*Tip - Hover or double click on comment bubble to see presenter notes

WISCONSIN
DEPT. OF NATURAL RESOURCES

# Introduction to the Watershed Model and Data Inputs

## Northeast Lakeshore TMDL

August 6, 2020

# Outline

- Watershed model overview
- Data inputs
  - Climate
  - Elevation
  - Hydrology
  - Soils
  - Point sources
  - Land cover
  - Agricultural land management
    - Agriculture questionnaire survey
    - Manure spreading analysis
  - Nitrogen evaluation – not included in the watershed model

# 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
Non-point (ag, ms4 natural)

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?

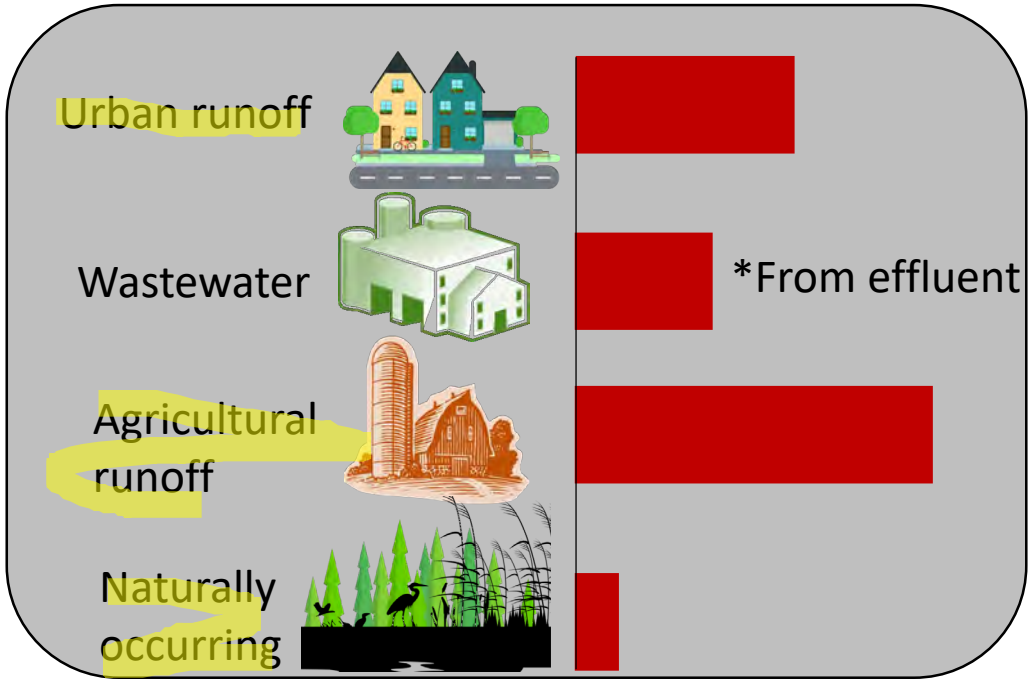
# Why do we need a watershed model ?

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

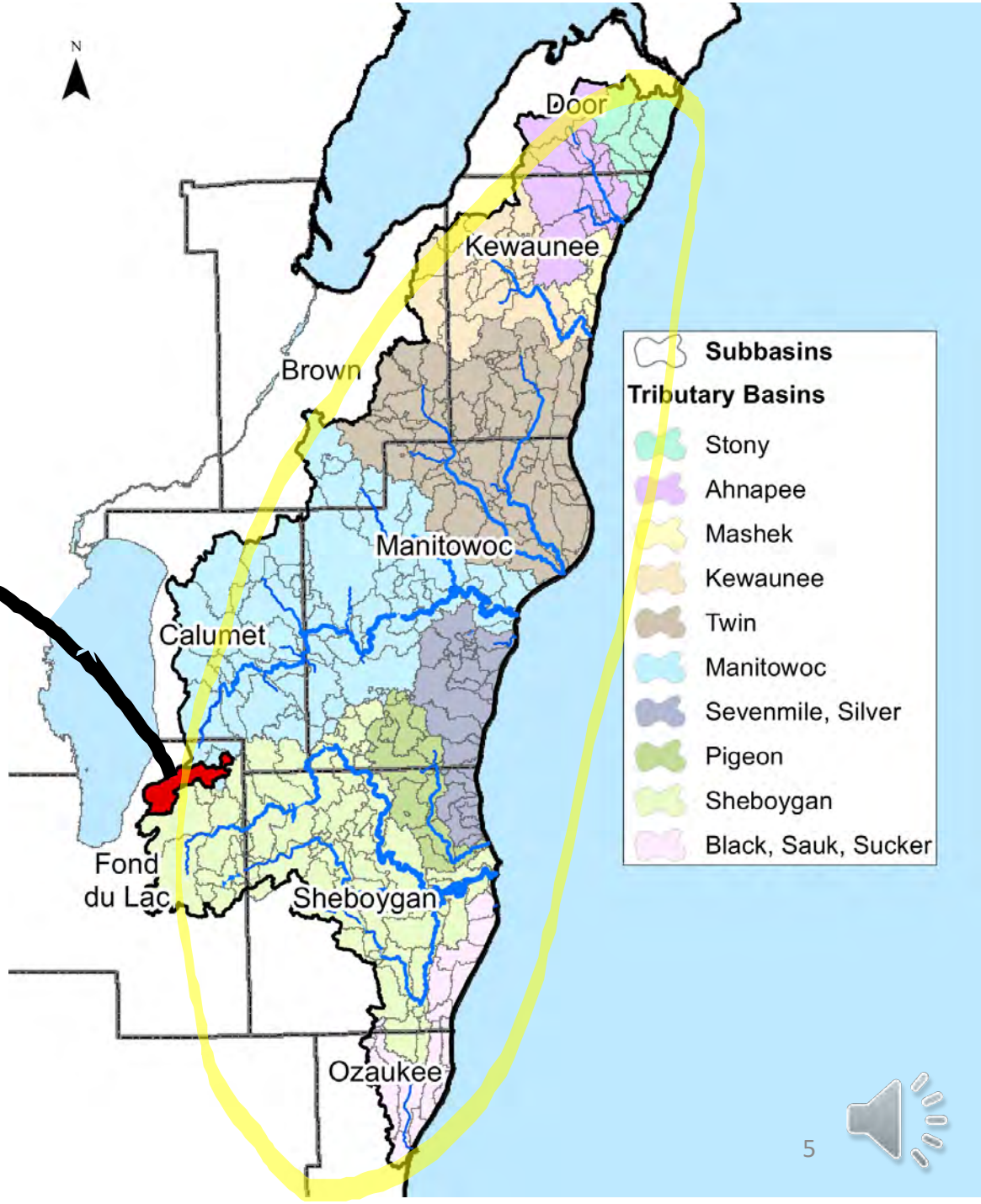
2) To provide the relative pollutant contribution from non-point pollutant sources in each of the 321 subbasins

**Example Baseline Load**

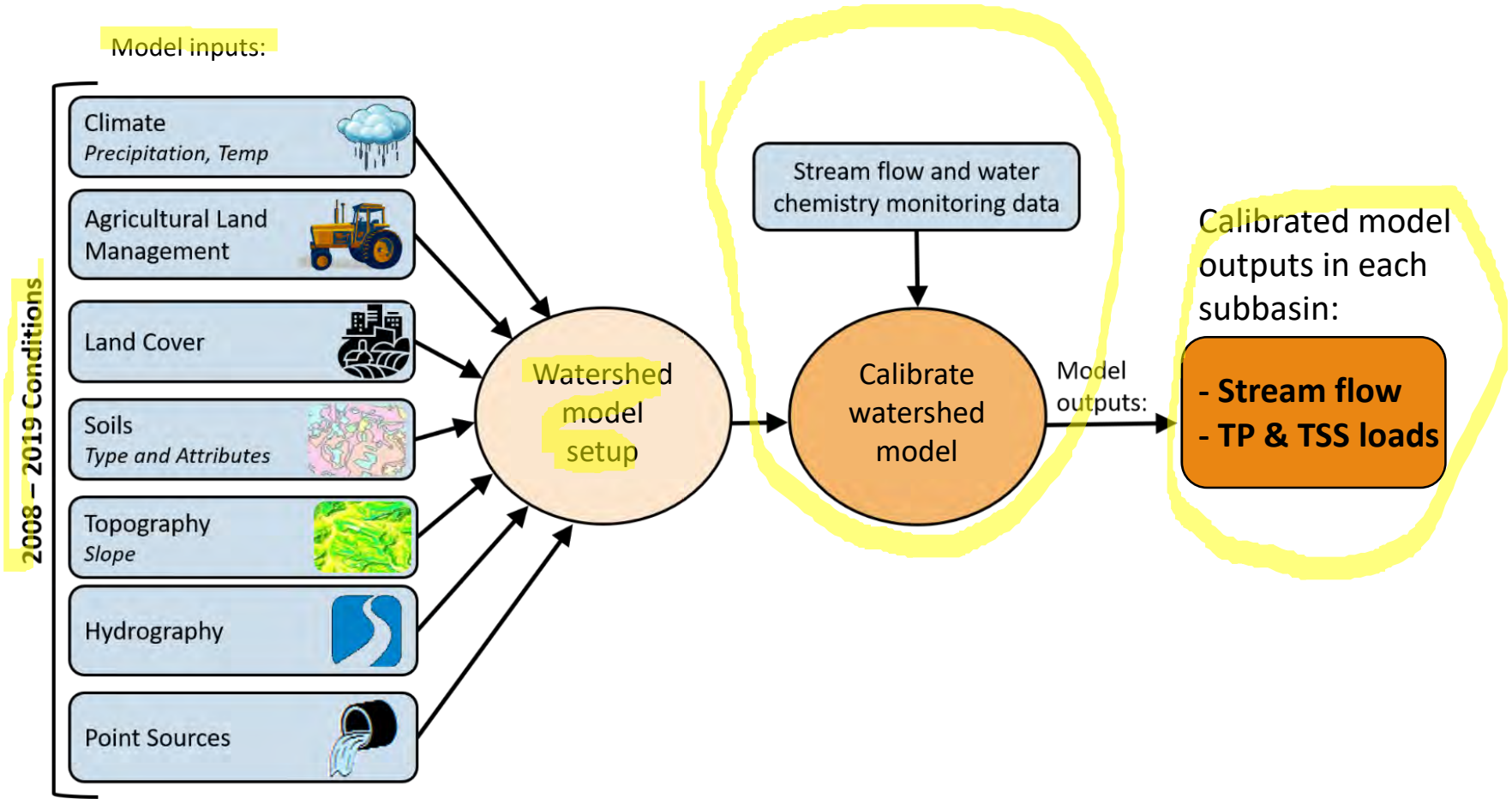
Subbasin 184

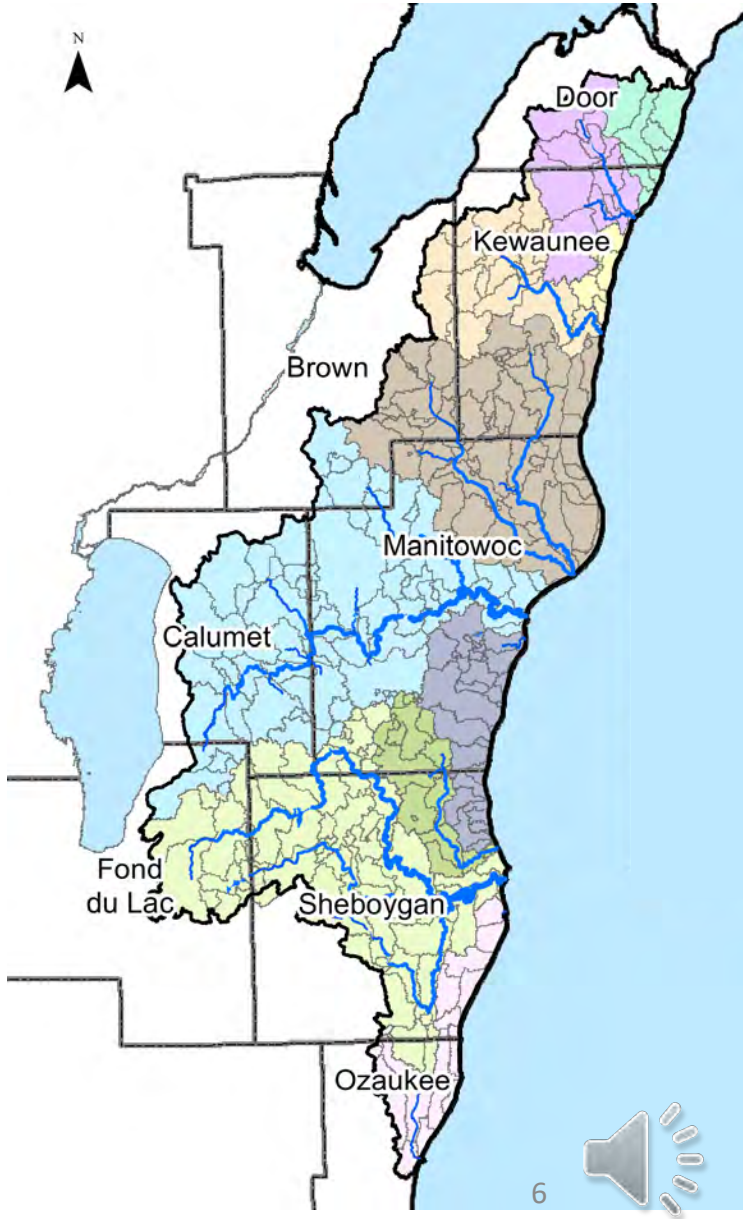



*From effluent monitoring



# Watershed model development process

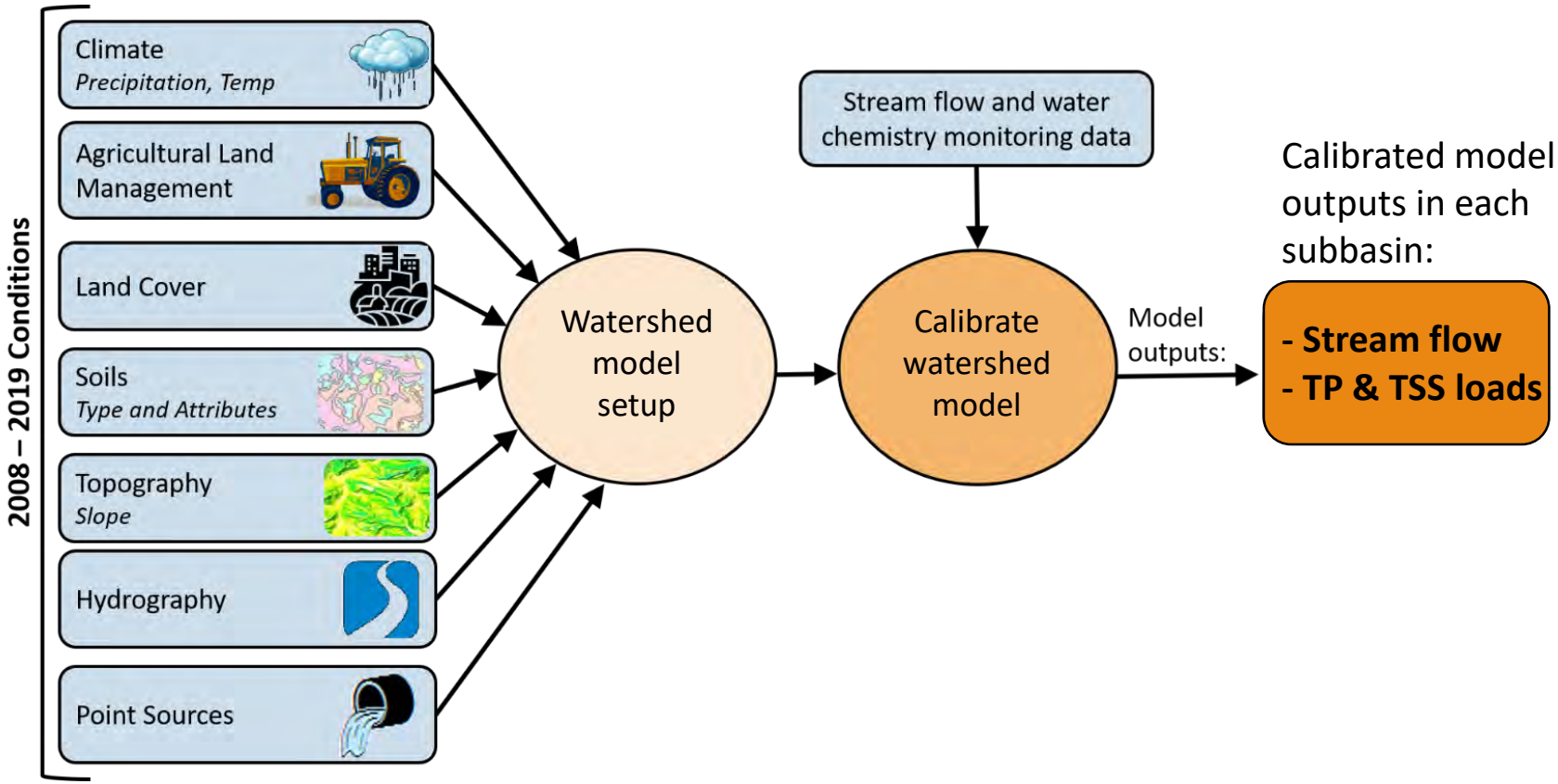


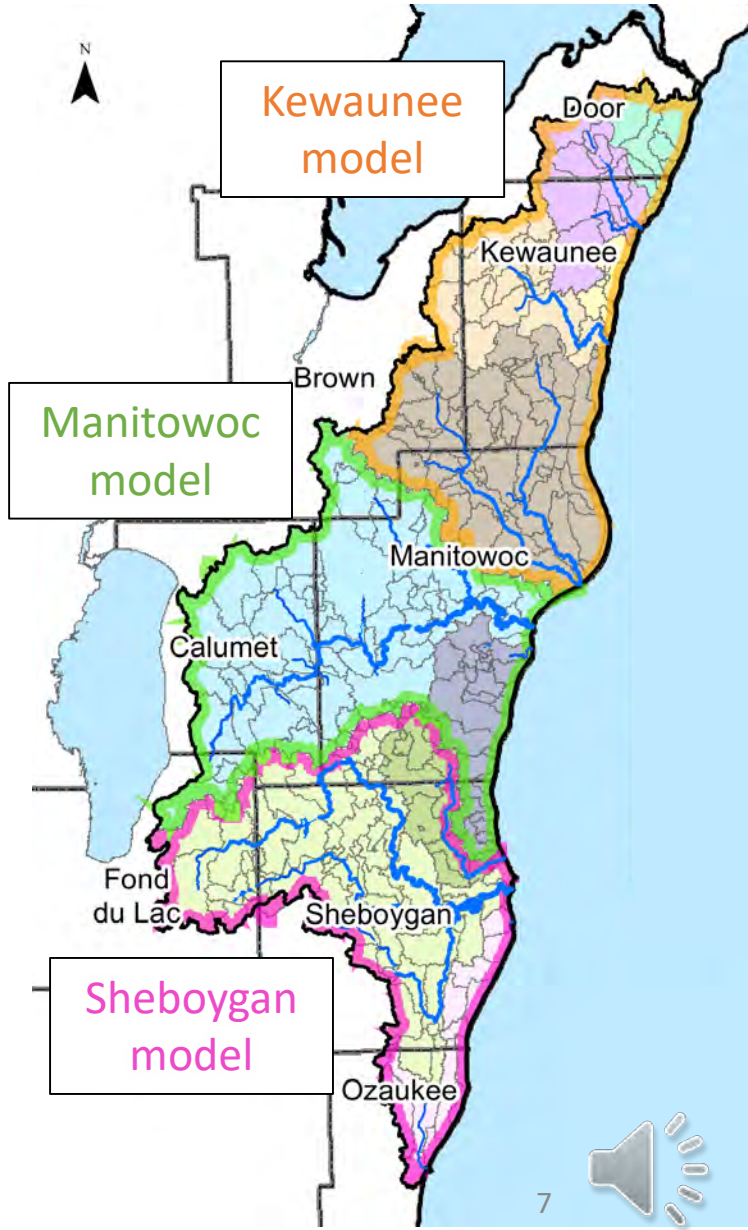
# Watershed model development process

Three separate models will be developed for the three major drainage basins

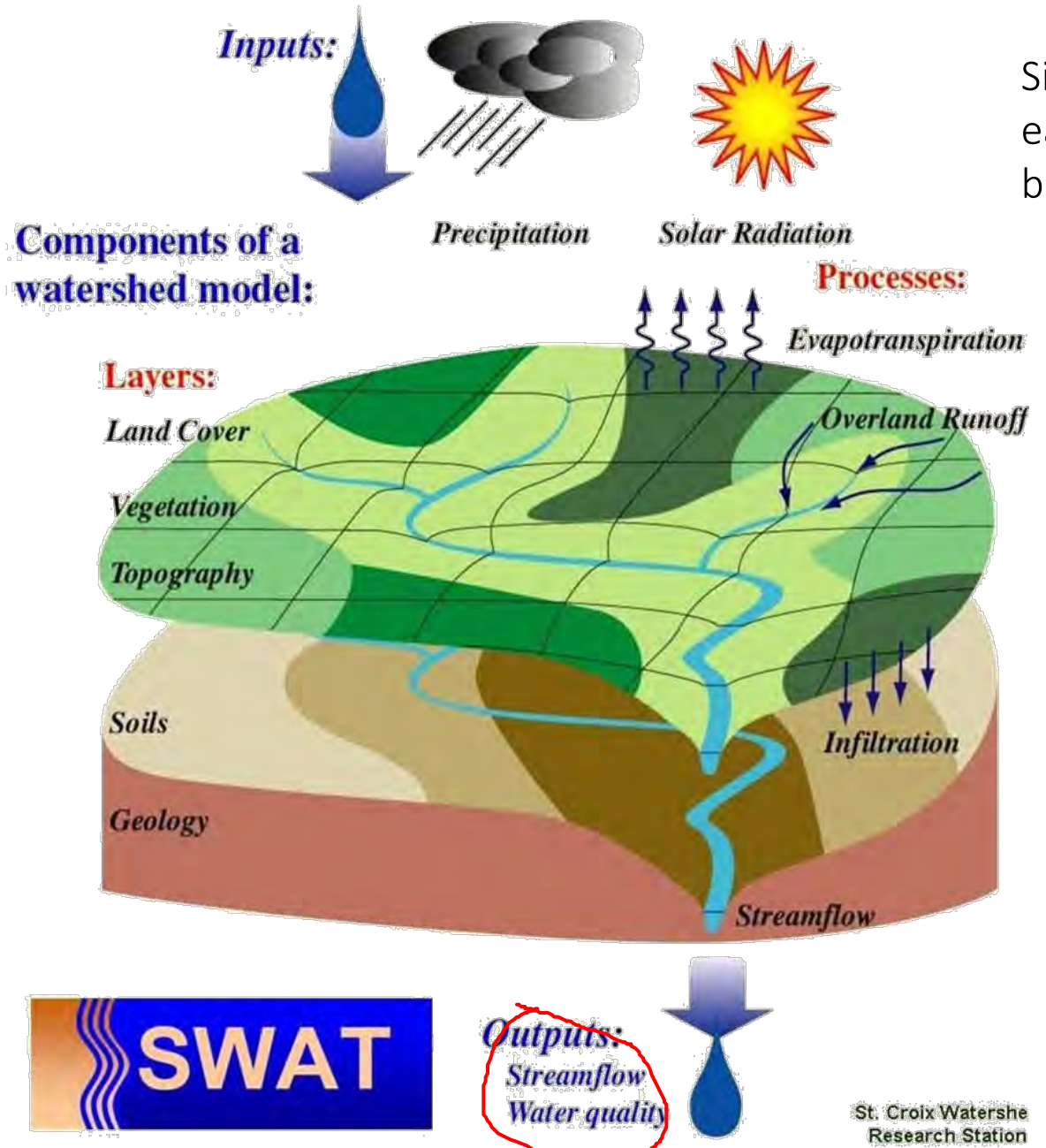
Model inputs:




Calibrated model outputs in each subbasin:



# Soil and Water Assessment Tool (SWAT)




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

# Watershed model development process

**Webinar 3 (today)**

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

**Webinar 4**

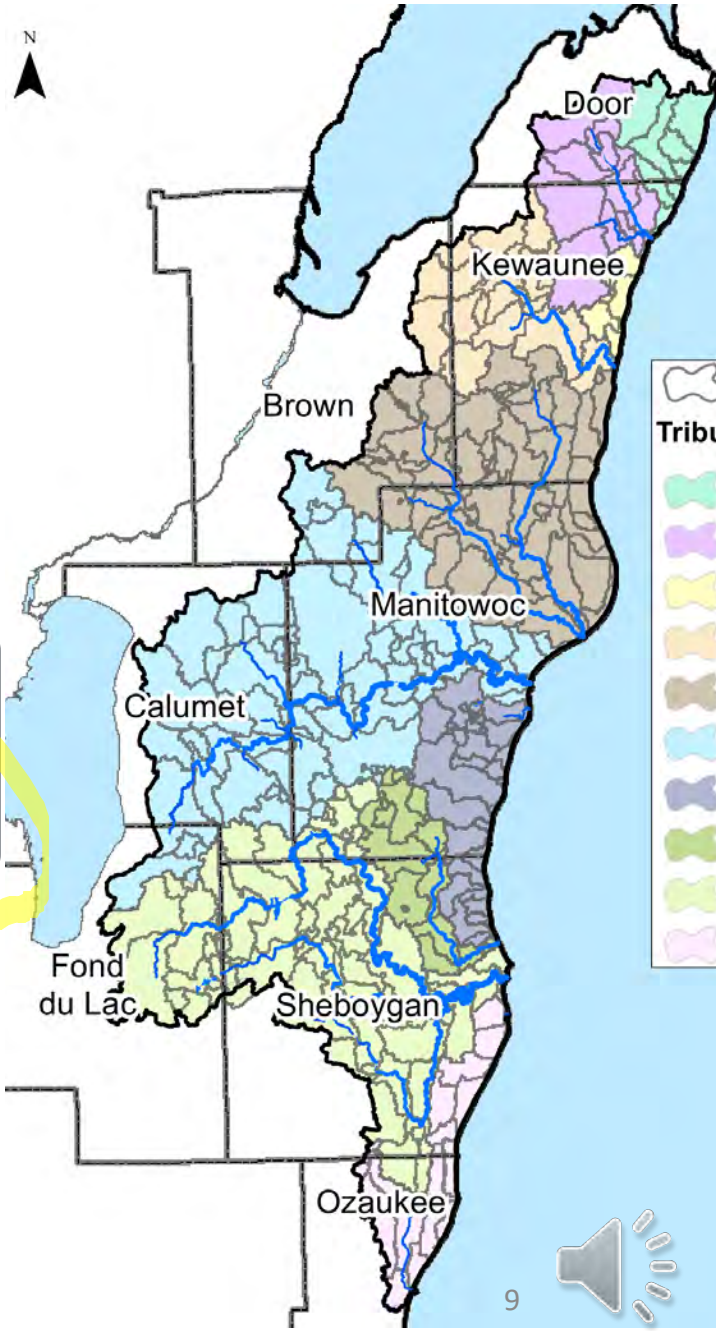
Watershed model setup

Calibrate watershed model

Model outputs:

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

**Future meeting/webinar**
**Late 2020/Early 2021**



# Subbasins

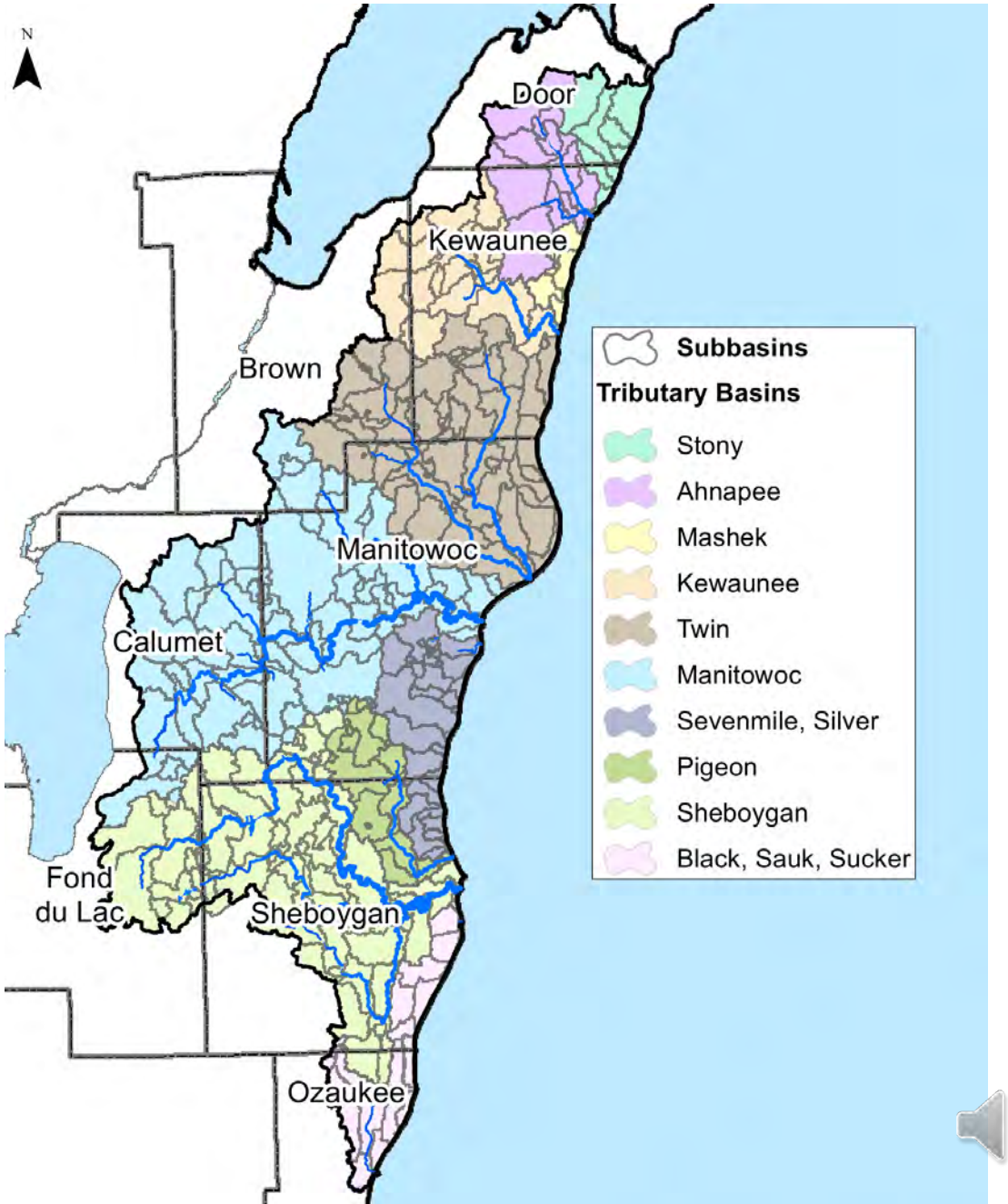
Divide the study area into smaller units used for many data inputs and outputs of the watershed model

321 subbasins in the NE Lakeshore TMDL

- Nest within HUC12 watersheds, a common unit used for TMDL implementation

Subbasins defined by:

- ✓ Changes in stream phosphorus criteria
- ✓ Impaired stream reaches
- ✓ Location of point source outfalls
- ✓ Significant changes in flow
- ✓ Stream monitoring locations
- ✓ Land use change (agriculture to city)



# Data Collection: Climate

- **Climate**
- Elevation
- Hydrology
- Soils
- Land cover
- Land Management
- Point Sources

**Daily weather data for each subbasin (1998 – 2019)**

- Daily Precipitation
- Min/Max Temperature
- Solar Radiation
- Humidity

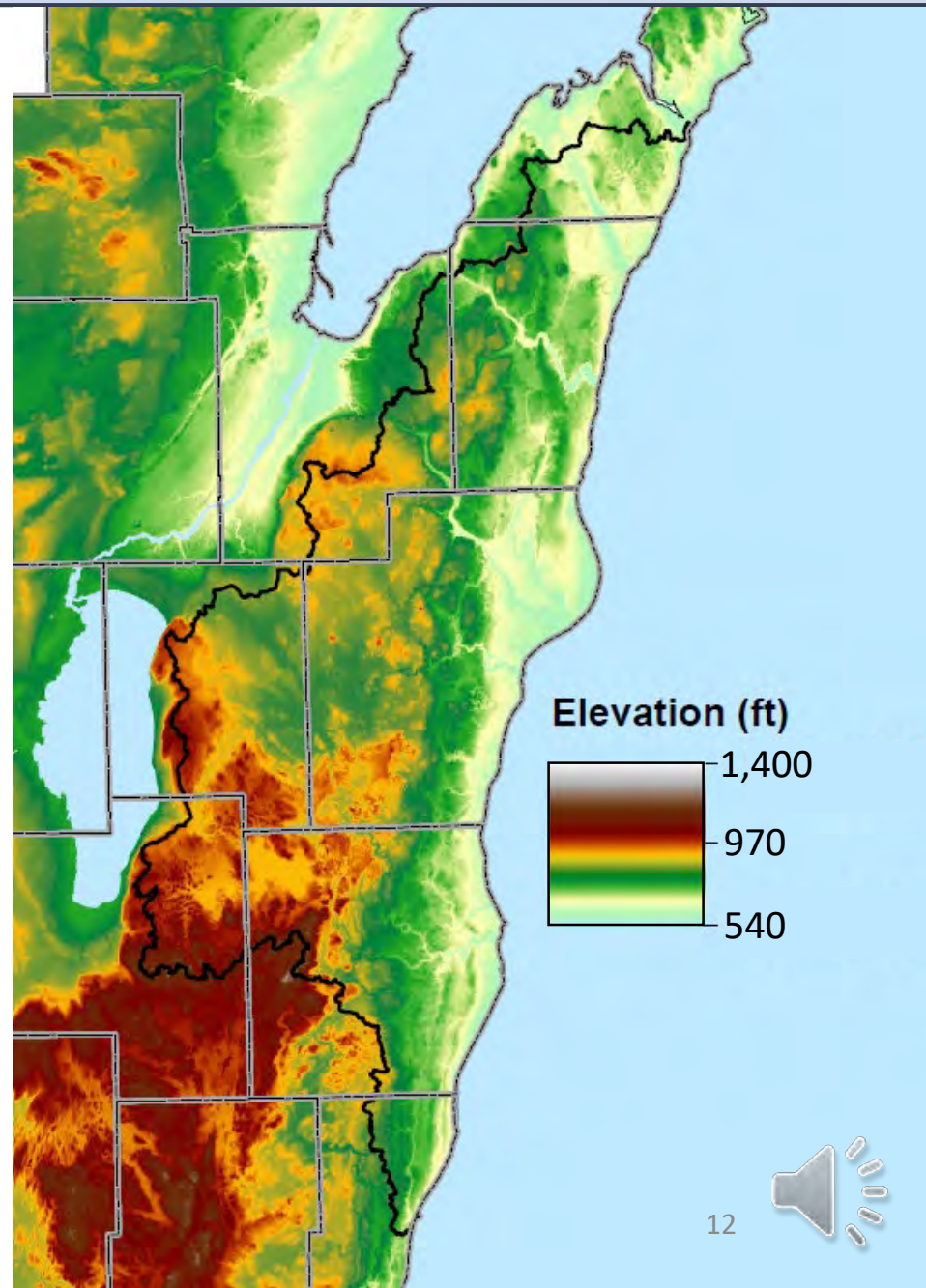
**Daymet dataset produced by Oak Ridge National Laboratory**

Continuous dataset with 1 $km^2$ resolution developed from observations at NOAA weather stations

# Data Collection: Elevation

- Climate
- **Elevation**
- Hydrology
- Soils
- Land cover
- Land Management
- Point Sources

Digital elevation model (DEM) used for watershed delineation and support of model parameters

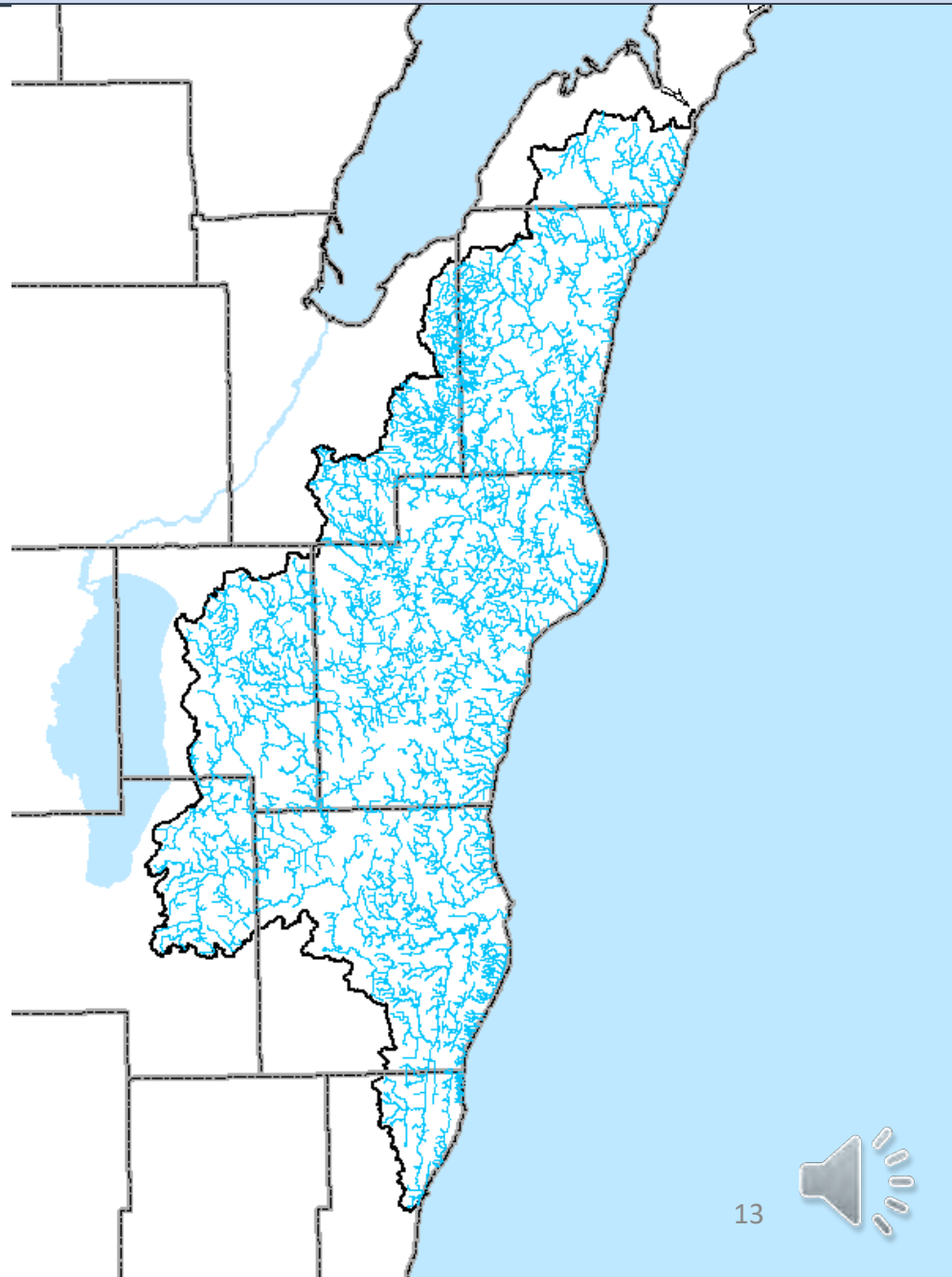


# Data Collection: Hydrologic Network

- Climate
- Elevation
- **Hydrology**
- Soils
- Land cover
- Land Management
- Point Sources

Streams and open water from the WDNR 24K Hydrography Geodatabase

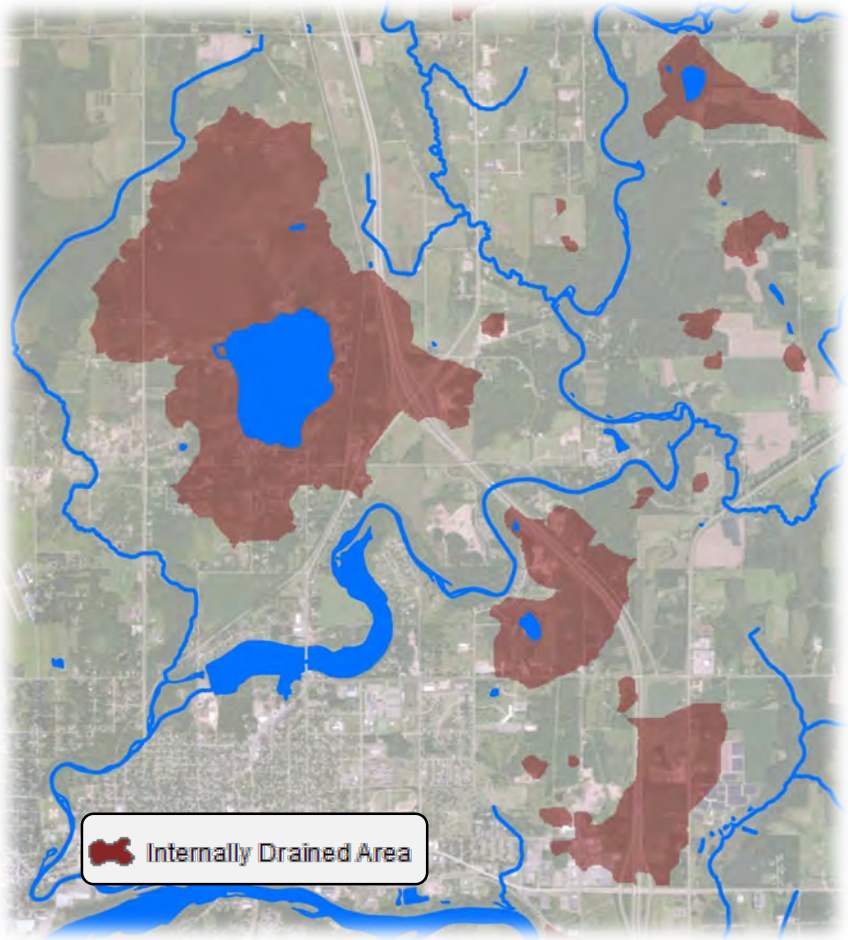
Used for hydraulic routing



# Data Collection: Internally Drained Areas

- Climate
- Elevation
- **Hydrology**
- Soils
- Land cover
- Land Management
- Point Sources

- Accounts for internally drained wetlands and waterbodies
- Internally drained areas were delineated used the DEM



# Data Collection: Groundwater inflow (baseflow)

- Climate
- Elevation
- **Hydrology**
- Soils
- Land cover
- Land Management
- Point Sources

- Timing and contribution of groundwater to streamflow
  - ✓ Calculated through BFLOW program
  - ✓ Used long-term USGS gage sites in the NEL area

| USGS ID | Gage Name | SWAT Sub-model | Start Year | End Year | Alpha Factor |
|---|---|---|---|---|---|
| 04086000 | Sheboygan River at Sheboygan, WI | Sheboygan River | 1989 | 2019 | 0.0449 |
| 040857005 | Otter Creek at Willow Road Near Plymouth, WI | Sheboygan River | 1990 | 2018 | 0.0374 |
| 04085427 | Manitowoc River at Manitowoc, WI | Manitowoc River | 1989 | 2019 | 0.0475 |
| 04085200 | Kewaunee River near Kewaunee, WI | Kewaunee River | 1989 | 2019 | 0.0470 |
| Average | | | | | 0.0442 |

