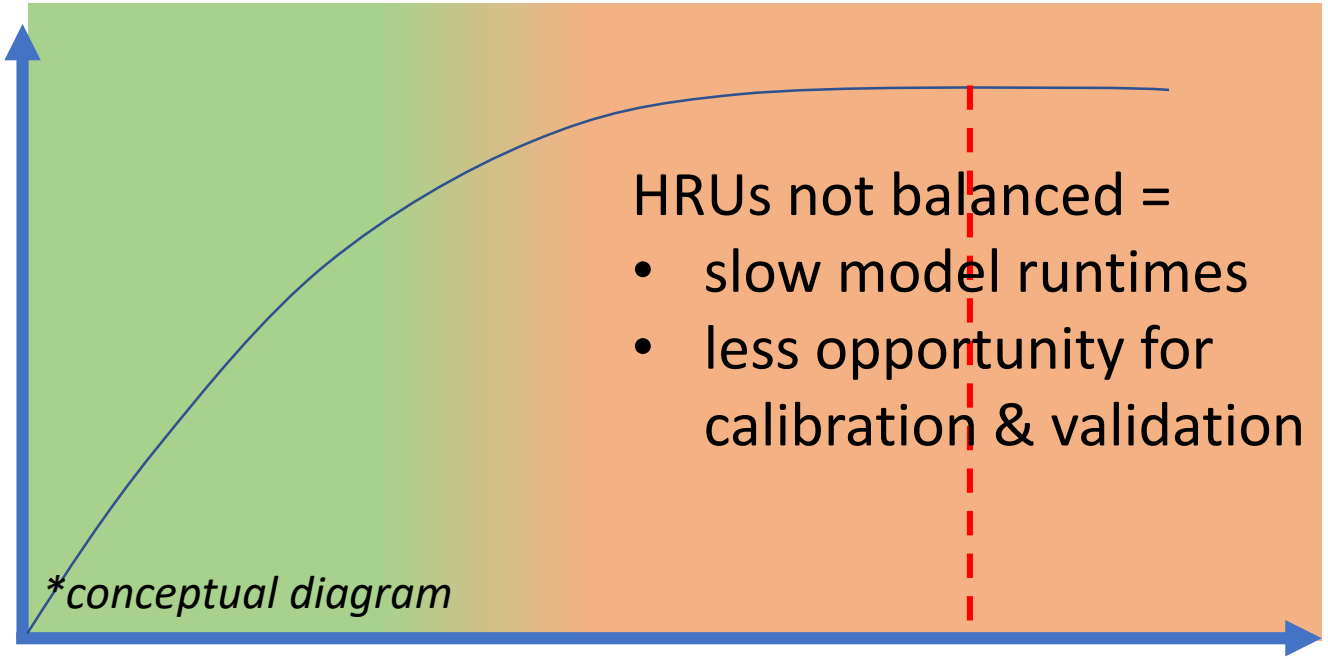

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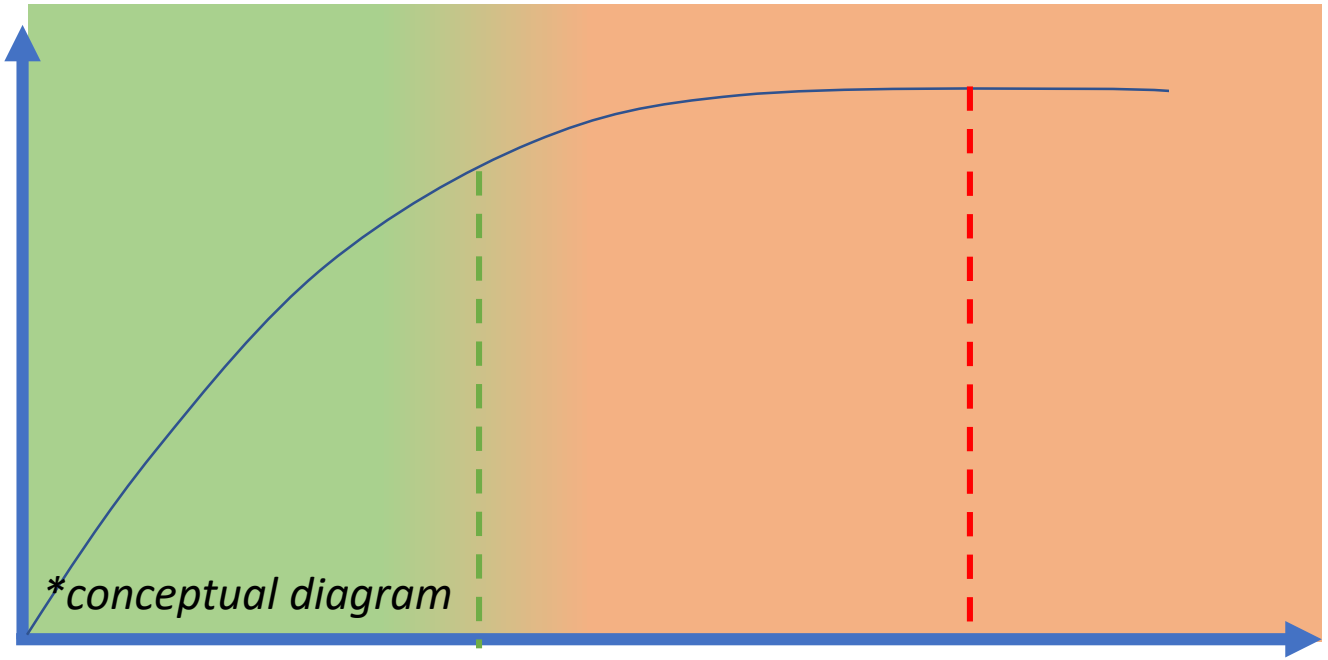

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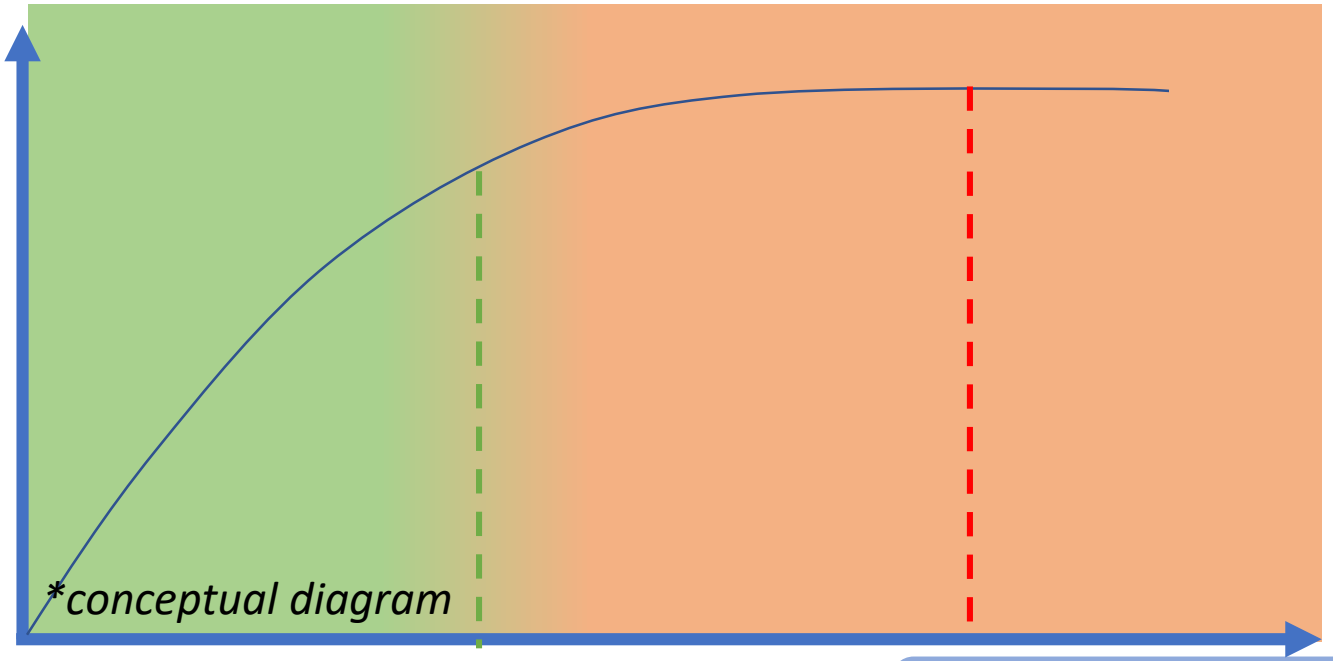
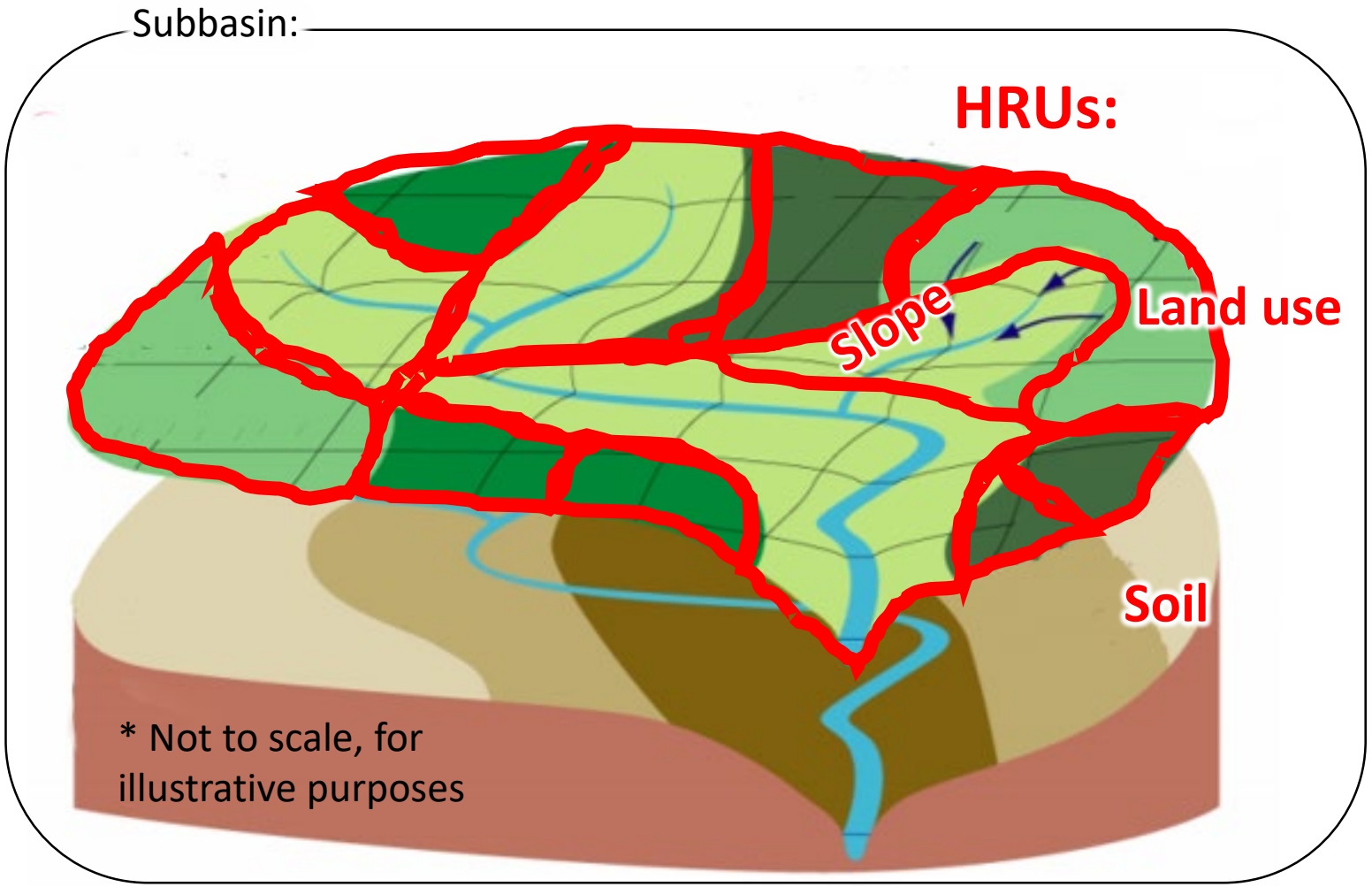