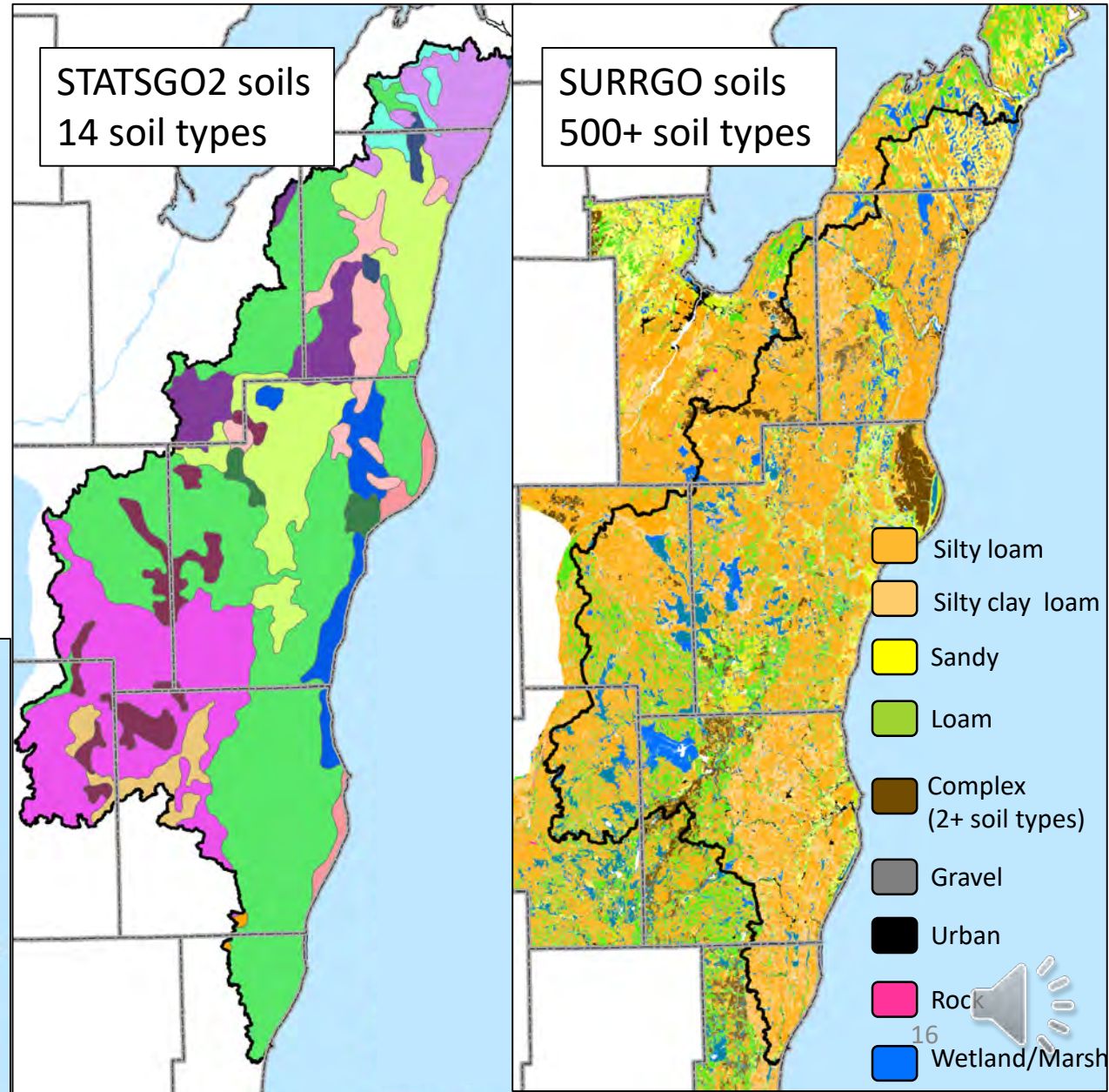
# Data Collection: Soils

- Climate
- Elevation
- Hydrology
- **Soils**
- Land cover
- Land Management
- Point Sources

USDA Natural Resources Conservation Service (NRCS)

- **STATSGO2** Digital General Soil Map of the United States
- **SSURGO** Soil Survey Geographic Database

Combined to create a custom dataset that provides soil properties that influence runoff potential and erosion



# Data Collection: Point Sources

- Climate
- Elevation
- Hydrology
- Soils
- Land cover
- Land Management
- **Point Sources**

# Point source data

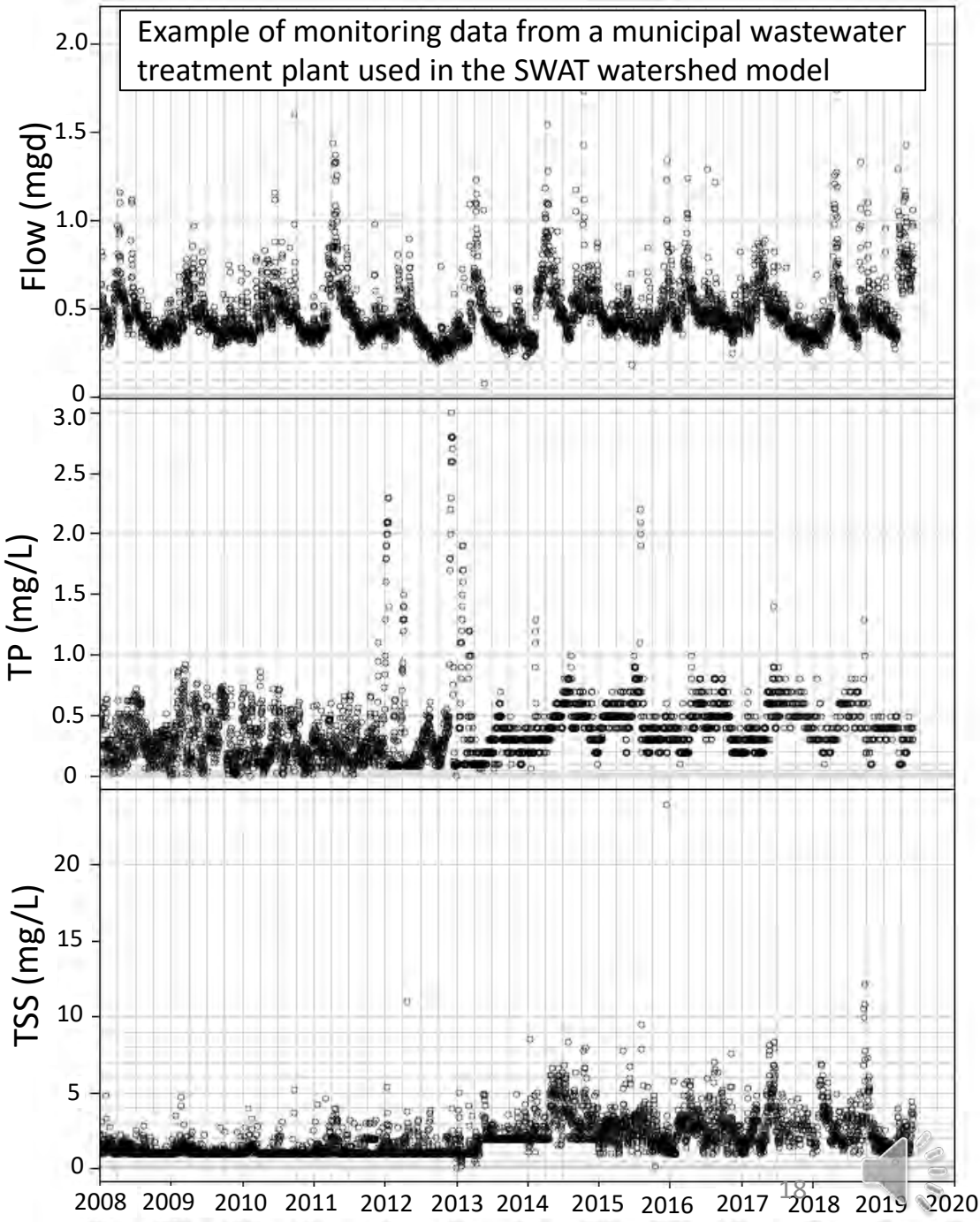
Industrial or Municipal wastewater treatment plants with individual WPDES permits

- Outfall location – WPDES permits
- Effluent monitoring data – Discharge Monitoring Reports (required by permit)
  - Flow
  - Total phosphorus
  - Total suspended solids

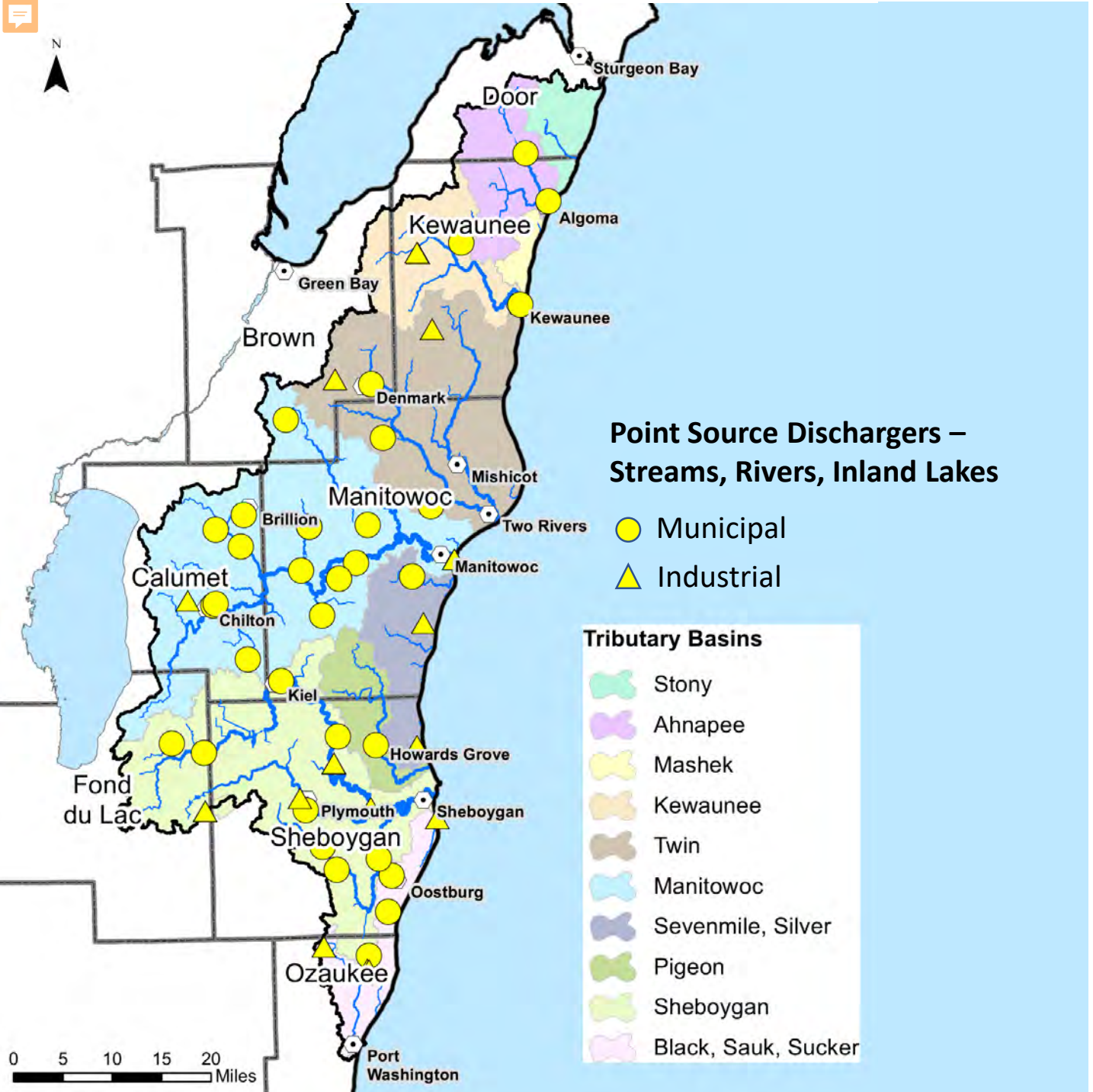
Verified with permit holders in July 2019

Verify again in late 2020 prior to allocations

- Last opportunity to supply information about new or expanding dischargers so that an allocation is received rather than reserve capacity



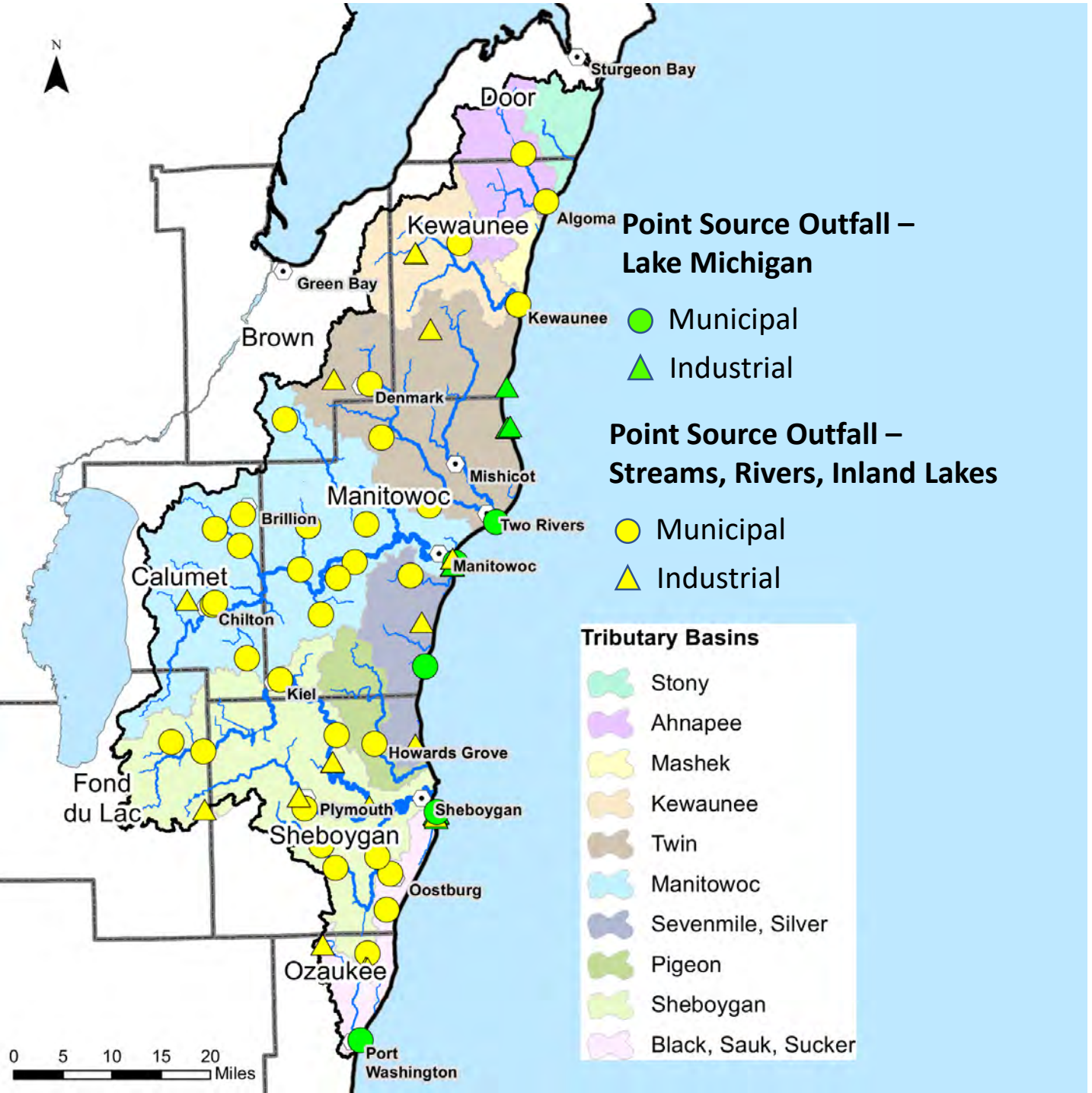
# Permitted Point Source Outfalls




**Streams, Rivers, Inland Lakes**

52 outfalls

- 34 municipal
- 18 industrial




# Permitted Point Source Outfalls

**Direct discharges to Lake Michigan – no allocations for NE Lakeshore TMDL**

18 outfalls

- 5 municipal
- 13 industrial

**Streams, Rivers, Inland Lakes**

52 outfalls

- 34 municipal
- 18 industrial

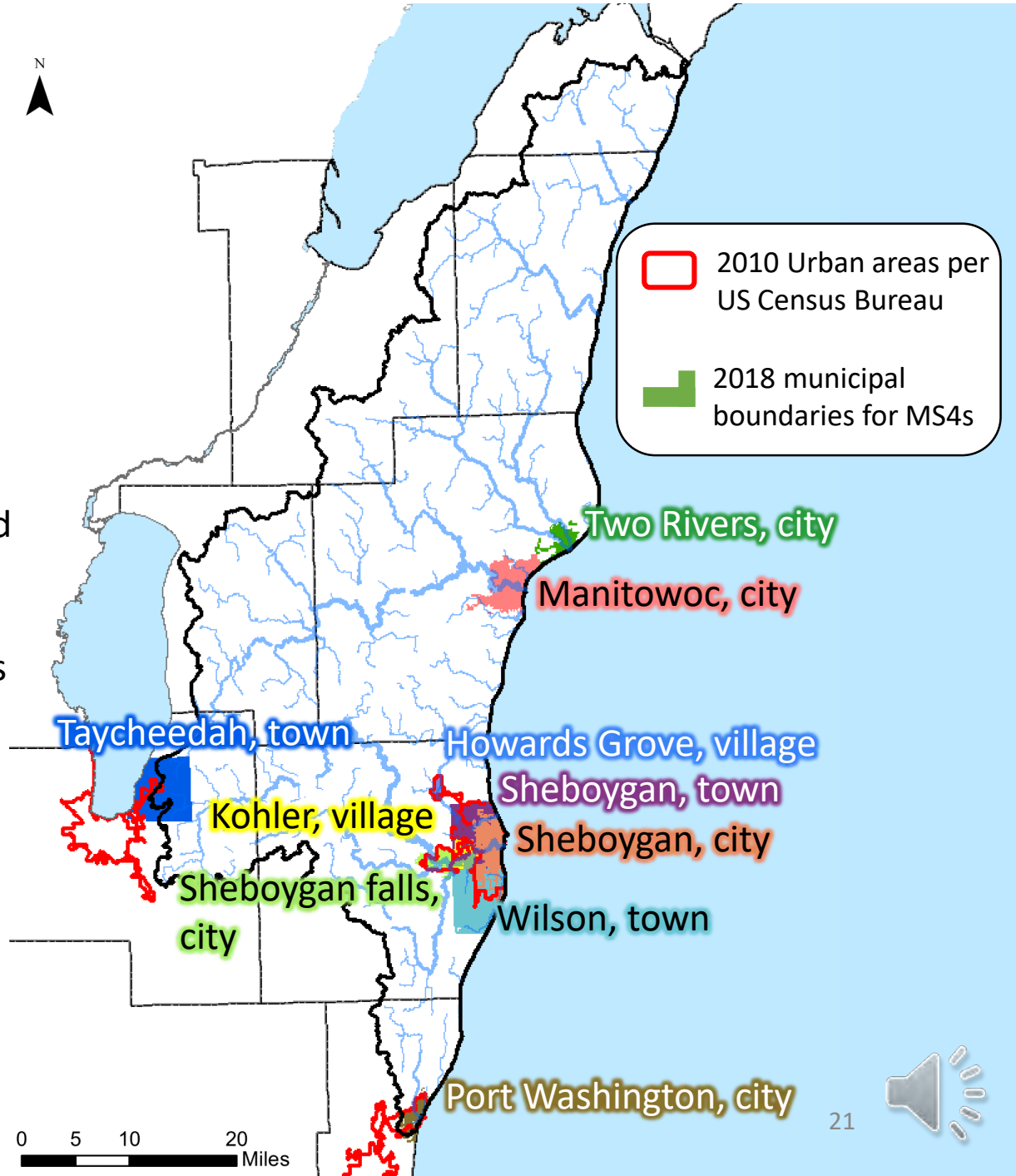
# Permitted Urban Stormwater Areas (MS4)

10 municipalities with MS4 permits

Permitted area

- Towns – municipal area within urban area (per 2010 US census)
- Villages and Cities – all of their municipal area (regardless of urban area designation)

Verified with permit holders in July 2019



# Data Collection: Land Cover

- Climate
- Elevation
- Hydrology
- Soils
- **Land cover**
- Land Management
- Point Sources

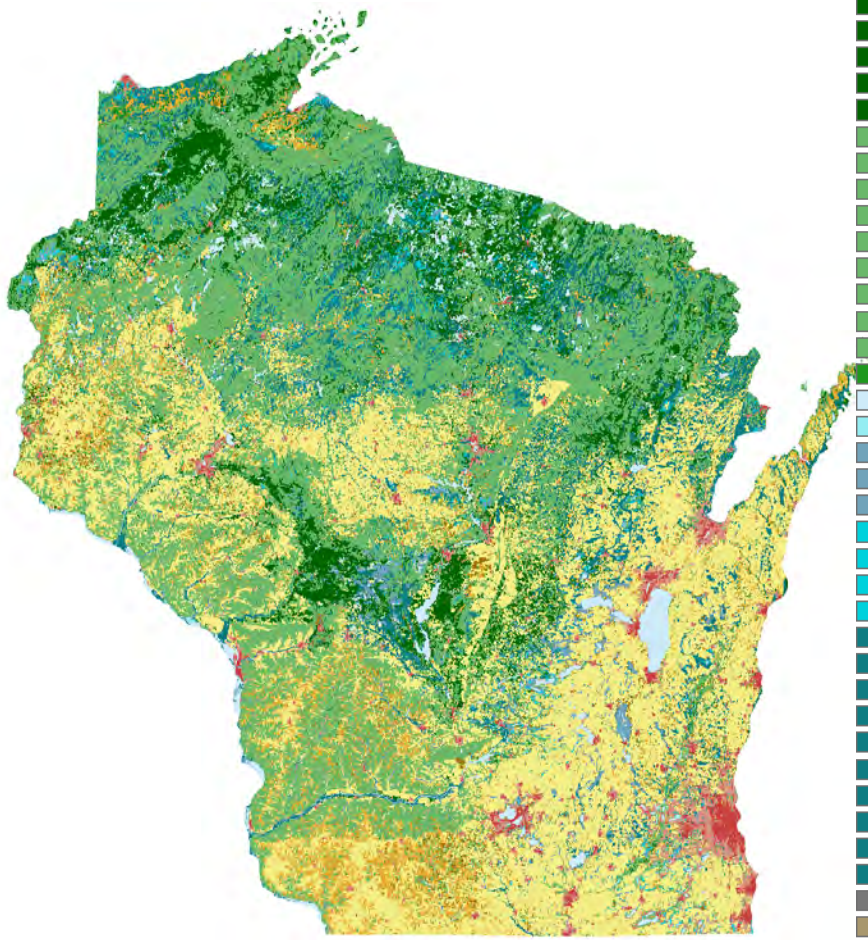
**Wiscland 2** Land cover dataset

Developed by UW Madison, WDNR, and WI State Cartography Office

<u>Non-Agricultural Classes</u>

Data source: Satellite imagery from Landsat 5, 7, and 8

Imagery from 2010 - 2014



Level 4 classifications

- Developed, High Intensity
- Developed, Low Intensity
- Cash Grain
- Continous Corn
- Dairy Rotation
- Potato/Vegetable
- Cranberries
- Hay
- Pasture
- Cool-season Grass
- Warm-season Grass
- Fir Spruce
- Jack Pine
- Red Pine
- White Pine
- Hemlock Hardwoods
- Aspen Forest
- Paper Birch
- Red Maple
- N. Pin Oak, Black Oak
- Red Oak
- White Oak, Burr Oak
- Central Hardwoods
- Sugar Maple
- Other Northern Hardwoods
- Mixed Deciduous/Coniferous Forest
- Open Water
- Floating Aquatic Herbaceous Vegetation
- Cattails
- Reed Canary Grass
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- White Cedar
- Black Spruce
- Tamarack
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- Silver Maple
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- Black Ash
- Other Swamp Hardwoods
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- Barren
- Shrubland

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## Non-Agricultural Classes

Data source: Satellite imagery from Landsat 5, 7, and 8

Imagery from 2010 - 2014

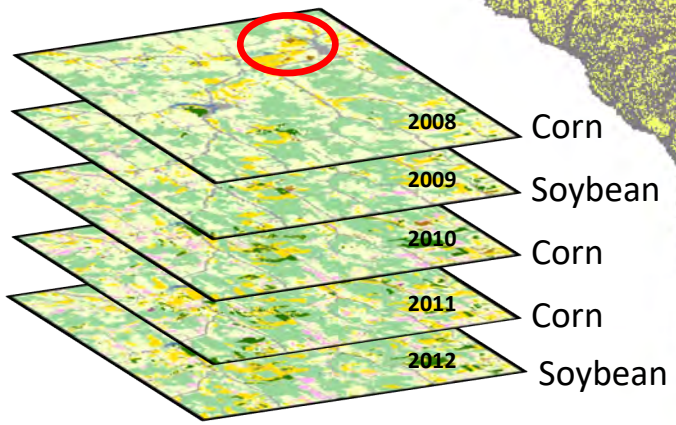
## Agricultural Classes

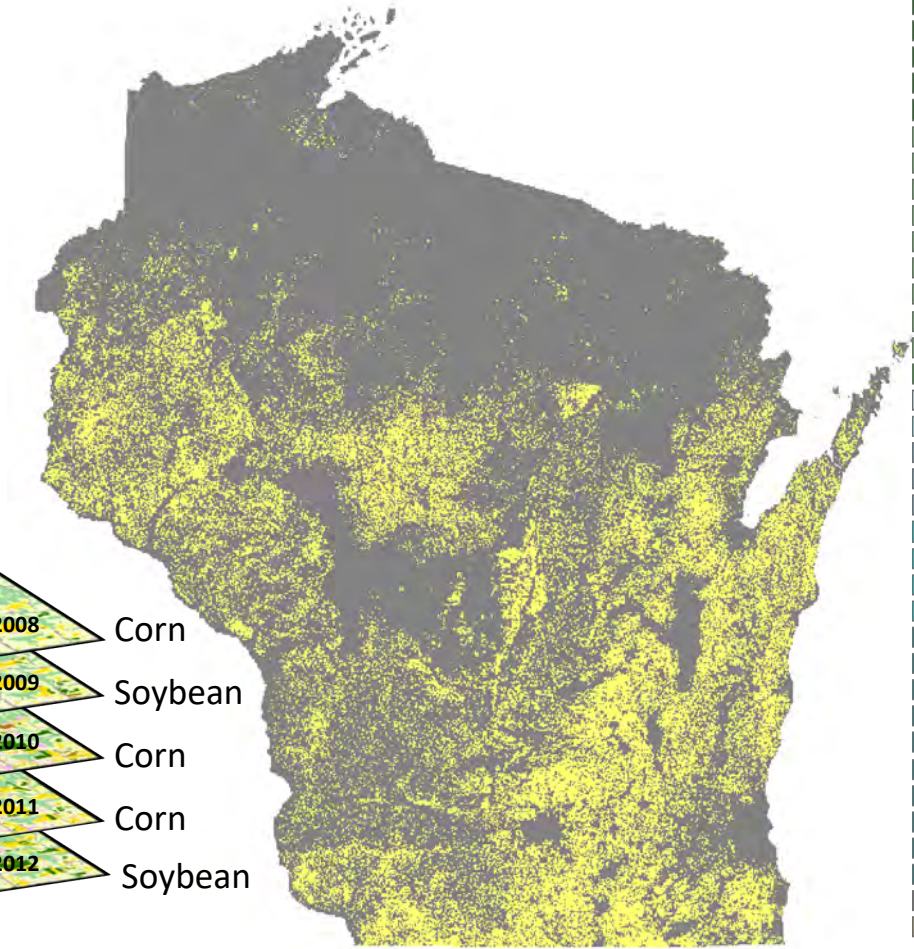
Data source: USDA National Agriculture Statistics Service (NASS) Cropland Data Layer (CDL)

Imagery from 2008 - 2012

WDNR defined crop rotation area for:

- Cash Grain
- Dairy
- Continuous Corn
- Potato Vegetable



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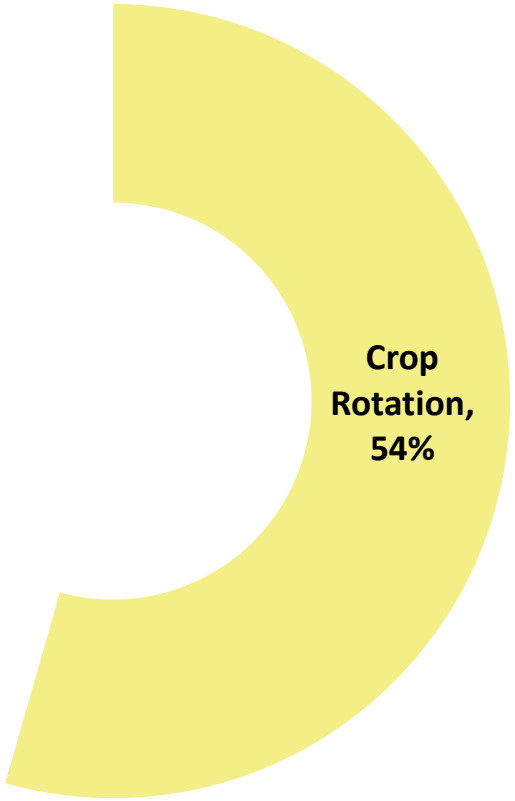
Wiscland 2 land cover in the NE Lakeshore TMDL area

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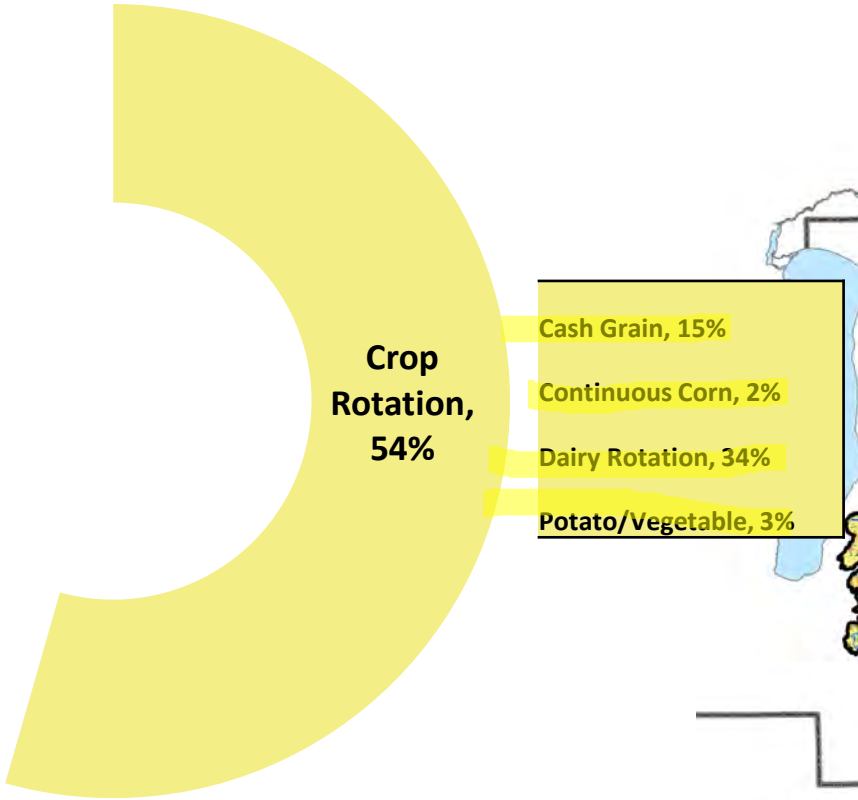


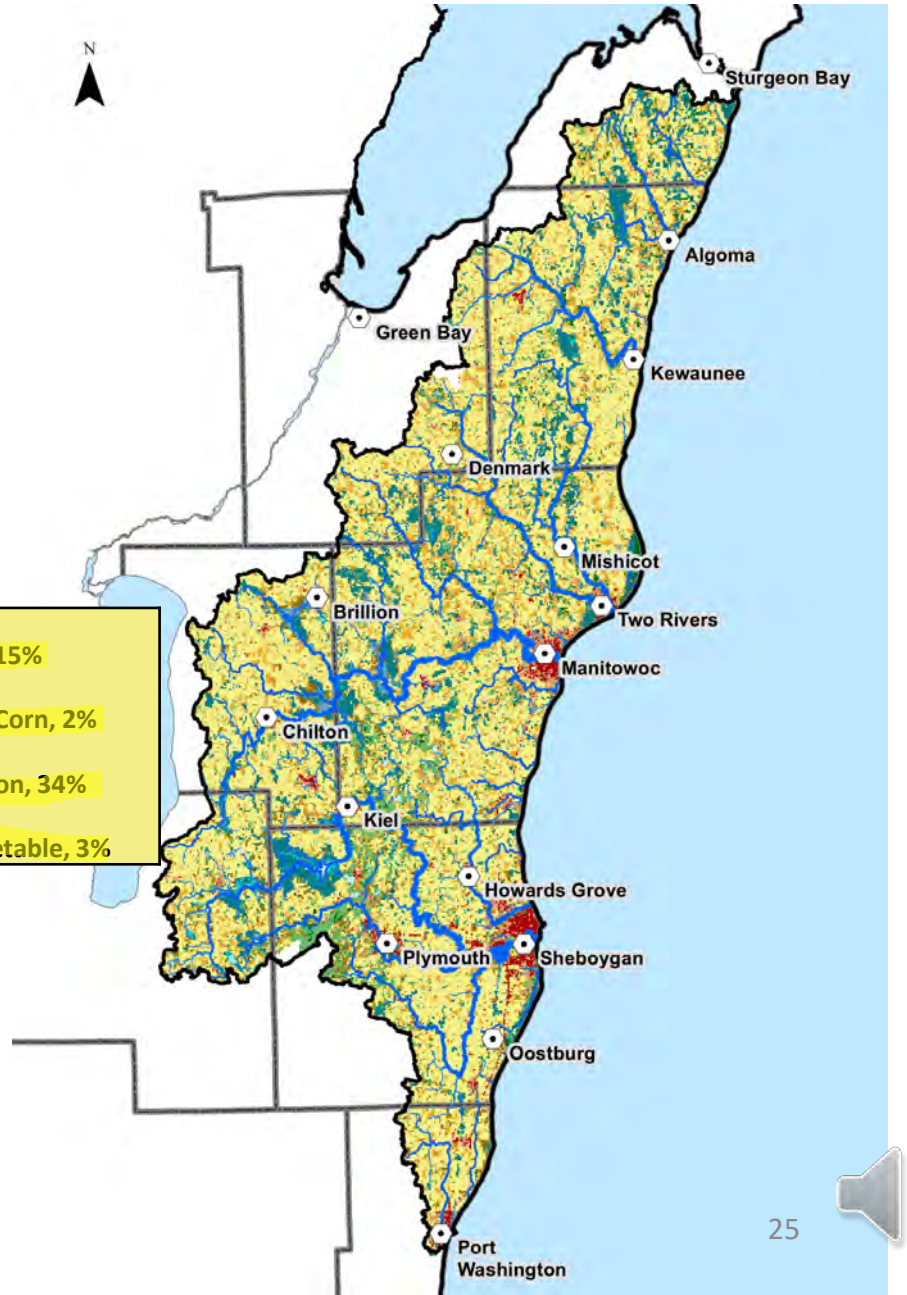

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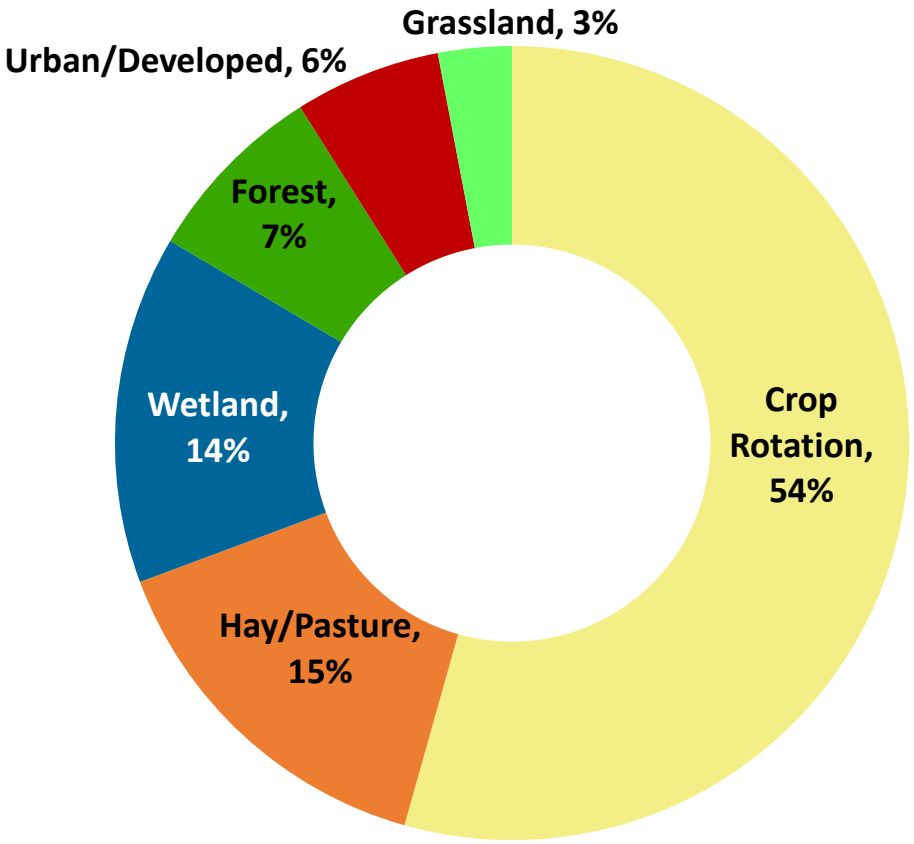
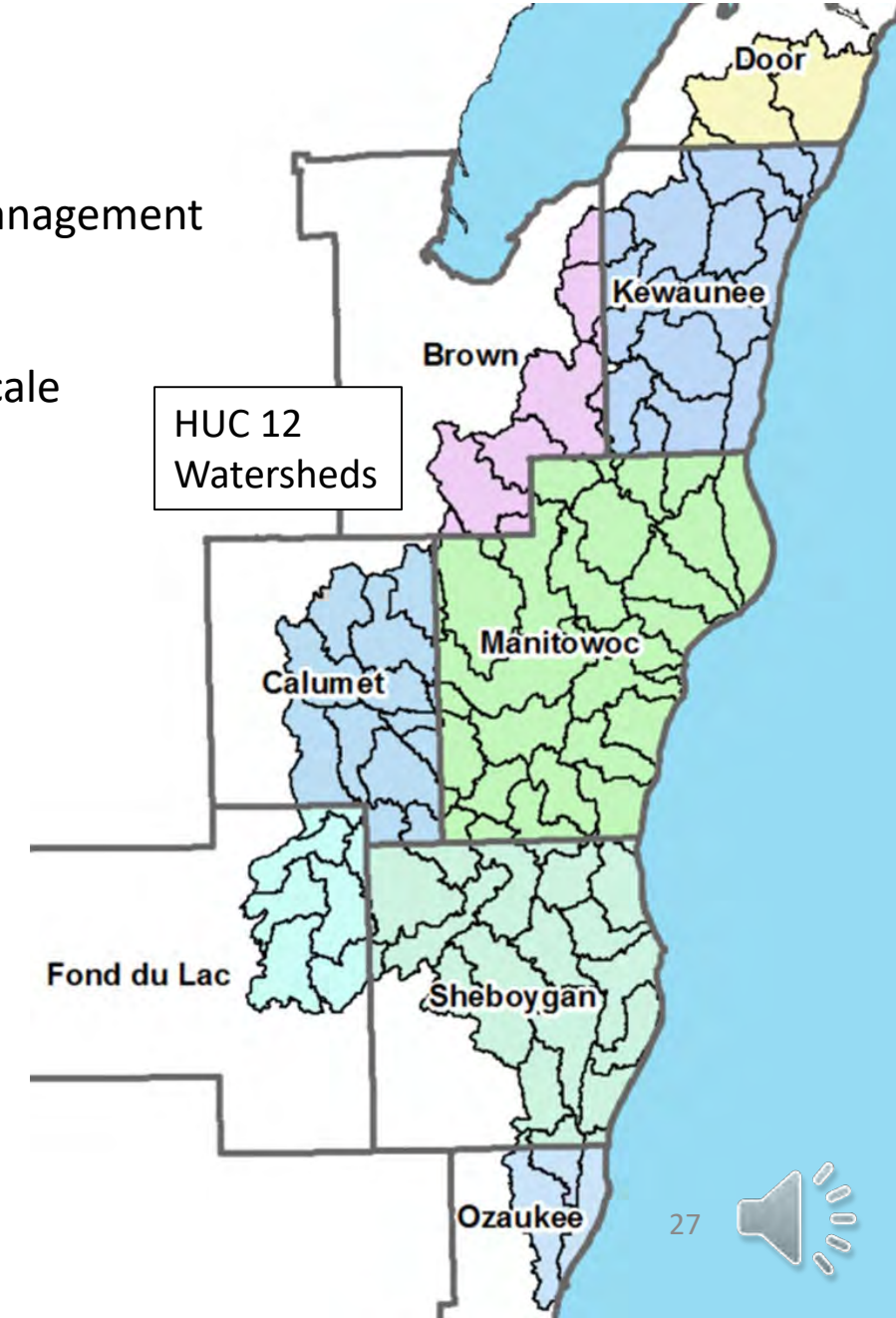



# Data Collection: Agricultural Land Management

- Climate
- Elevation
- Hydrology
- Soils
- Land Cover
- **Agricultural Land Management**
- Point Sources

## Source 1: Agricultural questionnaire survey

- Objective: gather local knowledge of agricultural land management
- Administered by WDNR in Spring 2019
- Completed by 8 County Land and Water Departments
- 24 questions at the County-wide to HUC 12 watershed scale
  - Agricultural land cover (Wiscland 2 verification)
  - Crops within a dairy rotation
  - Tillage
  - Chemical fertilizer
  - Manure spreading
  - Planting and harvest
  - Crop yields
  - Livestock grazing
  - Soil phosphorus content



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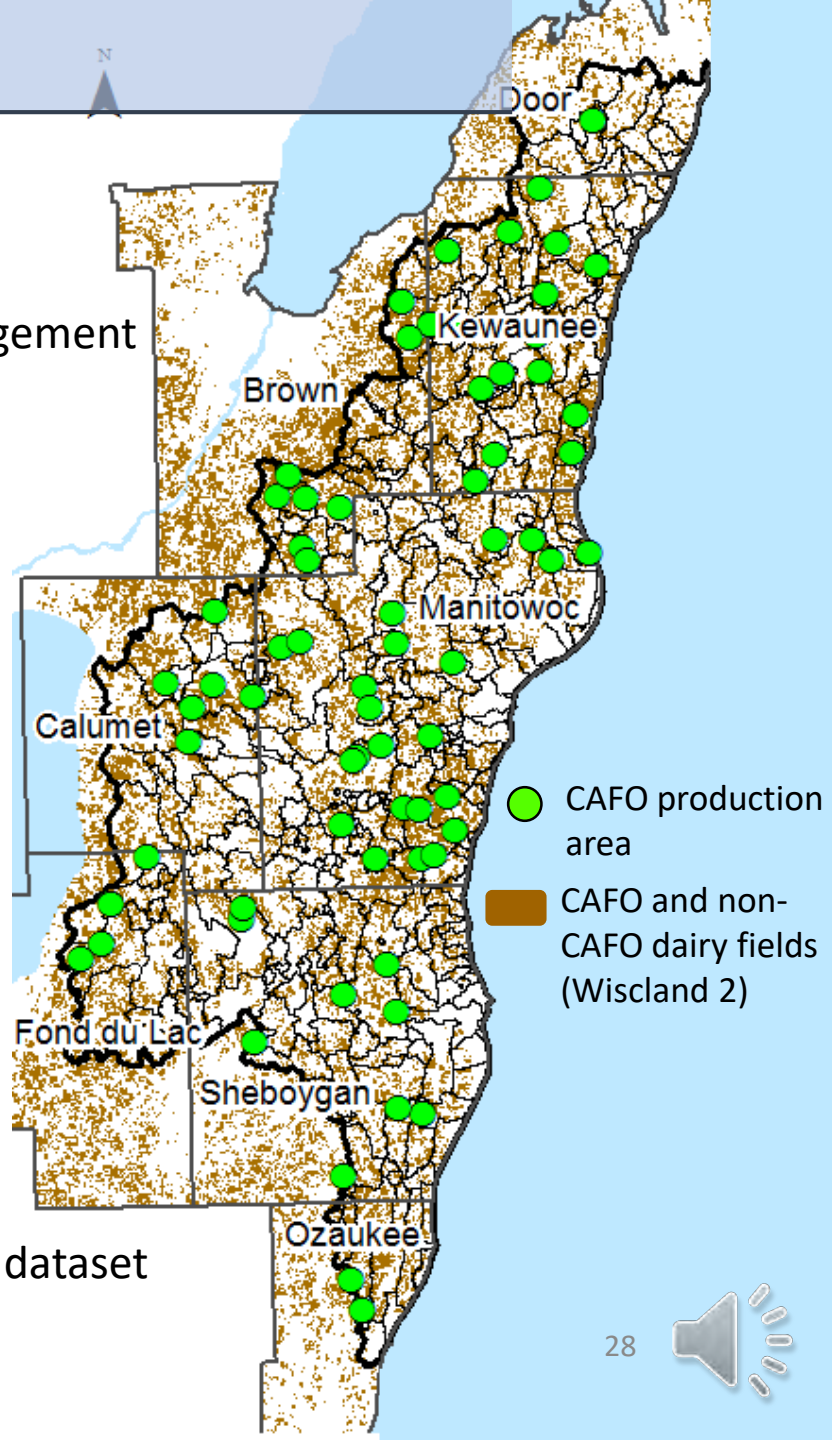



## Source 2: CAFO nutrient management plans

Analyzed by DNR for:

- **Soil phosphorus** – used to generate a soil phosphorus dataset
- **Manure spreading** – used to verify results of a manure spreading dataset generated by DNR

**Data sources:**

1) Agriculture survey responses
2) CAFO nutrient management plans

} Provided more detail than could be entered into watershed model

**Raw data**

- County agriculture survey results
- CAFO nutrient management plans

Two datasets developed from the raw data:

**1) Implementation scale** – preserved detail of the raw data for future implementation analysis

**2) Watershed Model scale** – practices with a similar effect on the landscape were aggregated. Result = dataset depicting a range of the most typical practices in the study area.

# Agricultural Land Management

Survey responses

- Counties provided more detail than could be incorporated into the model

Two datasets developed from the survey results

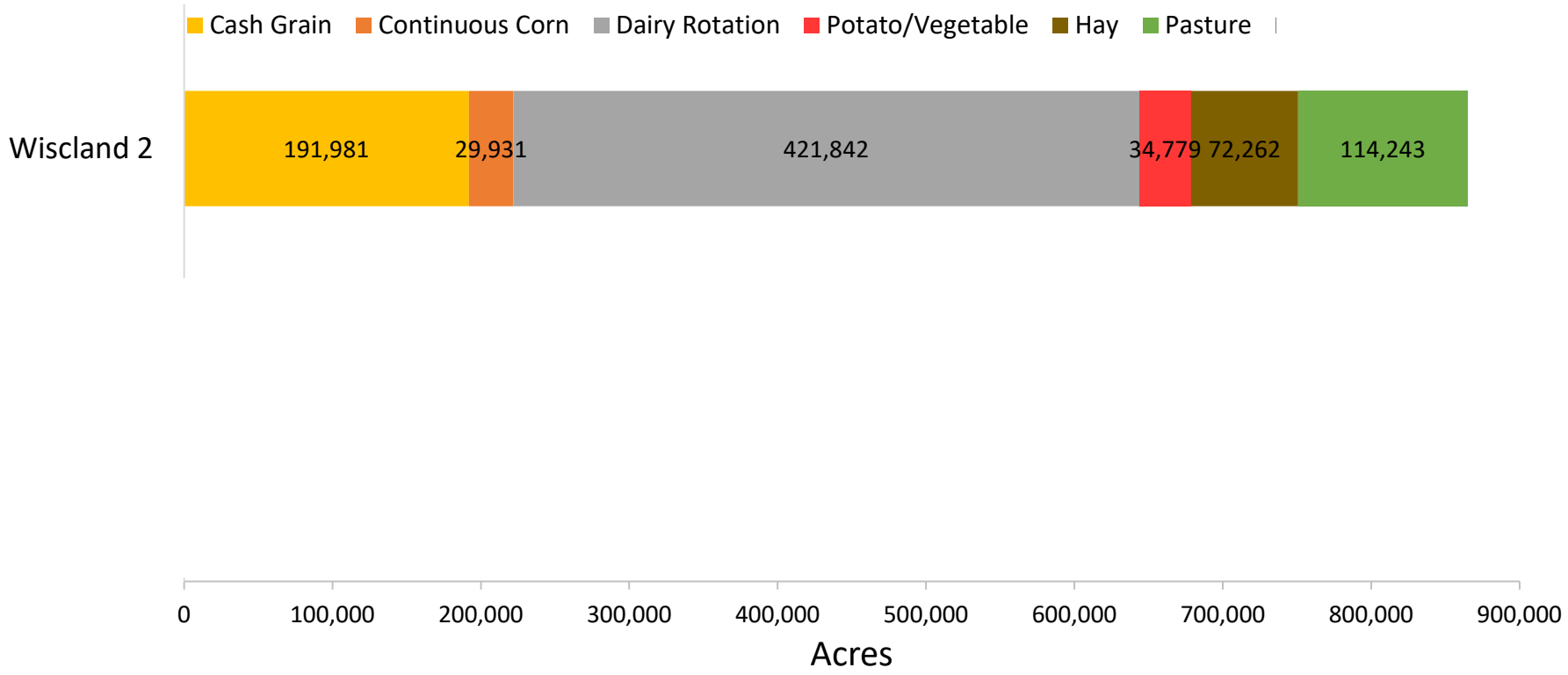
**Raw data**

- County ag surveys
- CAFO data/DNR analysis

**1) Implementation scale** – preserved detail of the raw data for future implementation analysis

**2) Watershed Model scale** – practices with a similar effect on the landscape were aggregated

# Review of the Wiscland2 dataset (agricultural land cover) by counties



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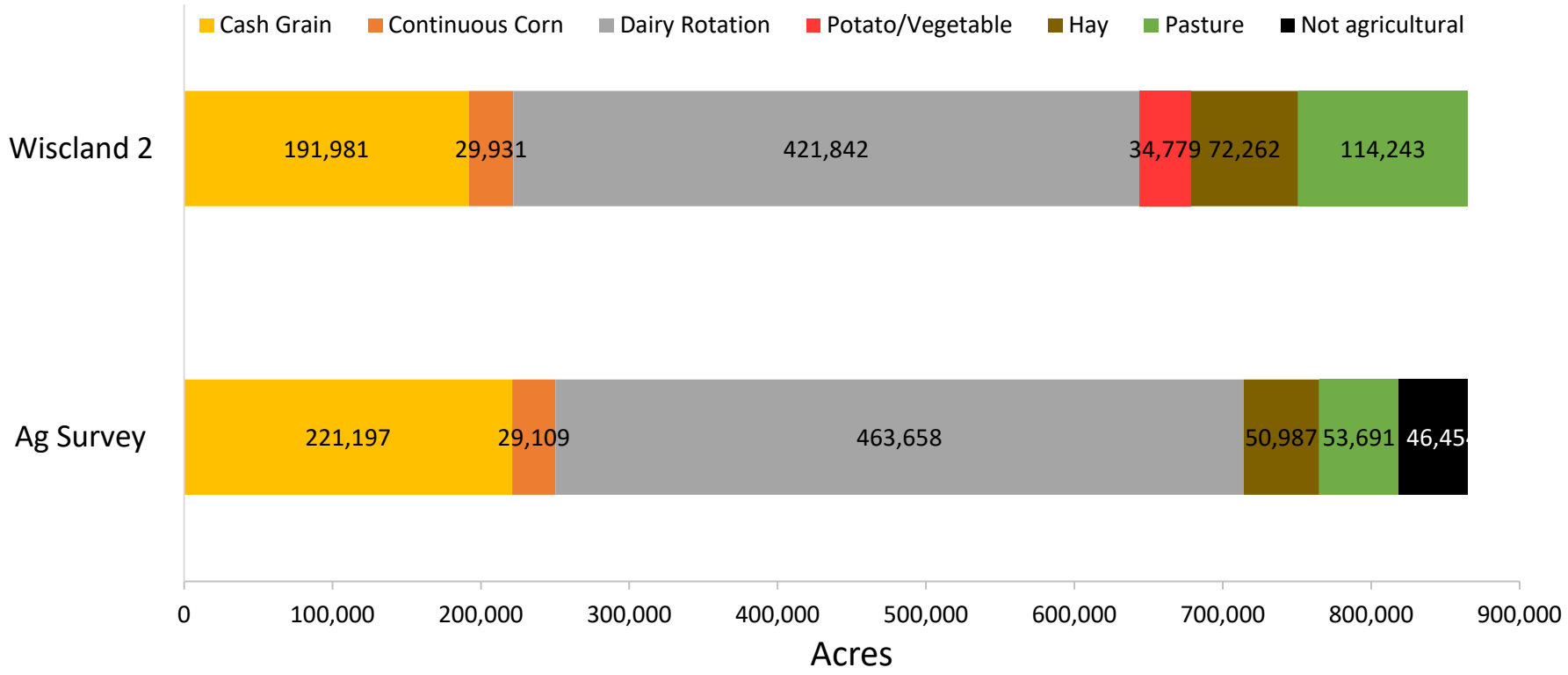


Agriculture survey results

# Dairy rotations

- 23 unique rotations provided
- 1 -5 rotations per county
- Length range from 4-8 years
- Average length = 7 years
- Crops = 10

| County | Area (ac) | Rotation Year 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Manitowoc | 132,039 | Cs | Cs | Cg | Cs | A | A | A | |
| Kewaunee | 82,799 | Cs | Cs | o/a | A | A | A | | |
| Sheboygan | 72,515 | Cs | S | Cs | S | A | A | A | |
| Calumet | 41,823 | Cs | Cs | Cs | A | A | A | A | |
| Brown | 22,447 | Cs | Cs | Cs | Cs | A | A | A | A |
| Brown | 16,346 | Cs | Cg | S | Ww | Cs | A | A | A |
| Door | 14,849 | Cs | Ww/o | A | A | A | A | | |
| Fond du Lac | 12,604 | Cs | Cs | p/o | A | A | A | | |
| Sheboygan | 8,685 | Cs | Ww | A | A | A | | | |
| Sheboygan | 8,410 | Cs | A | A | A | | | | |
| Fond du Lac | 7,878 | Cg | Cs | Cg | Cs | o/a | A | A | A |
| Ozaukee | 7,431 | Cs | Cs | S | Ww | p/o | A | A | A |
| Fond du Lac | 6,069 | Cs | S | Cs | A | A | A | A | |
| Fond du Lac | 5,752 | Cs | S | Cs | Ww | A | A | A | A |
| Calumet | 5,228 | Cs | Cs | Cg | A | A | A | A | |
| Ozaukee | 3,287 | Cs | Cs | Cs/a | A | A | A | A | Cg |
| Door | 3,273 | Cs | Cs | Ww/o | A | A | A | A | |
| Fond du Lac | 3,236 | Cs/cc | Cs/cc | o/a | A | A | A | | |
| Calumet | 2,613 | Cs | Cs | S | A | A | A | A | |
| Calumet | 2,613 | Cs | Cs | Ww | A | A | A | A | |
| Ozaukee | 2,515 | Cs/cc | Cs/cc | S | Ww | p/o | A | A | A |
| Ozaukee | 1,629 | Cs/cc | Cs/cc | Ww | S | A | A | A | Cg |
| Door | 1,490 | Cs | Cs | A | A | A | A | | |

| | |
|---|---|
| A | Alfalfa |
| Cg | Corn grain |
| Cs | Corn silage |
| Cs/cc | Corn silage w/ cover crop |
| Cs/a | Corn silage w/ alfalfa |
| o/a | Oats/alfalfa |
| p/o | Peas/oats |
| S | Soybean |
| Ww | Winter wheat |
| Ww/o | Winter wheat w/ oat |

Agriculture survey results

# Dairy rotations

- 23 unique rotations provided
- 1 -5 rotations per county
  - For example Manitowoc
- Length range from 4-8 years
- Average length = 7 years
- Crops = 10

| County | Area (ac) | Rotation Year 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Manitowoc | 132,039 | Cs | Cs | Cg | Cs | A | A | A | |
| Kewaunee | 82,799 | Cs | Cs | o/a | A | A | A | | |
| Sheboygan | 72,515 | Cs | S | Cs | S | A | A | A | |
| Calumet | 41,823 | Cs | Cs | Cs | A | A | A | A | |
| Brown | 22,447 | Cs | Cs | Cs | Cs | A | A | A | A |
| Brown | 16,346 | Cs | Cg | S | Ww | Cs | A | A | A |
| Door | 14,849 | Cs | Ww/o | A | A | A | A | | |
| Fond du Lac | 12,604 | Cs | Cs | p/o | A | A | A | | |
| Sheboygan | 8,685 | Cs | Ww | A | A | A | | | |
| Sheboygan | 8,410 | Cs | A | A | A | | | | |
| Fond du Lac | 7,878 | Cg | Cs | Cg | Cs | o/a | A | A | A |
| Ozaukee | 7,431 | Cs | Cs | S | Ww | p/o | A | A | A |
| Fond du Lac | 6,069 | Cs | S | Cs | A | A | A | A | |
| Fond du Lac | 5,752 | Cs | S | Cs | Ww | A | A | A | A |
| Calumet | 5,228 | Cs | Cs | Cg | A | A | A | A | |
| Ozaukee | 3,287 | Cs | Cs | Cs/a | A | A | A | A | Cg |
| Door | 3,273 | Cs | Cs | Ww/o | A | A | A | A | |
| Fond du Lac | 3,236 | Cs/cc | Cs/cc | o/a | A | A | A | | |
| Calumet | 2,613 | Cs | Cs | S | A | A | A | A | |
| Calumet | 2,613 | Cs | Cs | Ww | A | A | A | A | |
| Ozaukee | 2,515 | Cs/cc | Cs/cc | S | Ww | p/o | A | A | A |
| Ozaukee | 1,629 | Cs/cc | Cs/cc | Ww | S | A | A | A | Cg |
| Door | 1,490 | Cs | Cs | A | A | A | A | | |

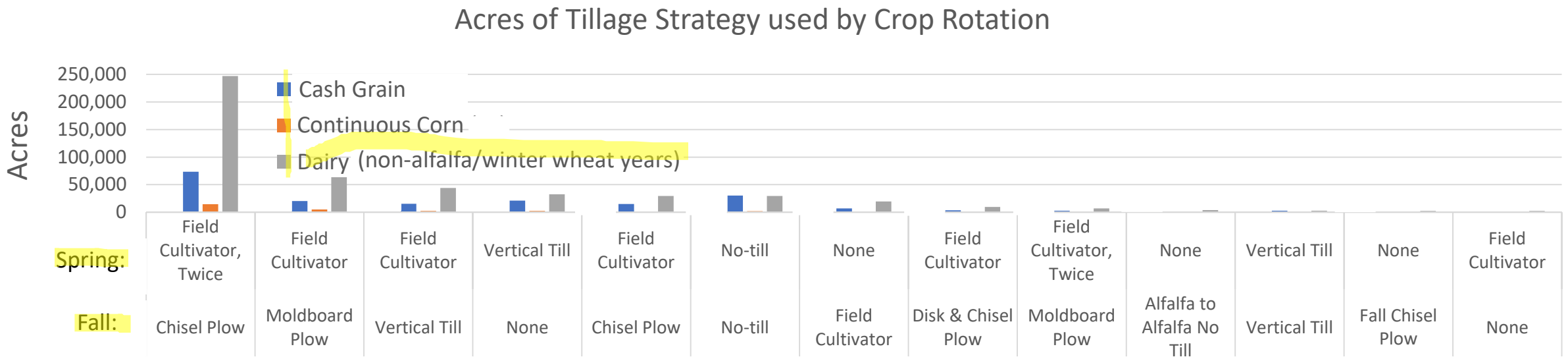
| | |
|---|---|
| A | Alfalfa |
| Cg | Corn grain |
| Cs | Corn silage |
| Cs/cc | Corn silage w/ cover crop |
| Cs/a | Corn silage w/ alfalfa |
| o/a | Oats/alfalfa |
| p/o | Peas/oats |
| S | Soybean |
| Ww | Winter wheat |
| Ww/o | Winter wheat w/ oat |

Dairy Rotations for the Watershed Model:

| Class Name | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|---|---|---|---|---|---|
| Dairy Sequence 1 | CS | CS | CS | ALF | ALF | ALF |
| Dairy Sequence 2 | CS | CS | CG | ALF | ALF | ALF |
| Dairy Sequence 3 | CS | CS | SOY | WW | ALF | ALF |

Agriculture survey results

# Tillage strategies

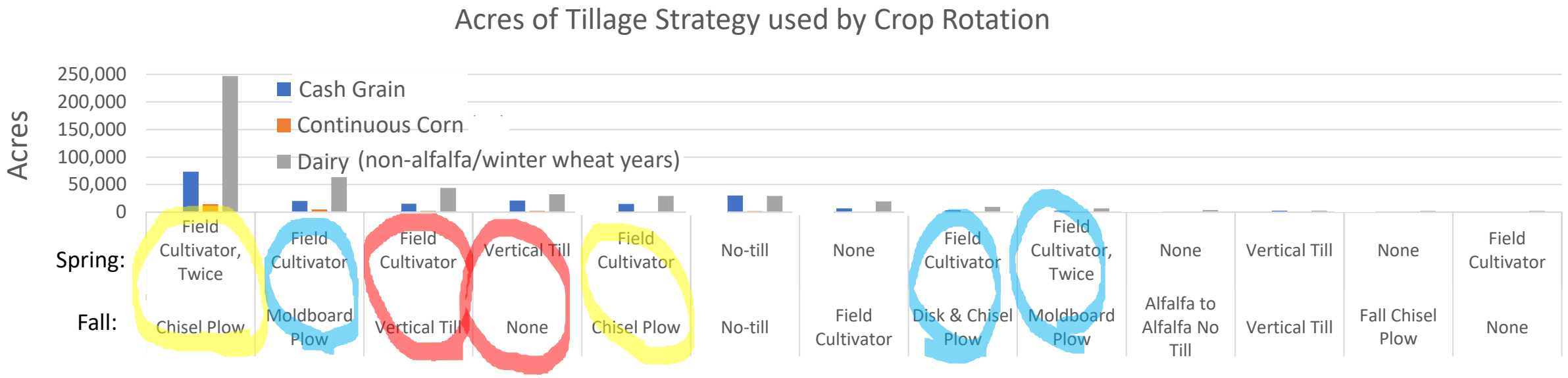



Tillage strategies for the watershed model:

| ID | Spring | Fall |
|---|---|---|
| Till 1 | Cultivator, 2X | Chisel Plow |
| Till 2 | Cultivator | Disk/Moldboard Plow |
| Till 3 | Vertical Till | None |
| Till 4 (Cash Grain only) | Cultivator (Corn), No Till (Soybean) | Chisel Plow (Corn), No Till (Soybean) |

Agriculture survey results

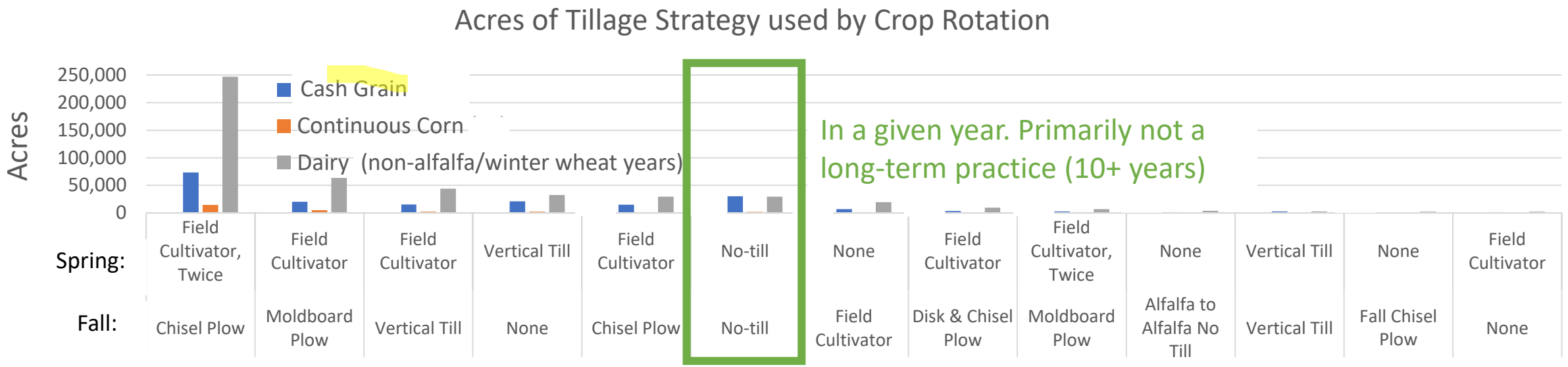
# Tillage strategies




Tillage strategies for the watershed model:

| ID | Spring | Fall |
|---|---|---|
| Till 1 | Cultivator, 2X | Chisel Plow |
| Till 2 | Cultivator | Disk Plow |
| Till 3 | Vertical Till | None |
| Till 4 (Cash Grain only) | Cultivator (Corn), No Till (Soybean) | Chisel Plow (Corn), No Till (Soybean) |

# Tillage strategies



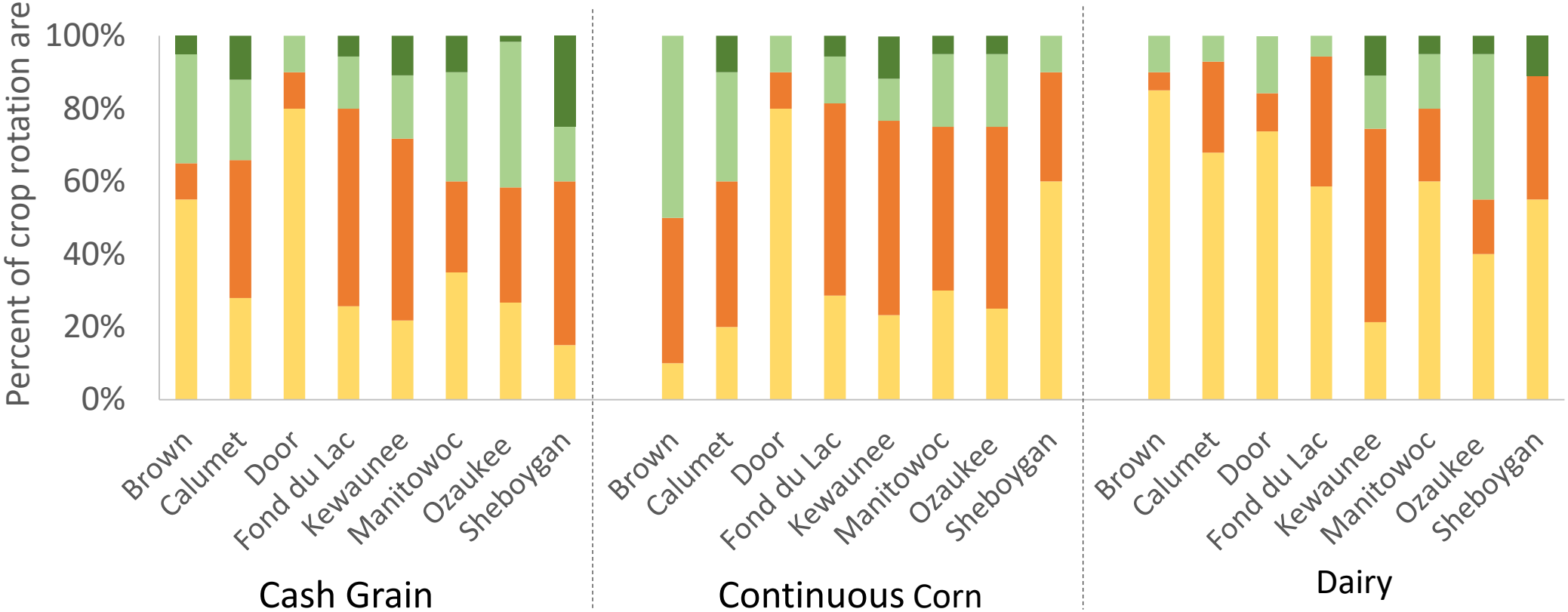

Tillage strategies for the watershed model:

| ID | Spring | Fall |
|---|---|---|
| Till 1 | Cultivator, 2X | Chisel Plow |
| Till 2 | Cultivator | Disk/Moldboard Plow |
| Till 3 | Vertical Till | None |
| Till 4 (Cash Grain only) | Cultivator (Corn), No Till (Soybean) | Chisel Plow (Corn), No Till (Soybean) |

Agriculture survey results

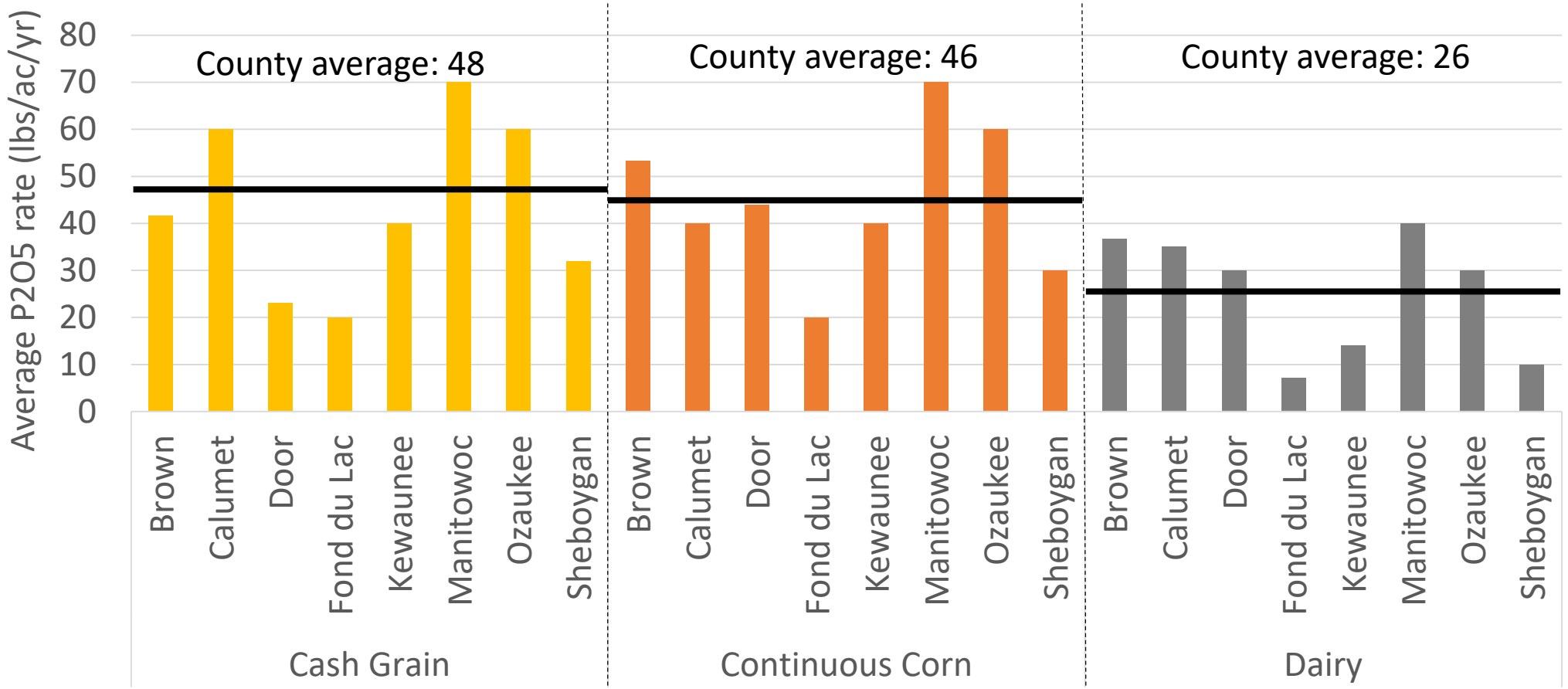
# Crop Residue


Residue Class: 0 – 15% 16 – 30% > 30 % No-till/ Zone-Till

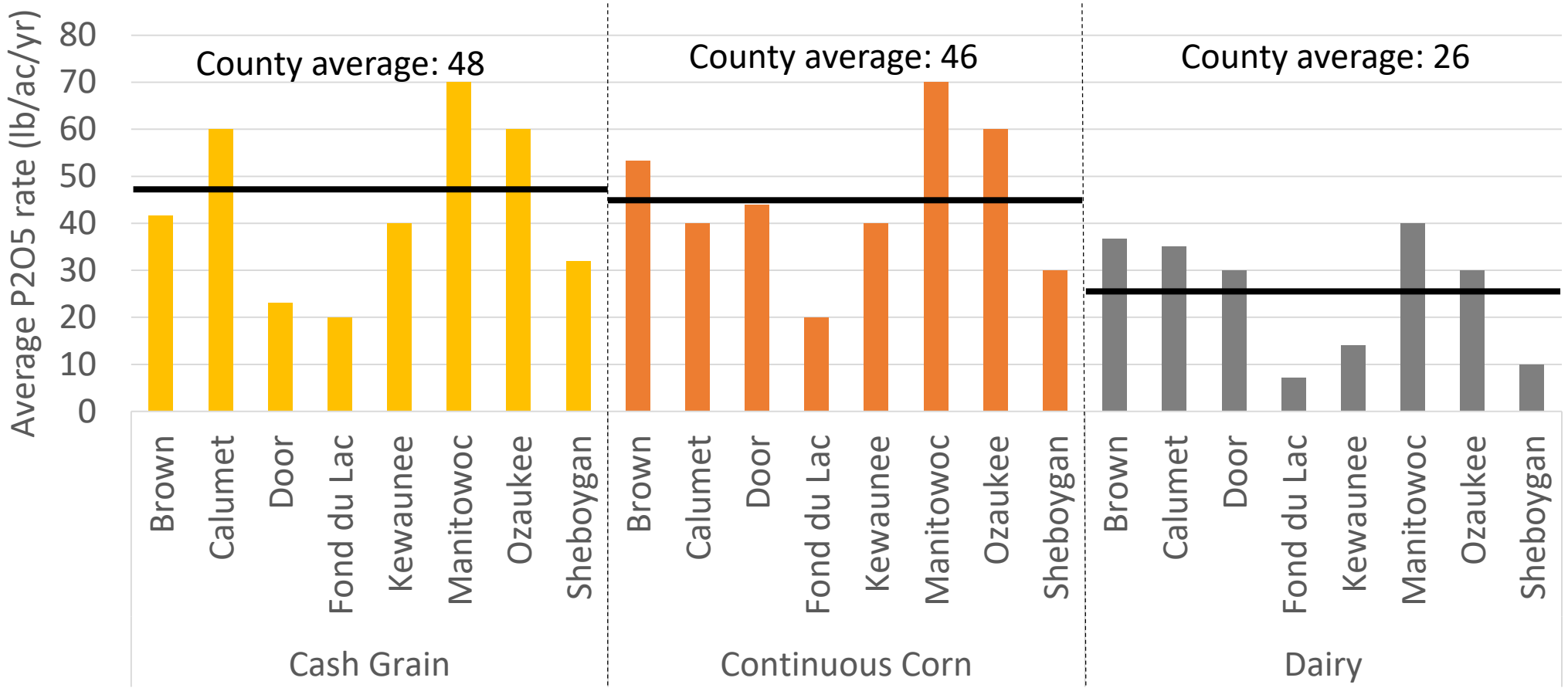



(non-alfalfa/winter wheat years)

# Chemical Phosphate Fertilizer



# Chemical Phosphorus Fertilizer




Timing:

3 x per year

3 x per year

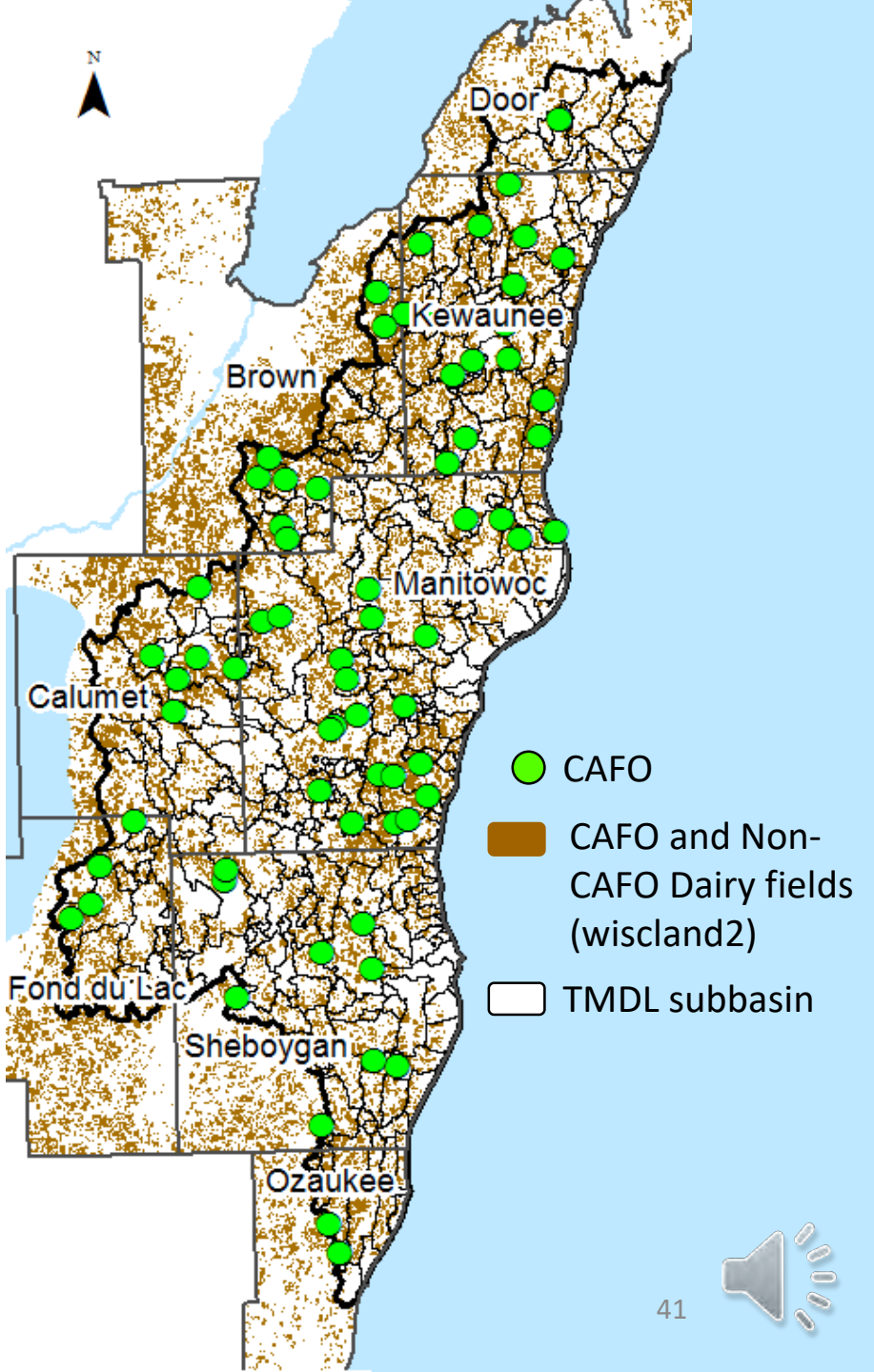
Corn or Soy – 3 x per year
Alfalfa or Winter Wheat – 2 x per year

# Soil Phosphorous

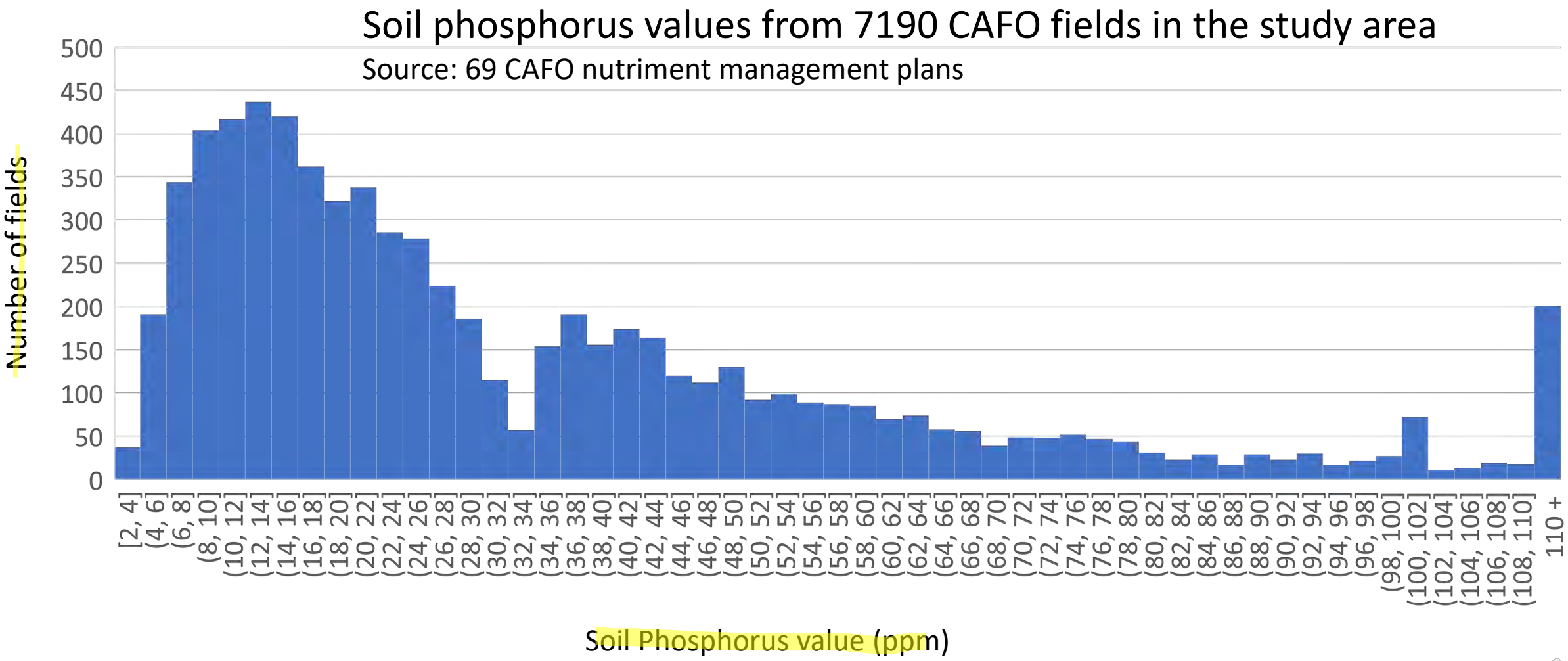
Two information sources

1) County agriculture survey
   - Average per HUC12

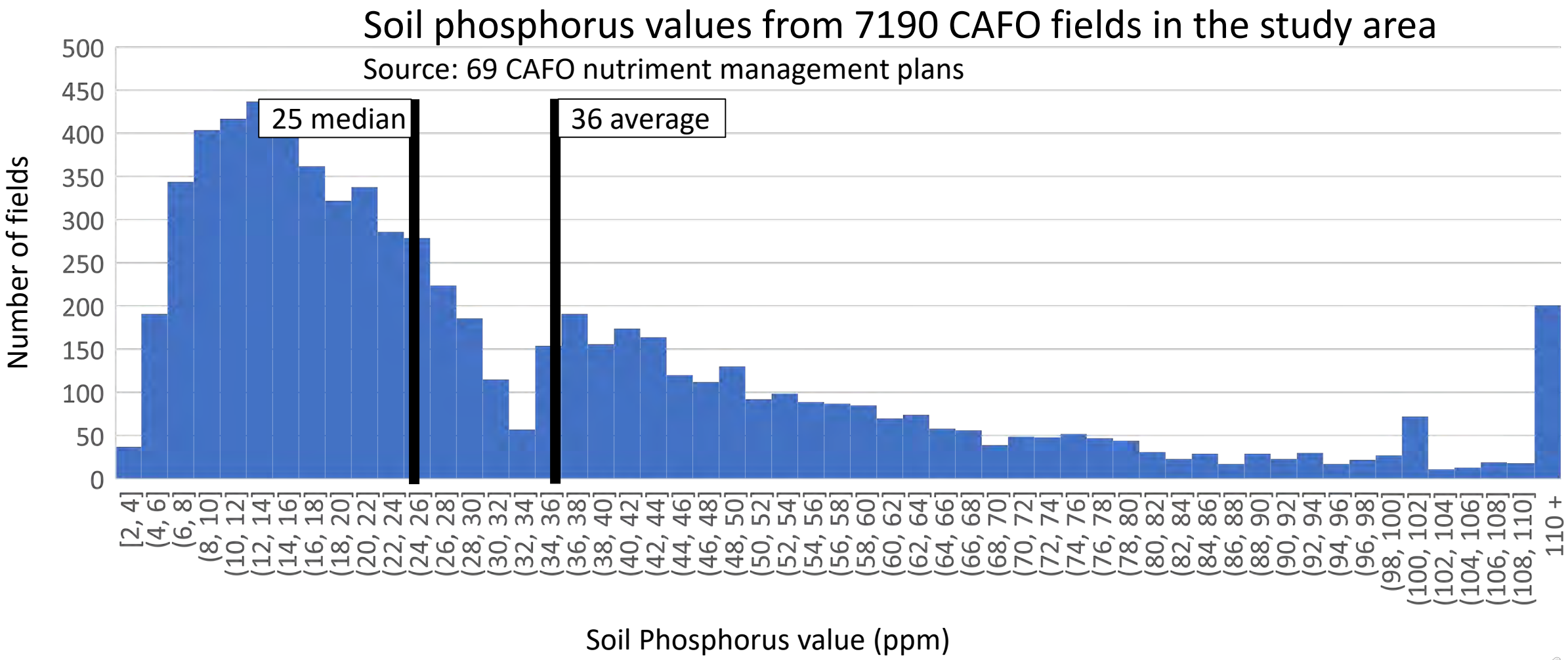
2) CAFO nutrient management plans
   - 69 CAFOs
   - Data aggregated and represented as **Median per subbasin**



# Soil P results (ppm) from CAFO Nutrient Management Plans



# Soil P results (ppm) from CAFO Nutrient Management Plans

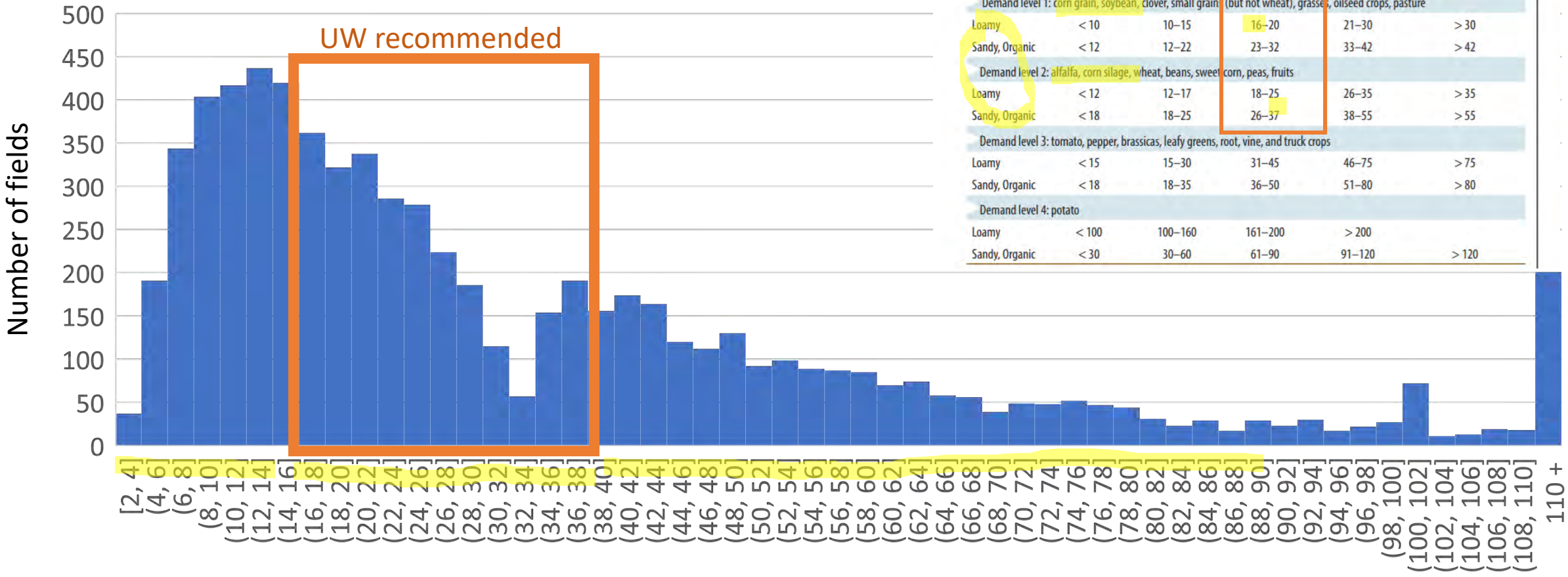


# Soil P results (ppm) from CAFO Nutrient Management Plans

UW extension document A2809: Nutrient application guidelines for field, vegetable, and fruit crops in WI