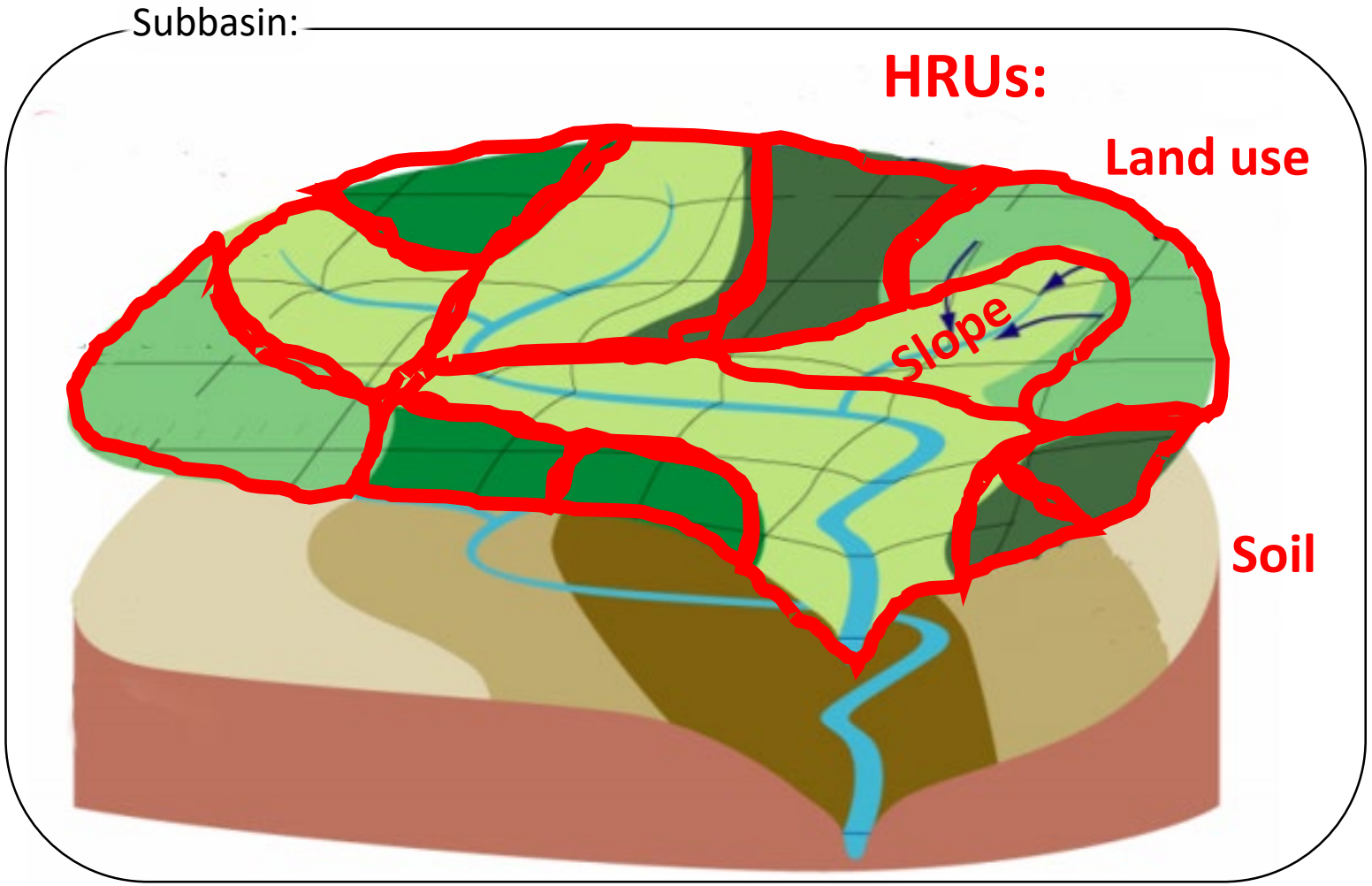
Original slope, soil, and land use layers still preserved and used for TMDL implementation

Reducing HRUs for the NE Lakeshore TMDL SWAT model



- Minimum area thresholds
- Prevents the creation of HRUs for land cover, soil, and slope classes that cover only a small area in the subbasin
- Results in…
  - less HRUs
  - improved model efficiency
  - increased opportunity for model calibration and validation

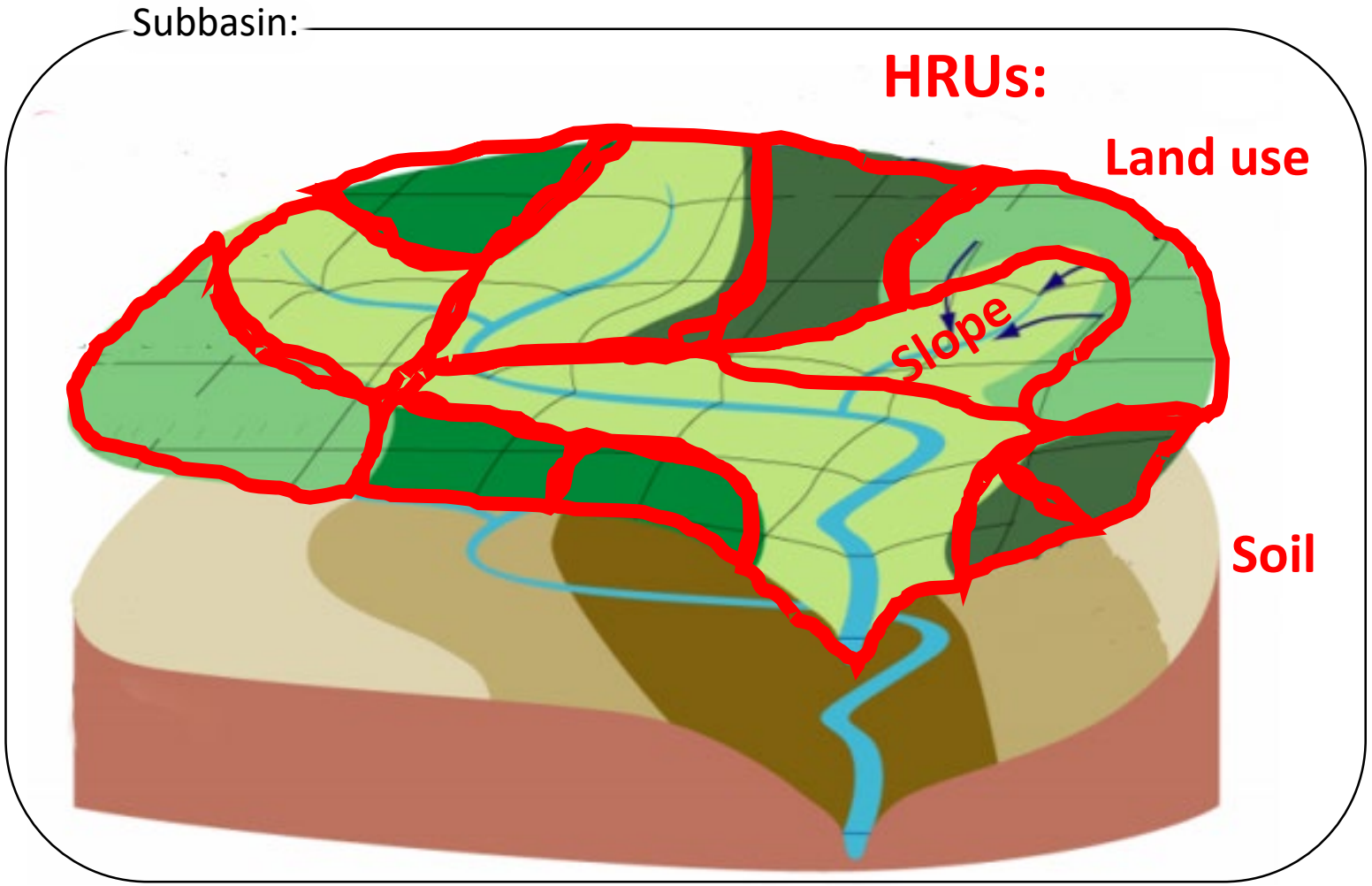
Reducing HRUs for the NE Lakeshore TMDL SWAT model



Threshold development

Iteratively developed thresholds until HRUs were optimized against model efficiency (runtime)

Reducing HRUs for the NE Lakeshore TMDL SWAT model

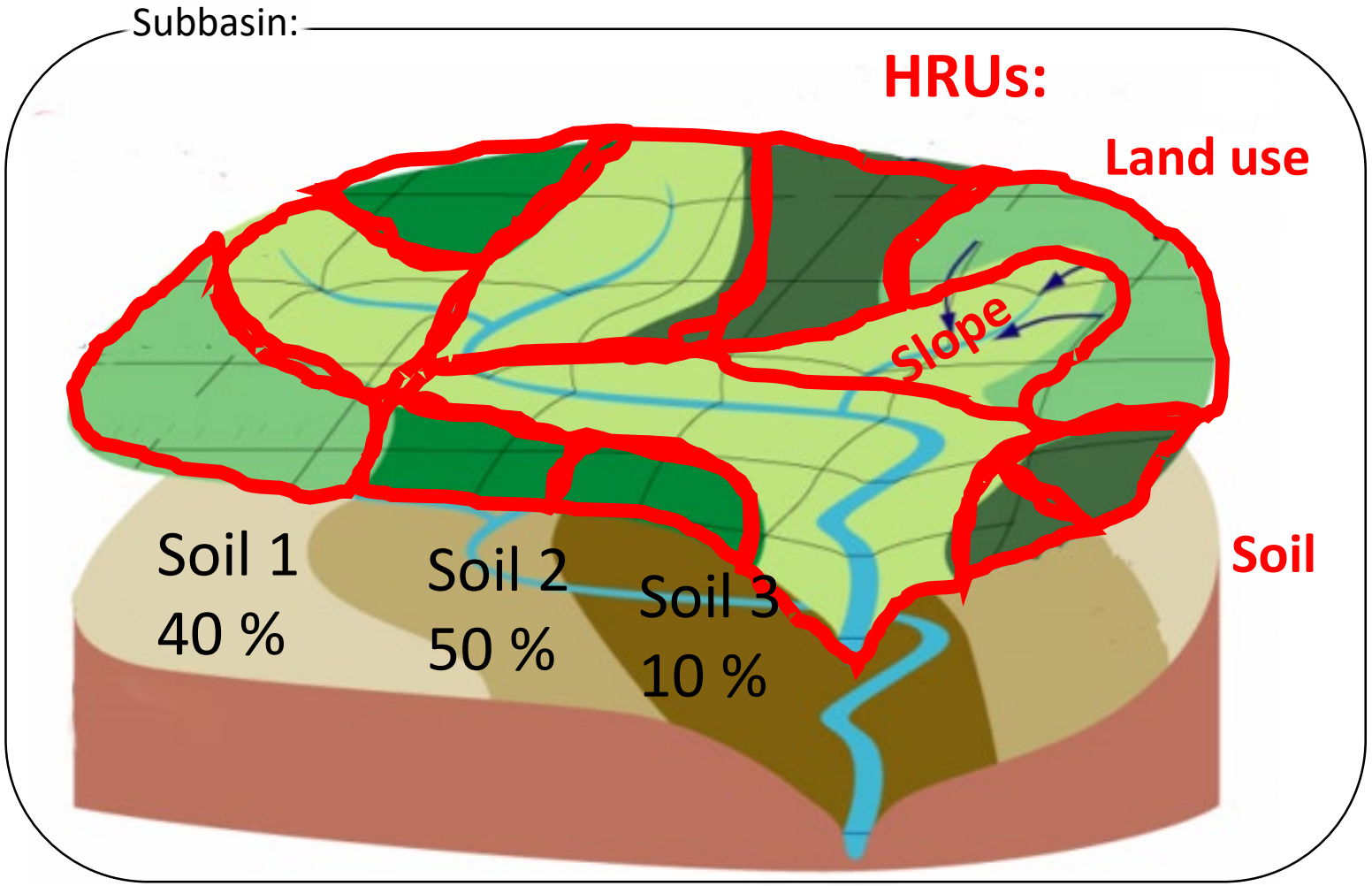


Soil Threshold

Soil class must be more than 20% of area in subbasin to be preserved

If less than 20% of area, soil class was re-classified based on the amount of other soil classes that were over 20% in the subbasin

Reducing HRUs for the NE Lakeshore TMDL SWAT model



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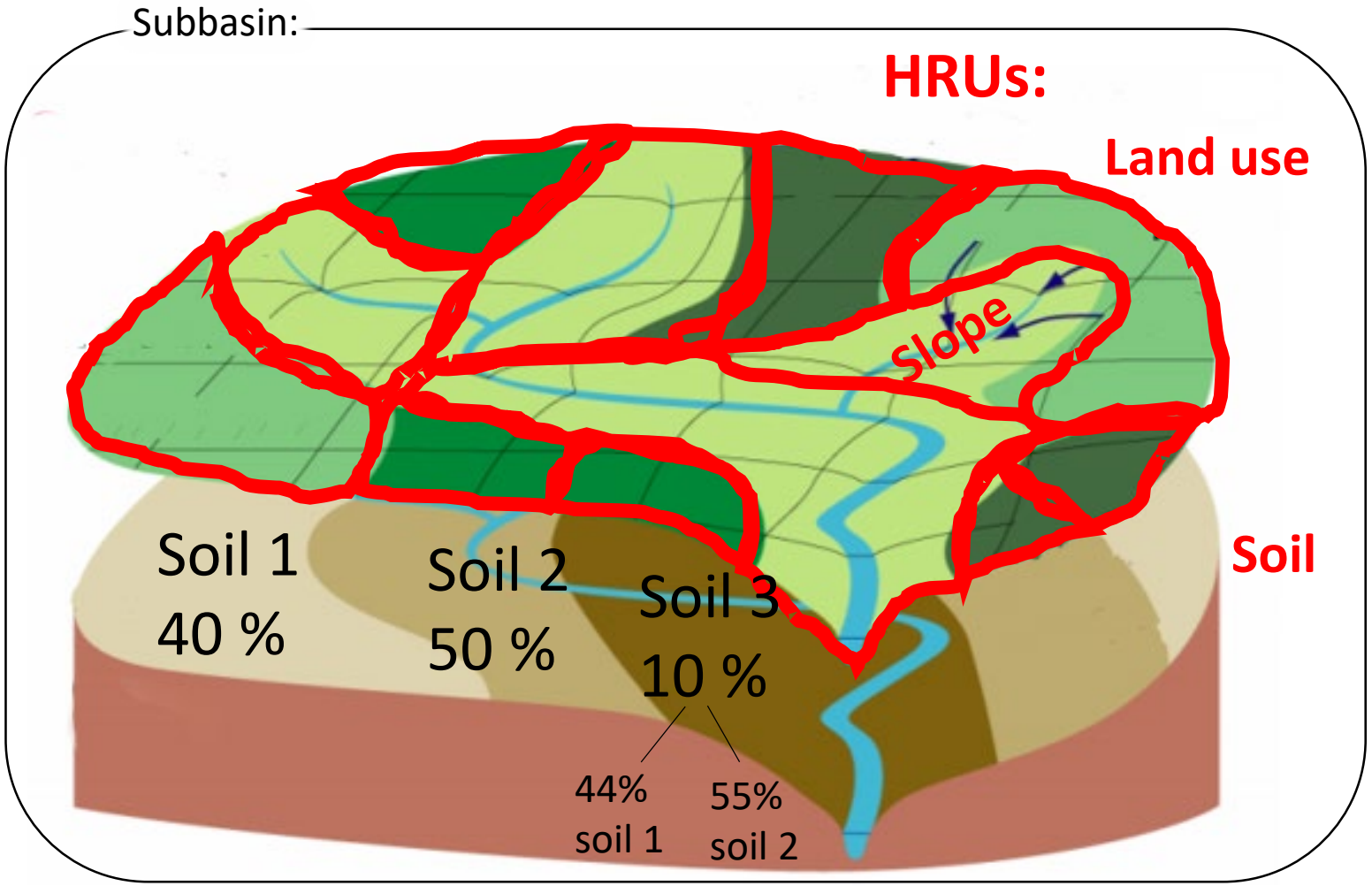

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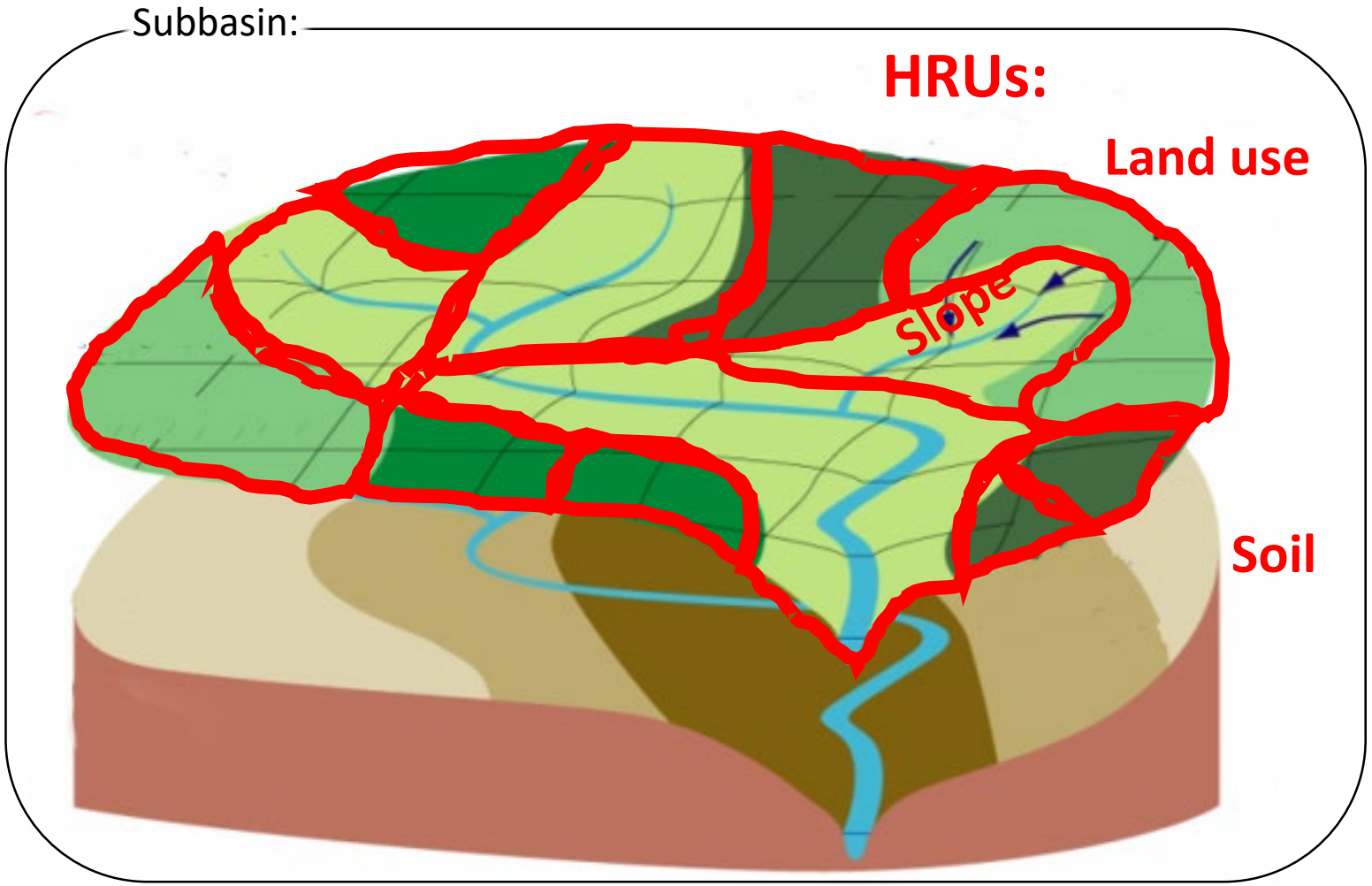
Reducing HRUs for the NE Lakeshore TMDL SWAT model