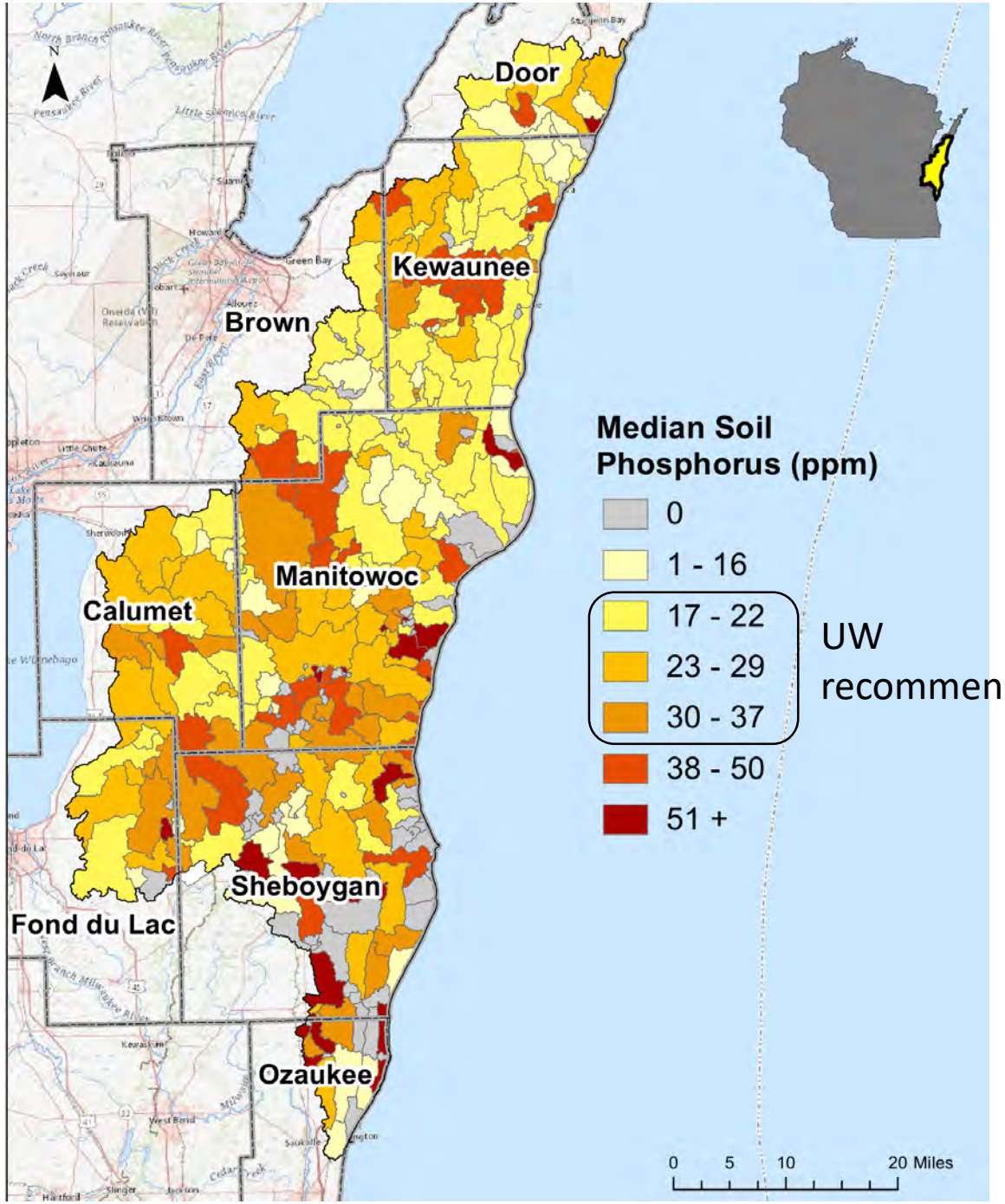
**Table 7.1.** Soil test phosphorus (P) interpretation categories. Choose the highest demanding crop in your rotation to set the soil test interpretation categories for the rotation. If the desired crop is not listed on the table, consult Table 4.2 to determine its demand level.

| | Soil test category | | | | |
|---|---|---|---|---|---|
| | Very low (VL) | Low (L) | Optimum (O) | High (H) | Excessively high (EH) |
| Soil group[a] | soil test P ppm[b] | | | | |
| Demand level 1: corn grain, soybean, clover, small grains (but not wheat), grasses, oilseed crops, pasture | | | | | |
| Loamy | < 10 | 10–15 | 16–20 | 21–30 | > 30 |
| Sandy, Organic | < 12 | 12–22 | 23–32 | 33–42 | > 42 |
| Demand level 2: alfalfa, corn silage, wheat, beans, sweet corn, peas, fruits | | | | | |
| Loamy | < 12 | 12–17 | 18–25 | 26–35 | > 35 |
| Sandy, Organic | < 18 | 18–25 | 26–37 | 38–55 | > 55 |
| Demand level 3: tomato, pepper, brassicas, leafy greens, root, vine, and truck crops | | | | | |
| Loamy | < 15 | 15–30 | 31–45 | 46–75 | > 75 |
| Sandy, Organic | < 18 | 18–35 | 36–50 | 51–80 | > 80 |
| Demand level 4: potato | | | | | |
| Loamy | < 100 | 100–160 | 161–200 | > 200 | |
| Sandy, Organic | < 30 | 30–60 | 61–90 | 91–120 | > 120 |



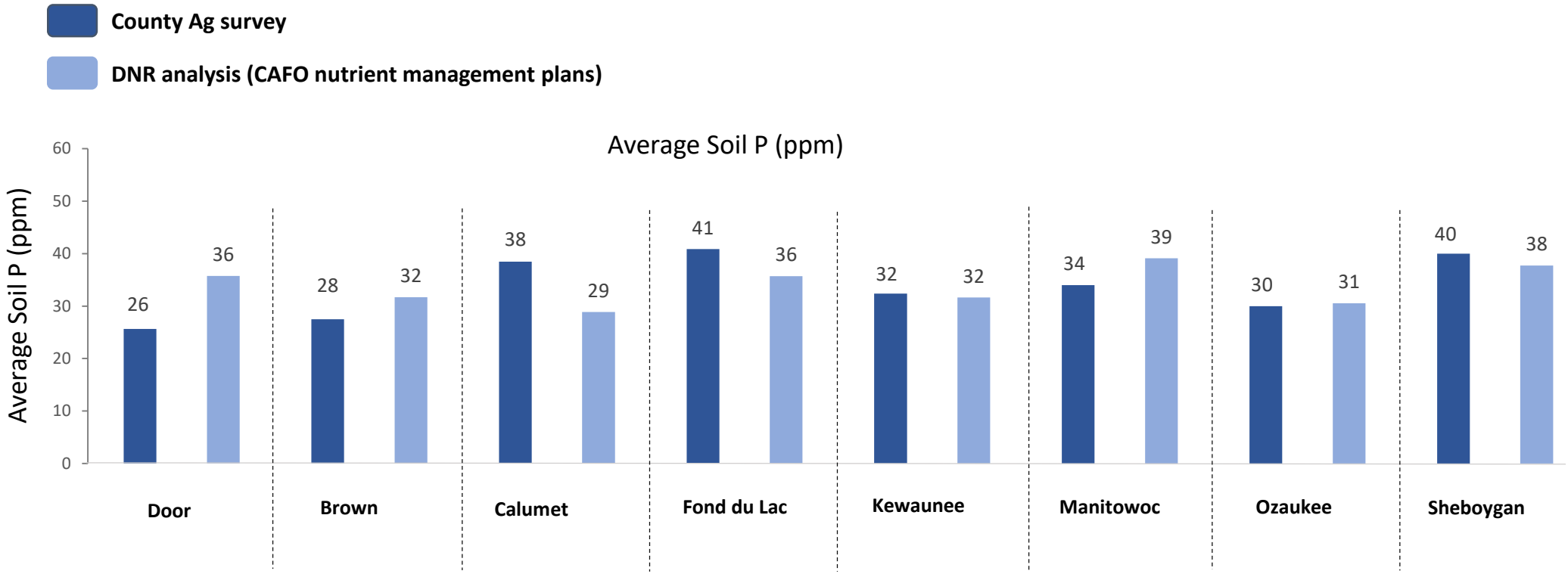
# Median soil P for CAFO fields per subbasin

Results of the DNR's analysis of 69 CAFO nutrient management plans with production areas in the TMDL area.



# Validation of DNR soil P analysis (CAFO NMPs)

Comparison of County-wide average provided by County land and water departments with DNR's county wide average from the CAFO nutrient management plans



## Agricultural classes for SWAT

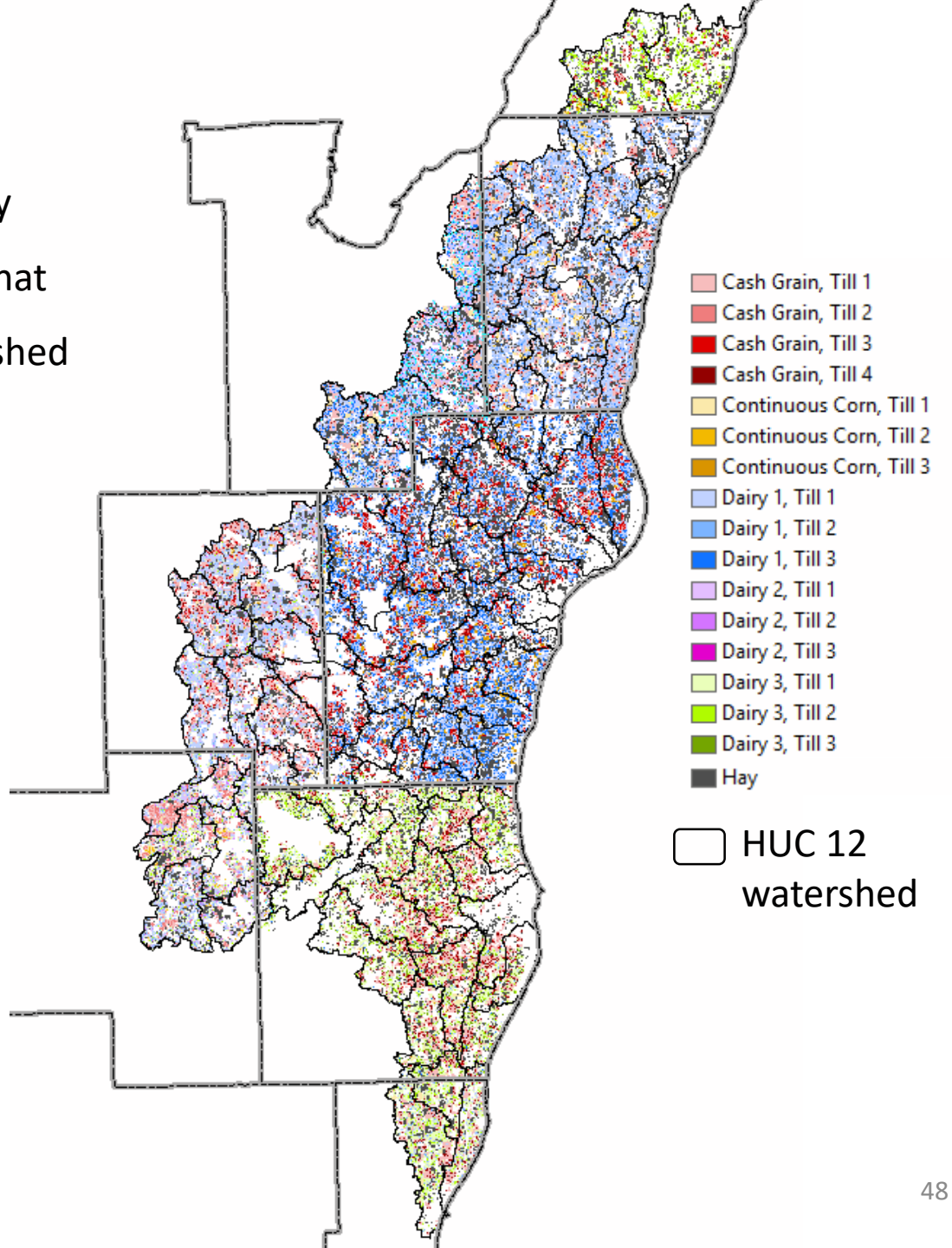
- Survey resulted in 17 agricultural classes
- Wiscland 2 + Agriculture survey = spatial & temporal agricultural dataset for the SWAT watershed model

| Crop Rotation Type | Crop | | | | | | Fall Tillage | Spring Tillage | Chemical P2O5 (lb/ac/yr) | Manure |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | | | | |
| Dairy Sequence 1 | CS | CS | CS | ALF | ALF | ALF | *Chisel Plow | *Cultivator, 2X | **26** Divided between 2 -3 applications | **Liquid**; unique rate per subbasin. 2 times per year. None for alfalfa/winter wheat |
| | | | | | | | *Disk Plow | *Cultivator | | |
| | | | | | | | *None | *Vertical Till | | |
| Dairy Sequence 2 | CS | CS | CG | ALF | ALF | ALF | *Chisel Plow | *Cultivator, 2X | | |
| | | | | | | | *Disk Plow | *Cultivator | | |
| | | | | | | | *None | *Vertical Till | | |
| Dairy Sequence 3 | CS | CS | SOY | WW | ALF | ALF | *Chisel Plow | *Cultivator, 2X | | |
| | | | | | | | *Disk Plow | *Cultivator | | |
| | | | | | | | *None | *Vertical Till | | |
| Cash Grain Sequence | CG | SOY | CG | SOY | CG | SOY | Chisel Plow | Cultivator, 2X | **48** Divided between 3 applications | None |
| | | | | | | | Disk Plow | Cultivator | | |
| | | | | | | | None | Vertical Till | | |
| | | | | | | | Chisel Plow (Corn), No Till (Soybean) | Cultivator (Corn), No Till (Soybean) | | |
| Continuous Corn Sequence | CG | CG | CG | CG | CG | CG | Chisel Plow | Cultivator, 2X | **46** Divided between 3 applications | |
| | | | | | | | Disk Plow | Cultivator | | |
| | | | | | | | None | Vertical Till | | |
| Continuous Hay | ALF | ALF | ALF | ALF | ALF | ALF | None | None | None | |

* Alfalfa and winter wheat in the dairy rotation will not receive tillage

## Agricultural classes for SWAT

The 17 agricultural classes were then spatially applied in the model based on percentages that the counites provided for each HUC12 watershed



## Agricultural classes for SWAT

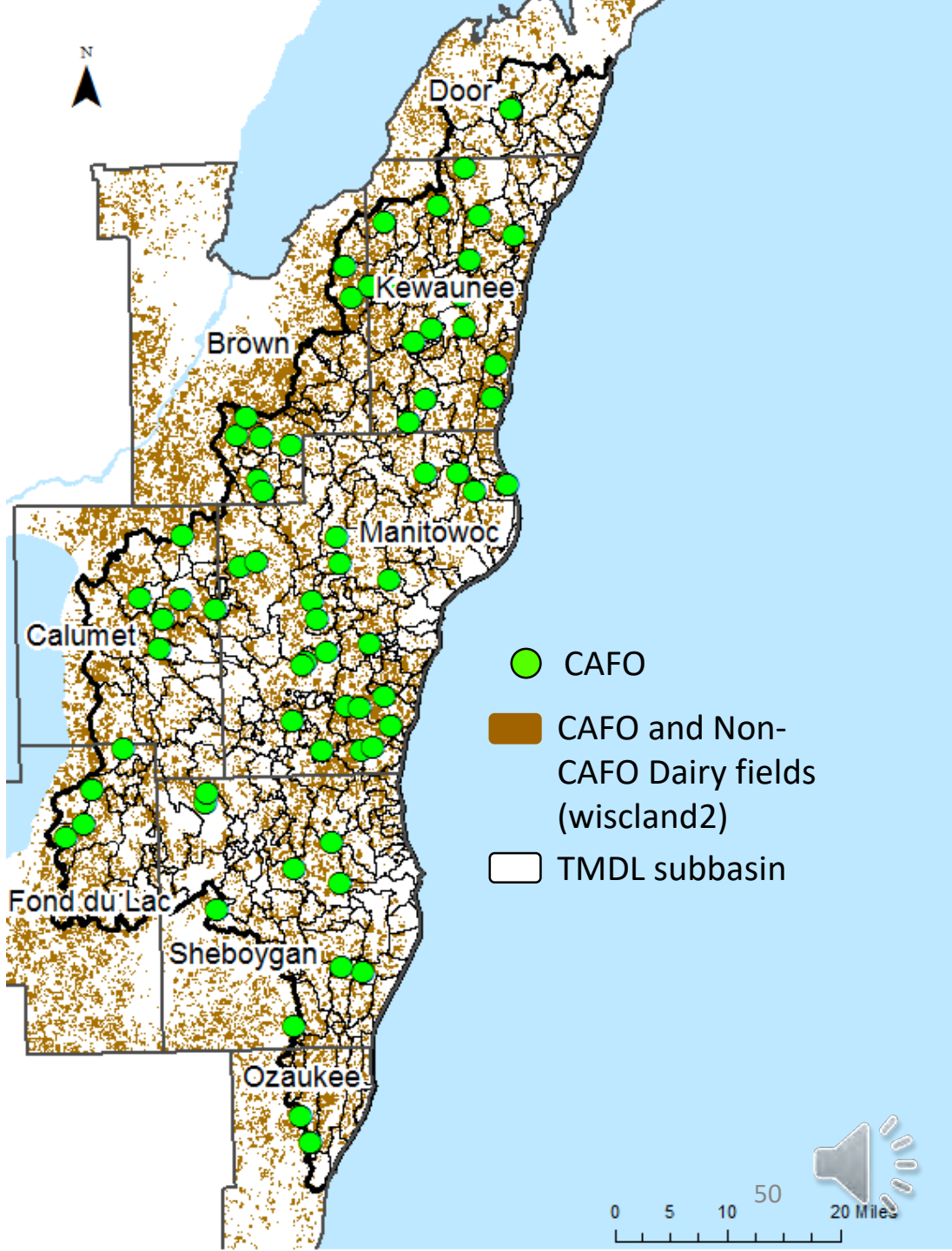
- Survey resulted in 17 agricultural classes
- Wiscland 2 + Agriculture survey = spatial & temporal agricultural dataset for the SWAT watershed model

| Crop Rotation Type | Crop | | | | | | Fall Tillage | Spring Tillage | Chemical P2O5 (lb/ac/yr) | Manure |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | | | | |
| Dairy Sequence 1 | CS | CS | CS | ALF | ALF | ALF | *Chisel Plow | *Cultivator, 2X | **26** Divided between 2 -3 applications | **Liquid**; unique rate per subbasin. 2 times per year. None for alfalfa/winter wheat |
| | | | | | | | *Disk Plow | *Cultivator | | |
| | | | | | | | *None | *Vertical Till | | |
| Dairy Sequence 2 | CS | CS | CG | ALF | ALF | ALF | *Chisel Plow | *Cultivator, 2X | | |
| | | | | | | | *Disk Plow | *Cultivator | | |
| | | | | | | | *None | *Vertical Till | | |
| Dairy Sequence 3 | CS | CS | SOY | WW | ALF | ALF | *Chisel Plow | *Cultivator, 2X | | |
| | | | | | | | *Disk Plow | *Cultivator | | |
| | | | | | | | *None | *Vertical Till | | |
| Cash Grain Sequence | CG | SOY | CG | SOY | CG | SOY | Chisel Plow | Cultivator, 2X | **48** Divided between 3 applications | None |
| | | | | | | | Disk Plow | Cultivator | | |
| | | | | | | | None | Vertical Till | | |
| | | | | | | | Chisel Plow (Corn), No Till (Soybean) | Cultivator (Corn), No Till (Soybean) | | |
| Continuous Corn Sequence | CG | CG | CG | CG | CG | CG | Chisel Plow | Cultivator, 2X | **46** Divided between 3 applications | |
| | | | | | | | Disk Plow | Cultivator | | |
| | | | | | | | None | Vertical Till | | |
| Continuous Hay | ALF | ALF | ALF | ALF | ALF | ALF | None | None | None | |

* Alfalfa and winter wheat in the dairy rotation will not receive tillage

# Manure spreading analysis

69 CAFOs with production areas in the NE Lakeshore study area



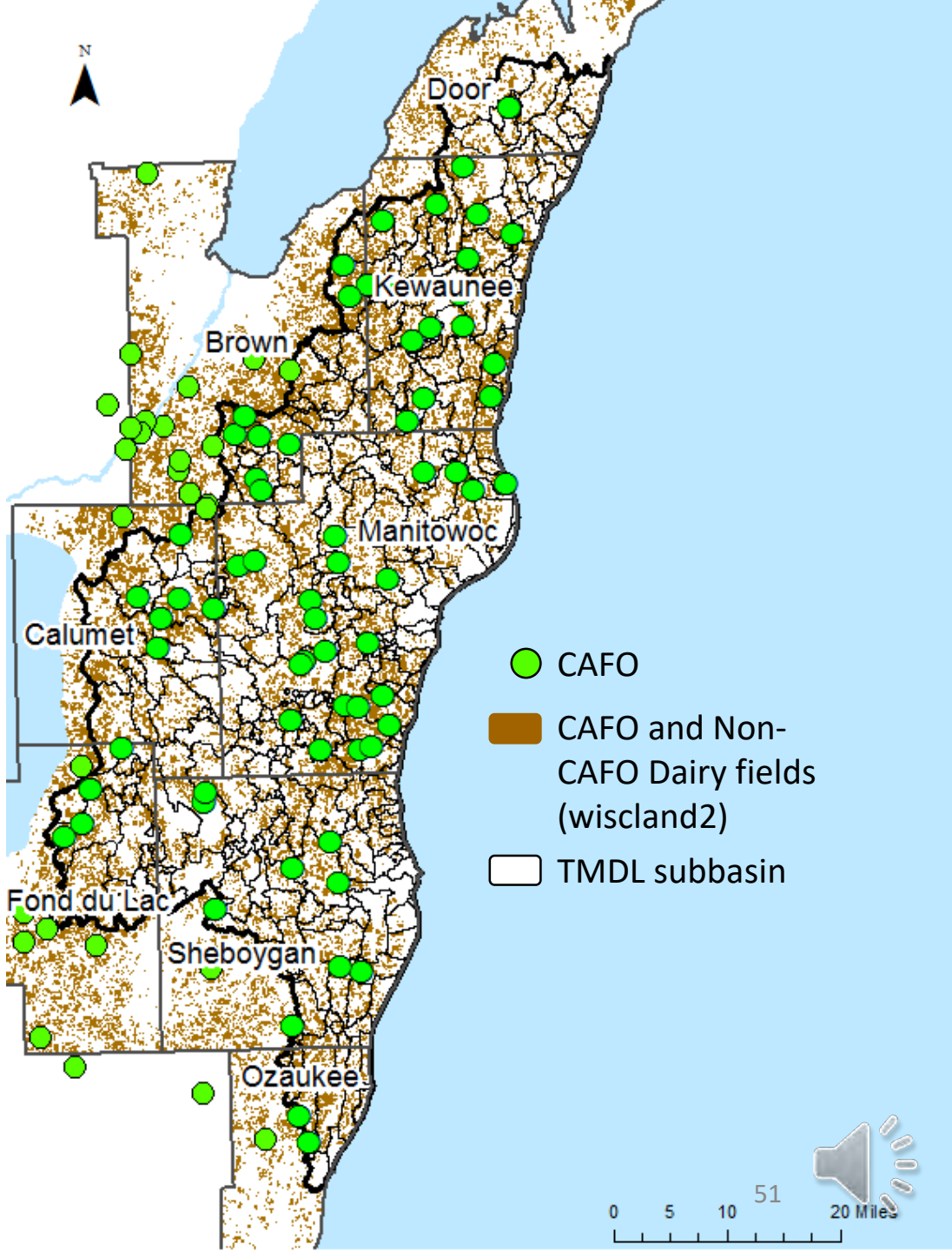
# Manure spreading analysis

69 CAFOs with production areas in the NE Lakeshore study area

19 additional CAFOs with fields inside the NE Lakeshore study area

88 CAFOs

Manure spreading data in CAFO nutrient management plans was used to verify results of the DNR's manure spreading analysis



# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

Phosphate = $P_2O_5$

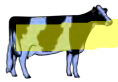
# DNR manure spreading analysis

## Method Summary

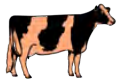
Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

1

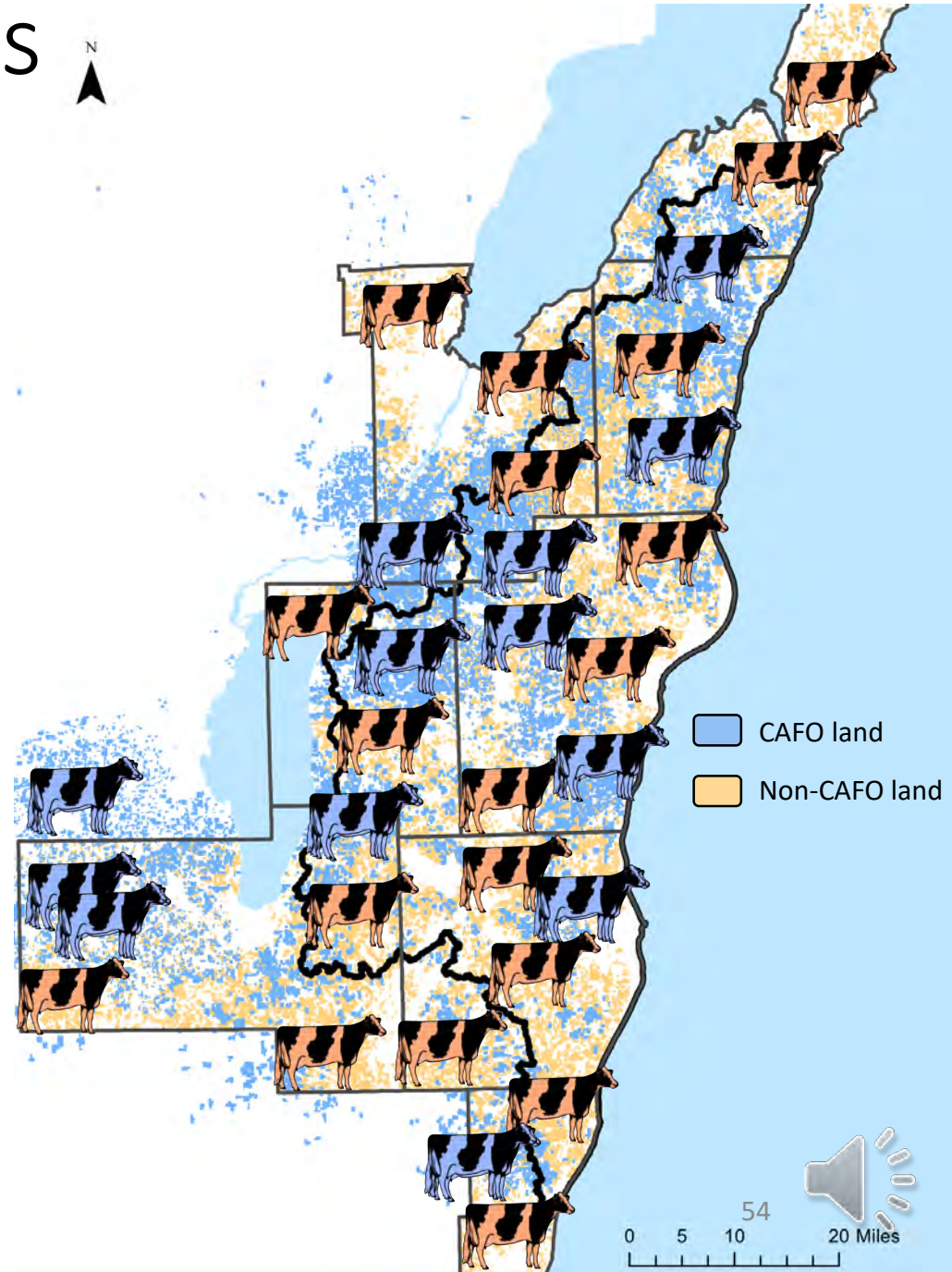
Number of cattle contributing manure in each subbasin



CAFO cattle



Non-CAFO cattle



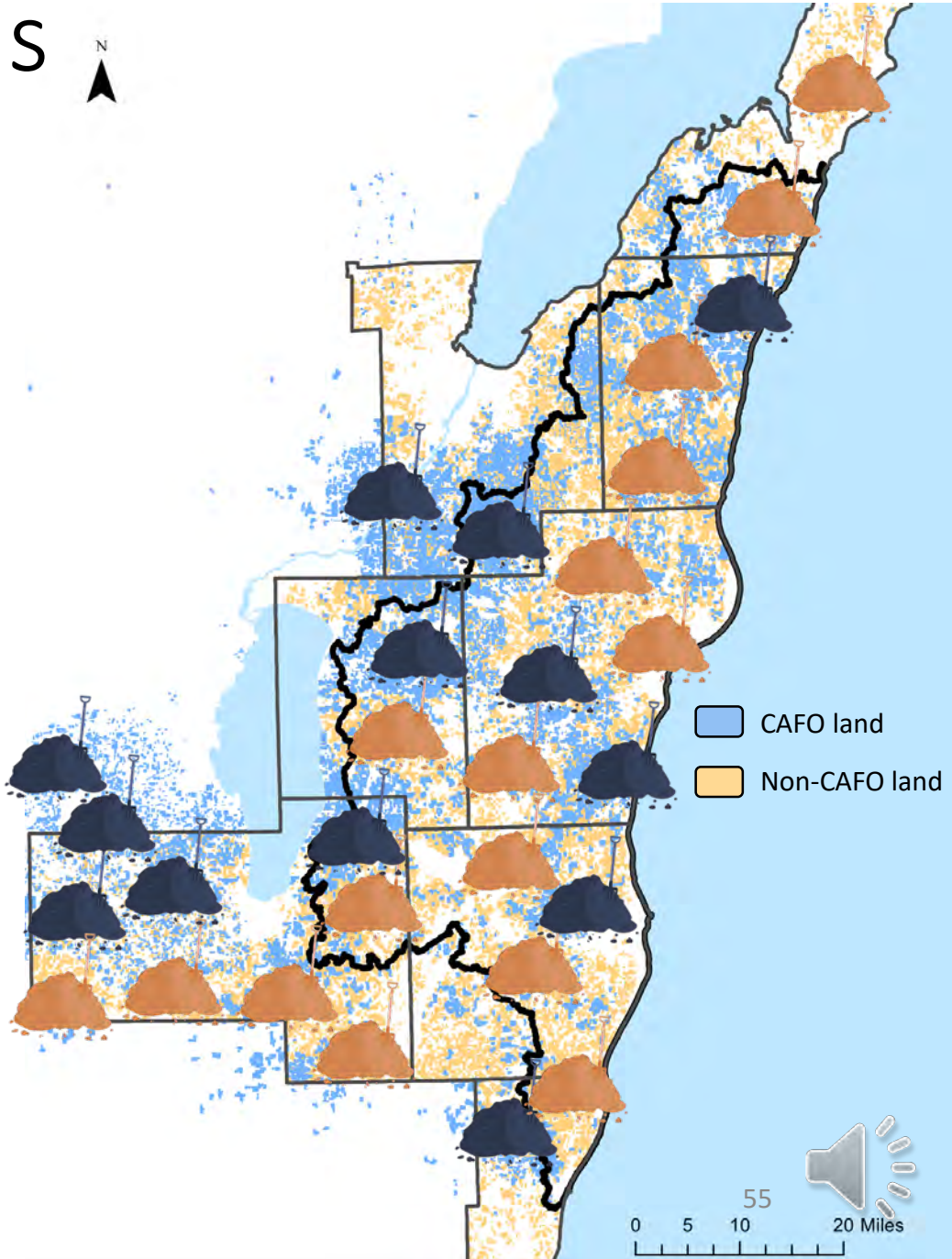
# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

1. 
   Number of cattle contributing manure in each subbasin

2. 
   Amount of liquid manure per subbasin

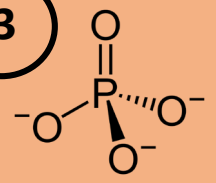
# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

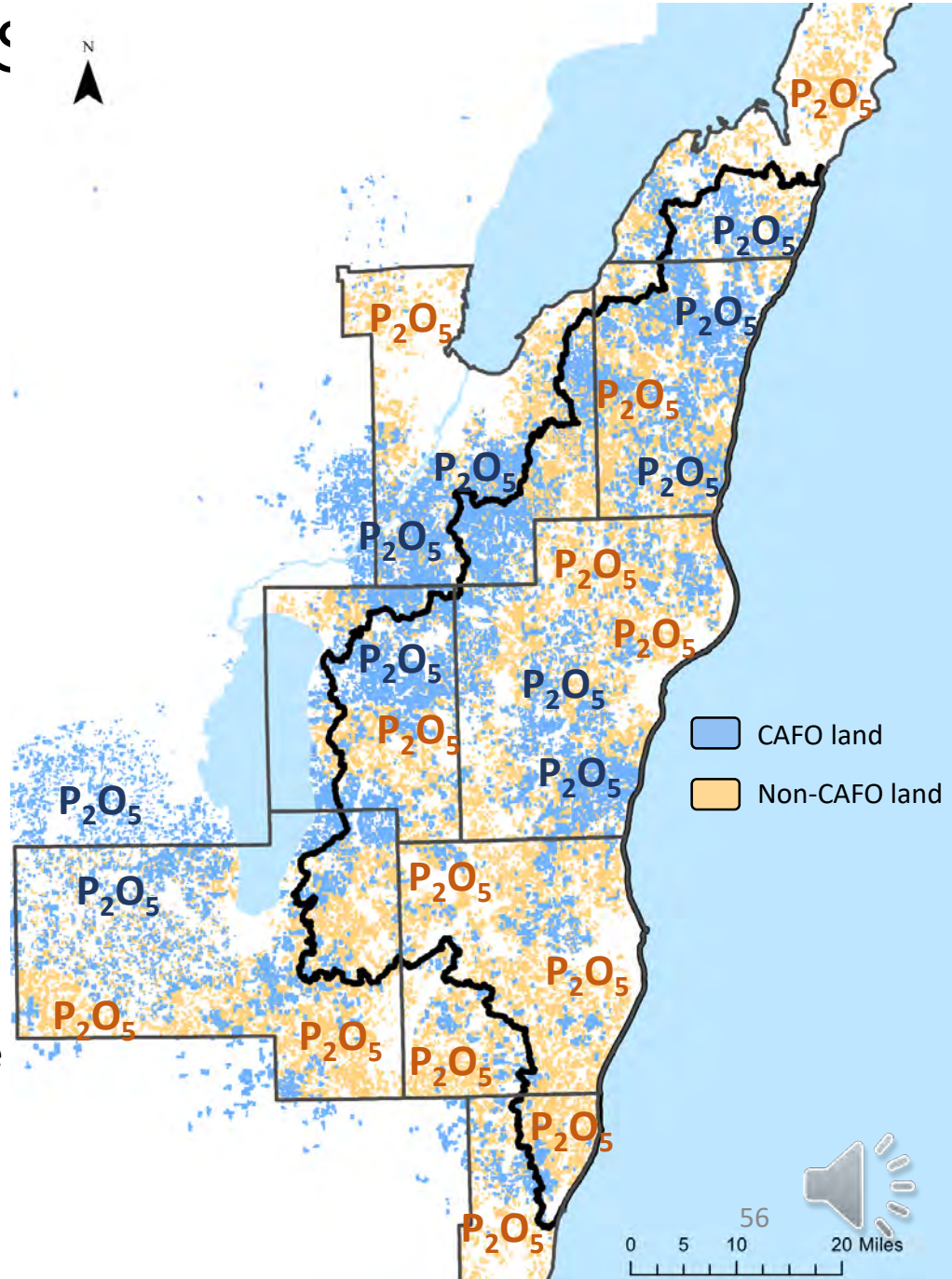
1. 
   Number of cattle contributing manure in each subbasin

2. 
   Amount of liquid manure per subbasin

3. 
   Amount of phosphate per subbasin

$P_2O_5$ CAFO phosphate

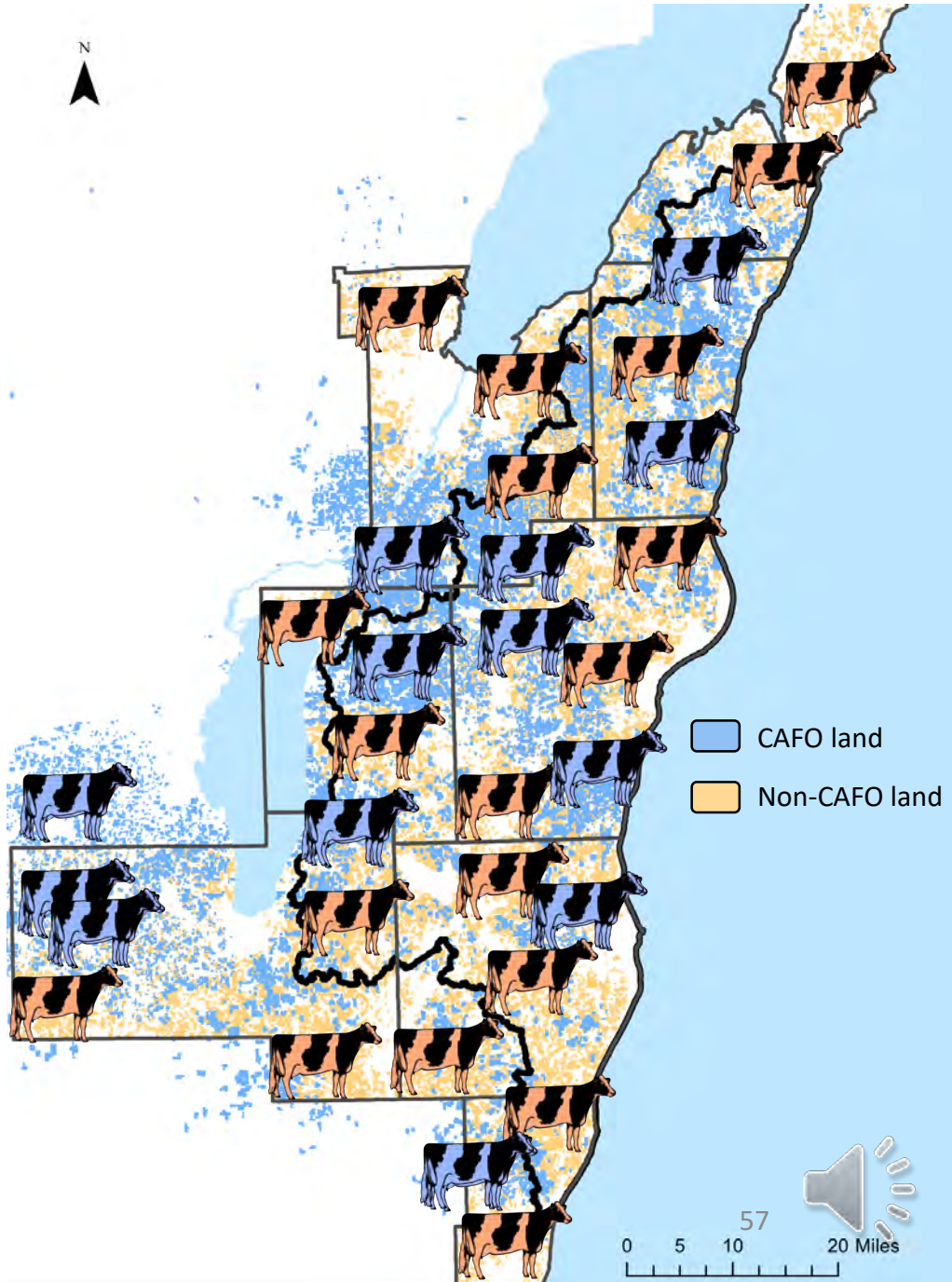
$P_2O_5$ Non-CAFO phosphate



Step 1: Number of cattle

CAFO cattle spread on CAFO acres

Non-CAFO cattle spread on Non-CAFO acres



## Step 1: Number of cattle

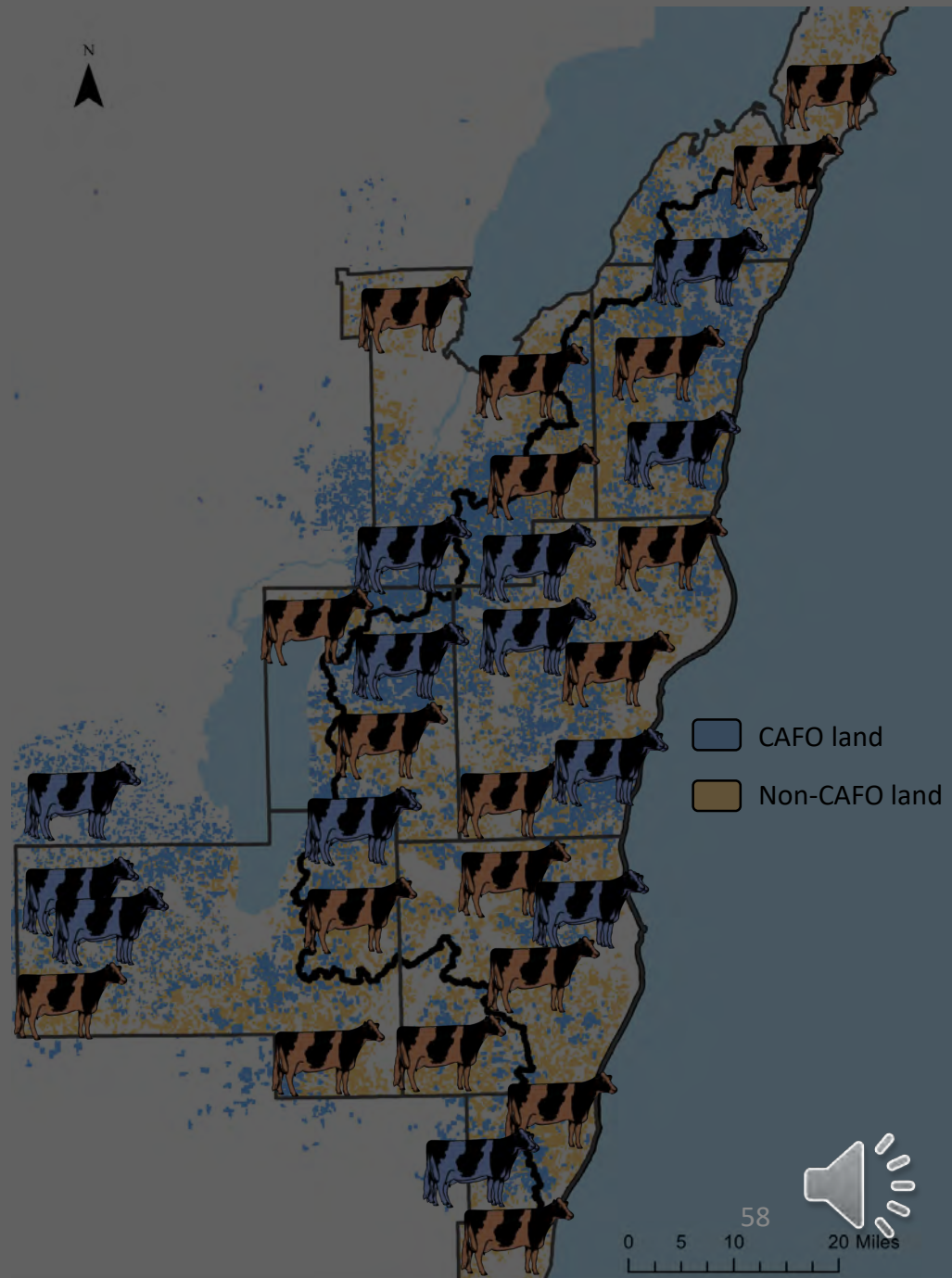
**CAFO cattle** spread on CAFO acres

Source: 2019 WPDES permits, cattle per facility

Cattle types

- Calves
- Small heifer
- Large heifer
- Steer or Beef Cow
- Dairy Cow
- Bull

**Non-CAFO cattle** spread on Non-CAFO acres



# Step 1: Number of cattle

**CAFO cattle** spread on CAFO acres

Source: 2019 WPDES permits, cattle per facility

Cattle types

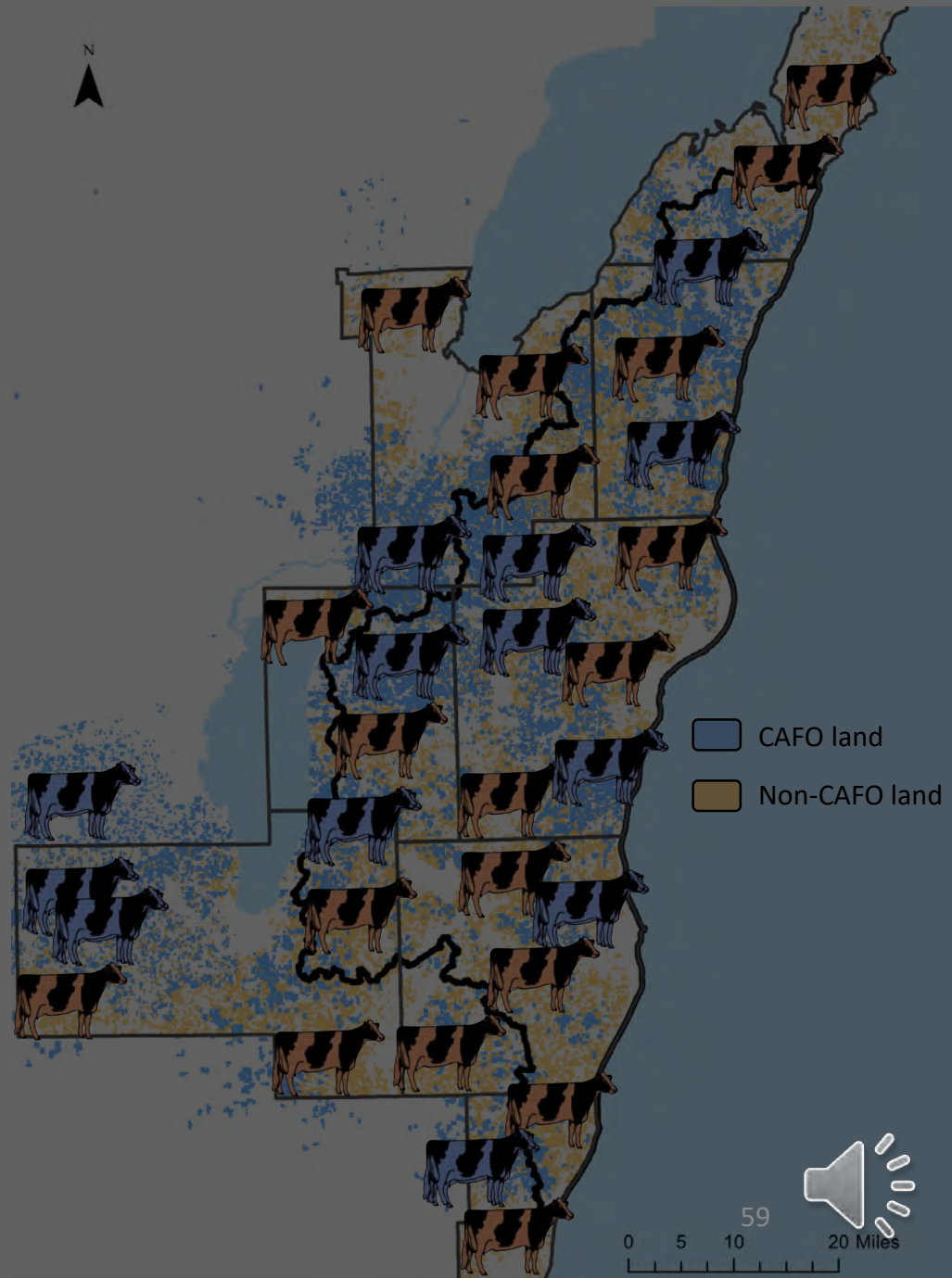
- Calves
- Small heifer
- Large heifer
- Steer or Beef Cow
- Dairy
- Bull