Use minimum area thresholds prevent the definition of HRUs for land cover and soil classes that cover only a small proportion of a subbasin, thereby reducing the total number of HRUs and improving model efficiency



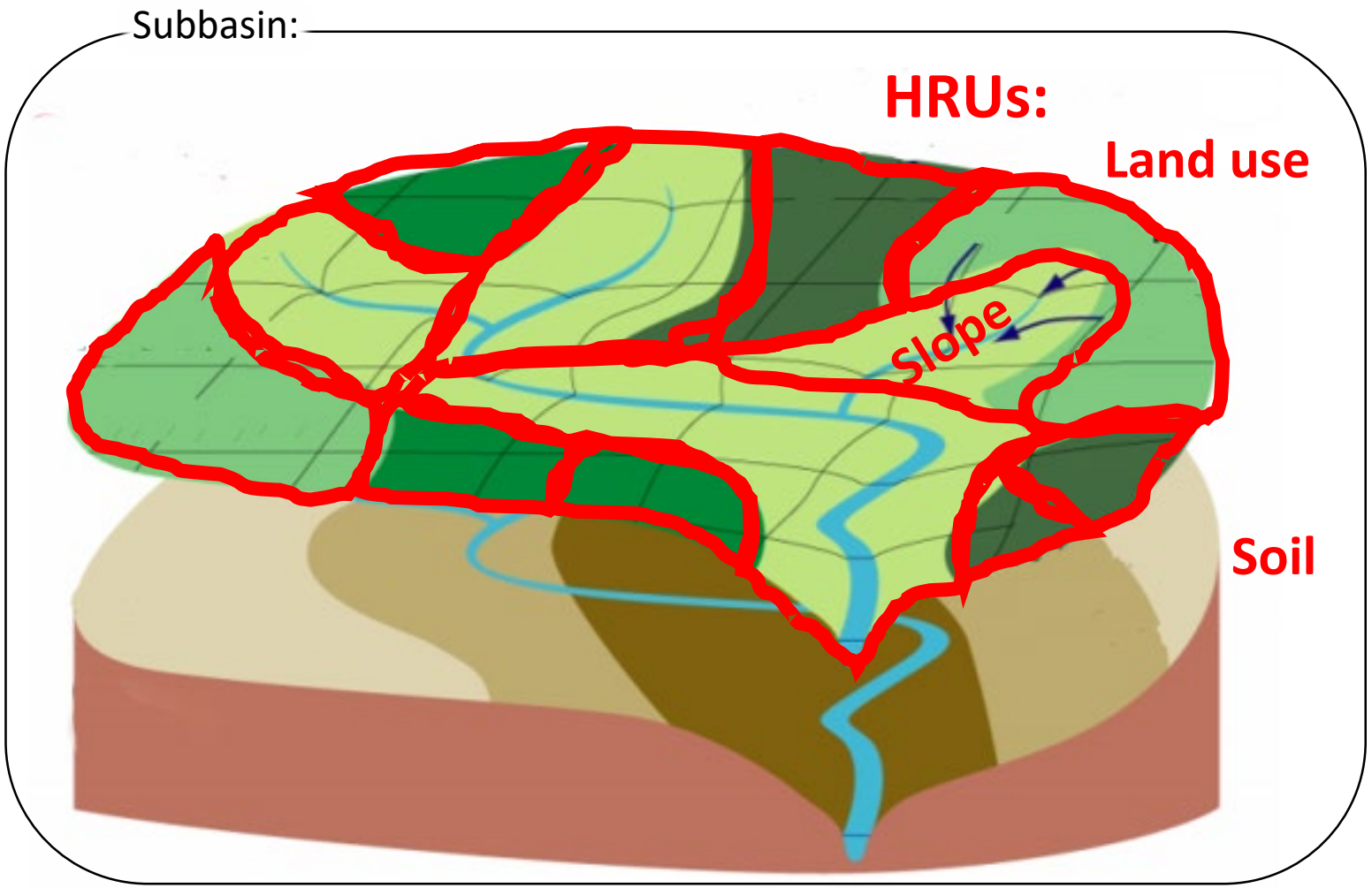
Slope Threshold Summary

1 slope type per subbasin (Average slope of subbasin)

Slope could vary among subbasins.

Reducing HRUs for the NE Lakeshore TMDL SWAT model

Use minimum area thresholds prevent the definition of HRUs for land cover and soil classes that cover only a small proportion of a subbasin, thereby reducing the total number of HRUs and improving model efficiency



Land Use Threshold Summary

In general, land use had to be greater than 5 % of subbasin area to be preserved

Reducing HRUs for the NE Lakeshore TMDL SWAT model

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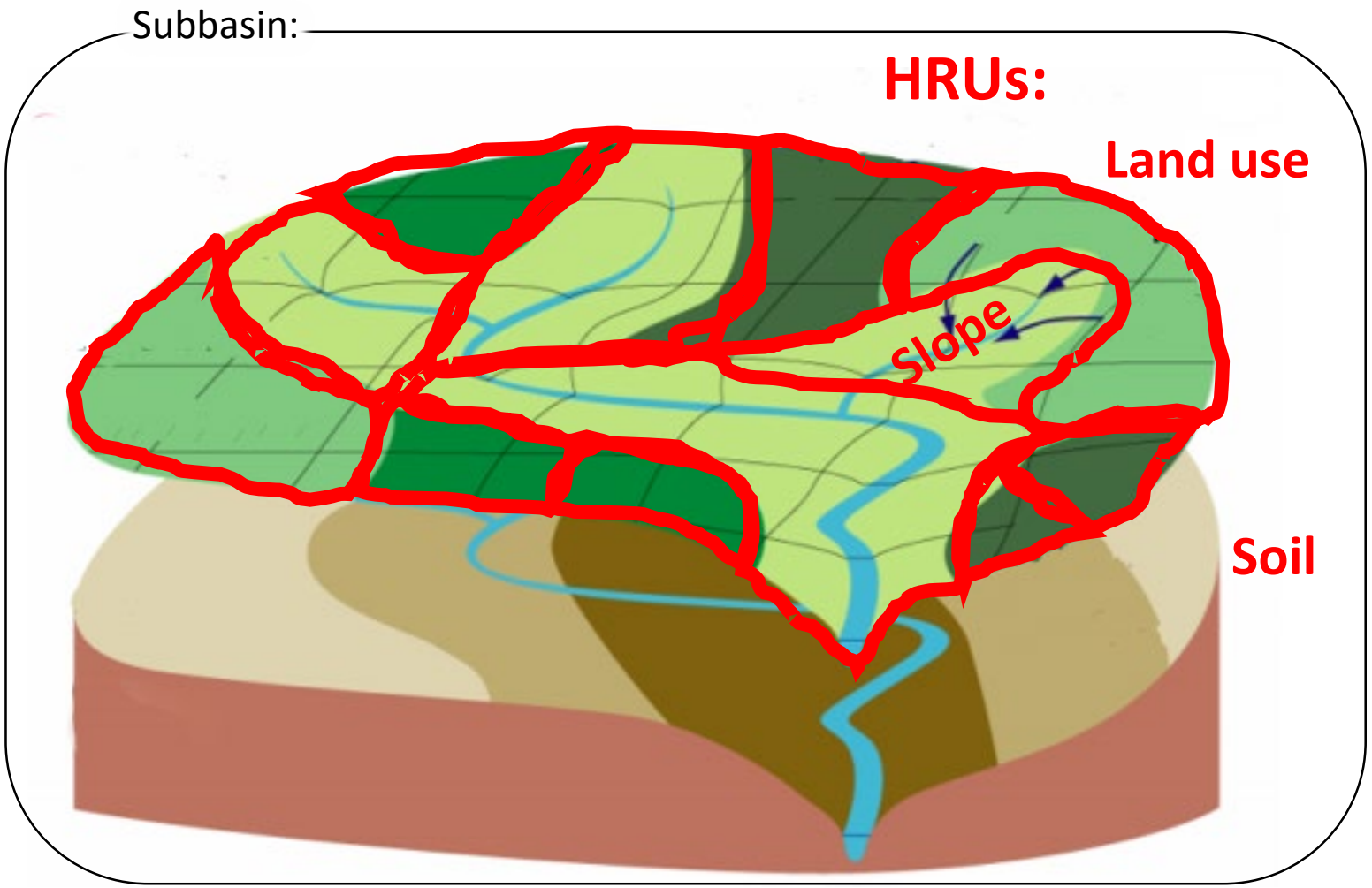

Land Use Threshold Summary

In general, land use had to be greater than 5 % of subbasin area

Original amount of agricultural, natural, and urban area conserved…

Reducing HRUs for the NE Lakeshore TMDL SWAT model

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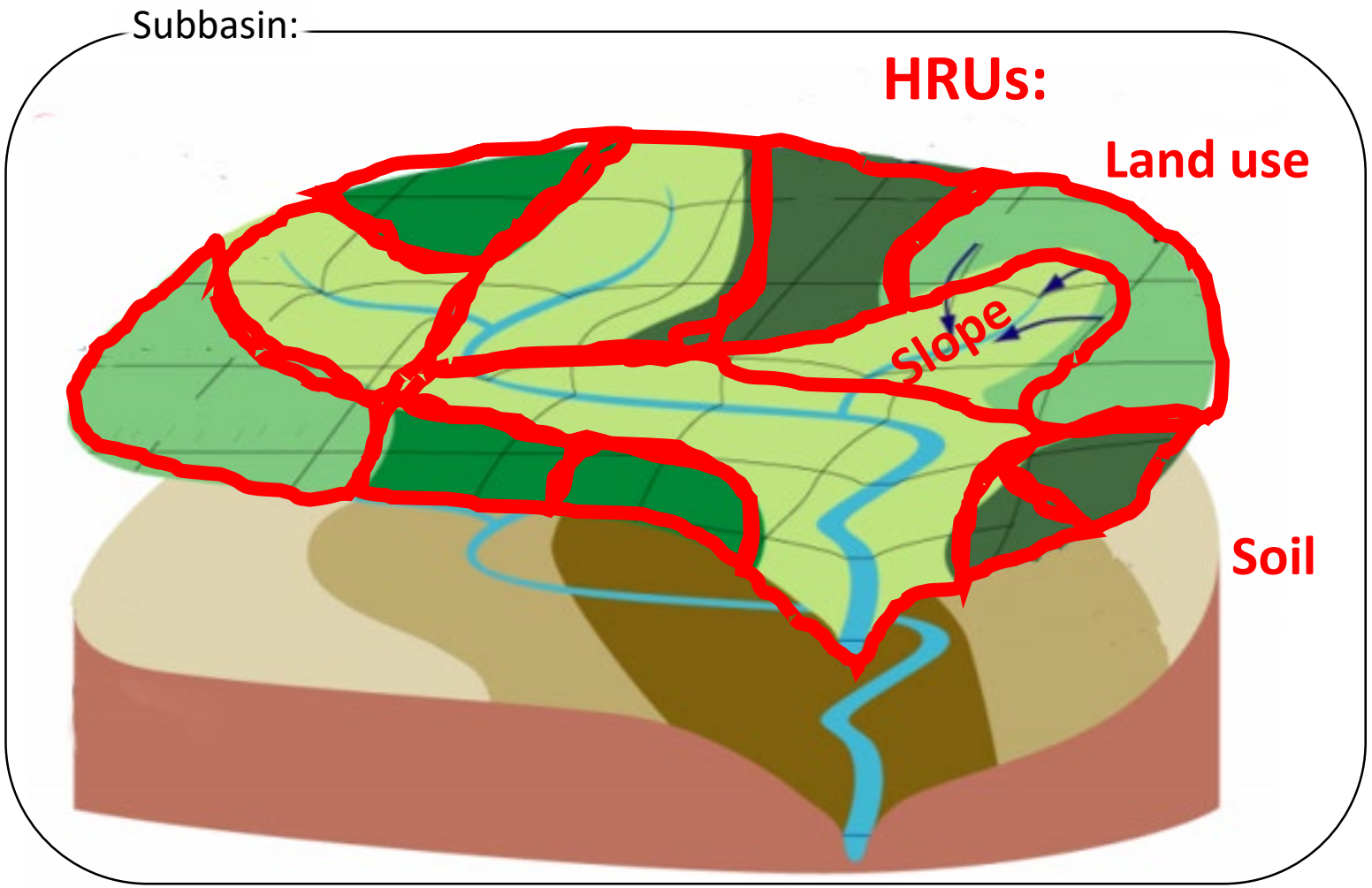


Land Use Threshold Summary

In general, land use had to be greater than 5 % of subbasin area

Original amount of agricultural, natural, and urban area conserved…

- Ag classes only aggregated with other ag classes
- Natural classes only aggregated with other natural classes
- Urban classes -> No thresholds applied (all classes conserved per subbasin)

Initial land cover classes

Dairy
- Dairy Rotation 1, Till 1
- Dairy Rotation 1, Till 2
- Dairy Rotation 1, Till 3
- Dairy Rotation 2, Till 1
- Dairy Rotation 2, Till 2
- Dairy Rotation 2, Till 3
- Dairy Rotation 3, Till 1
- Dairy Rotation 3, Till 2
- Dairy Rotation 3, Till 3

Cash Grain
- Cash Grain 1, Till 1
- Cash Grain 1, Till 2
- Cash Grain 1, Till 3
- Cash Grain 1, Till 4

Continuous Corn
- Continuous Corn, Till 1
- Continuous Corn, Till 2
- Continuous Corn, Till 3

Hay
- Continuous Hay, no till

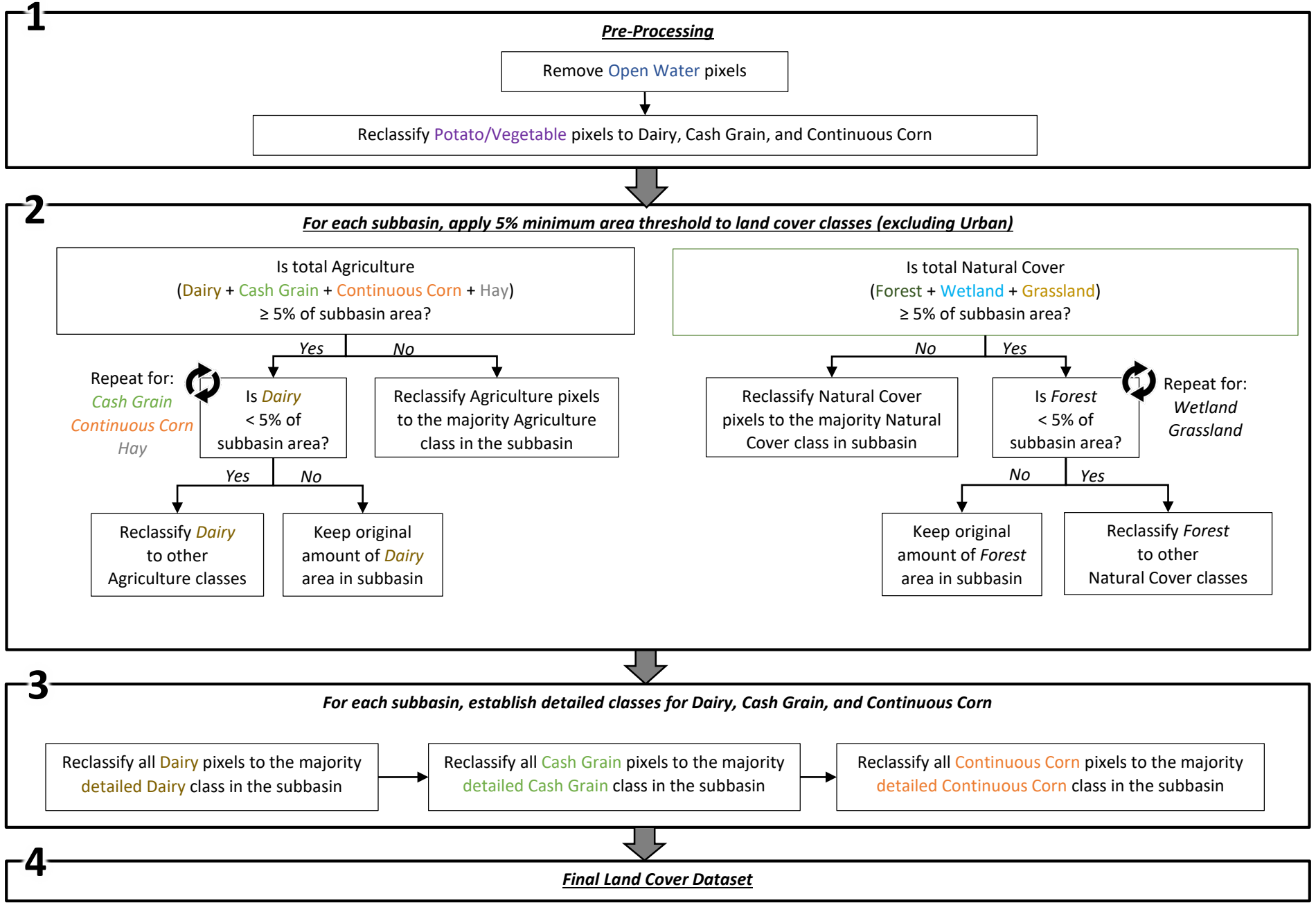
Potato/Veg

Ag

Urban
- Urban, low intensity
- Urban, low intensity, MS4
- Urban, high intensity
- Urban high intensity, MS4

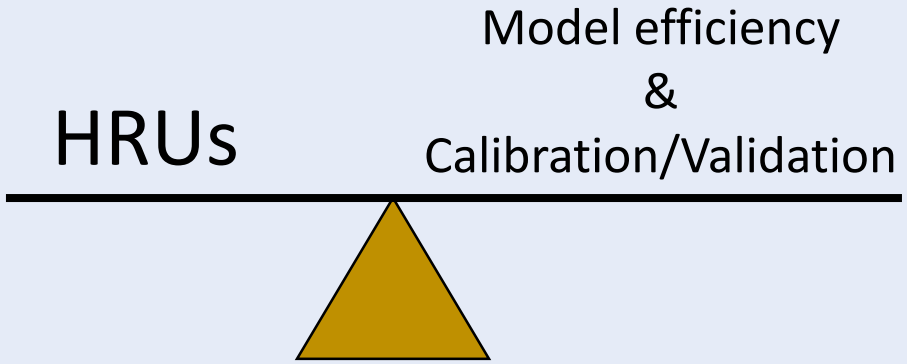
Natural
- Open Water
- Forest
- Wetland
- Grassland

Application of land cover thresholds in the NE Lakeshore SWAT model



HRU summary

HRUs were developed to balance the number of HRUs against model runtimes and opportunity for model calibration/validation