**Non-CAFO cattle** spread on Non-CAFO acres

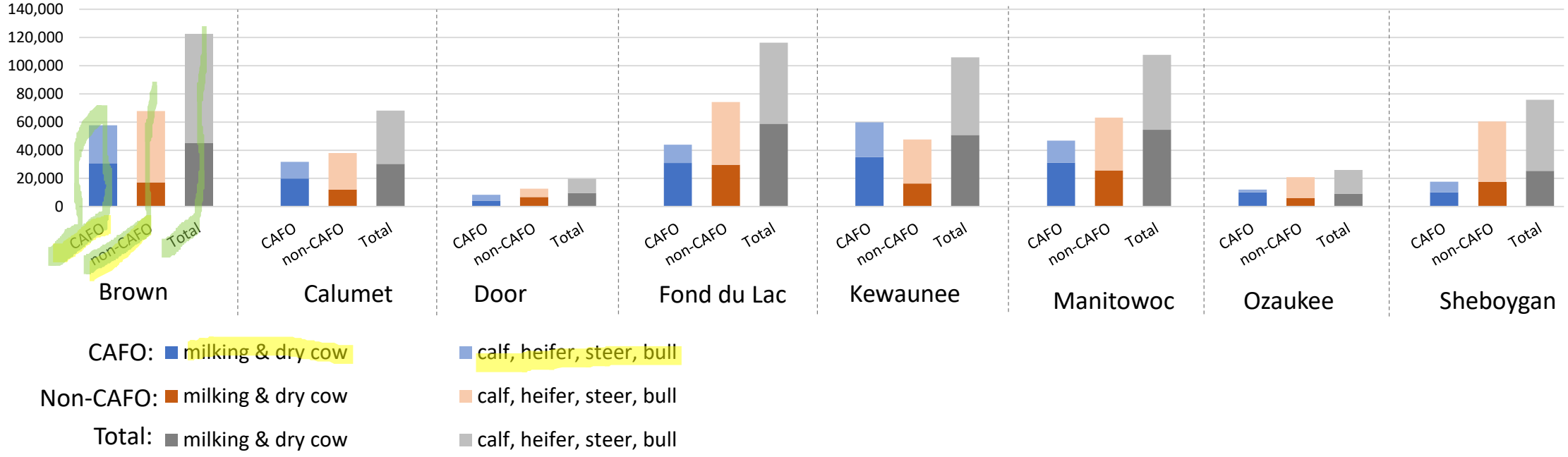
Source: 2017 Cattle Census by USDA NASS, cattle per county

Cattle types

- Calves
- Small heifer/small steer
- Large heifer
- Cattle on feed
- Dairy Cow
- Beef Cow



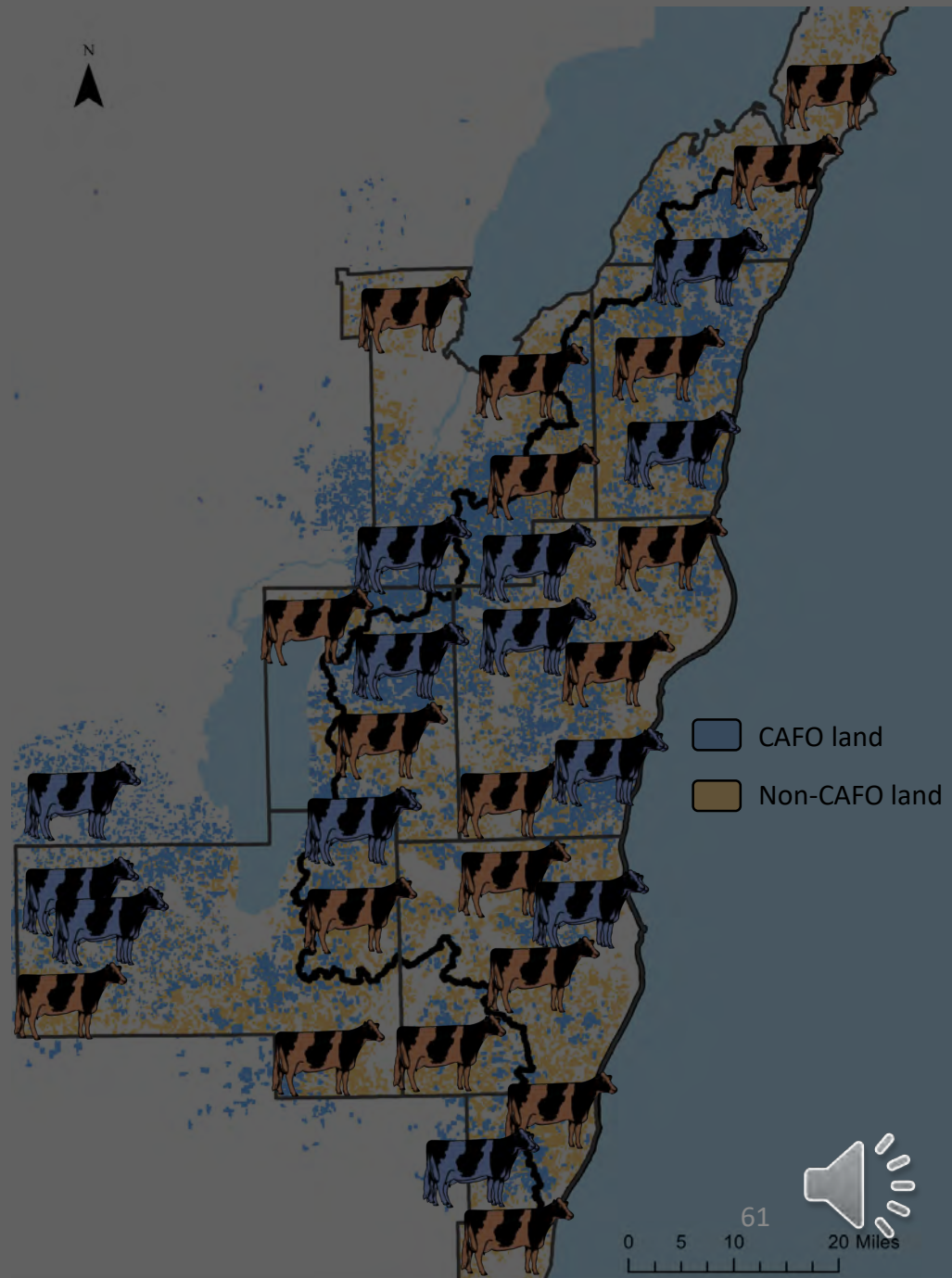
# Step 1: Cattle numbers and cattle types



Step 1: Number of cattle

CAFO cattle spread on **CAFO acres**

Non-CAFO cattle spread on **Non-CAFO acres**



## Step 1: Number of cattle

CAFO cattle spread on **CAFO acres**

Source:
CAFO nutrient management plans

Spreading strategy: Cattle from CAFO ‘x’ were spread only on CAFO ‘x’ acres

Non-CAFO cattle spread on **Non-CAFO acres**

Source:
Wiscland 2 dairy areas

Spreading strategy: Cattle from county ‘z’ were only spread on non-CAFO dairy acres within county ‘z’

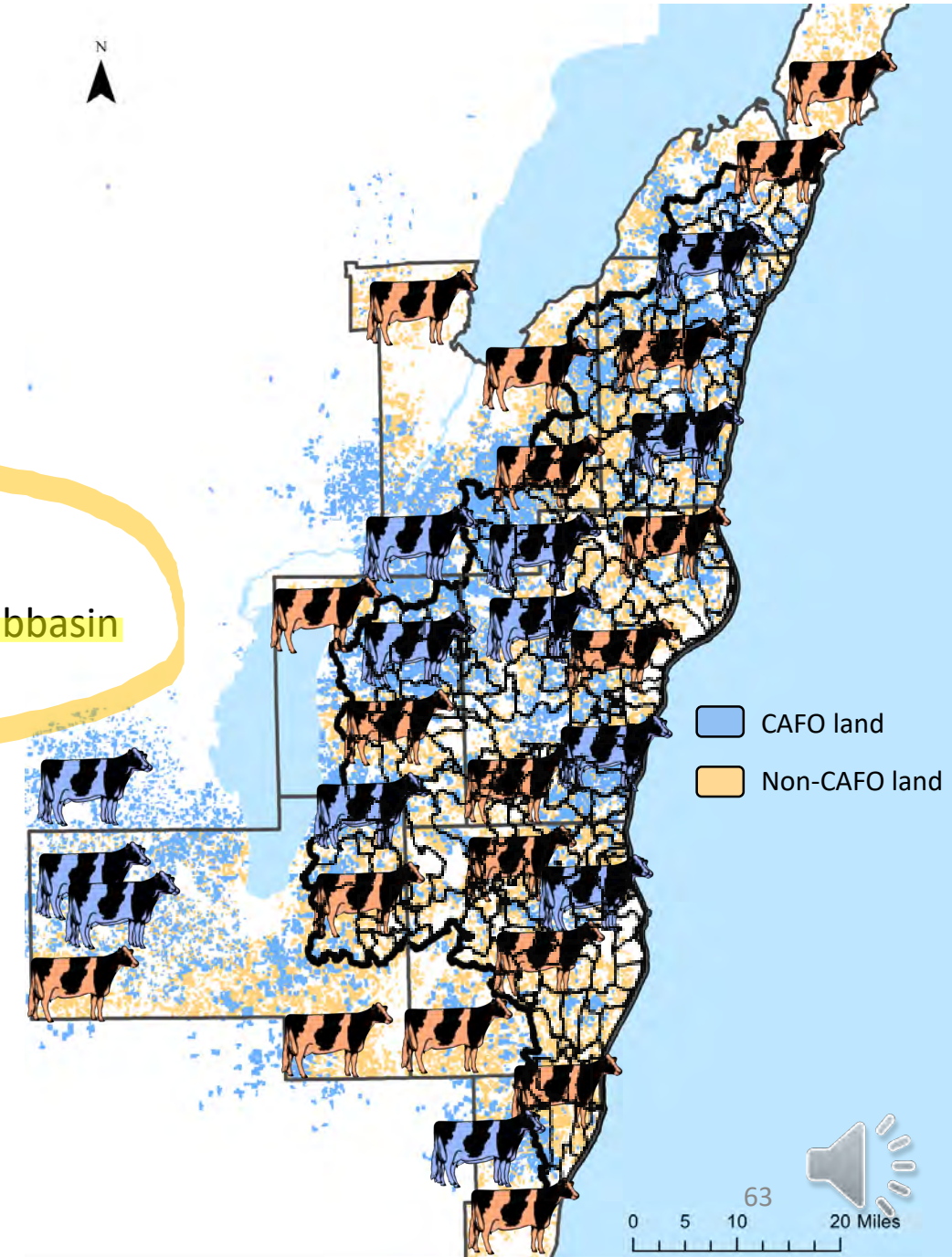
Step 1: Number of cattle

CAFO cattle spread on CAFO acres

Non-CAFO cattle spread on Non-CAFO acres

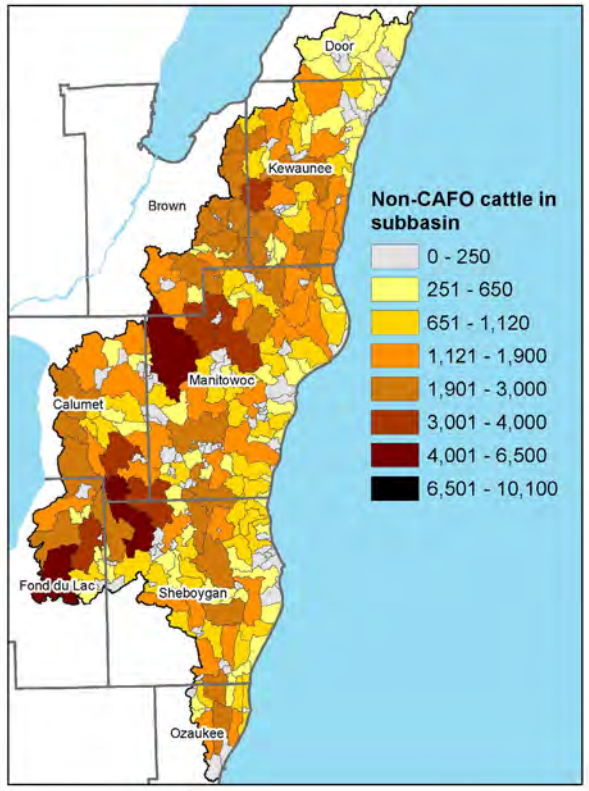
Overlay subbasins

- Cattle per subbasin
- Cattle per acre per subbasin

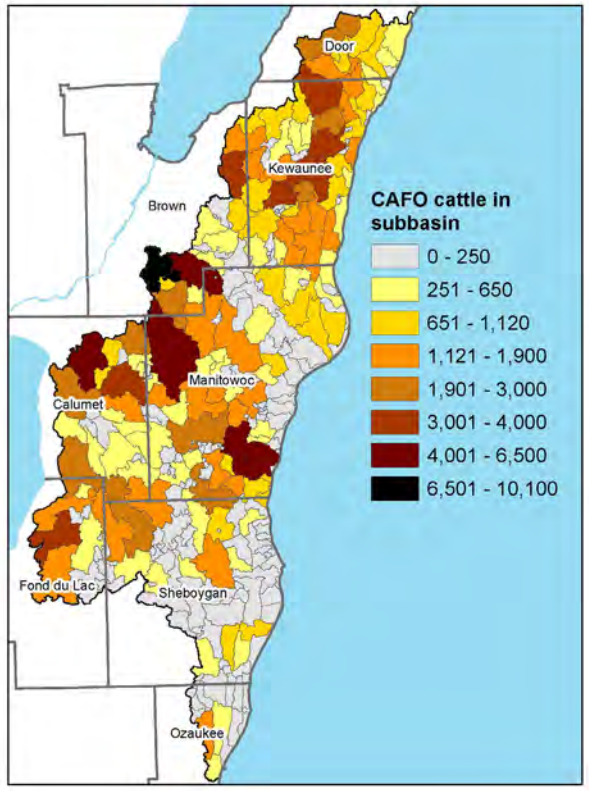


# Total cattle contributing manure per subbasin
(not adjusted for animal units)

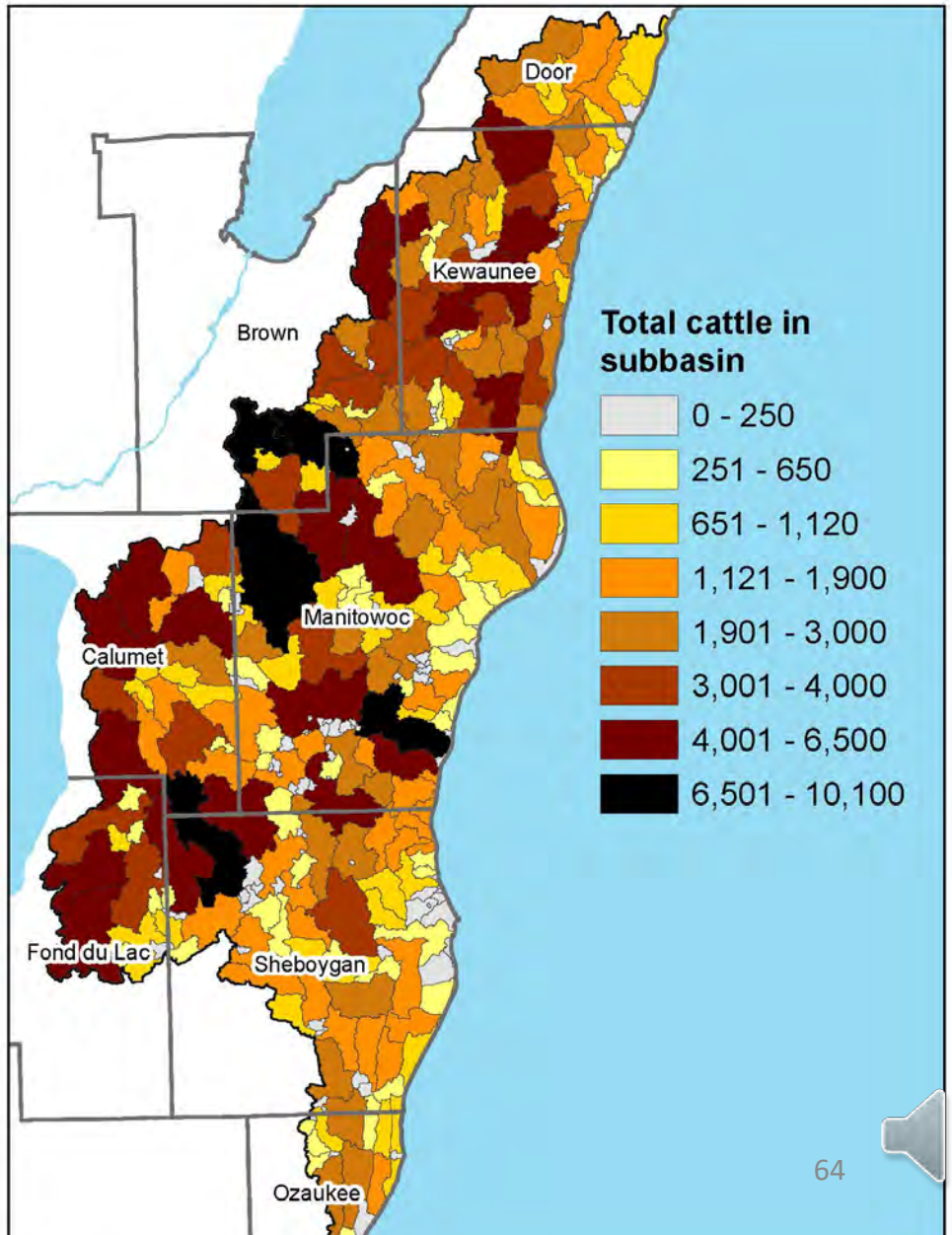
Non-CAFO




CAFO



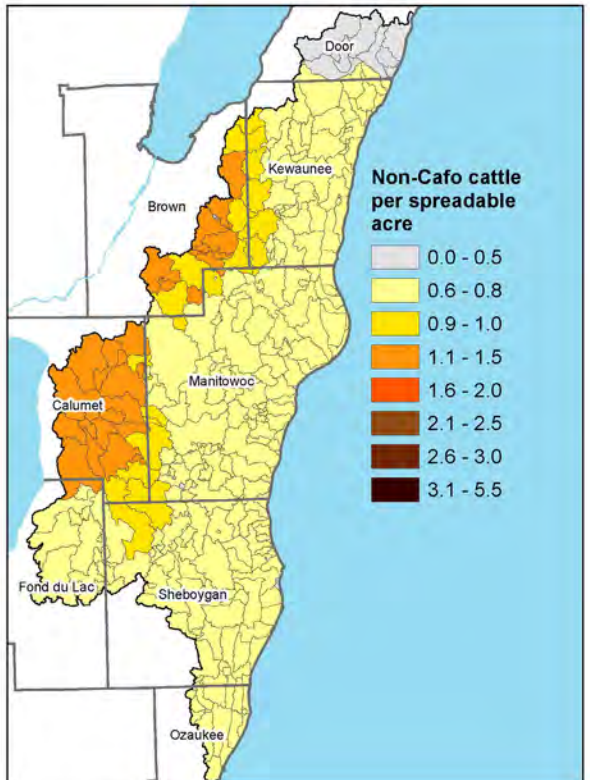

Total



# Cattle contributing manure per available acre per year
(not adjusted for animal units)

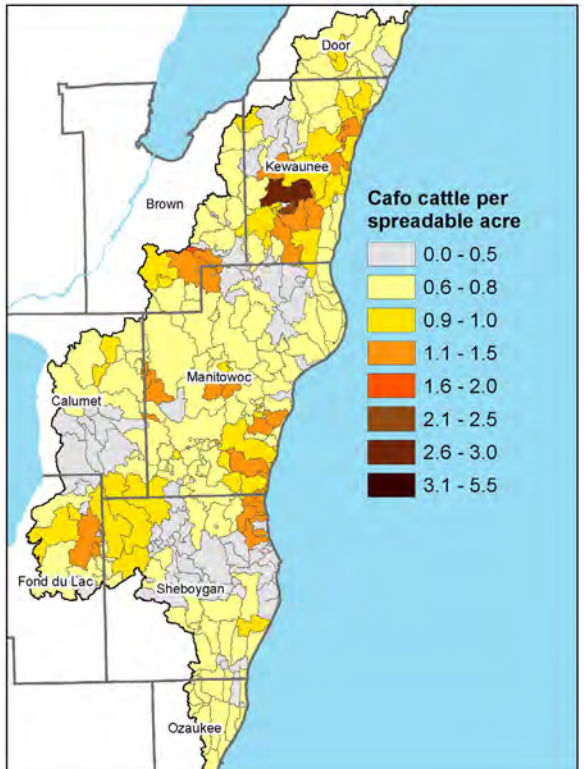
Non-CAFO

Available acres = Wiscland 2 dairy fields that were not identified as CAFO land

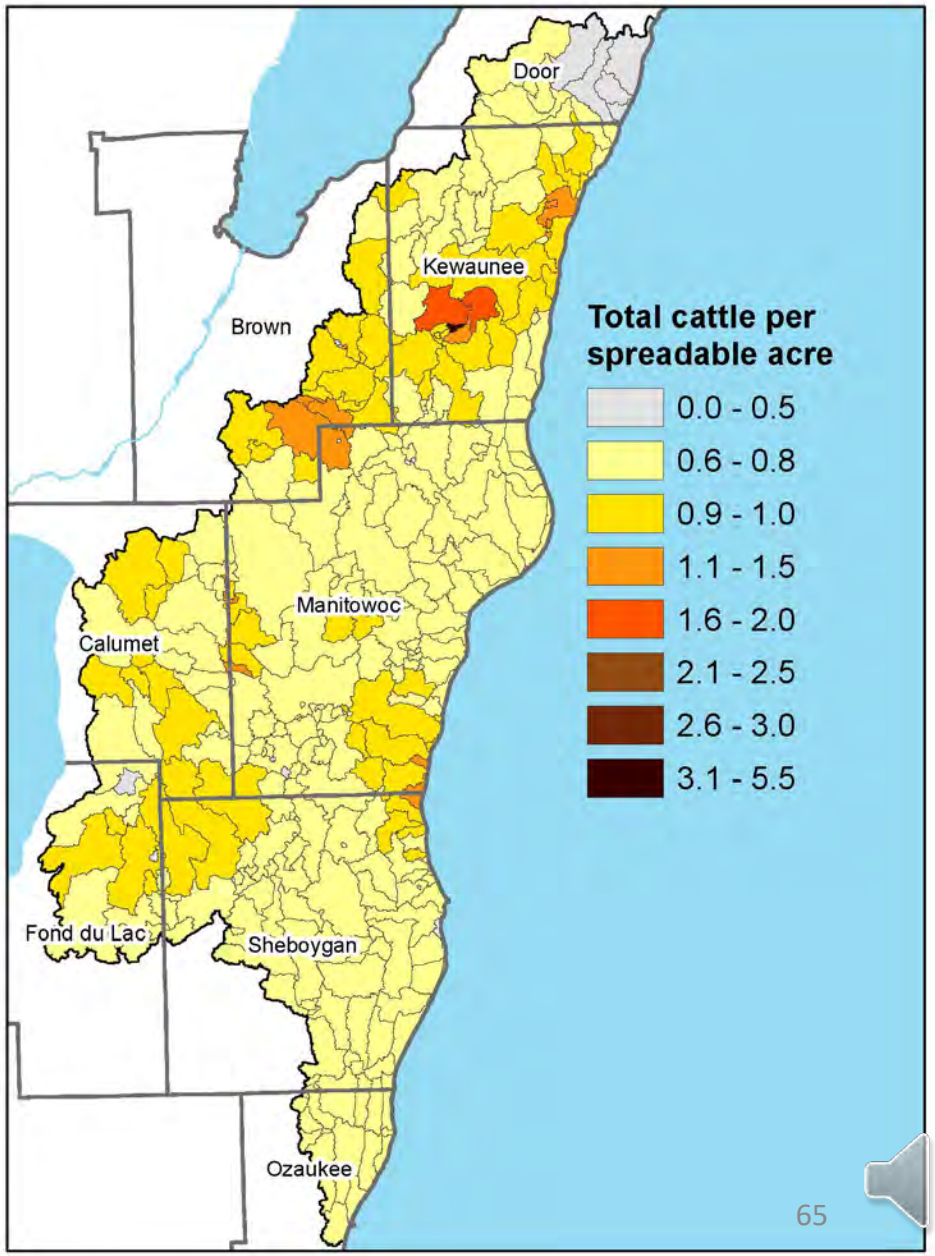



CAFO

Available acres = acres/locations provided in CAFO nutrient management plans

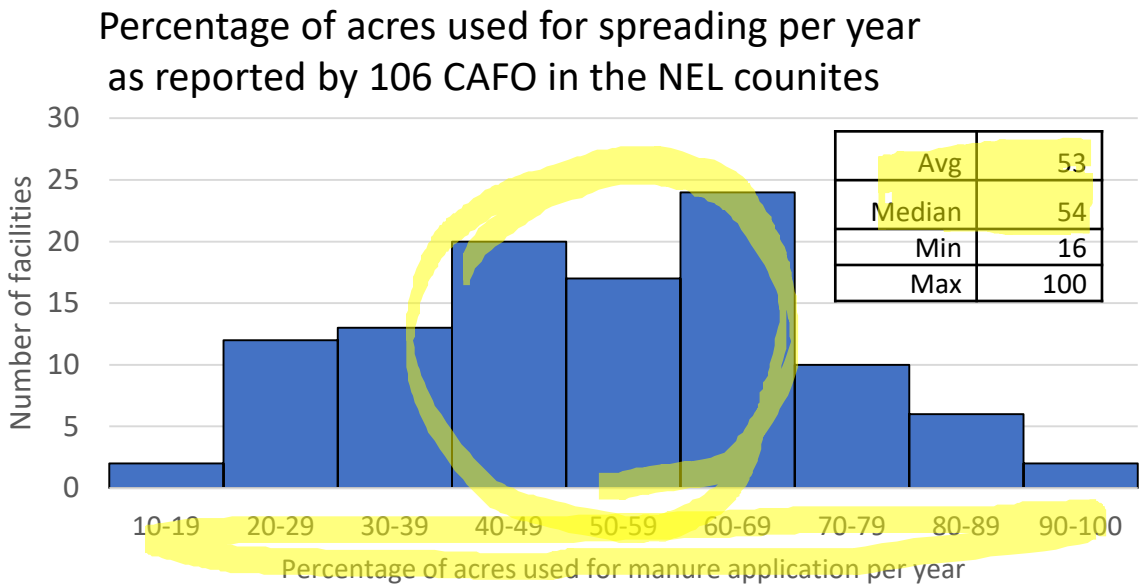



Total



# Cattle contributing manure per receiving acre per year

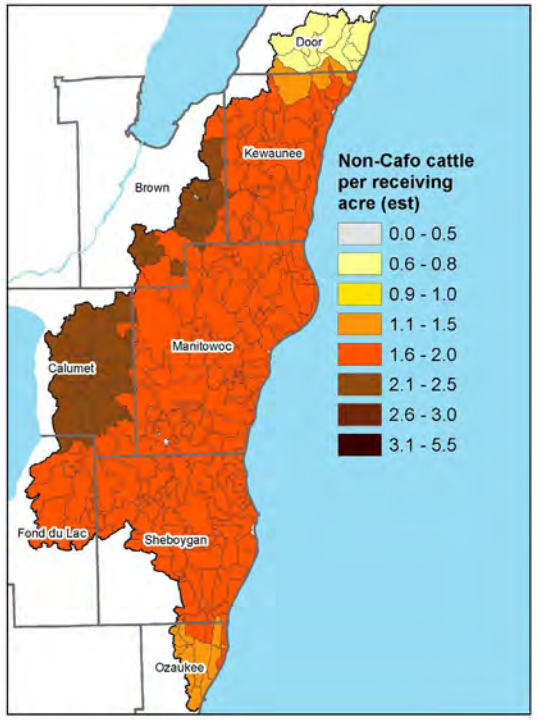
Receiving acres = 50% of available acres



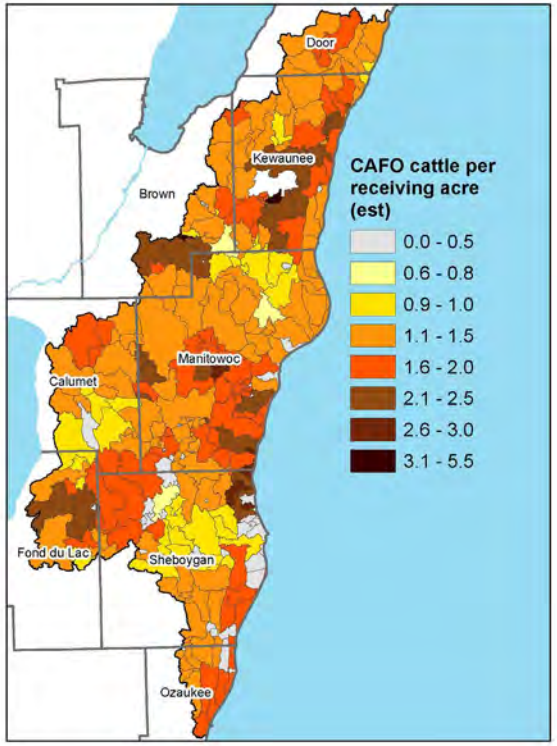
# Cattle contributing manure per receiving acre per year
(not adjusted for animal units)

Receiving acres = 50% of available acres

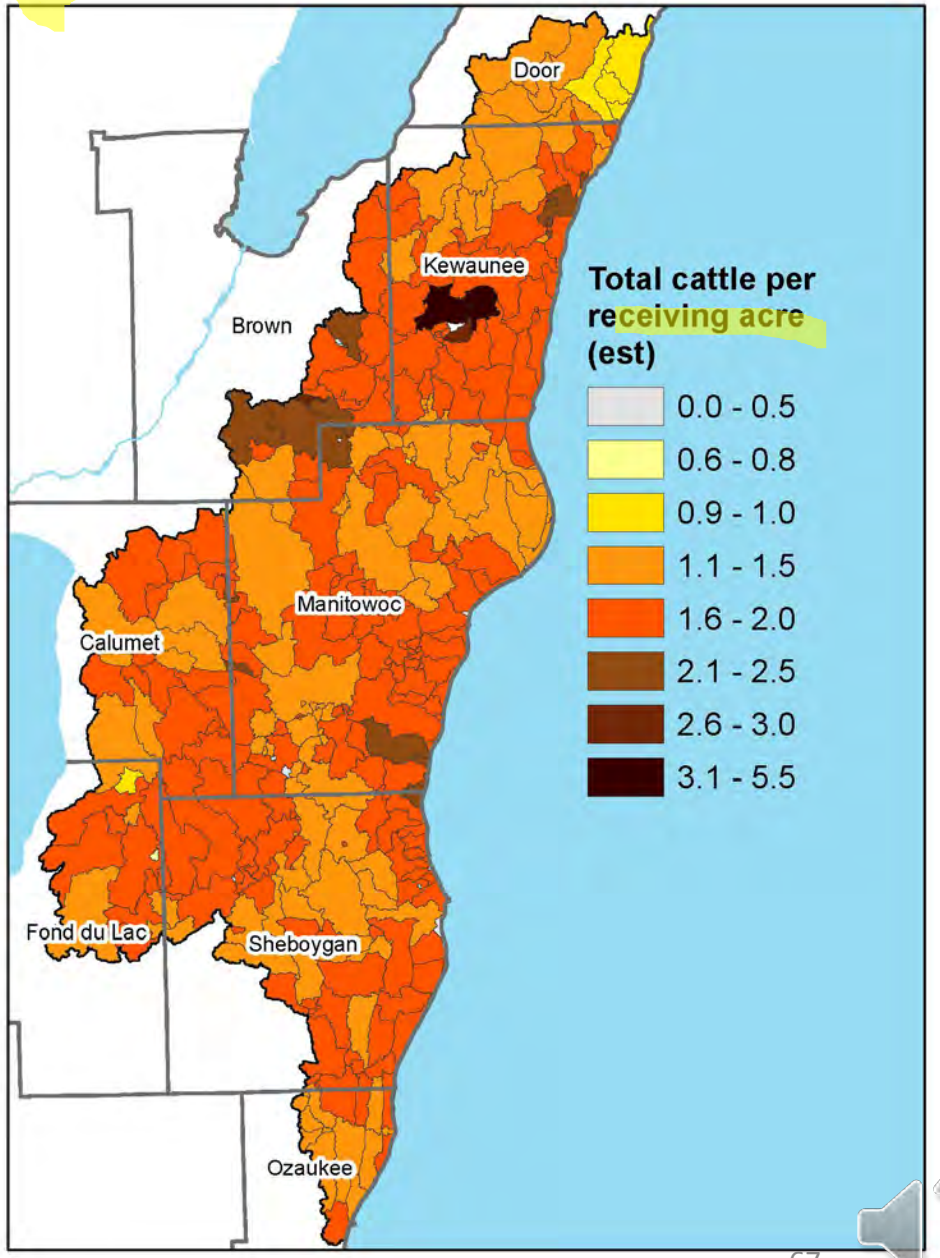
Non-CAFO




CAFO




Total

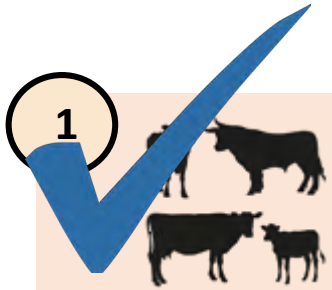


# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

1

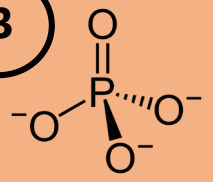


Number of cattle contributing manure in each subbasin

2

Amount of liquid manure per subbasin

3

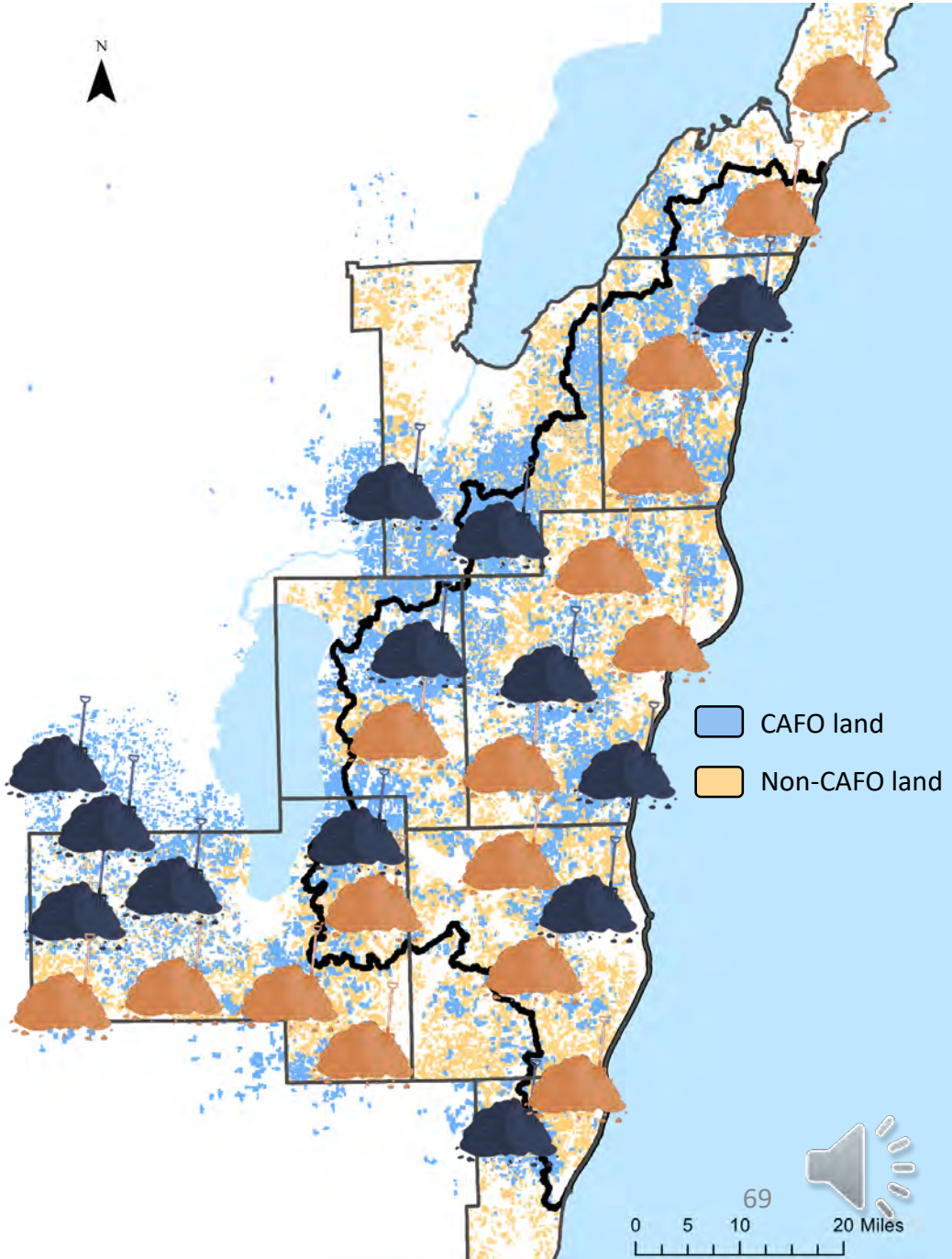



Amount of phosphate per subbasin

Step 2: Yearly liquid manure per subbasin

CAFO manure spread on CAFO acres

Non-CAFO manure spread on Non-CAFO acres



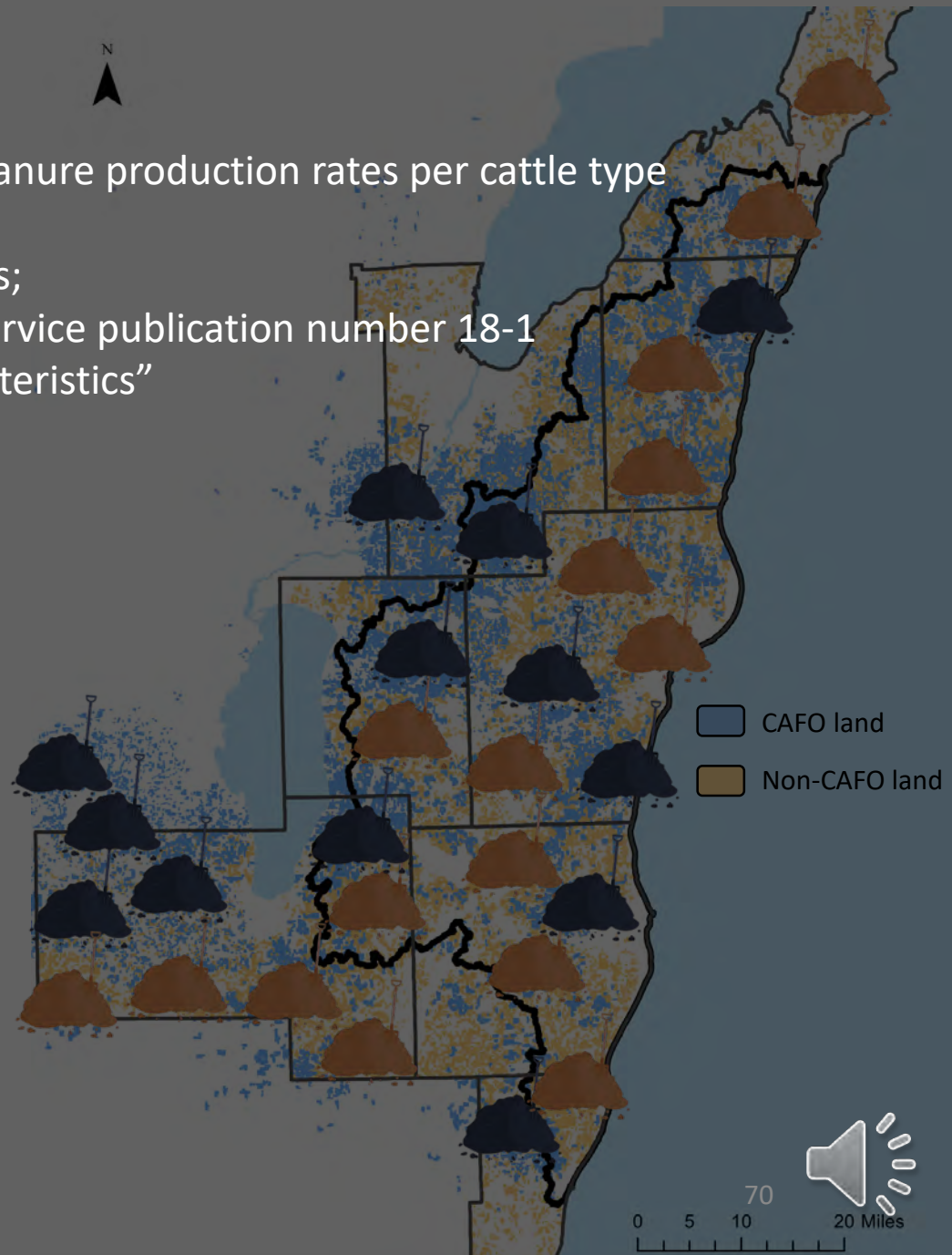
Step 2: Yearly liquid manure production per subbasin