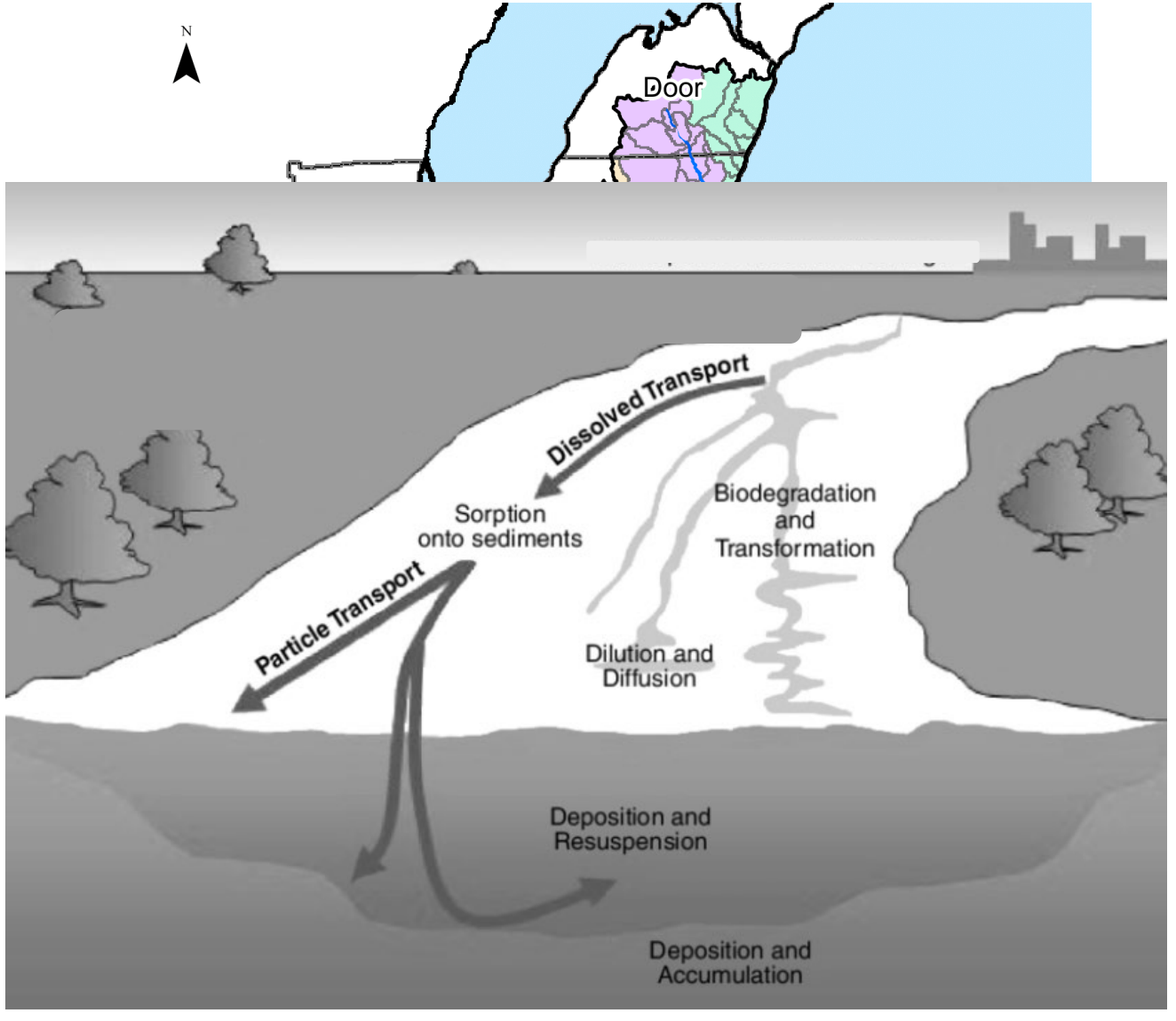


HRU aggregation preserved the original amount of agricultural, urban, and natural landcover in each subbasin

The original detail of land cover layer has been preserved and will be used for TMDL implementation

Subbasins and Routing

- After phosphorus and sediment runoff is calculated for HRUs, it is routed downstream through subbasins.
- The model simulates the loss of pollutants in stream channels from deposition



Adapted From S.L. Neitsch et al., Soil and Water Assessment Tool theoretical documentation version 2000, 2001

Outline of the Watershed Model Report

Prepared by The Cadmus Group

Upcoming Comment Period

Webinar 3 topics

Webinar 4 topics (today)

1. **Overview**
2. **Model Setup**
   - 2.1. ArcSWAT and SWAT software
   - 2.2. Subbasin and Reach Delineation
   - 2.3 Hydrologic Response Units
     - 2.3.1. Land Cover
     - 2.3.1. Soils
     - 2.3.2. Slope
     - 2.3.4. HRU Definition
   - 2.4. Weather
     - 2.4.1. Weather Data
     - 2.4.2. Potential Evapotranspiration
   - 2.5. Point Sources
     - 2.5.1. Wastewater Treatment Facilities
     - 2.5.2. Municipal Separate Storm Systems
     - 2.5.3. CAFOs
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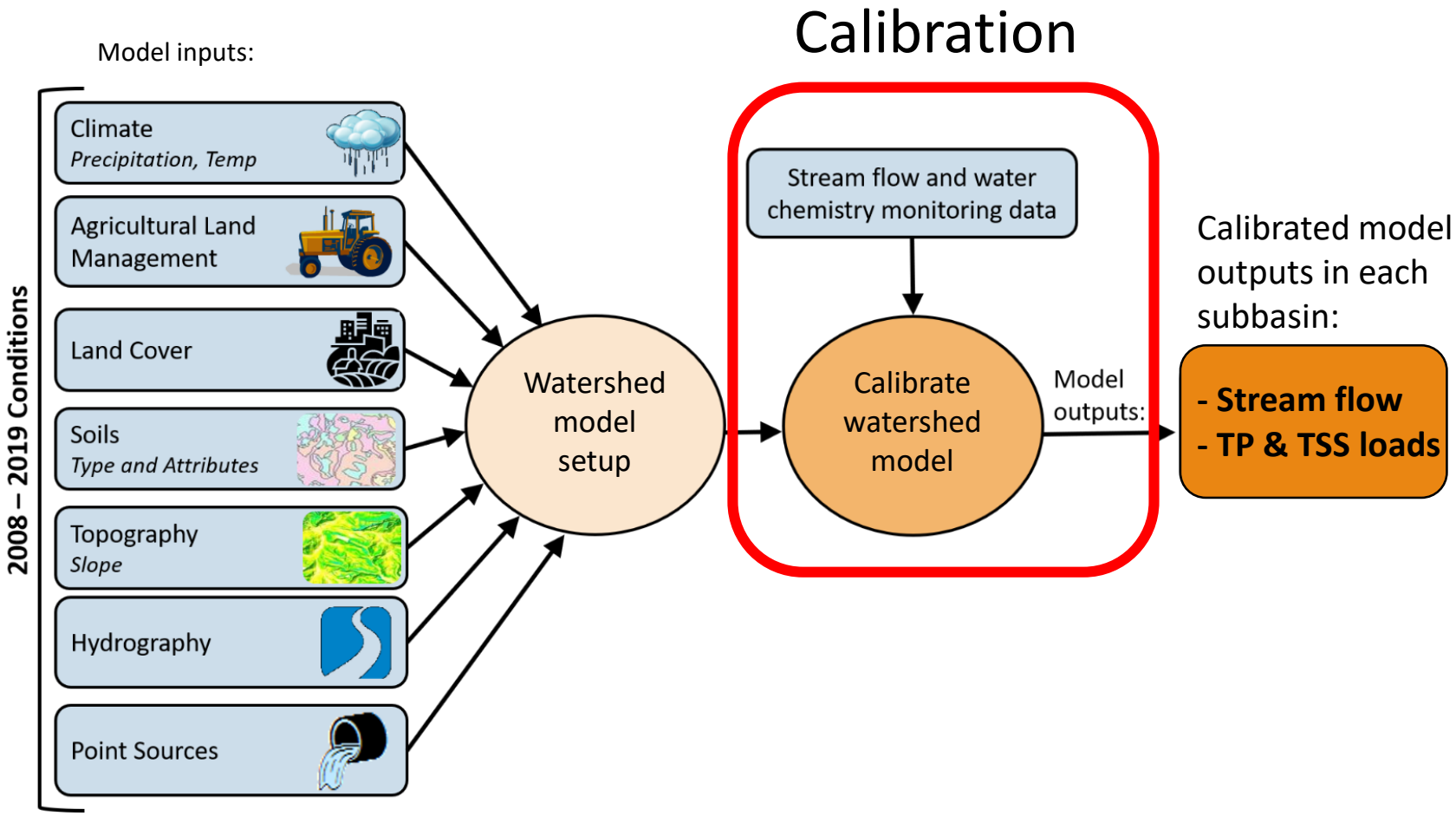
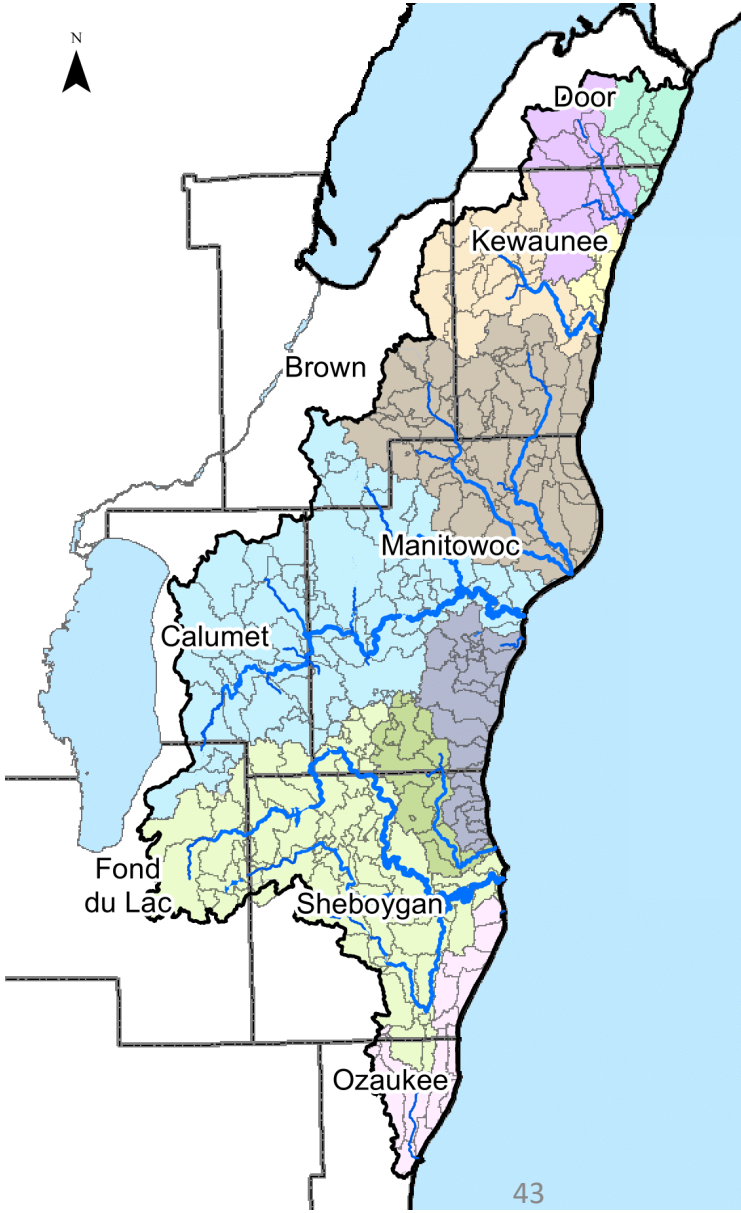
   - 2.6. Soil Phosphorus
   - 2.7. Manure Application
   - 2.8. Baseflow Alpha Factor
   - 2.9. Internally Drained Areas
   - 2.10. Mannings N
   - 2.11. Subbasin Slope Length
   - 2.12 Simulation Period