**CAFO manure** spread on CAFO acres

**Non-CAFO manure** spread on Non-CAFO acres

Unique liquid manure production rates per cattle type

Source: SnapPlus;
Midwest Plan Service publication number 18-1
“Manure Characteristics”



Step 2: Yearly liquid manure production per subbasin

**CAFO manure** spread on CAFO acres

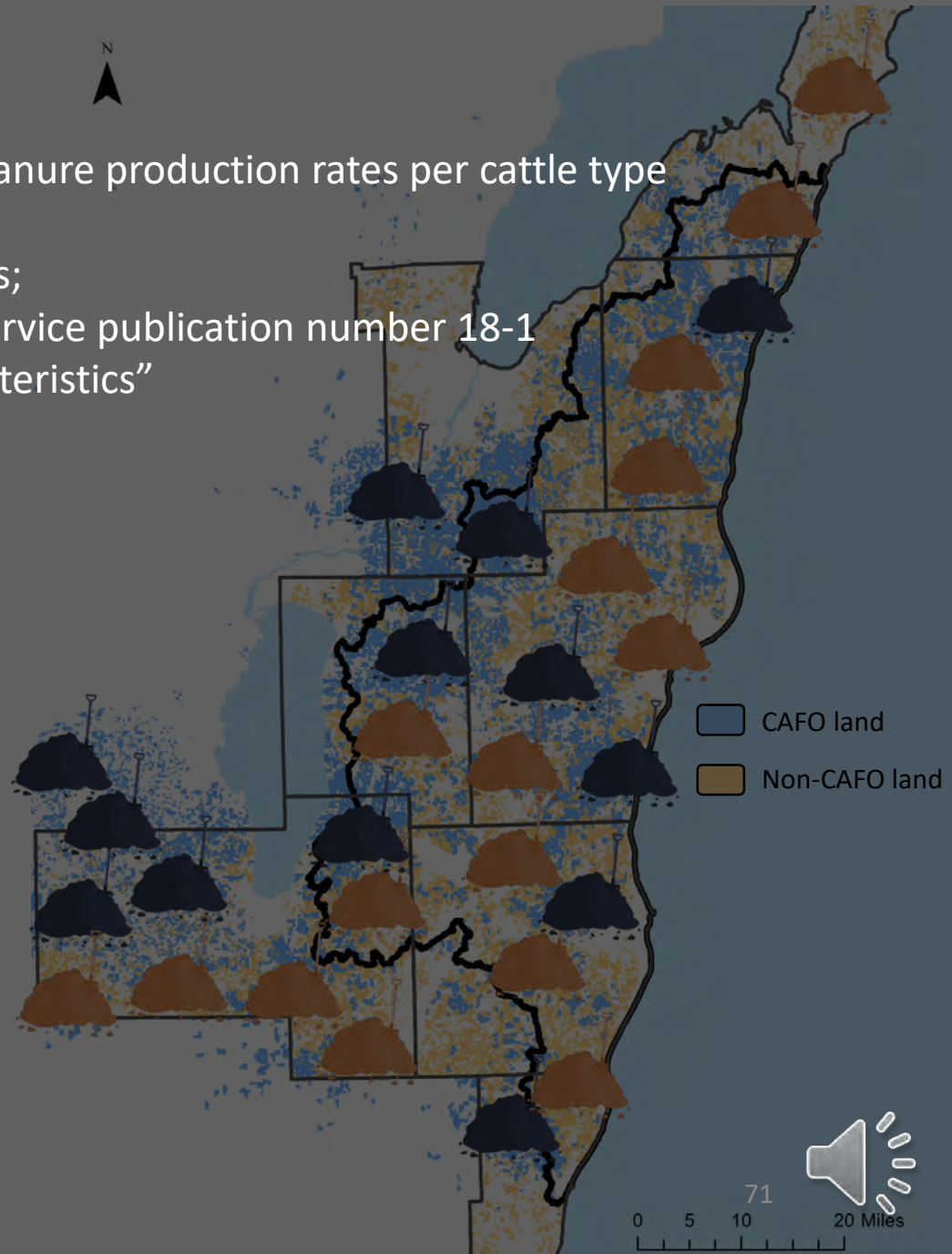
**Non-CAFO manure** spread on Non-CAFO acres

Unique liquid manure production rates per cattle type

Source: SnapPlus;
Midwest Plan Service publication number 18-1
"Manure Characteristics"

Liquid manure production rates used for DNR manure spreading analysis

| CAFO cattle type | Non-CAFO cattle type | Manure production rate (gal per day) |
|---|---|---|
| Calf | Calf | 5.5 |
| Small Heifer | Small Heifer or Small Steer | 13.8 |
| Large Heifer | Large Heifer | 18 |
| Steer or Beef Cow | Cattle on Feed | 30.5 |
| Dairy Cow | Dairy Cow | 27.5 |
| Bull | NA | 25 |
| NA | Beef Cow | 24 |



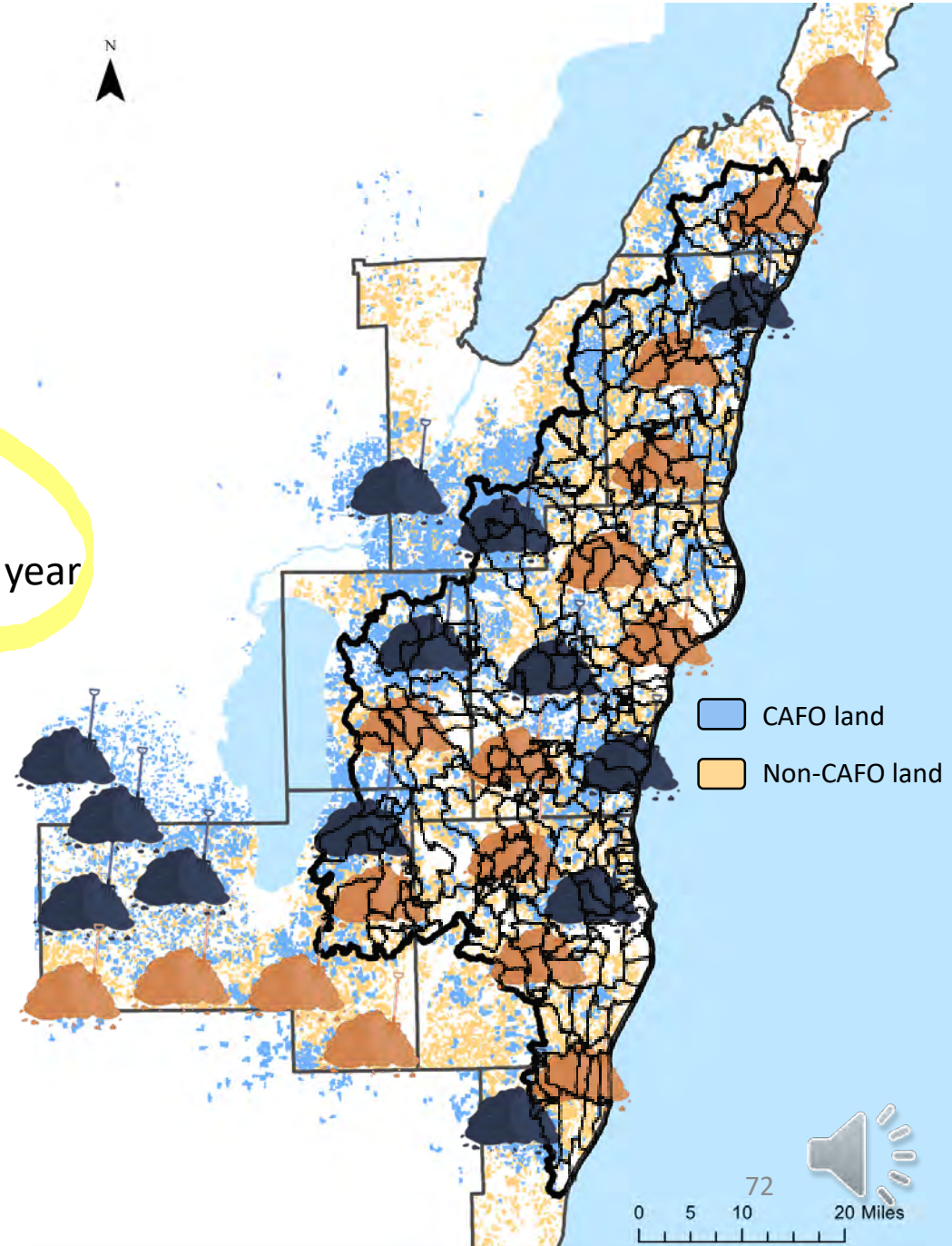
Step 2: Yearly liquid manure production per subbasin

CAFO manure spread on CAFO acres

Non-CAFO manure spread on Non-CAFO acres

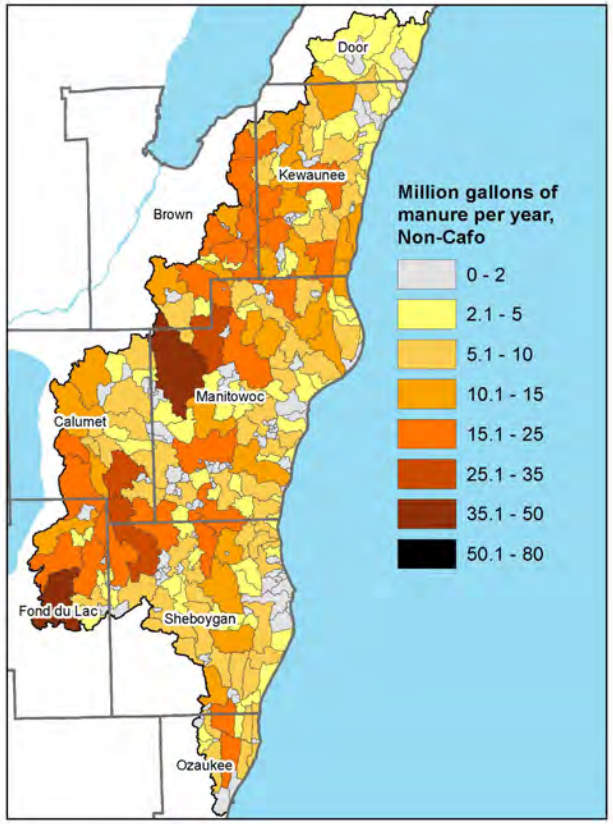
Overlay subbasins

- Liquid manure per subbasin per year
- Liquid manure per acre per subbasin per year

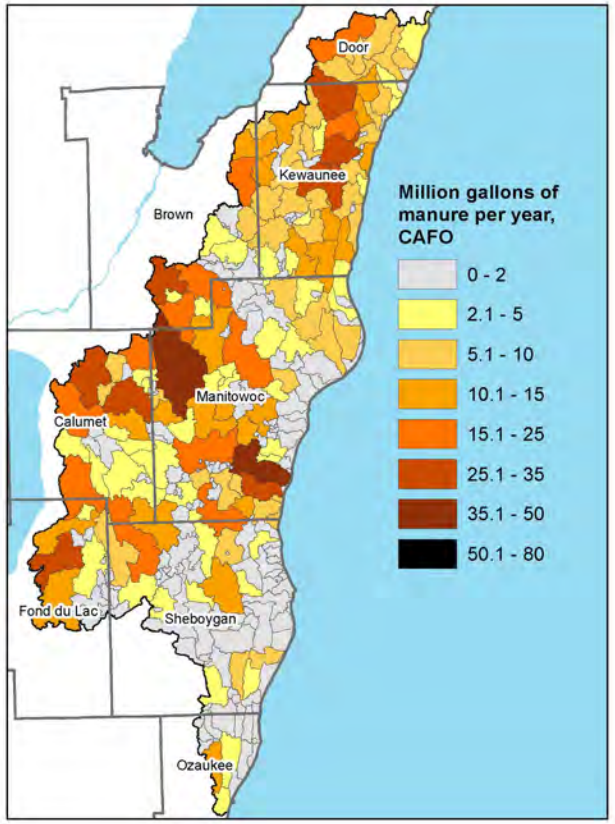


# Gallons of manure per year per subbasin

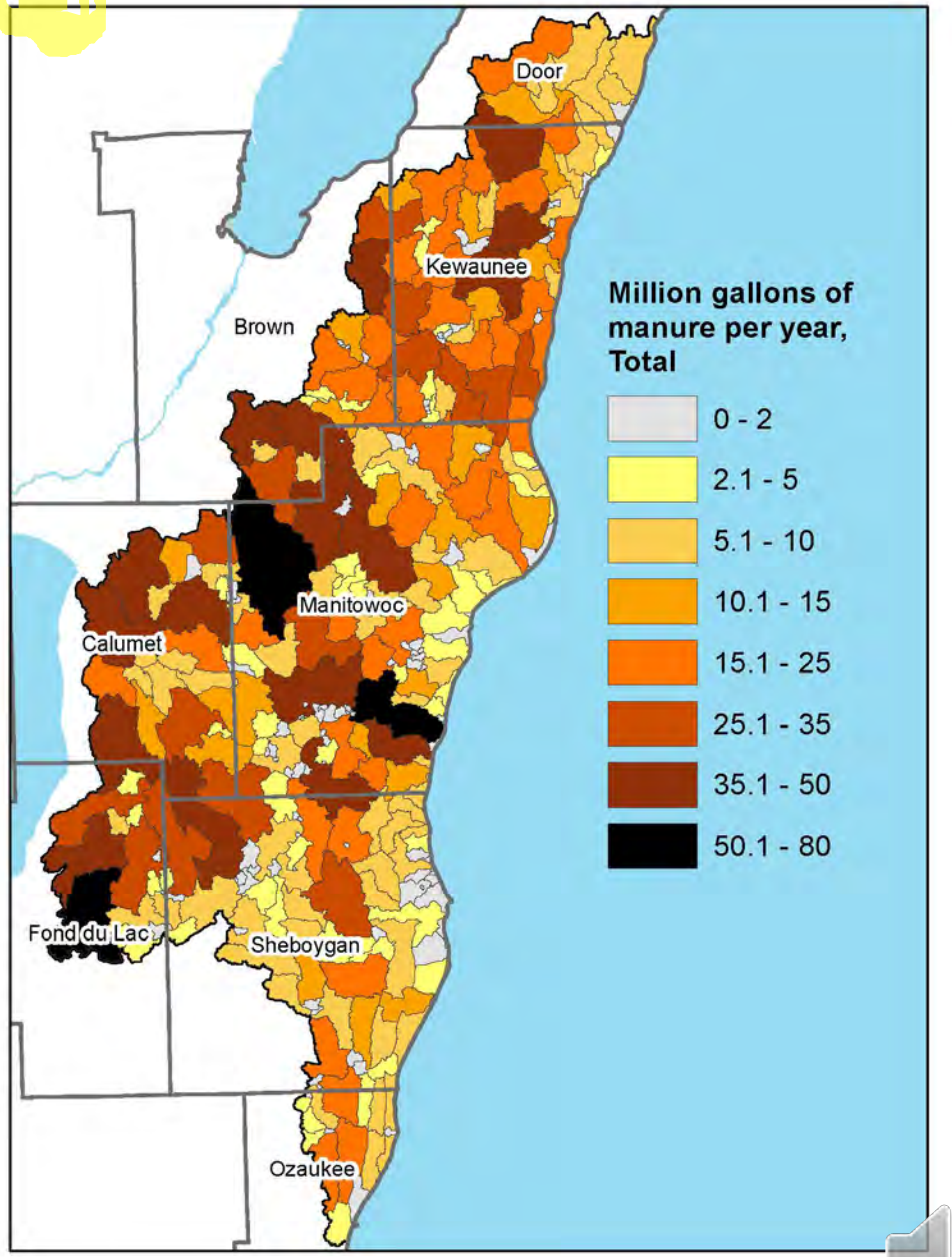
Non-CAFO




CAFO



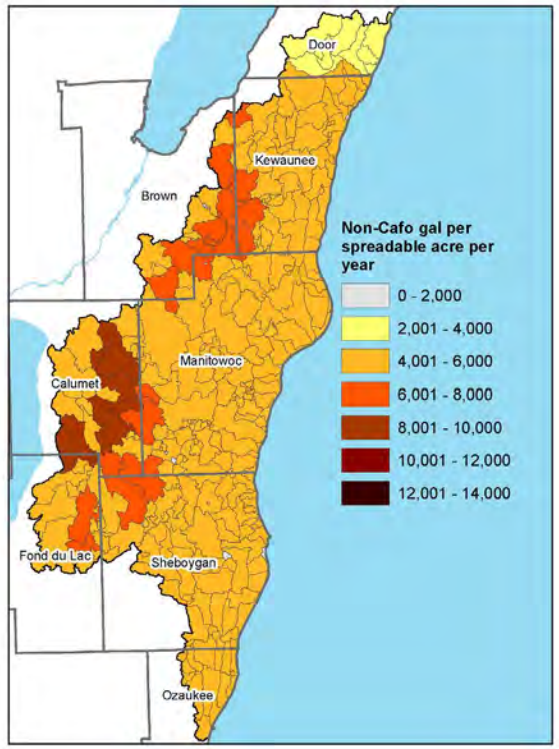

Total



# Manure (gal) per available acre per year

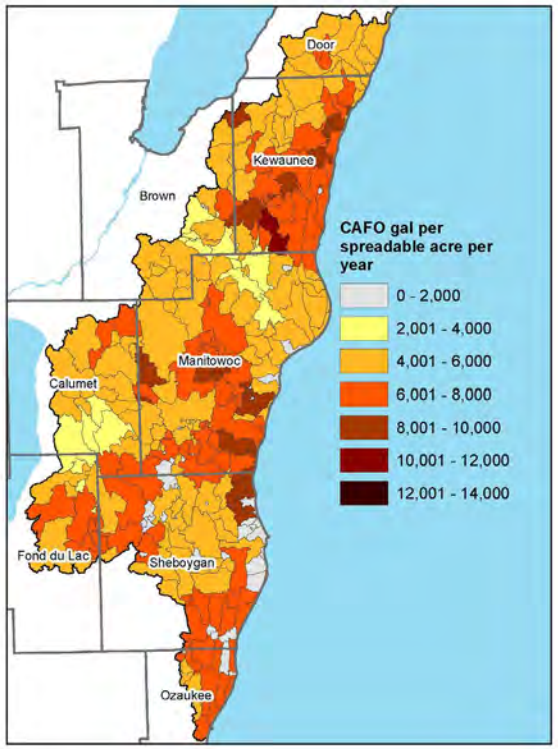
Non-CAFO

available acres = Wiscland 2 dairy fields that were not identified as CAFO land

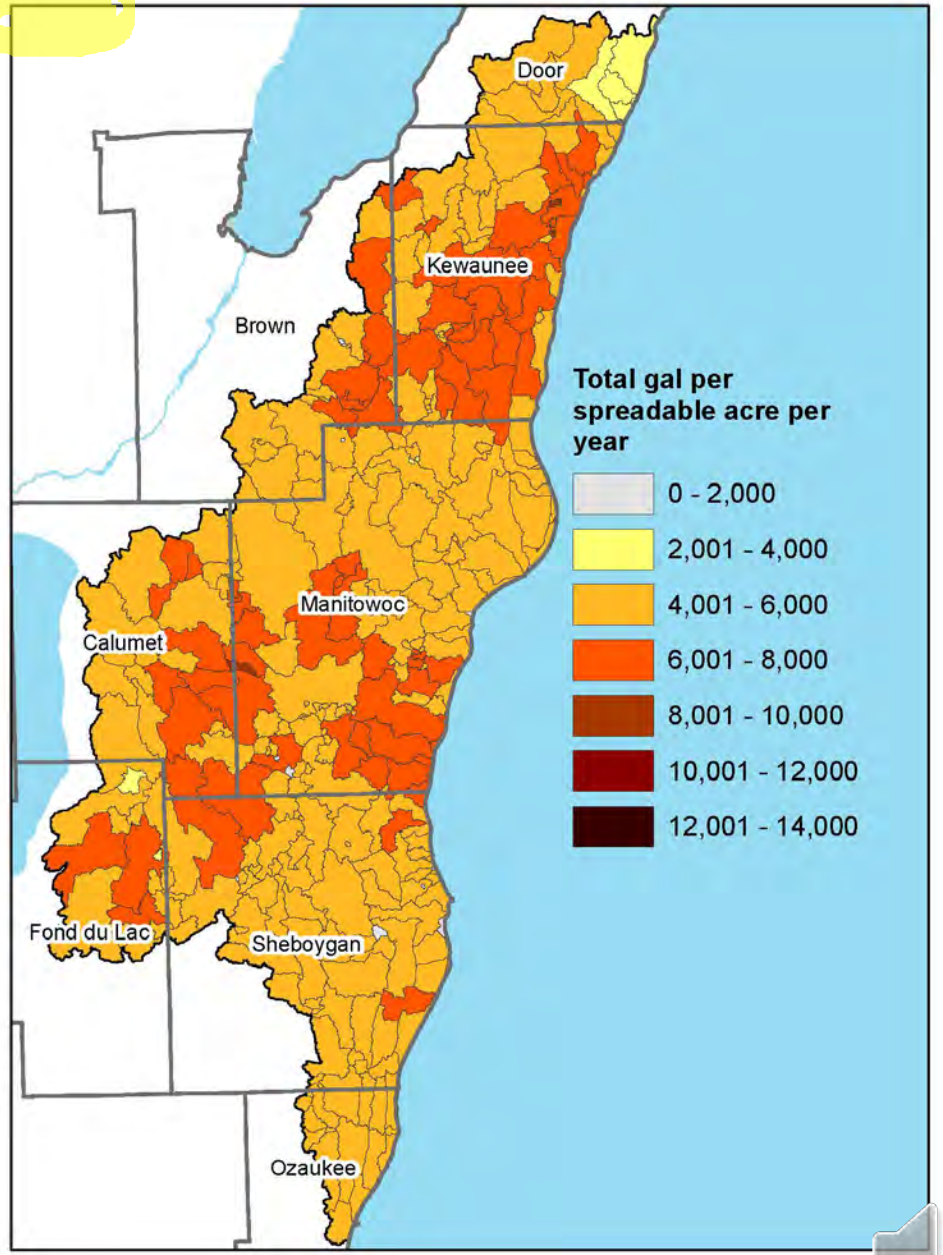



CAFO

available acres = acres/locations provided in CAFO nutrient management plans



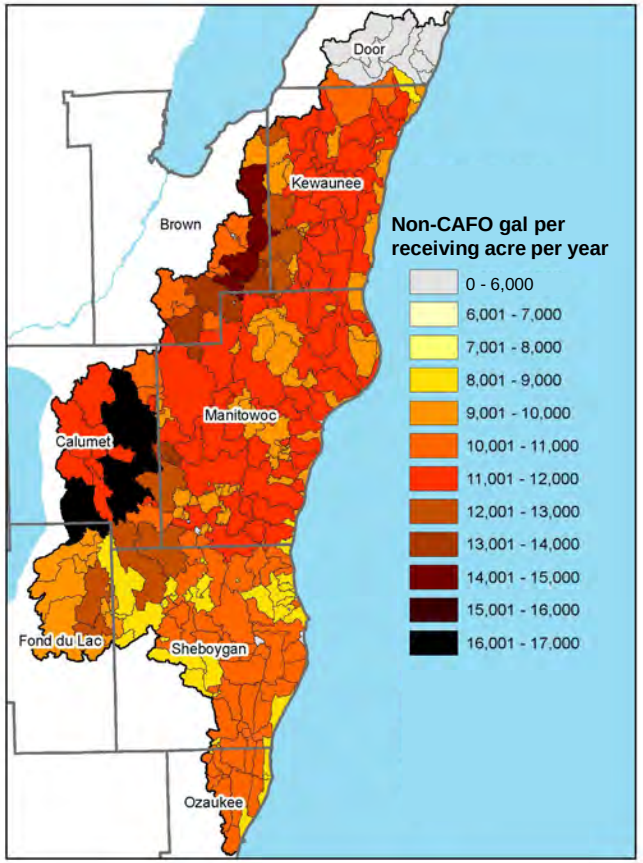

Total



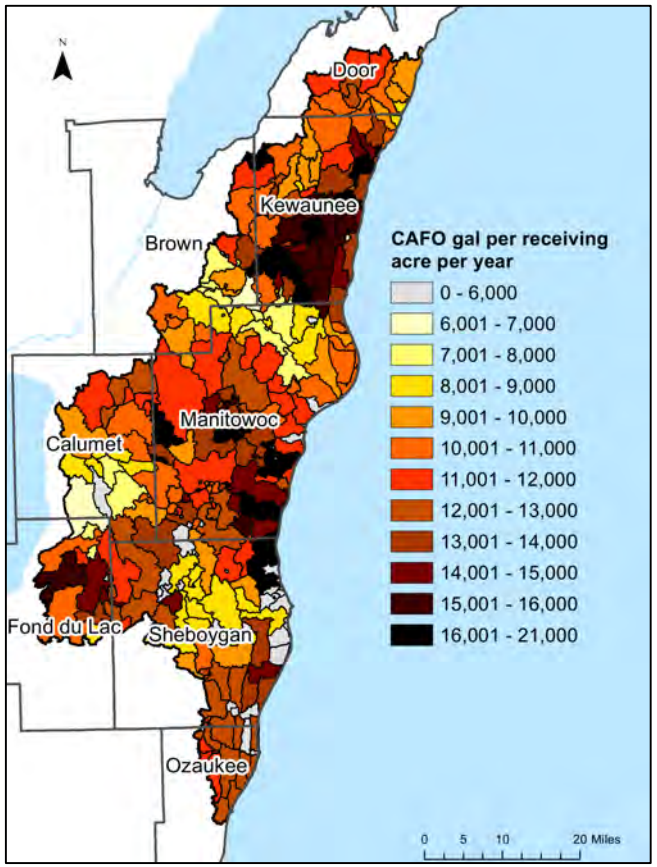
# Manure (gal) per receiving acre per year

Receiving acres = 50% of available acres

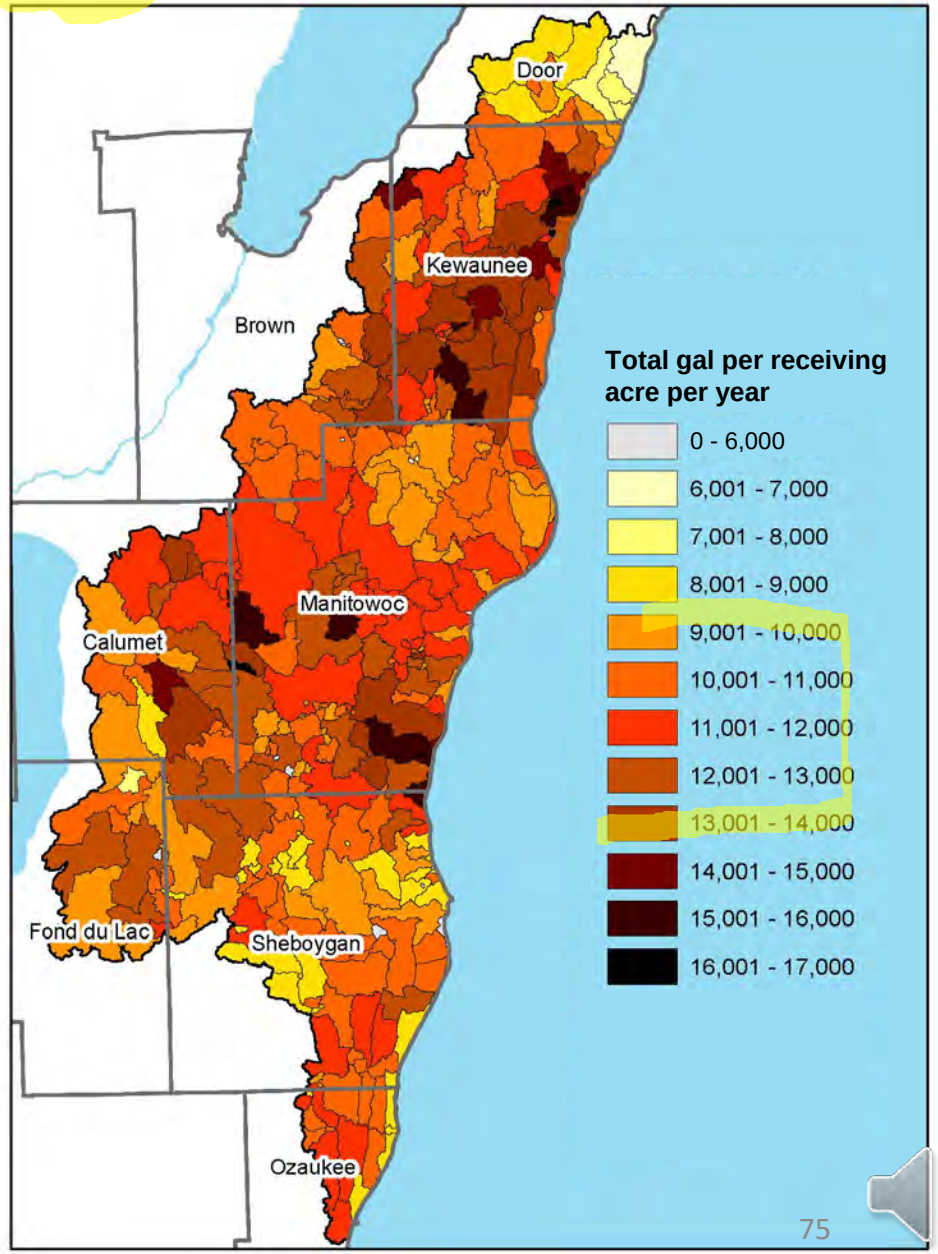
Non-CAFO




CAFO




Total



# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

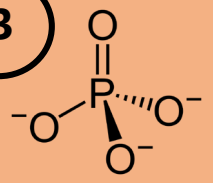
1

Number of cattle contributing manure in each subbasin

2

Amount of liquid manure per subbasin

3

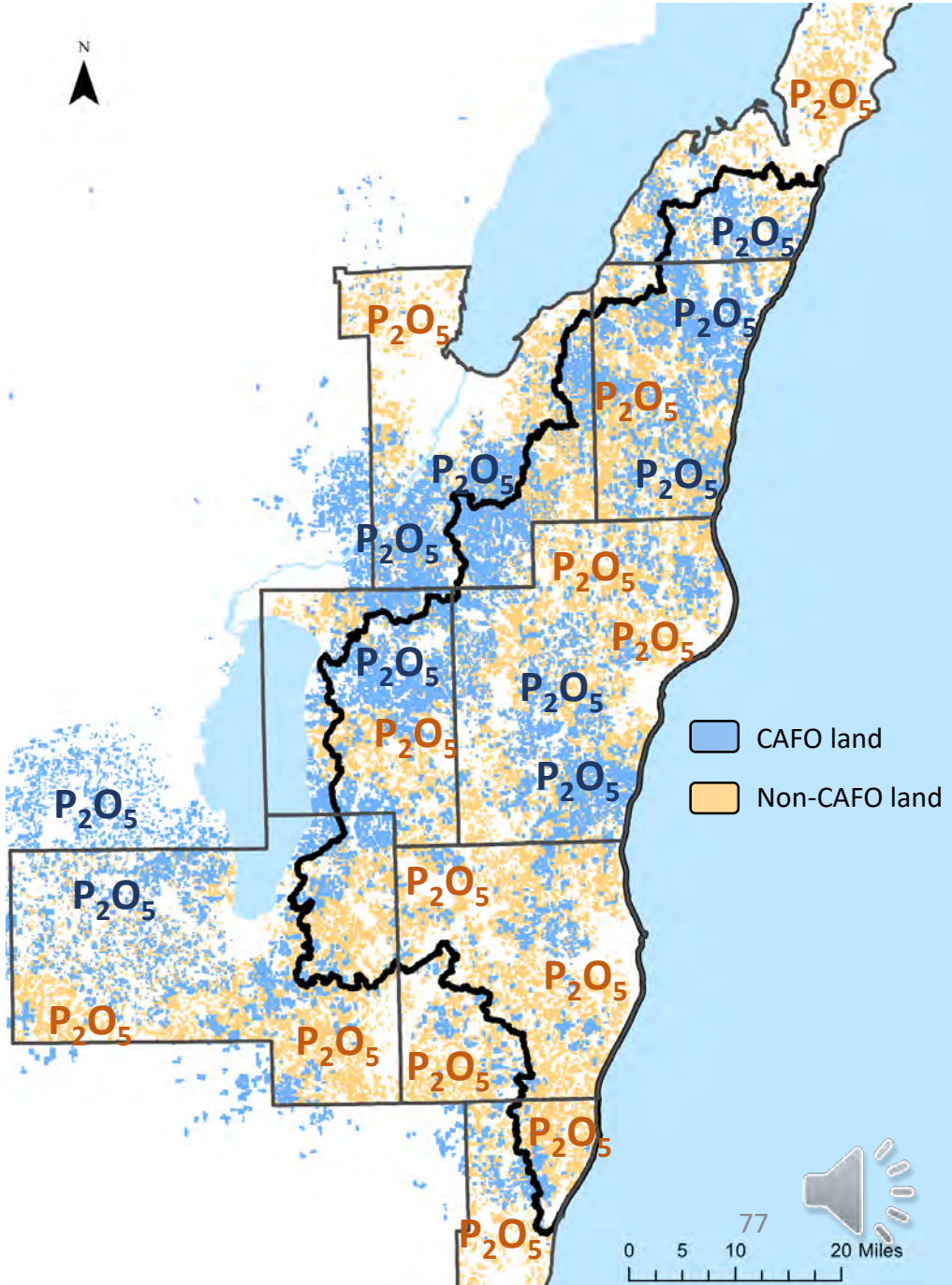



Amount of phosphate per subbasin

Step 3: Yearly phosphate production per subbasin

$P_2O_5$ CAFO phosphate spread on CAFO acres $P_2O_5$

$P_2O_5$ Non-CAFO phosphate spread on Non-CAFO acres $P_2O_5$

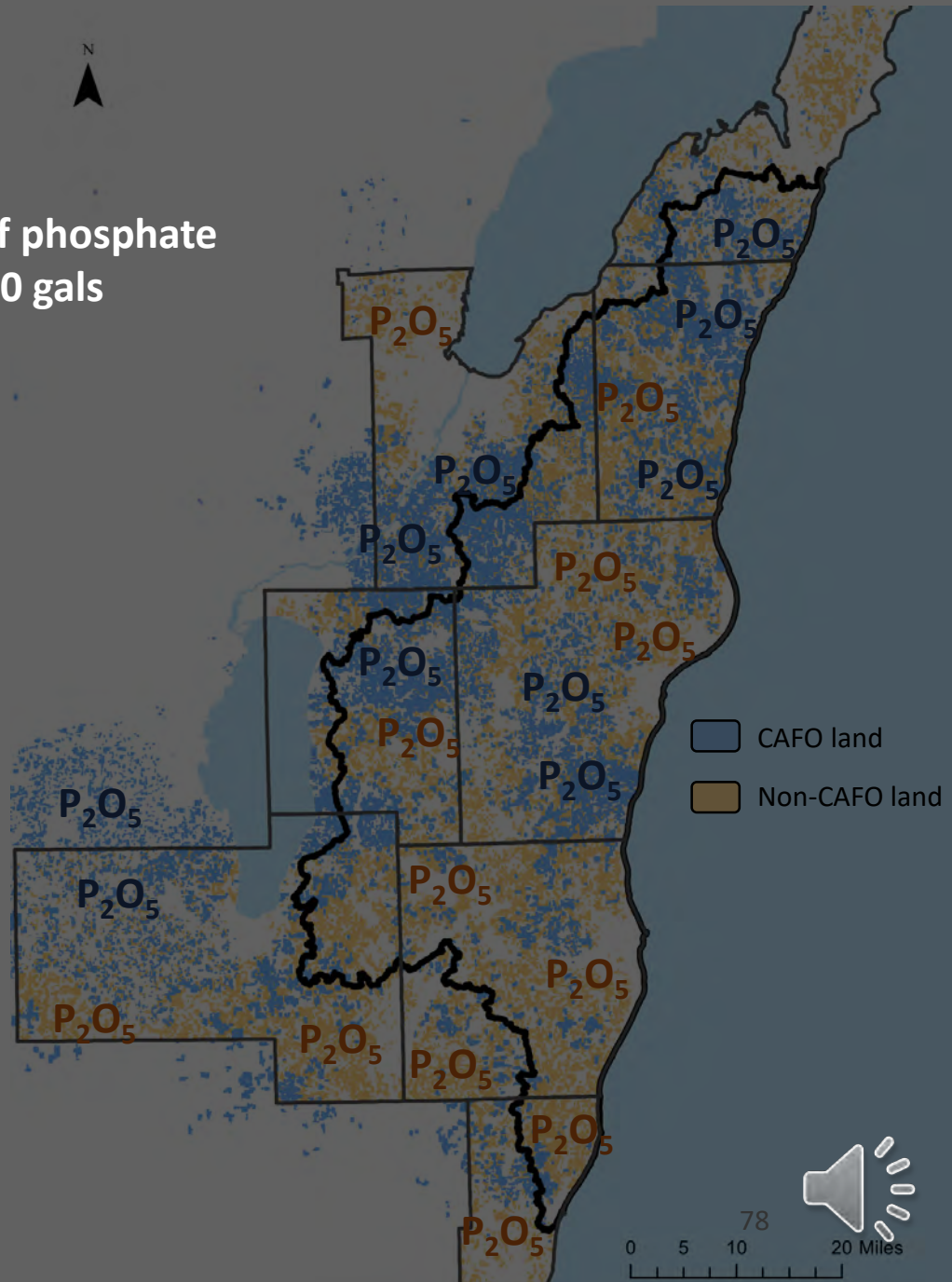


Step 3: Yearly phosphate production per subbasin

$PO_4^{3-}$ CAFO phosphate spread on CAFO acres $PO_4^{3-}$

$PO_4^{3-}$ Non-CAFO phosphate spread on Non-CAFO acres $PO_4^{3-}$

**7.5 lb of phosphate per 1000 gals**



# Step 3: Yearly phosphate production per subbasin

$P_2O_5$ **CAFO phosphate** spread on CAFO acres $P_2O_5$

$P_2O_5$ **Non-CAFO phosphate** spread on Non-CAFO acres $P_2O_5$

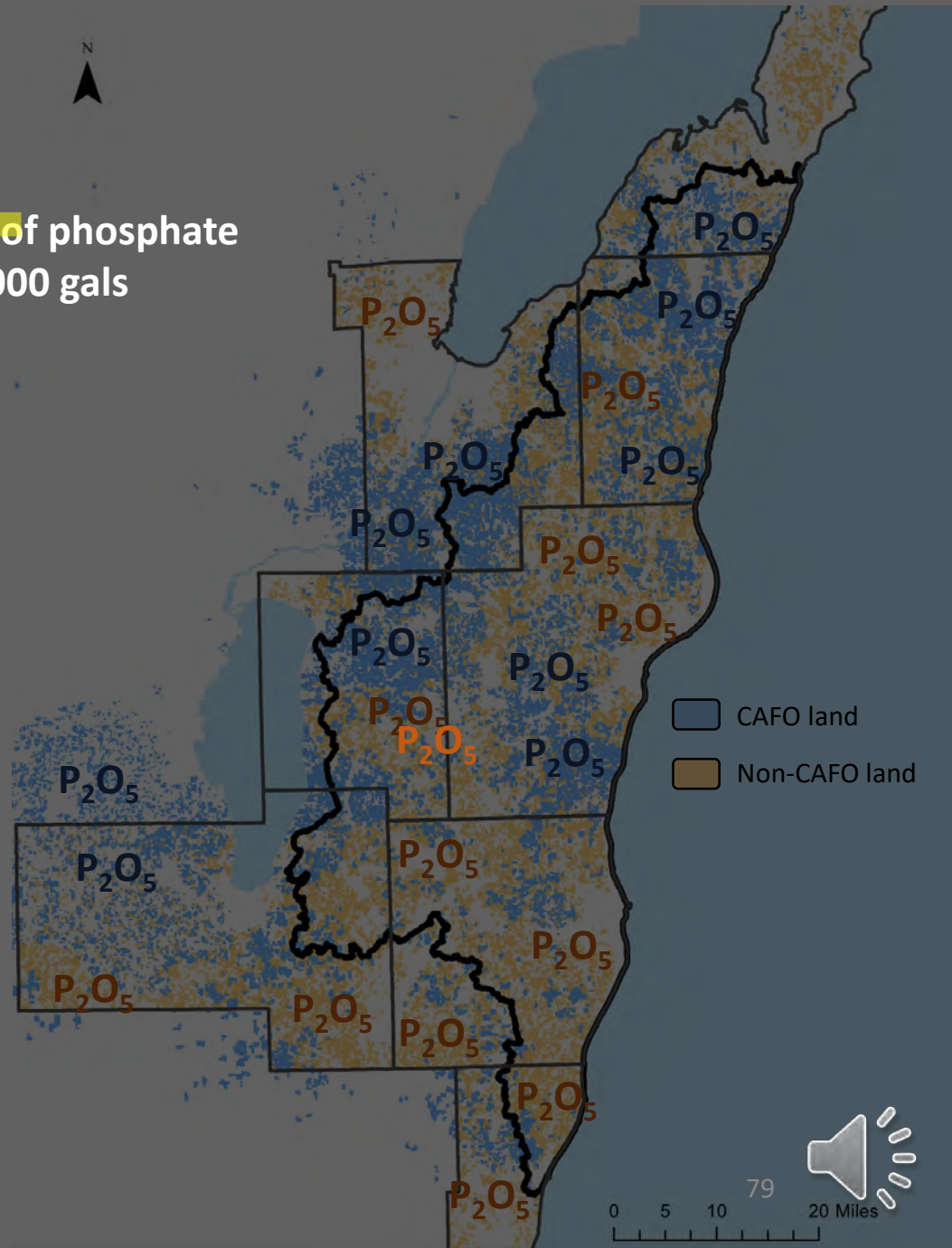
**7.5 lb of phosphate per 1000 gals**

Source 1: SnapPlus Document A2809

Nutrient Application guidelines for field vegetable and fruit crops in Wisconsin

**Table 9.2.** Typical total nutrient content of manures tested in Wisconsin (1998–2012).

| | Dry Matter (DM) | N | $P_2O_5$ | $K_2O$ | S |
|---|---|---|---|---|---|
| **Solid manure** | % | lb/ton | | | |
| Beef | 29 | 13 | 8 | 12 | 1.9 |
| Dairy: semi-solid (11.1–20.0% DM) | 15 | 8 | 4 | 6 | 0.8 |
| Dairy: solid (> 20.0% DM) | 33 | 9 | 4 | 7 | 1.2 |
| Goat | 43 | 13 | 7 | 10 | 2.0 |
| Horse | 33 | 10 | 6 | 8 | 1.3 |
| Poultry: chicken | 57 | 49 | 44 | 33 | 3.0 |
| Poultry: duck | 36 | 12 | 10 | 9 | 1.8 |
| Poultry: turkey | 59 | 51 | 44 | 31 | 3.8 |
| Sheep | 34 | 19 | 9 | 24 | 2.2 |
| Swine | 19 | 18 | 13 | 10 | 2.0 |
| **Liquid manure** | % | lb/1,000 gal | | | |
| Beef | 3 | 16 | 7 | 15 | 1.6 |
| Dairy: liquid (< 4.0% DM) | 2 | 14 | 4 | 14 | 1.1 |
| Dairy: slurry (4.1–11.0% DM) | 6 | 24 | 8 | 21 | 2.2 |
| Goat | 4 | 17 | 8 | 19 | 1.7 |
| Poultry | 2 | 12 | 7 | 9 | 1.3 |
| Swine: finish (indoor pit) | 5 | 43 | 18 | 28 | 3.2 |
| Swine: finish (outdoor pit) | 2 | 18 | 7 | 10 | 1.0 |
| Swine: (farrow-nursery, indoor pit) | 2 | 21 | 8 | 13 | 1.0 |
| Veal calf | 1 | 9 | 3 | 16 | 0.6 |



Step 3: Yearly phosphate production per subbasin

$P_2O_5$ **CAFO phosphate** spread on CAFO acres $P_2O_5$

$P_2O_5$ **Non-CAFO phosphate** spread on Non-CAFO acres $P_2O_5$

**7.5 lb of phosphate per 1000 gals**

Source 1: SnapPlus Document A2809

Nutrient Application guidelines for field vegetable and fruit crops in Wisconsin

**Table 9.2.** Typical total nutrient content of manures tested in Wisconsin (1998–2012).

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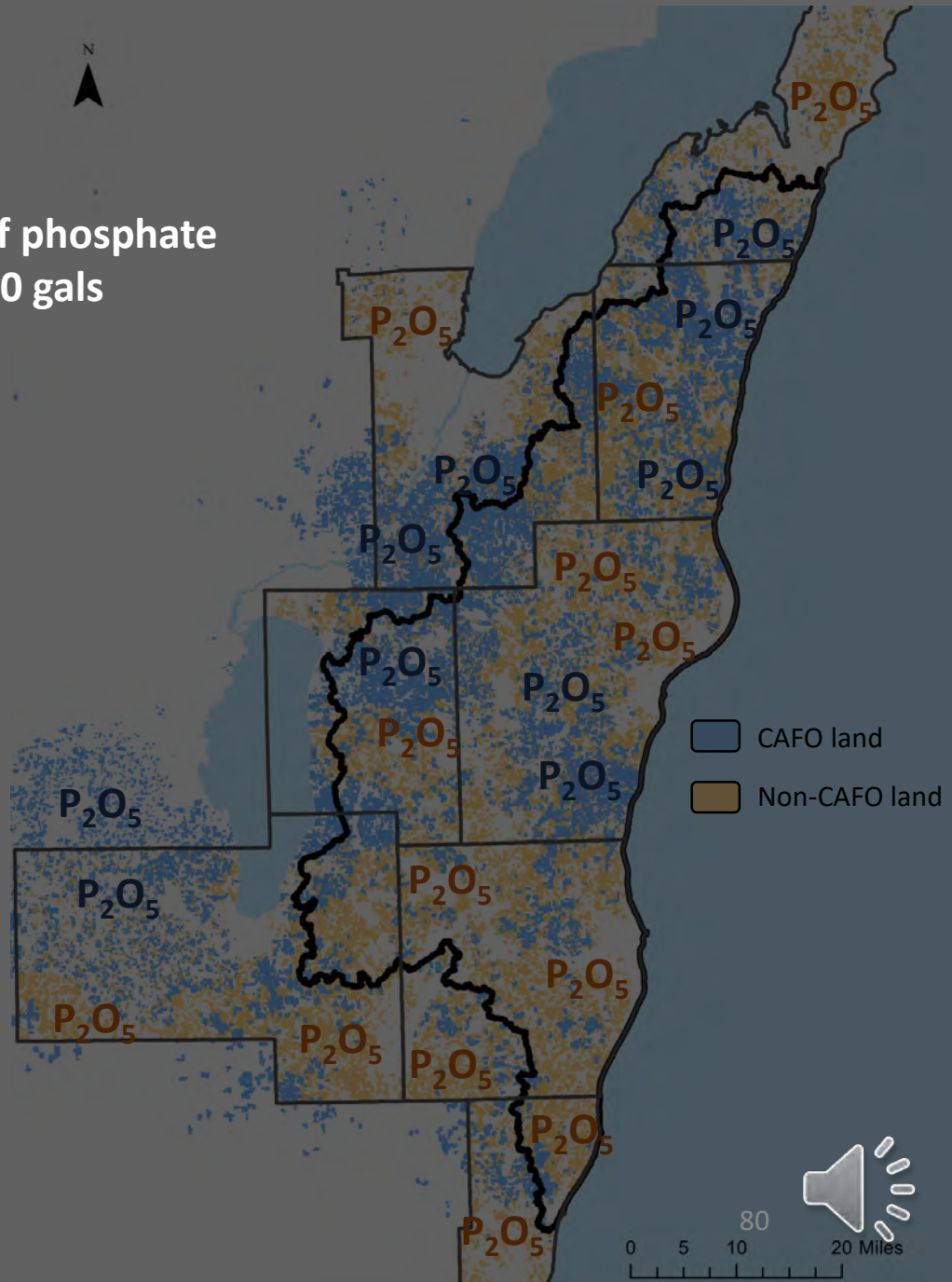
| Goat | 43 | 13 | 7 | 10 | 2.0 |
| Horse | 33 | 10 | 6 | 8 | 1.3 |
| Poultry: chicken | 57 | 49 | 44 | 33 | 3.0 |
| Poultry: duck | 36 | 12 | 10 | 9 | 1.8 |
| Poultry: turkey | 59 | 51 | 44 | 31 | 3.8 |
| Sheep | 34 | 19 | 9 | 24 | 2.2 |
| Swine | 19 | 18 | 13 | 10 | 2.0 |
| **Liquid manure** | % | | lb/1,000 gal | | |
| Beef | 3 | 16 | 7 | 15 | 1.6 |
| Dairy: liquid (< 4.0% DM) | 2 | 14 | 4 | 14 | 1.1 |
| Dairy: slurry (4.1–11.0% DM) | 6 | 24 | 8 | 21 | 2.2 |
| Goat | 4 | 17 | 8 | 19 | 1.7 |
| Poultry | 2 | 12 | 7 | 9 | 1.3 |
| Swine: finish (indoor pit) | 5 | 43 | 18 | 28 | 3.2 |
| Swine: finish (outdoor pit) | 2 | 18 | 7 | 10 | 1.0 |
| Swine: (farrow-nursery, indoor pit) | 2 | 21 | 8 | 13 | 1.0 |
| Veal calf | 1 | 9 | 3 | 16 | 0.6 |

Source 2: CAFO nutrient management plans (2014-2018)

Manure P2O5 Concentration at subset of NE Lakeshore CAFOs

| Statistic | Concentration lb per 1000 gals |
|---|---|
| Average | 6.9 |
| Median | 6.5 |
| Min | 1.5 |
| Max | 19.1 |

sample size = 37 facilities



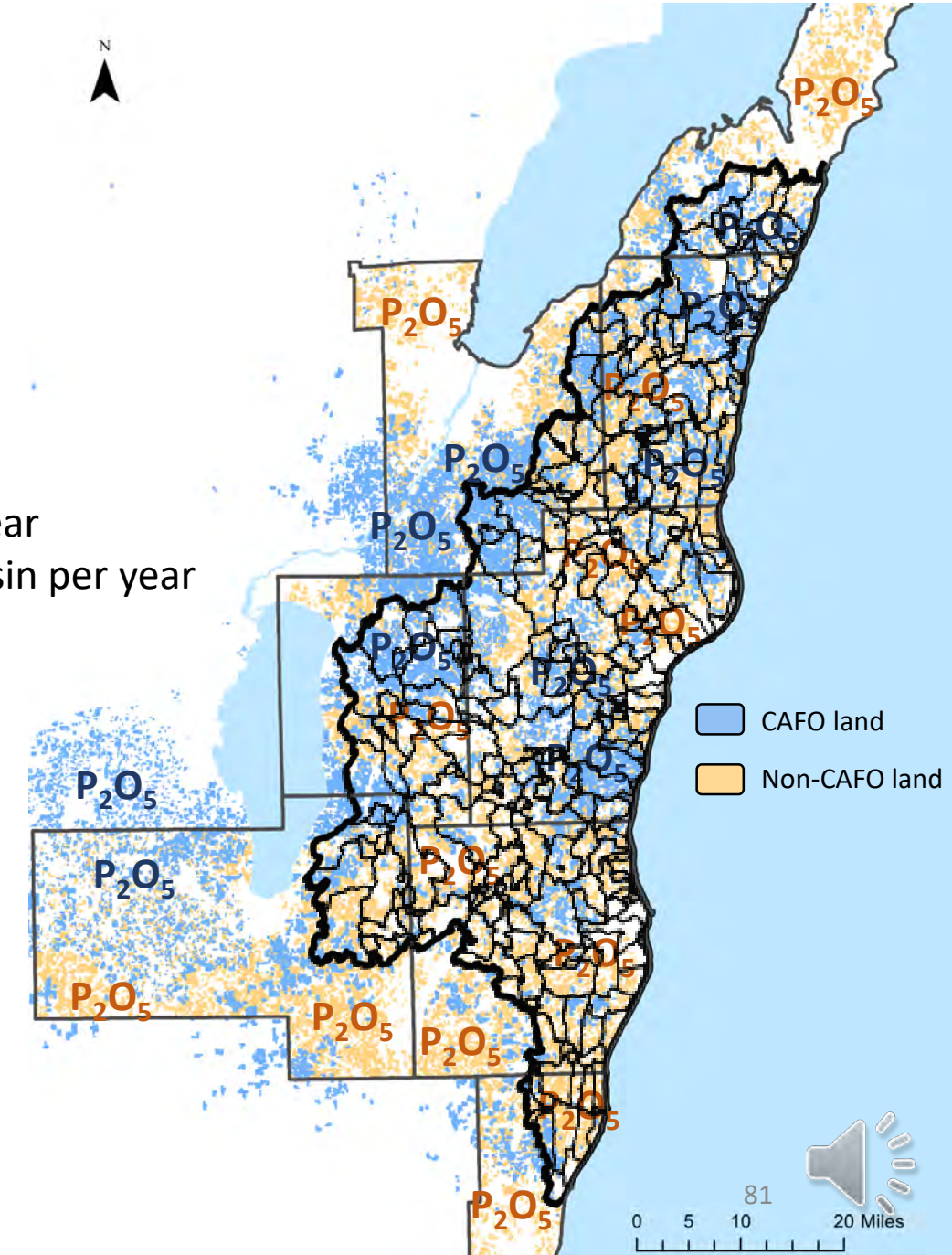
Step 3: Yearly phosphate production per subbasin

$PO_4^{3-}$ CAFO phosphate spread on CAFO acres $PO_4^{3-}$

$PO_4^{3-}$ Non-CAFO phosphate spread on Non-CAFO acres $PO_4^{3-}$

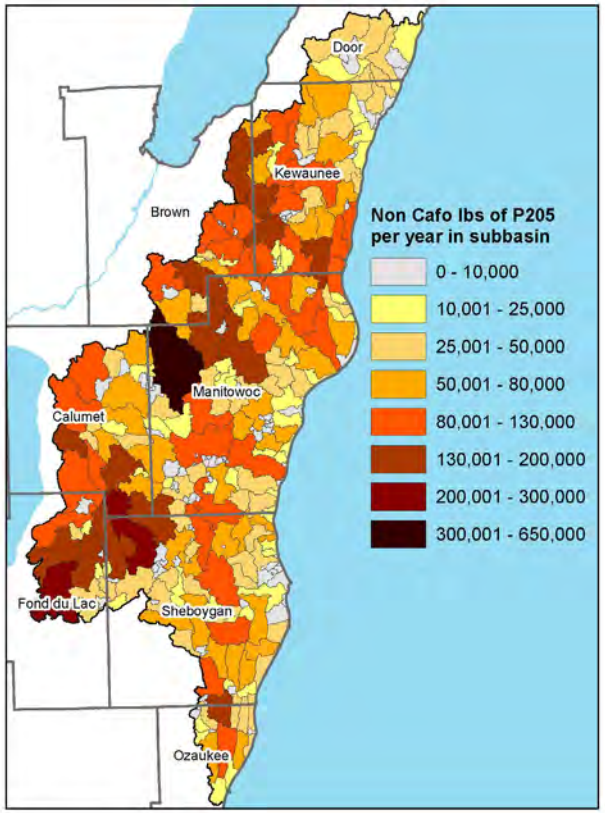
Overlay subbasins

- Pounds of phosphate per subbasin per year
- Pounds of phosphate per acre per subbasin per year

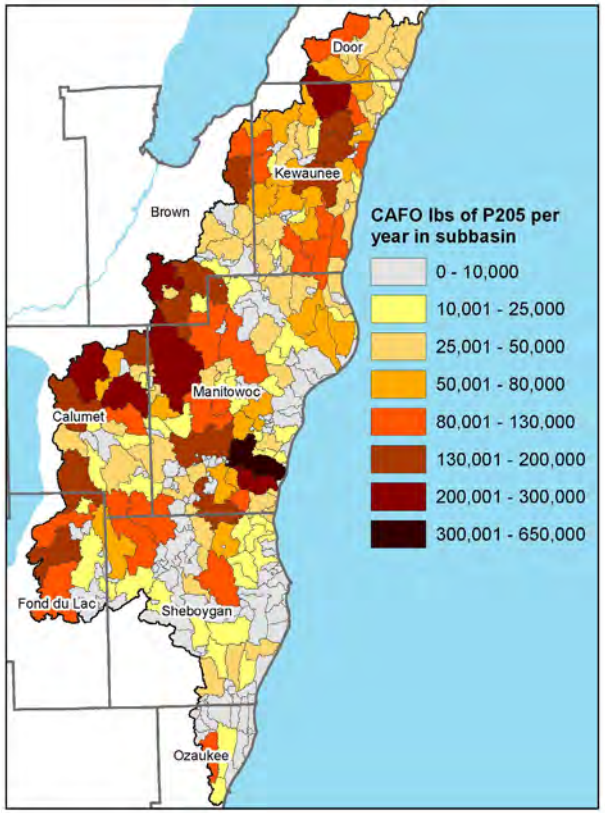


# P2O5 (lbs) per subbasin per year

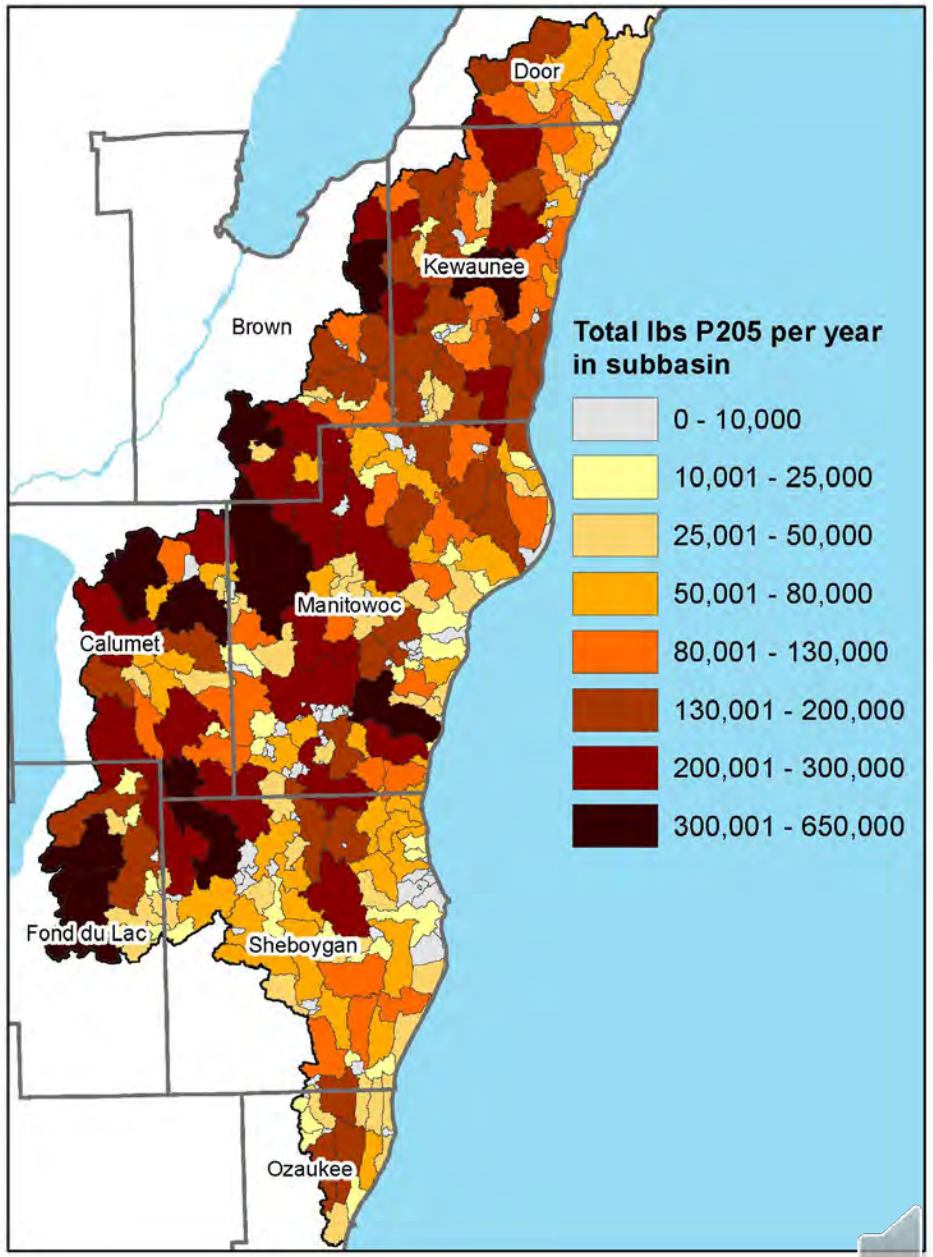
Non-CAFO




CAFO

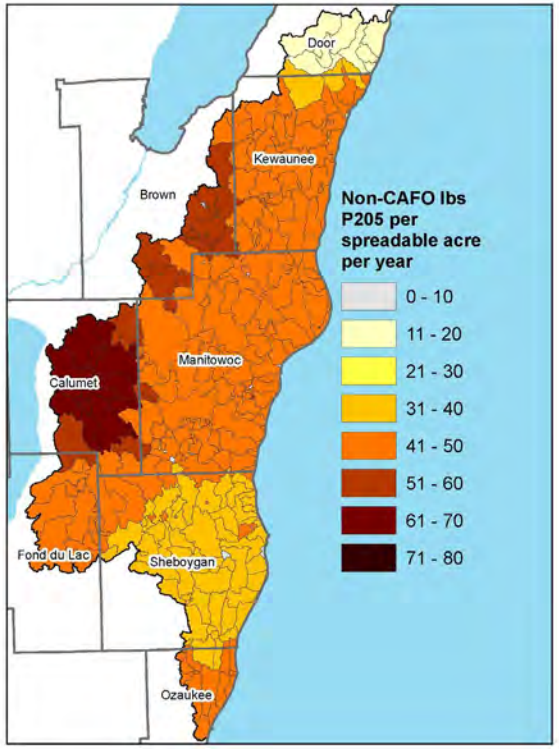



Total

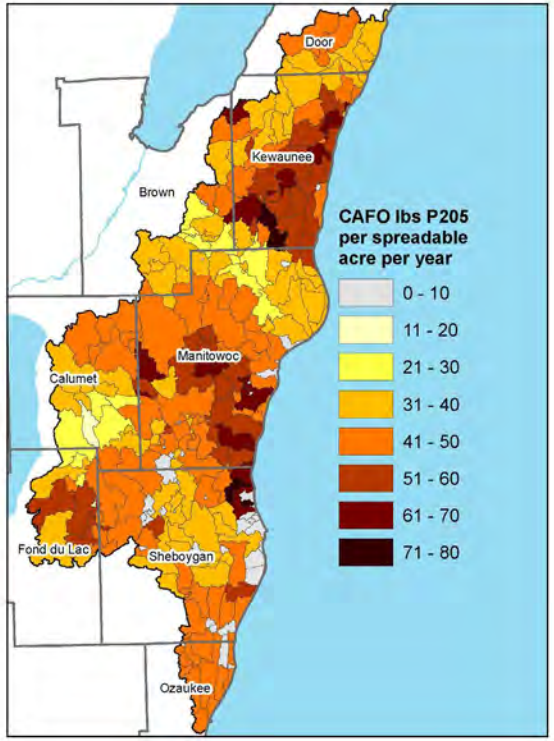


# P2O5 (lbs) per available acre per year

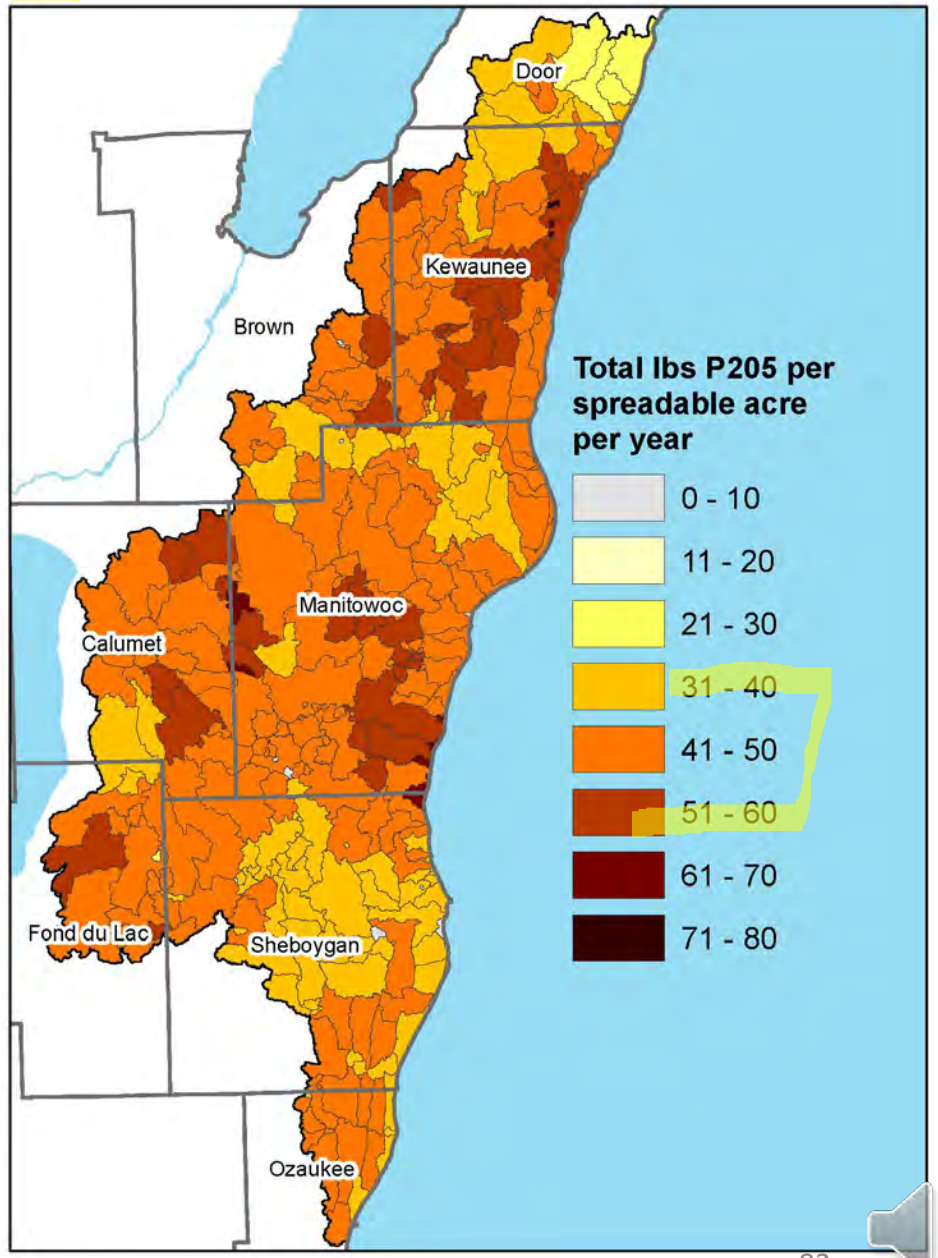
Non-CAFO




CAFO



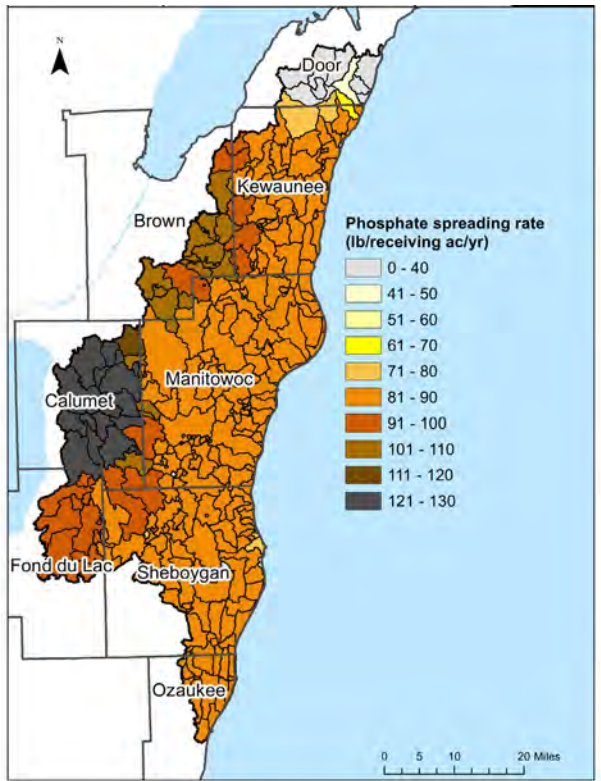

Total



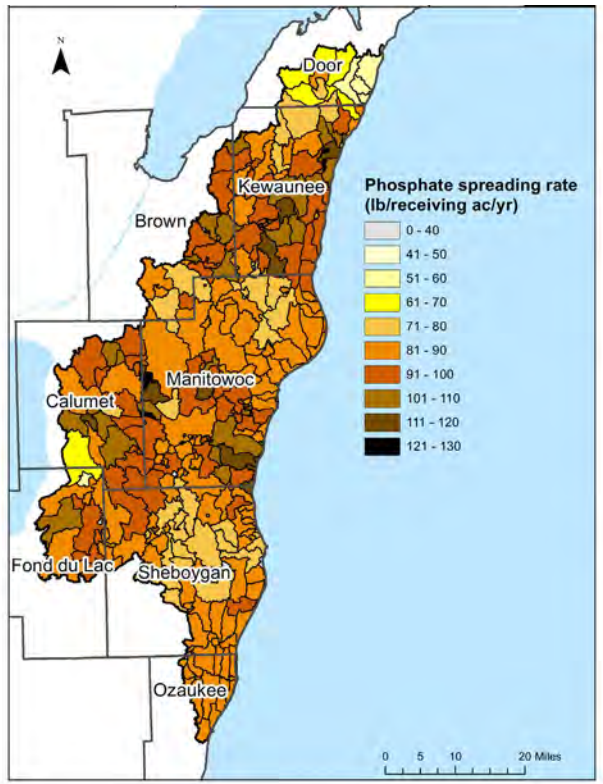
# P2O5 (lbs) per receiving acre per year

Receiving acres = 50% of available acres

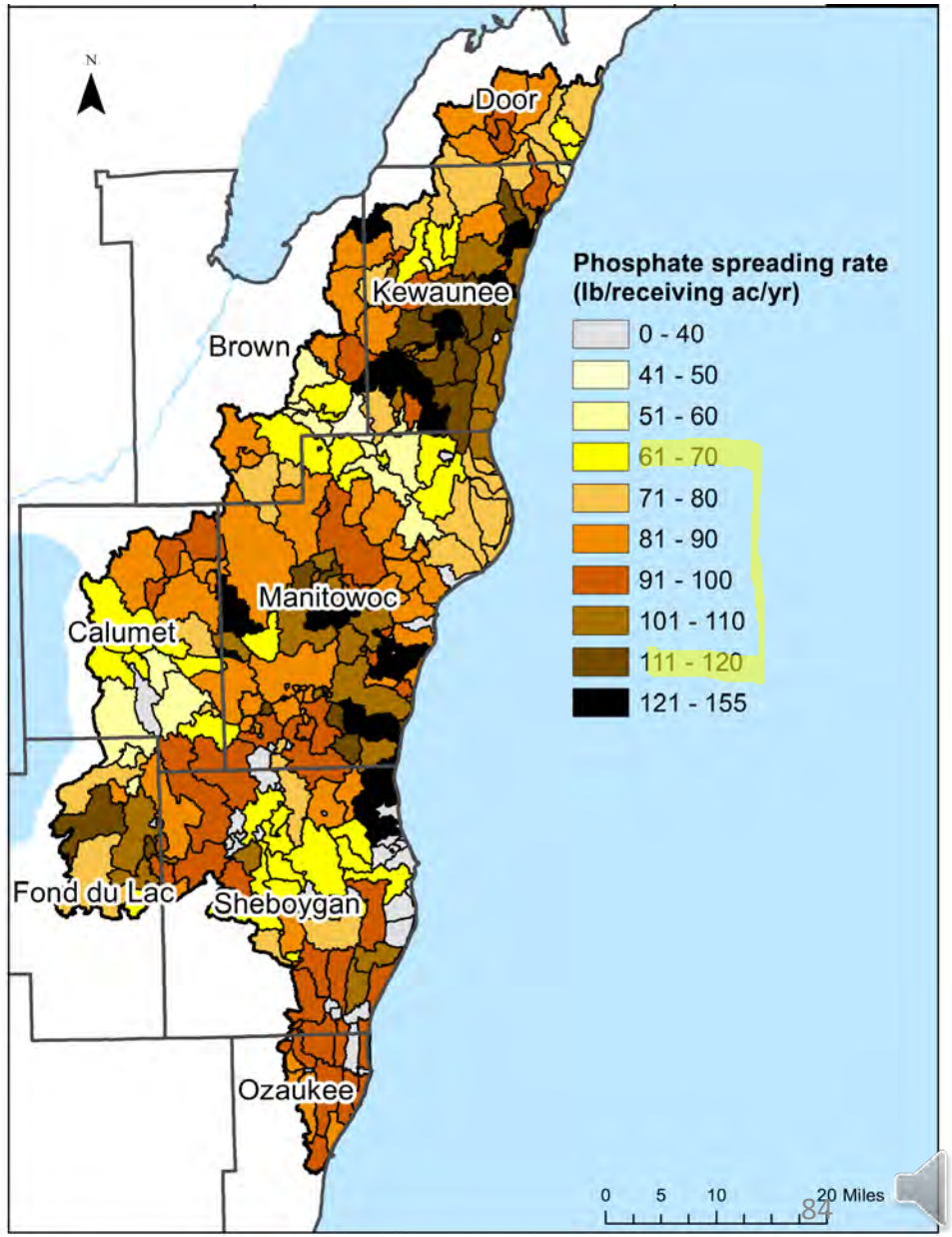
Non-CAFO




CAFO




Total



# DNR manure spreading analysis

## Method Summary

Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

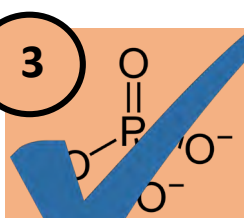
1

Number of cattle contributing manure in each subbasin

2

Amount of liquid manure per subbasin

3



Amount of phosphate (P2O5) per subbasin

# Validation of DNR manure spreading analysis

1

CAFO facility value from WDNR analysis


CAFO facility value from Nutrient Management plan

1) Gallons of manure per facility
2) Gallons of manure per facility per spreadable acre
3) Gallons of manure per facility per receiving acre
4) Phosphate per facility
5) Phosphate per facility per spreadable acre
6) Phosphate per facility per receiving acre

# Validation of DNR manure spreading analysis

1

CAFO facility value from WDNR analysis


CAFO facility value from Nutrient Management plan

1) Gallons of manure per facility
2) Gallons of manure per facility per spreadable acre
3) Gallons of manure per facility per receiving acre
4) Phosphate per facility
5) Phosphate per facility per spreadable acre
6) Phosphate per facility per receiving acre

2

WDNR calculated value
Yearly gallons per receiving acre per subbasin


County Land and Water Departments' estimated value
Yearly gallons per receiving acre per HUC12 watershed

# Validation of DNR manure spreading analysis

1

CAFO facility value from WDNR analysis

**Comparison**

CAFO facility value from Nutrient Management plan

1) Gallons of manure per facility
2) Gallons of manure per facility per spreadable acre
3) **Gallons of manure per facility per receiving acre**
4) Phosphate per facility
5) Phosphate per facility per spreadable acre
6) **Phosphate per facility per receiving acre**

2

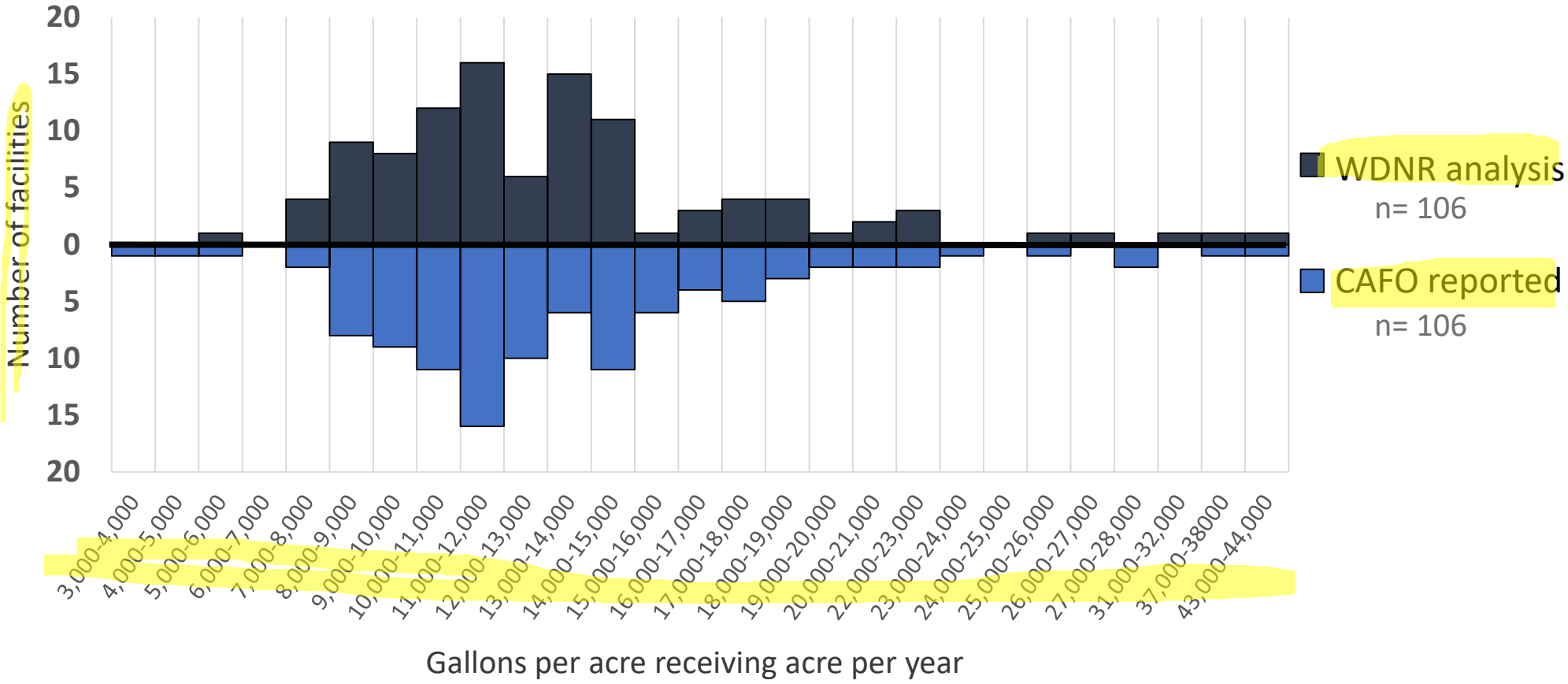
WDNR calculated value
Yearly gallons per receiving acre per subbasin

**Comparison**

County Land and Water Departments' estimated value
Yearly gallons per receiving acre per HUC12 watershed

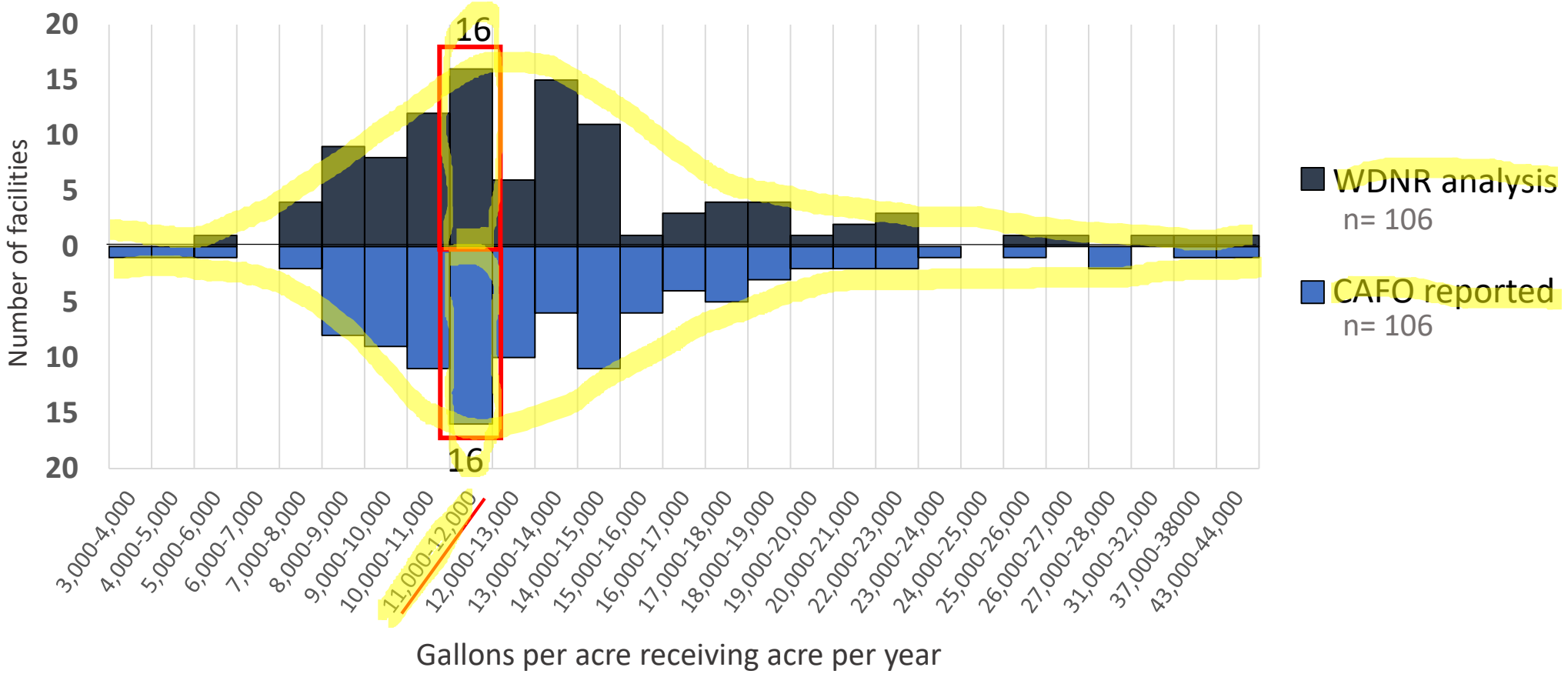
# Validation of DNR manure spreading analysis

## Yearly gallons of liquid manure per receiving acre



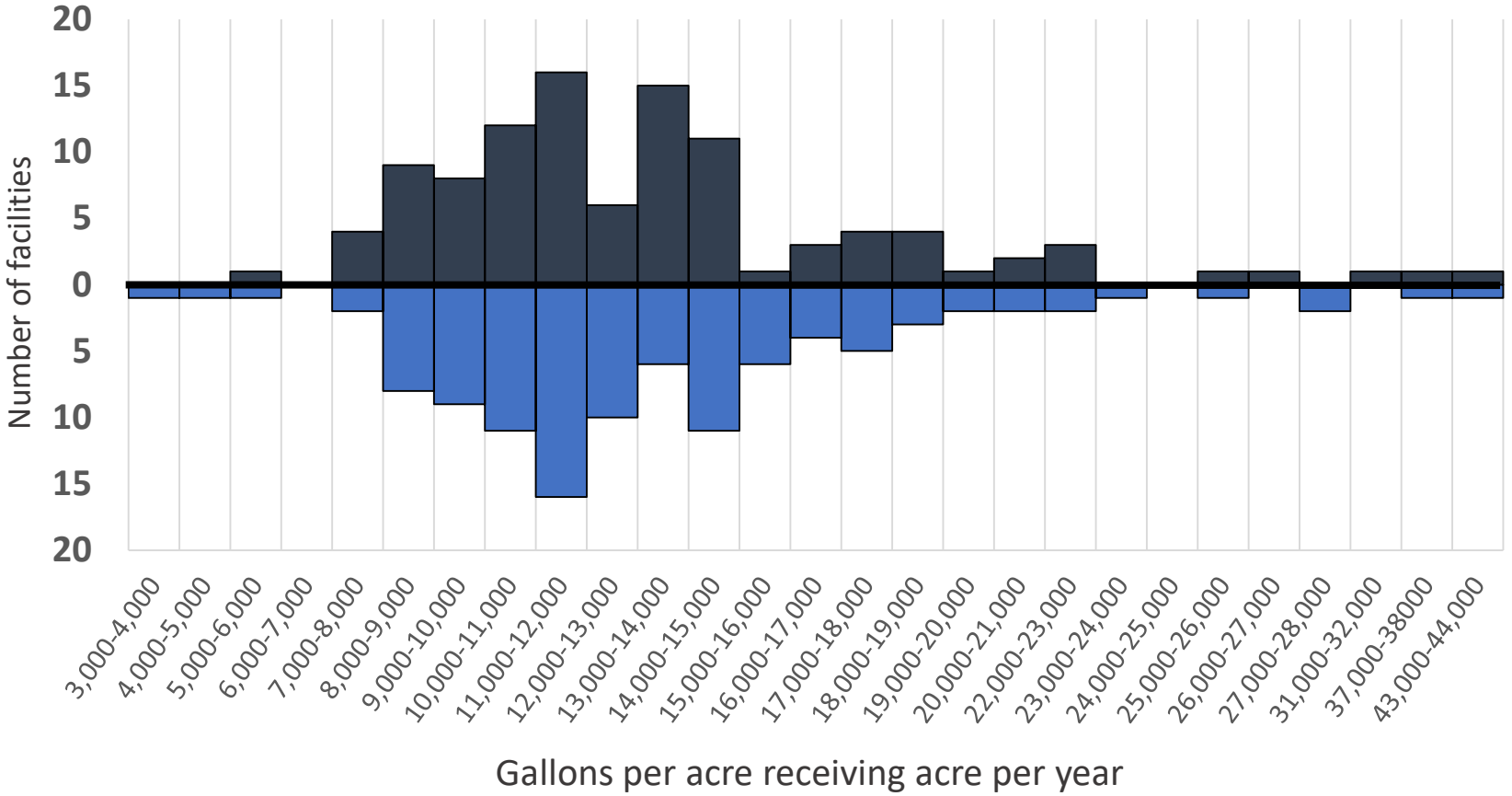
# Validation of DNR manure spreading analysis