Future Webinar and Comment Period (Late 2020/Early 2021)

3. **Model Calibration** (methods and results)
4. **Model Validation** (methods and results)
5. **Discussion of Model Performance**
6. **Summary of Model Results**
7. **References**

Watershed model development process



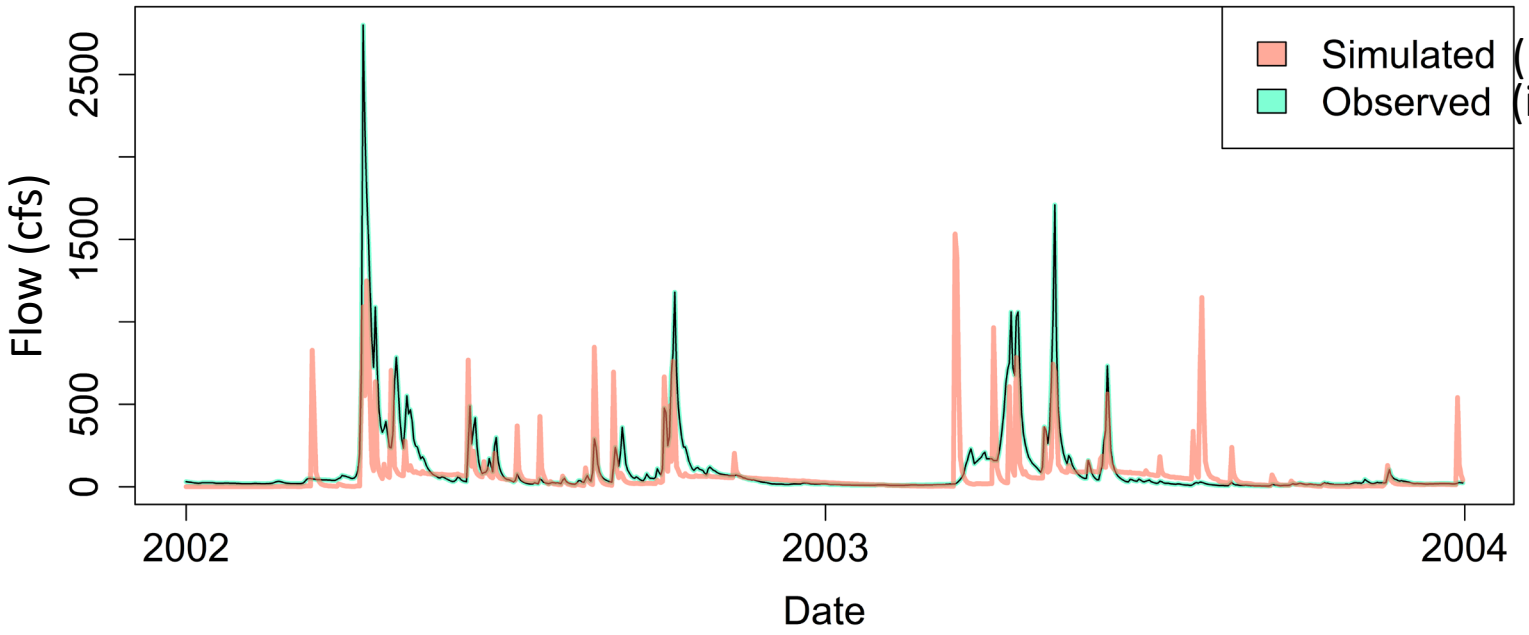


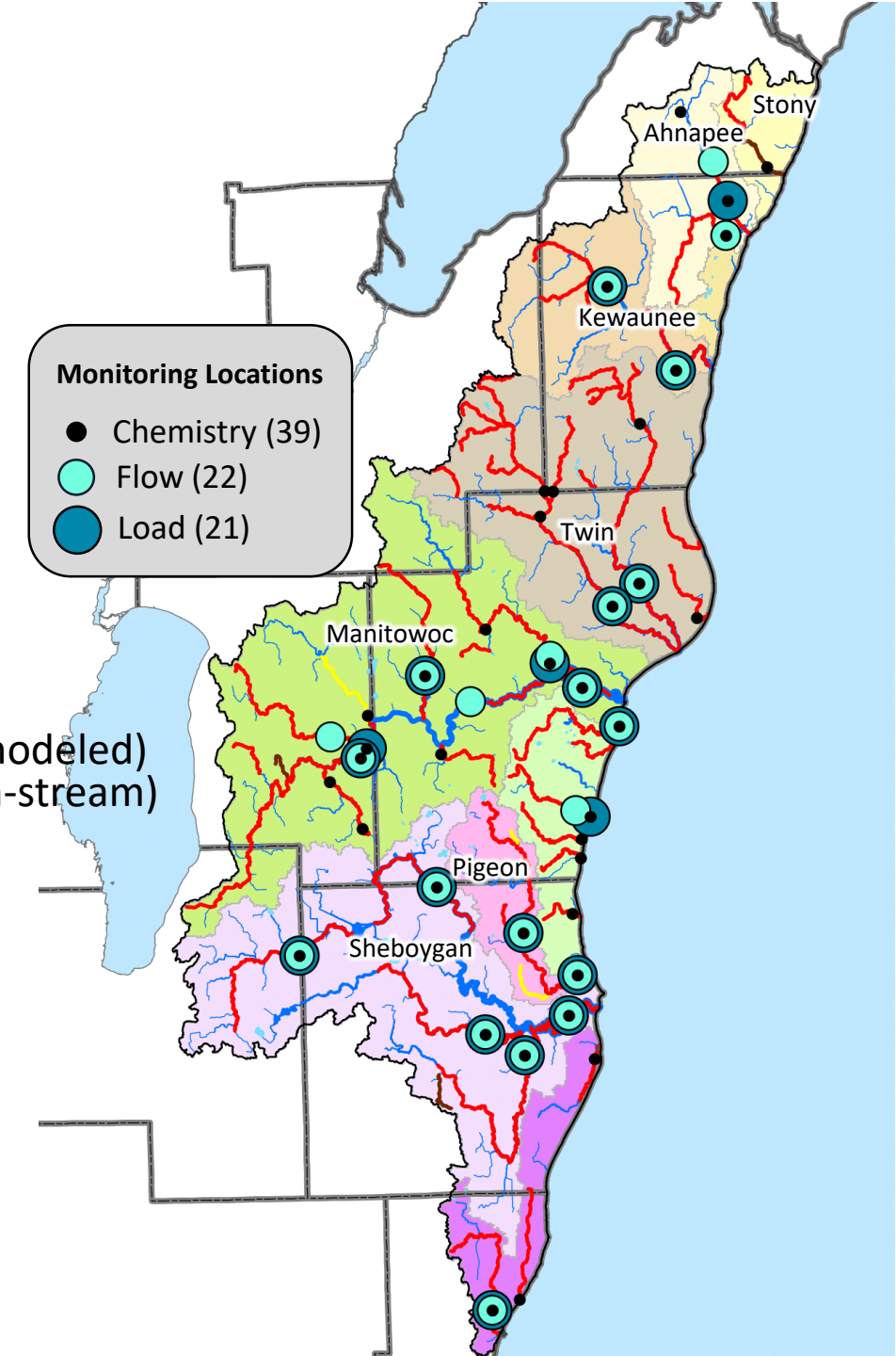
Model Calibration & Validation

The process of matching model simulated outputs (flow, sediment, phosphorus) to monitoring data

Modeler adjusts parameters to allow for better fit

Evaluation statistics (objective functions, for example: R^2 or PBIAS) are used to help quantify model calibration and validation