## Yearly gallons of liquid manure per receiving acre



# Validation of DNR manure spreading analysis

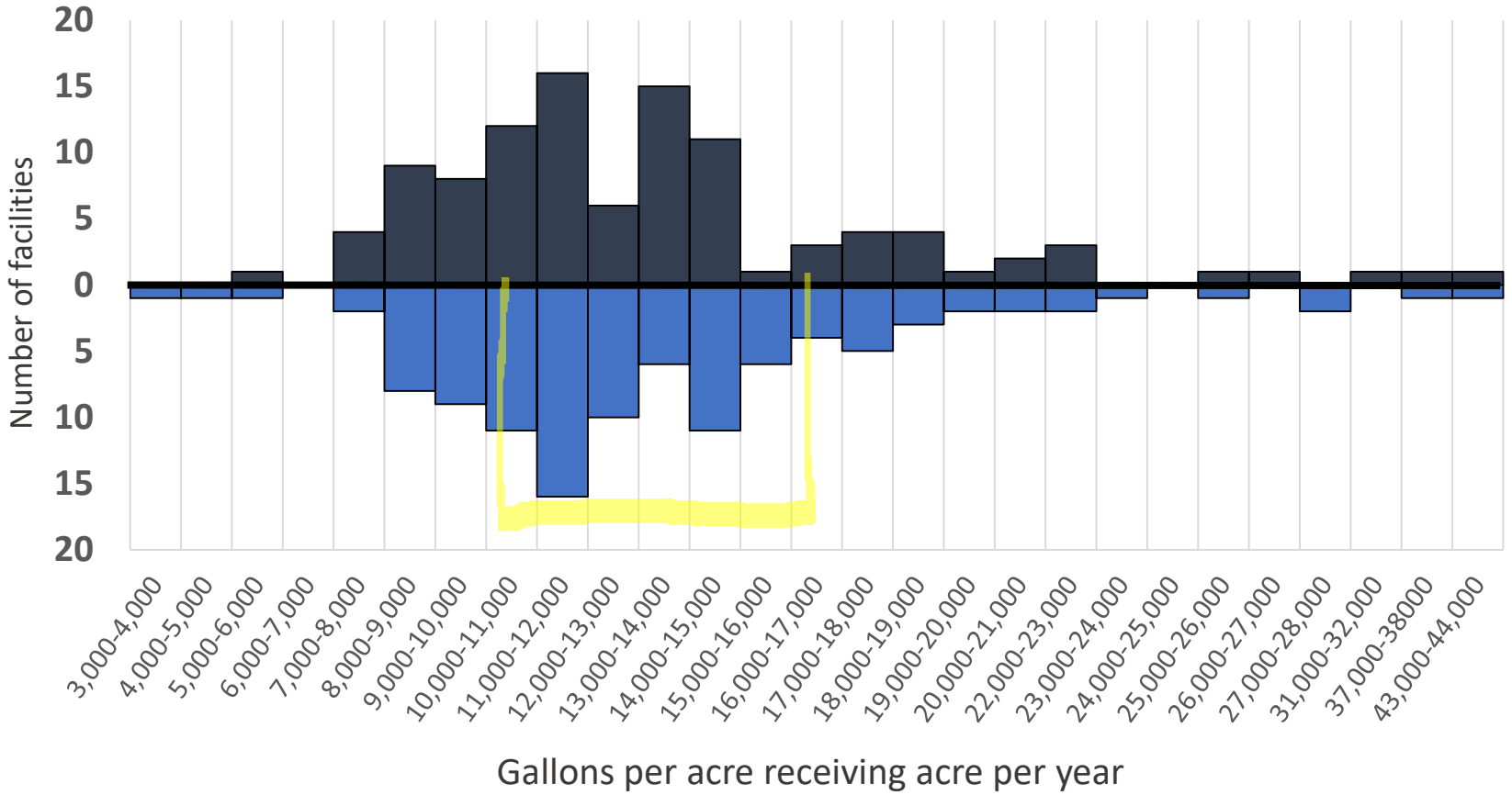
## Yearly gallons of liquid manure per receiving acre




| | Source | |
|---|---|---|
| | CAFO reported | DNR analysis |
| Average | 13,780 | 12,837 |
| Median | 12,484 | 11,657 |
| Max | 43,239 | 43,972 |
| Min | 3,434 | 4,248 |

# Validation of DNR manure spreading analysis

## Yearly gallons of liquid manure per receiving acre




| | Source | |
|---|---|---|
| | CAFO reported | DNR analysis |
| Average | 13,780 | 12,837 |
| Median | 12,484 | 11,657 |
| Max | 43,239 | 43,972 |
| Min | 3,434 | 4,248 |

WDNR analysis
n= 106

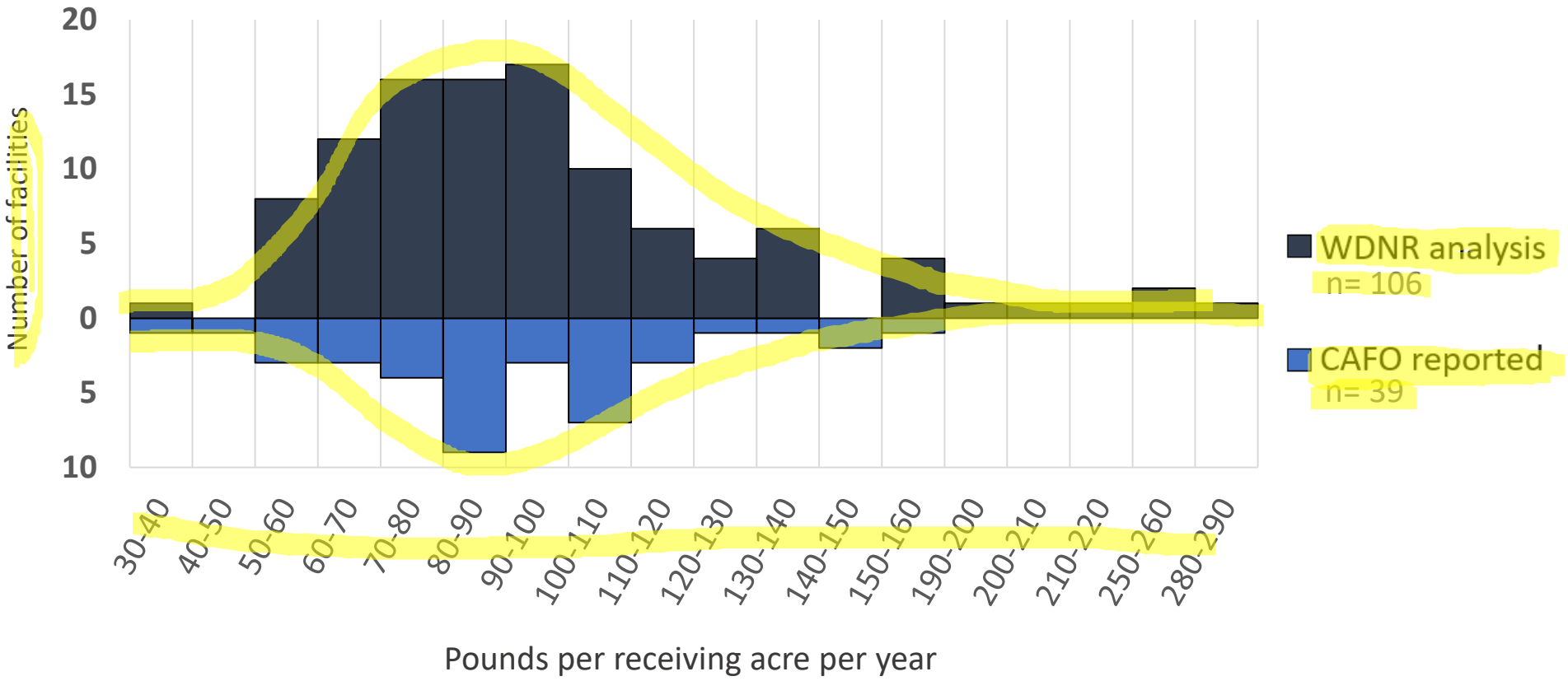
CAFO reported
n= 106

Non-CAFO countywide results
(according to DNR analysis)

| County | Gal. of manure per *receiving* acre per year |
|---|---|
| BROWN | 14,448 |
| CALUMET | 16,216 |
| DOOR | 5,082 |
| FOND DU LAC | 12,150 |
| KEWAUNEE | 11,886 |
| MANITOWOC | 11,502 |
| SHEBOYGAN | 10,714 |
| OZAUKEE | 10,844 |

# Validation of DNR manure spreading analysis

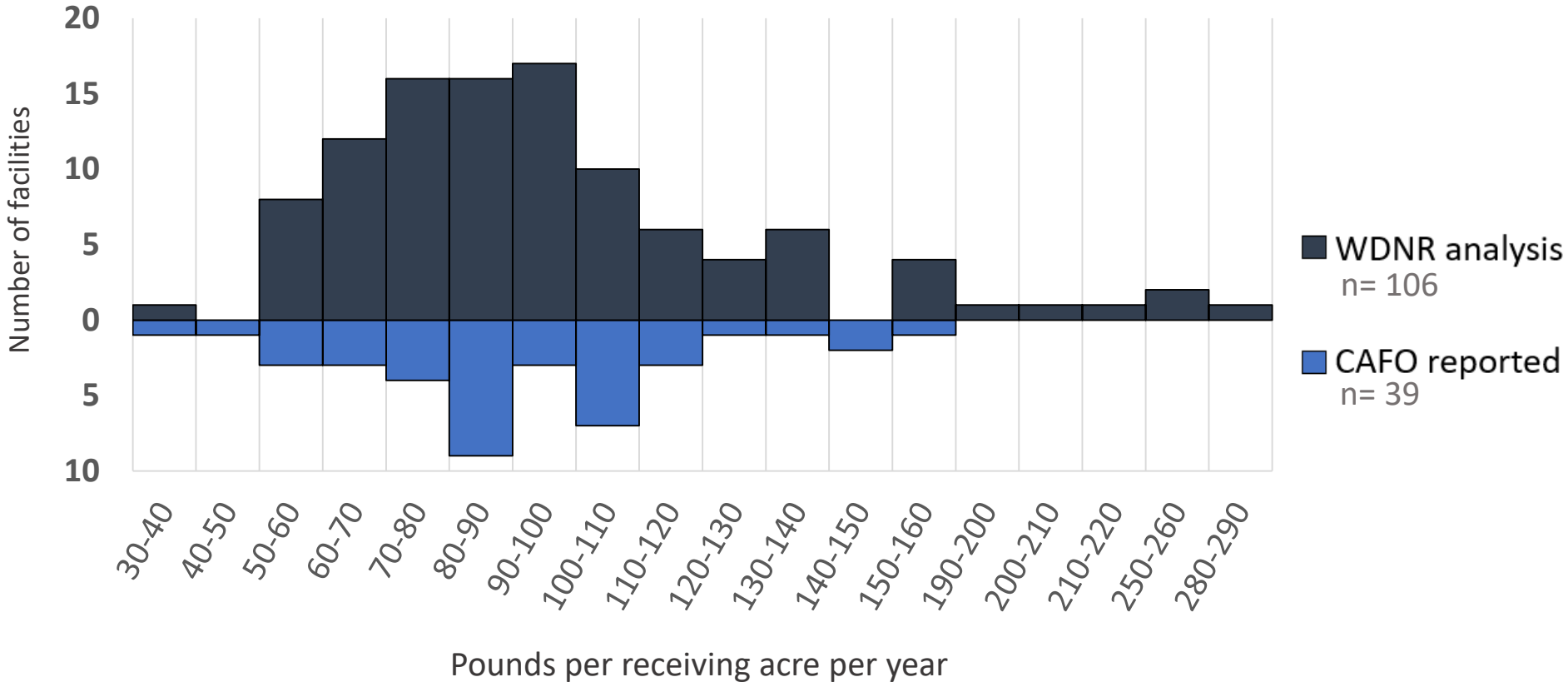
Yearly pounds of phosphate per receiving acre



# Validation of DNR manure spreading analysis

| | Method | |
|---|---|---|
| | CAFO reported | WDNR analysis |
| Average | 92 | 98 |
| Median | 88 | 90 |
| Max | 154 | 286 |
| Min | 31 | 32 |

## Yearly pounds of phosphate per receiving acre



# Validation of DNR manure spreading analysis

## Yearly pounds of phosphate per receiving acre

| | Method | |
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| | CAFO reported | WDNR analysis |
| Average | 92 | 98 |
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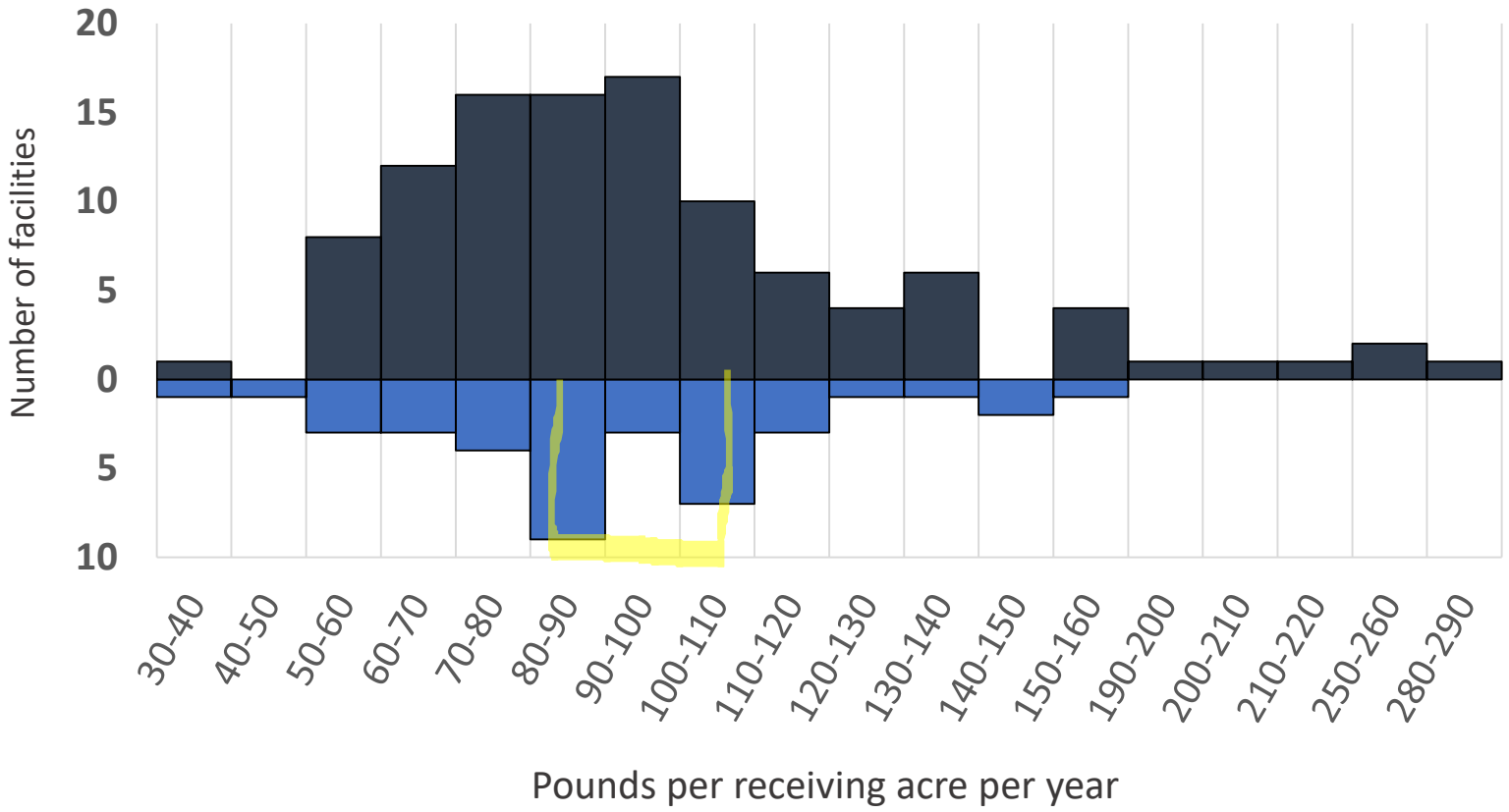


Non-CAFO countywide results (according to DNR analysis)

| County | lb of P205 per receiving acre per yr |
|---|---|
| BROWN | 108 |
| CALUMET | 102 |
| DOOR | 38 |
| FOND DU LAC | 92 |
| KEWAUNEE | 90 |
| MANITOWOC | 86 |
| SHEBOYGAN | 80 |
| OZAUKEE | 81 |

# Validation of DNR manure spreading analysis

1

CAFO facility value from WDNR analysis

**Comparison**

CAFO facility value from Nutrient Management plan

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2

WDNR calculated value
Yearly gallons per receiving acre per subbasin

**Comparison**

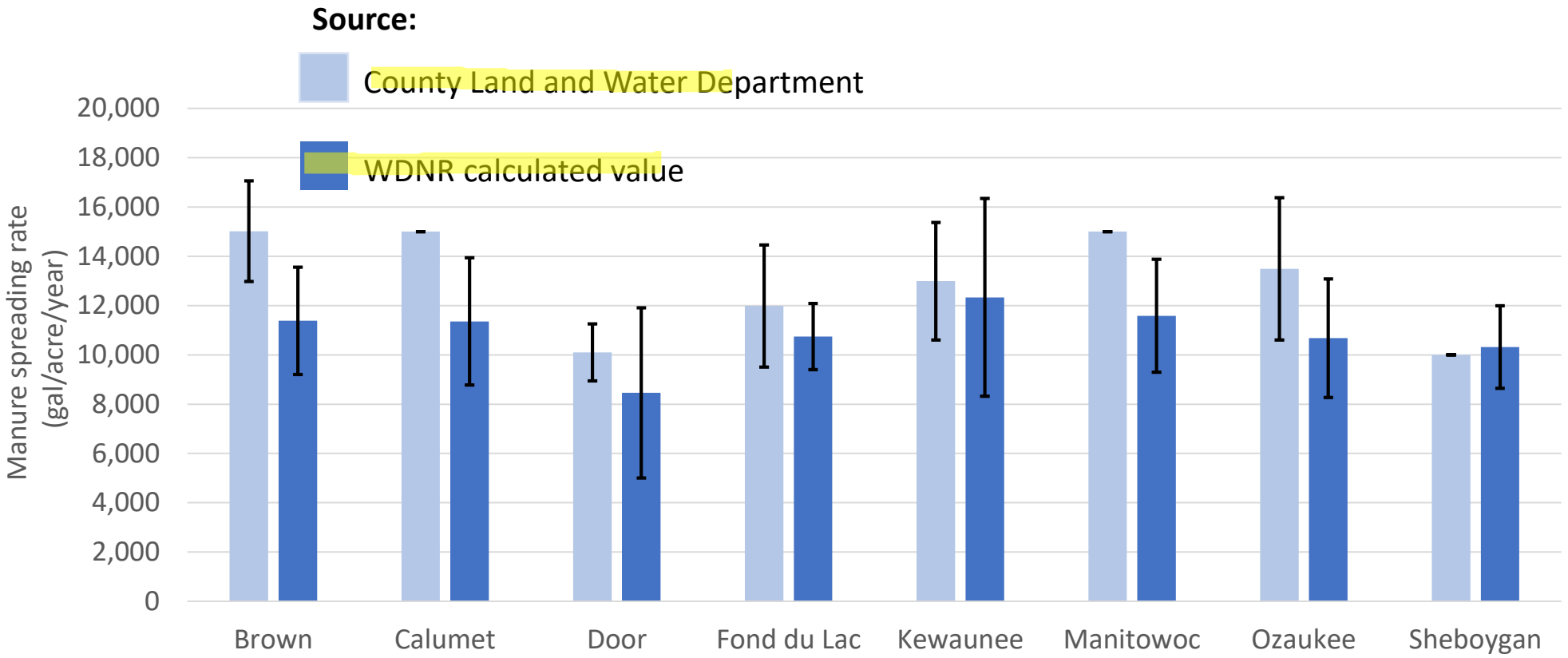
County Land and Water Departments' estimated value
Yearly gallons per receiving acre per HUC12 watershed

# Validation of DNR manure spreading analysis

WDNR calculated value
Yearly gallons per receiving acre per subbasin

Comparison

County Land and Water Departments' estimated value
Yearly gallons per receiving acre per HUC12 watershed



# DNR manure spreading analysis

## Method Summary

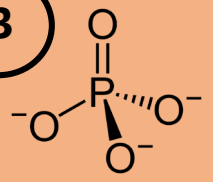
Objective: Obtain a yearly amount of manure phosphate applied per subbasin per year

1. 

   Number of cattle contributing manure in each subbasin

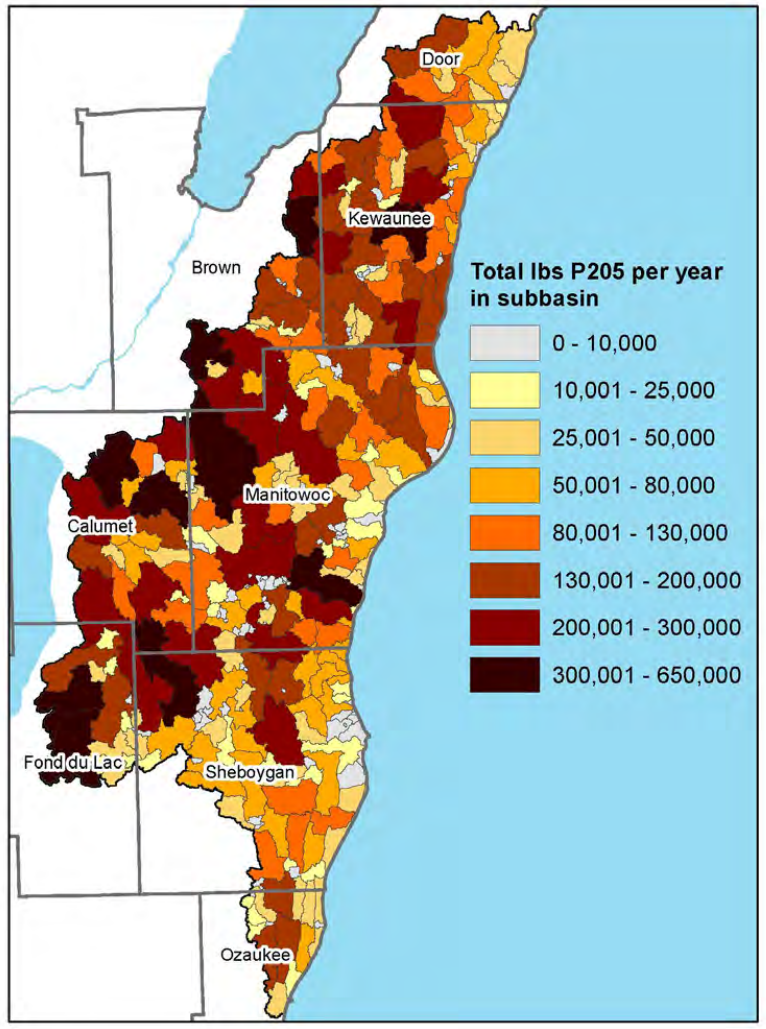
2. 

   Amount of liquid manure per subbasin

3. 

   Amount of phosphate per subbasin

Phosphate (lb) per subbasin per year

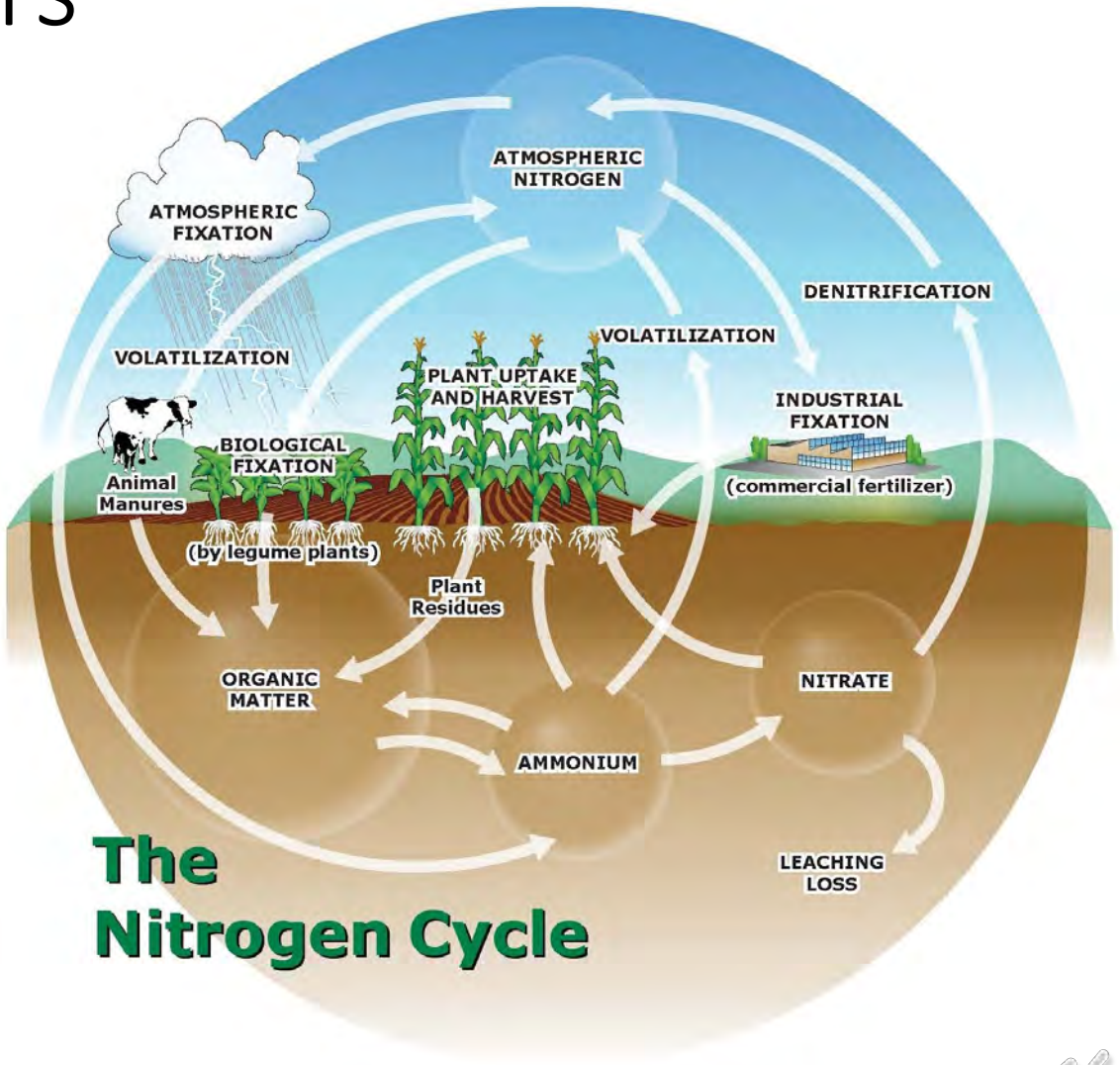


# Nitrogen in the NE Lakeshore TMDL

As directed by Wisconsin statute 281.145

# Nitrogen in Surface Waters

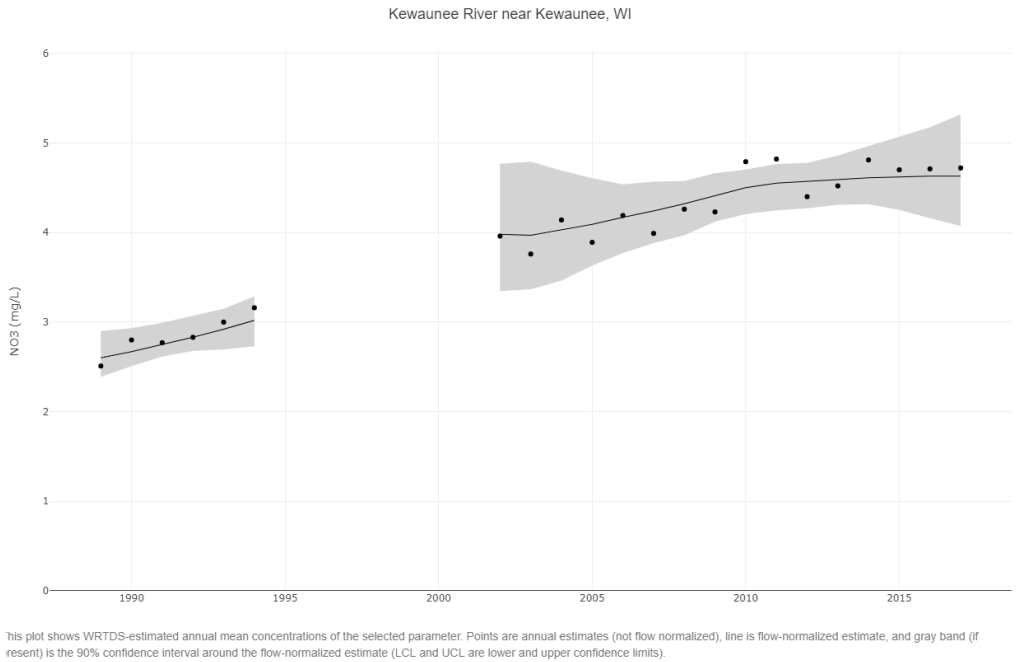
- Nitrogen species
  - Nitrate/Nitrite
  - Total Kjeldahl Nitrogen
  - Ammonia
- Sources
  - Animal manure
  - Commercial fertilizer
  - Biological fixation (legumes)
  - Atmospheric deposition

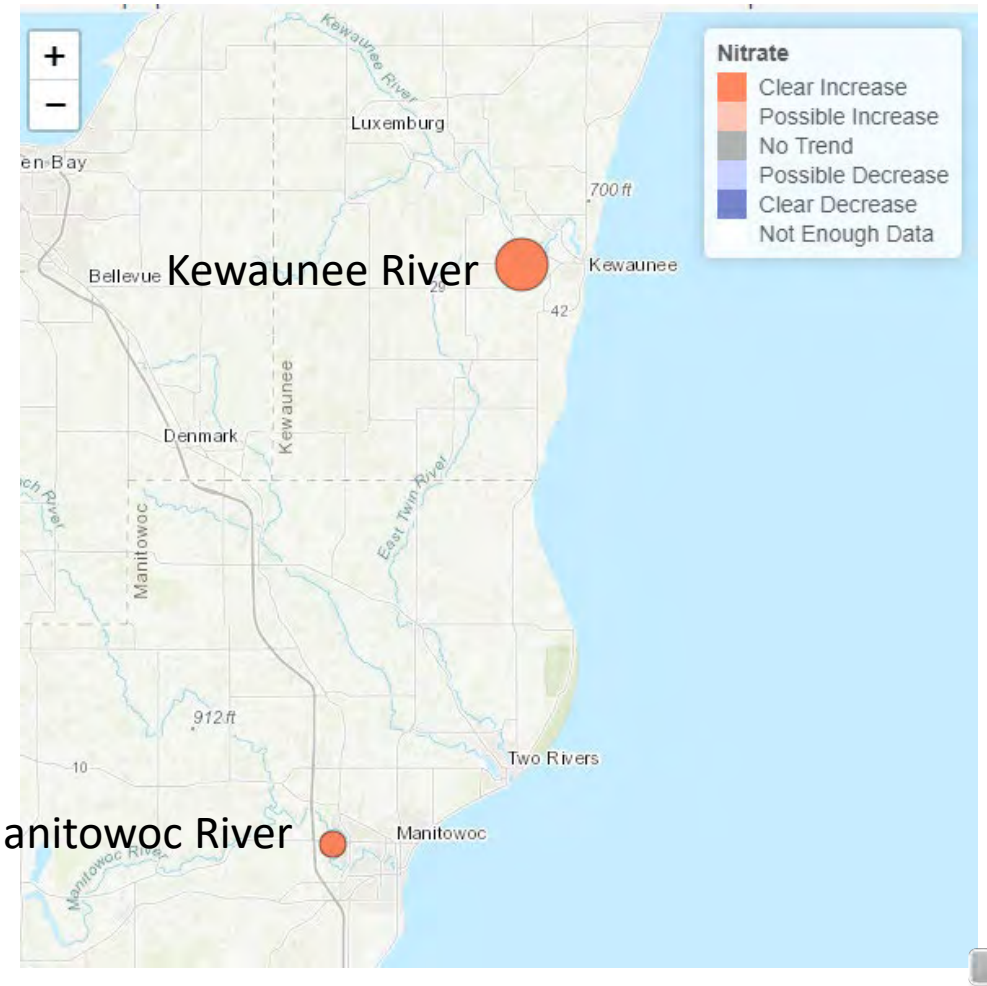



Source: http://managingnutrients.blogspot.com/2013/01/nitrogen-sources-for-organic-crop.html?_sm_au_=iVVZ2H867nrjFRvqtLQtvKQQssTN4

# Assessment of Surface Water Nitrogen

Concern: Surface water nitrate concentrations and loads have been increasing over time



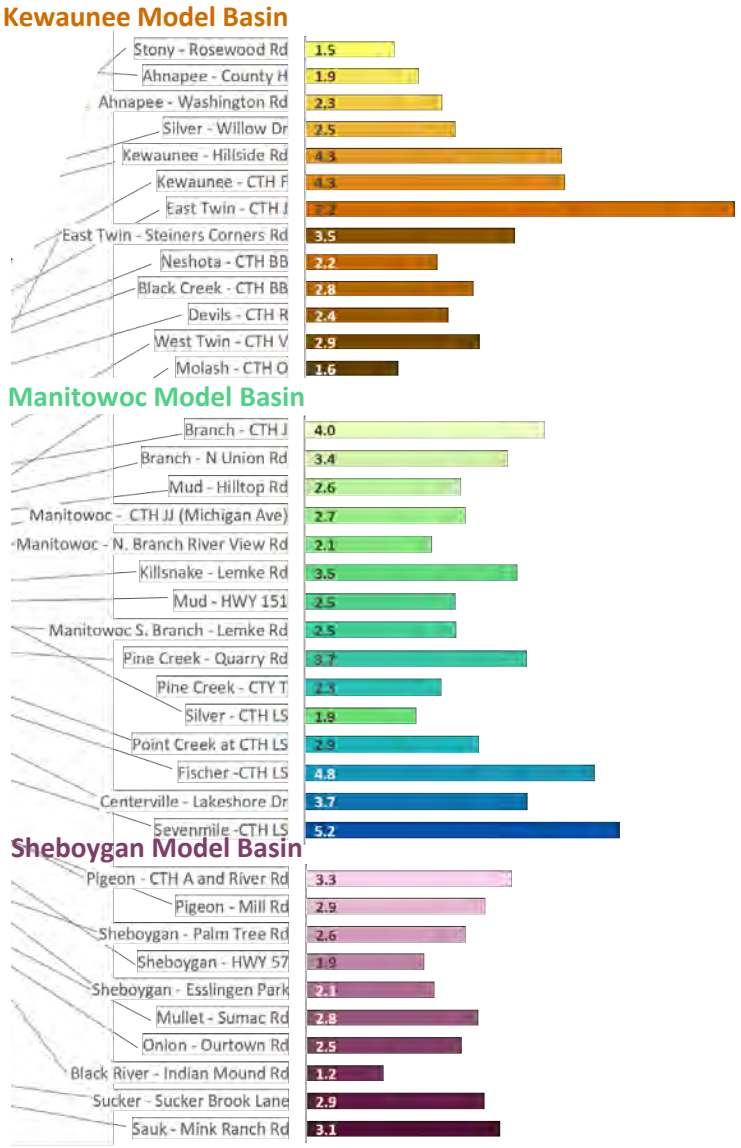

Source: https://wisconsindnr.shinyapps.io/riverwq/

# Evaluation of nitrogen in the NE Lakeshore TMDL

Monitoring data

Compare loads to landscape features to identify potential relationships:

- Land use
- Manure spreading
- Chemical fertilizer
- Groundwater discharge
- Tile drainage



# Goals of N evaluation in the NE Lakeshore

What it will do:

- Exploring sources of nonpoint nitrogen pollution to surface waters
- Potential linkage of landscape features and activies to instream nitrogen concentrations
- Evaluate trends of nitrogen loading over time

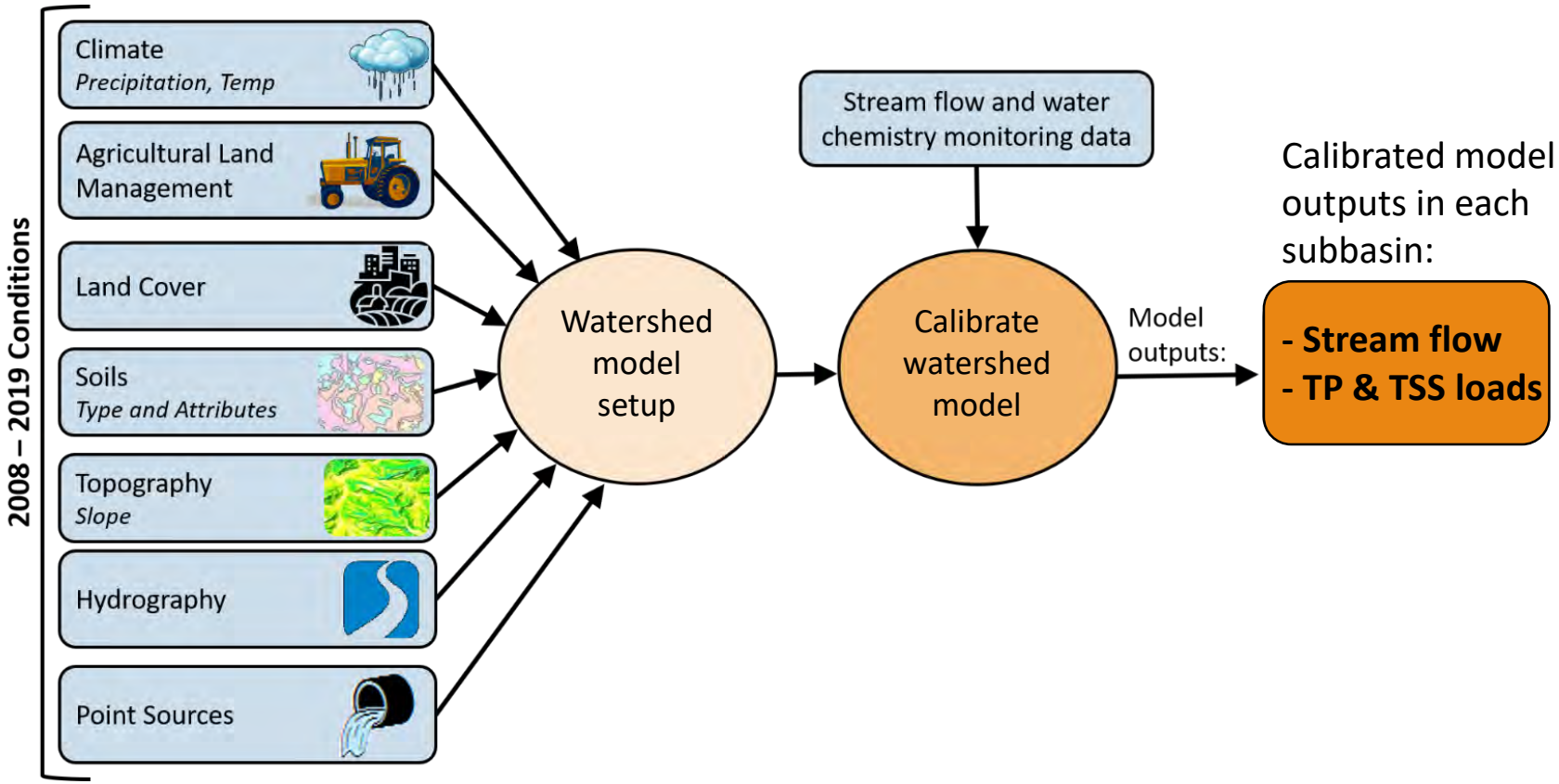
What it won't do:

- Will not assess the impacts of nitrogen on groundwater
- Will not include detailed SWAT modeling or nitrogen allocations though the TMDL because Wisconsin does not have numeric water quality criteria for nitrogen

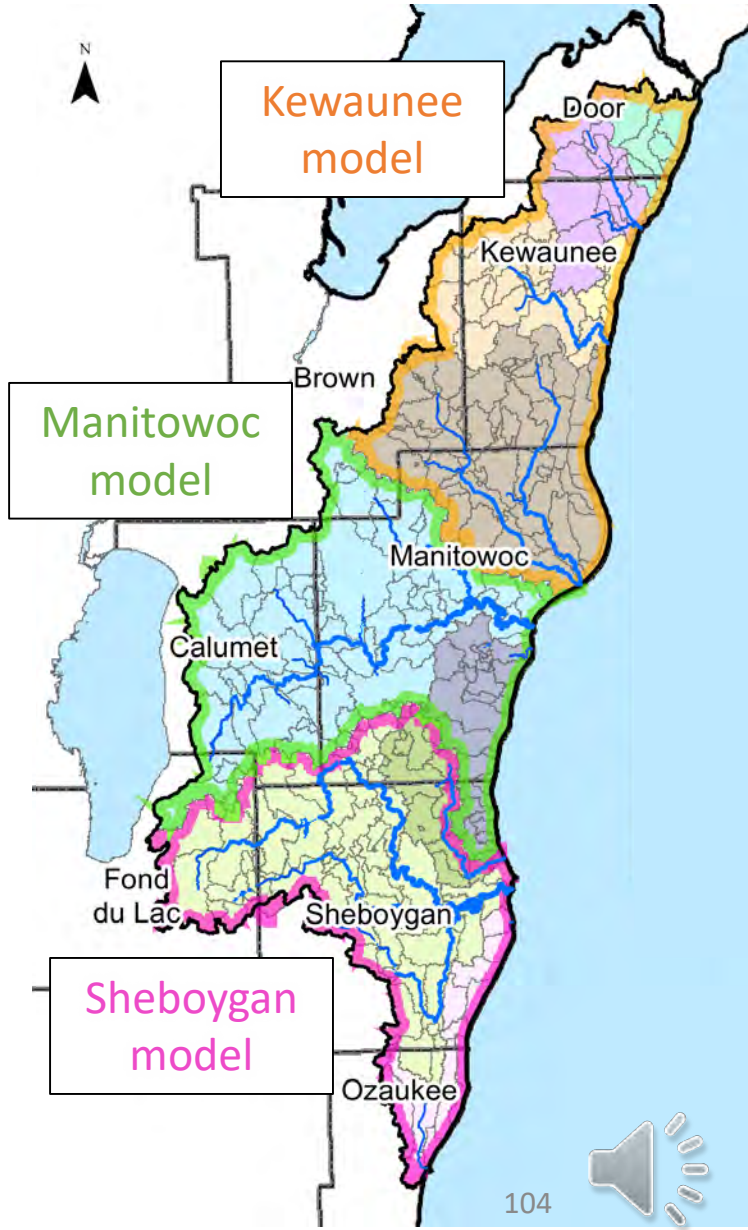
# Watershed model development process

Three separate models will be developed for the three major drainage basins

Model inputs:

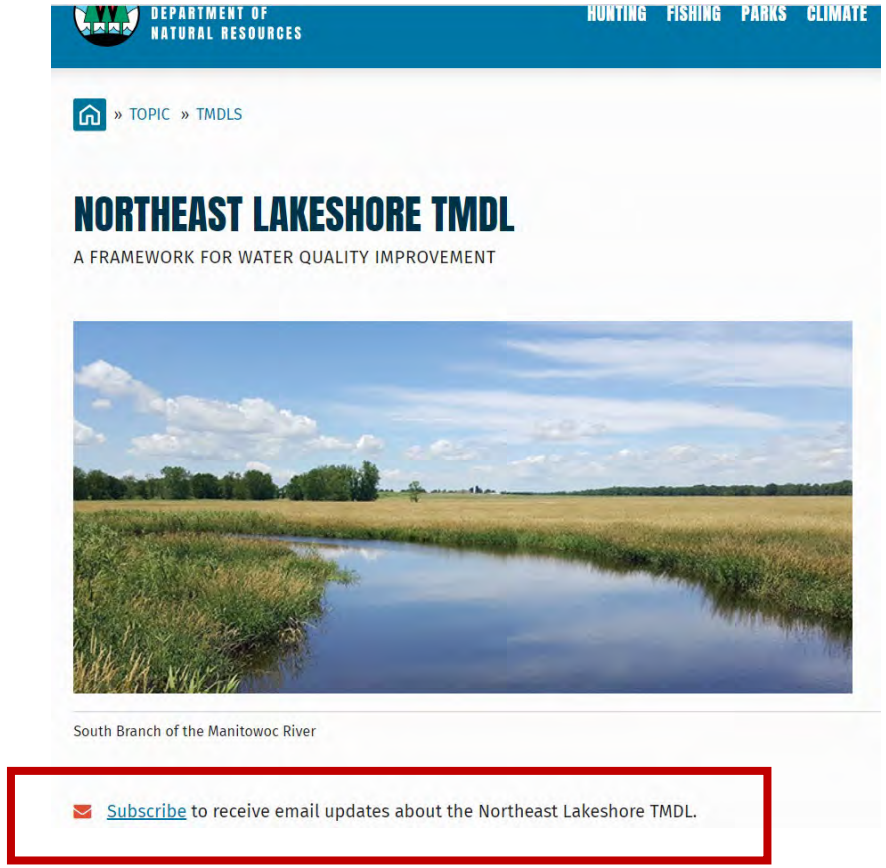



Calibrated model outputs in each subbasin:



# Future website updates…

- A recording a PDF of this presentation
- Announcement about date for webinar 4
- Document summarizing results of the County agricultural questionnaire survey
- Document summarizing results and methods of the DNR manure spreading analysis




Notifications on website updates will be sent out via GovDelivery

# Contact information

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