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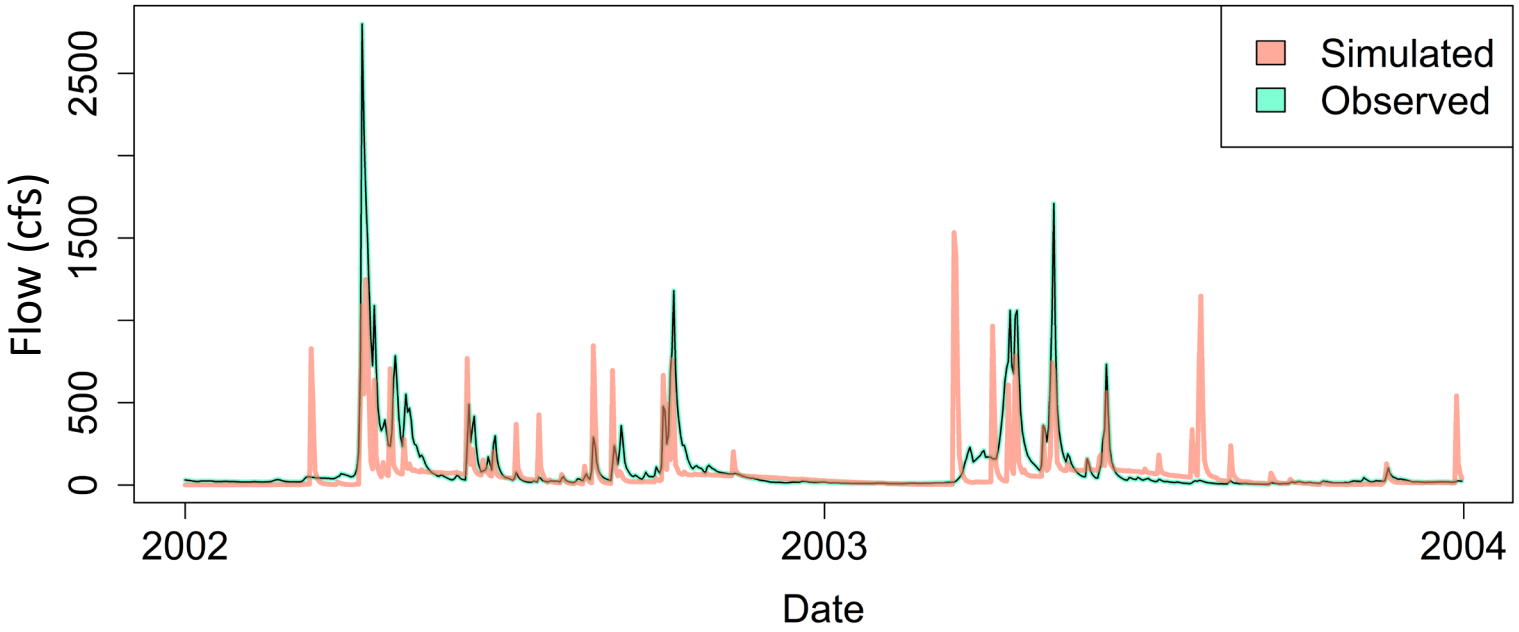
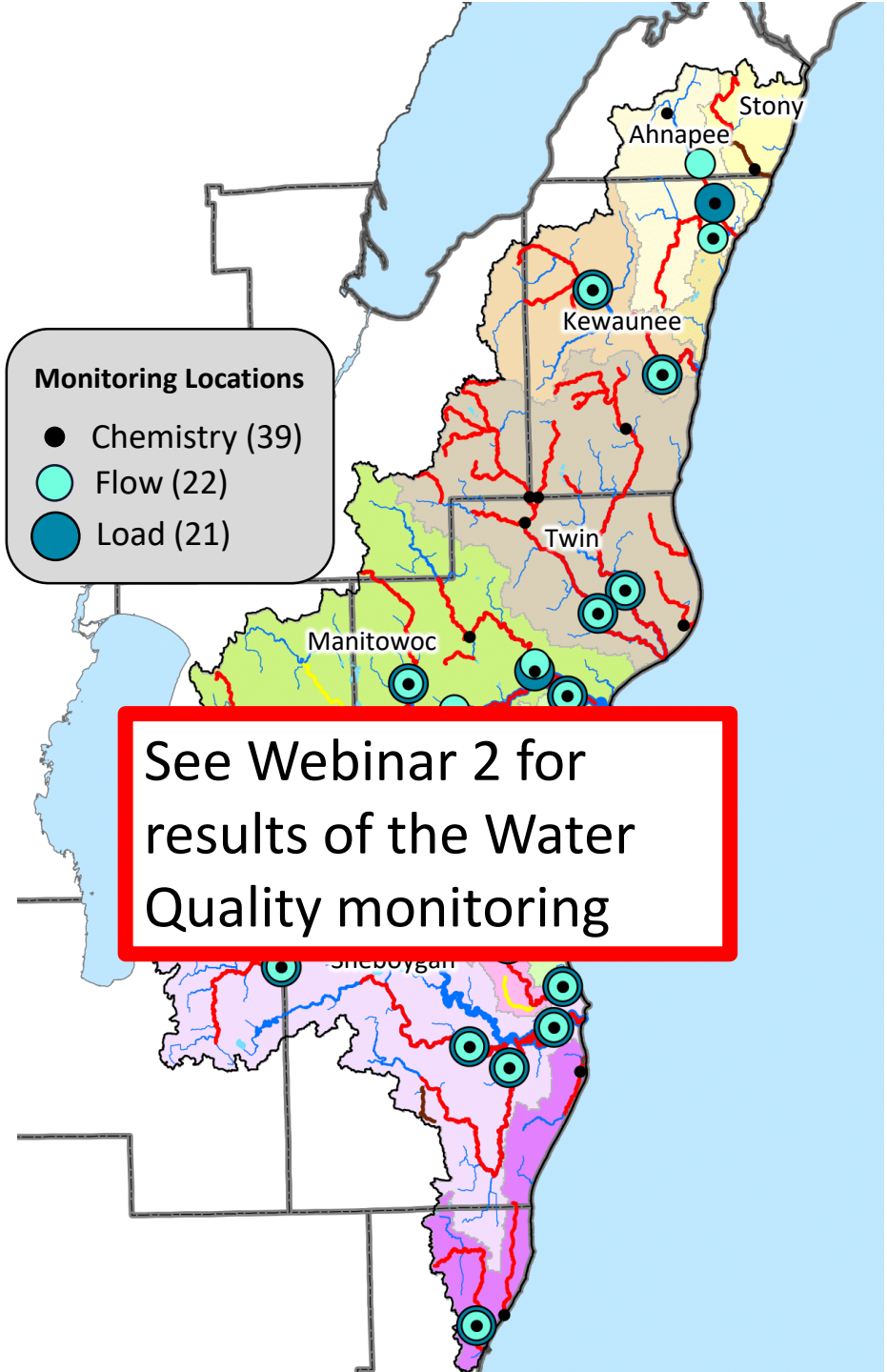




See Webinar 2 for results of the Water Quality monitoring

Watershed model development process

Webinar 3

Model inputs:

2008 – 2019 Conditions

- Climate
  Precipitation, Temp
- Agricultural Land Management
- Land Cover
- Soils
  Type and Attributes
- Topography
  Slope
- Hydrography
- Point Sources

Webinar 2

Stream flow and water chemistry monitoring data

Watershed model setup

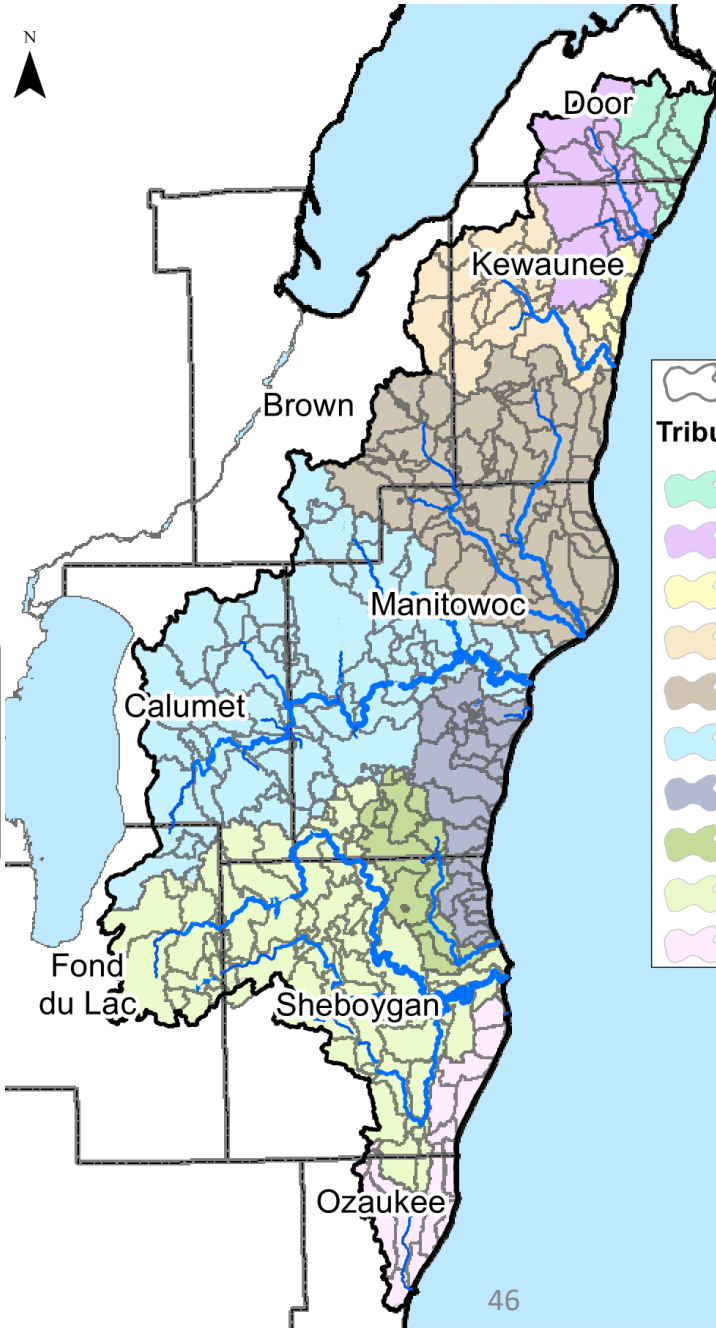
Calibrate watershed model

Model outputs:

For each subbasin:
- Stream flow
- Baseline TP & TSS loads

Webinar 4

Future meeting/webinar
Late 2020/Early 2021



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Prepared by The Cadmus Group

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Accepting comments until Oct 16th

Send comments to Kim Oldenborg Kimberly.Oldenborg@Wisconsin.gov

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Contact information

Kim Oldenborg – NE Lakeshore TMDL Project Coordinator
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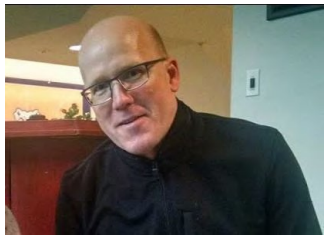
Keith Marquardt - NE Region TMDL Coordinator
KeithA.Marquardt@Wisconsin.gov



Kevin Kirsch- Statewide TMDL Coordinator
Kevin.Kirsch@Wisconsin.gov