Precision mitigation: using modern imagery and modeling technology to help growers reduce the impacts of intensive agriculture on water quality.

Paul Hendley[1], C.M. Harbourt[2], P.S. Miller[2], J.D. Davis[2], J. Prenger[2] and M. Andrus[2]

[1] Syngenta Crop Protection Inc. [2] Waterborne Environmental Inc.

Take Home Messages

- Sustainable Intensification of Agriculture is necessary
- Growers are stewards of land
- Stewardship impacts production – tools needed to maximize efficiency
- Data exist to categorize watershed vulnerability and sustainable status
- "Precision" deployment of mitigation elements feasible with newer tools
- High resolution Ag-related data have many uses & potential stakeholders
- BUT Stewardship happens one field at a time – technological solutions must be linked with developing trust/respect across stakeholders

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Challenges for Agriculture

- **There will be 9 billion people on the planet by 2050 and by 2030, global population will rise by about a third to 8 billion people**

BUT

- **Global calorie demand will increase by 50% by 2030**

The five challenges to food security are:
A. Balancing future demand and supply sustainably – to ensure that food supplies are affordable.
B. Ensuring that there is adequate stability in food supplies – and protecting the most vulnerable from the volatility that does occur.
C. Achieving global access to food and ending hunger. This recognizes that producing enough food in the world so that everyone can potentially be fed is not the same thing as ensuring food security for all.
D. Managing the contribution of the food system to mitigation of climate change.
*E. **Maintaining biodiversity and ecosystem services while feeding the world**.*

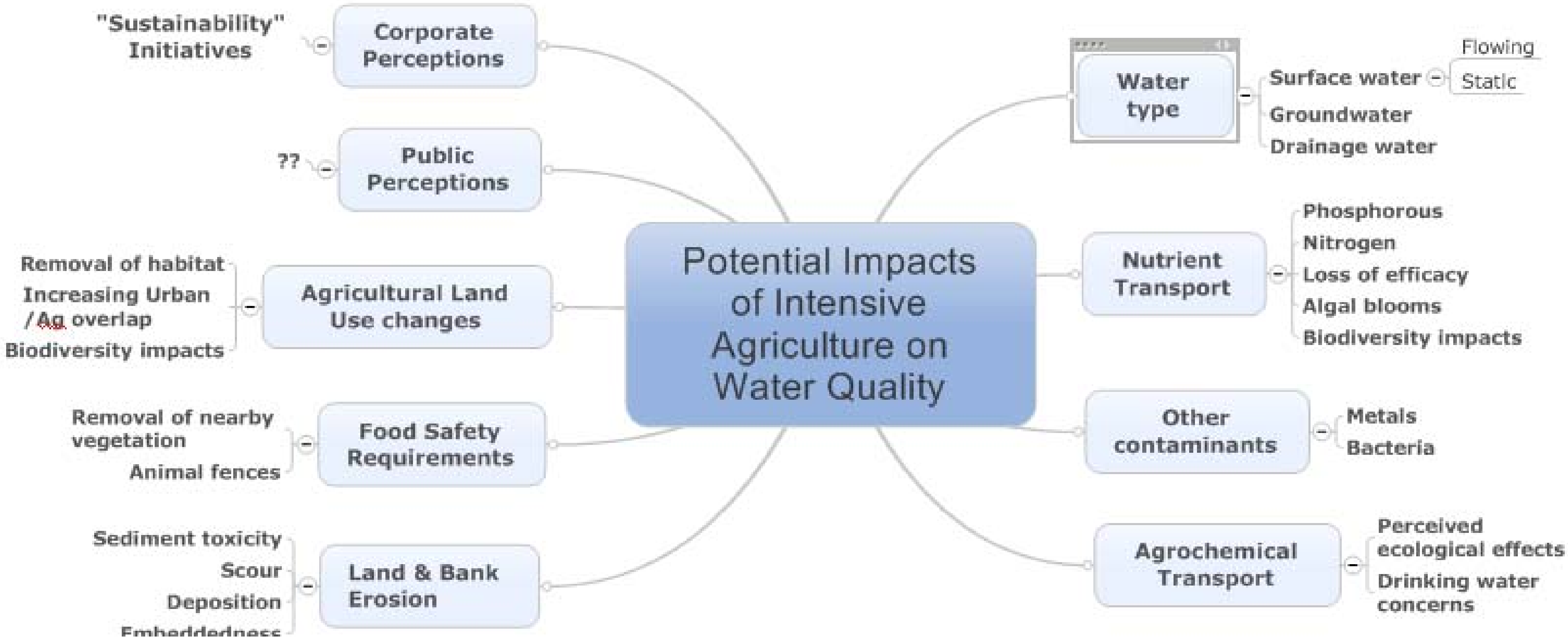
(The Future of Food and Farming: Challenges and choices for global sustainability UK - Foresight. The Future of Food and Farming (2011) Final Project Report. The Government Office for Science, London.)

Sustainable Intensification of Agriculture & Water Quality

Agriculture & Water Quality - What are we going to cover?

- Reducing impacts of Intensive Agriculture on water quality
- Precision Mitigation concept
- Data we have generated
  - Spatial modeling
  - Remote sensing
- Potential value
- Technology meets Reality

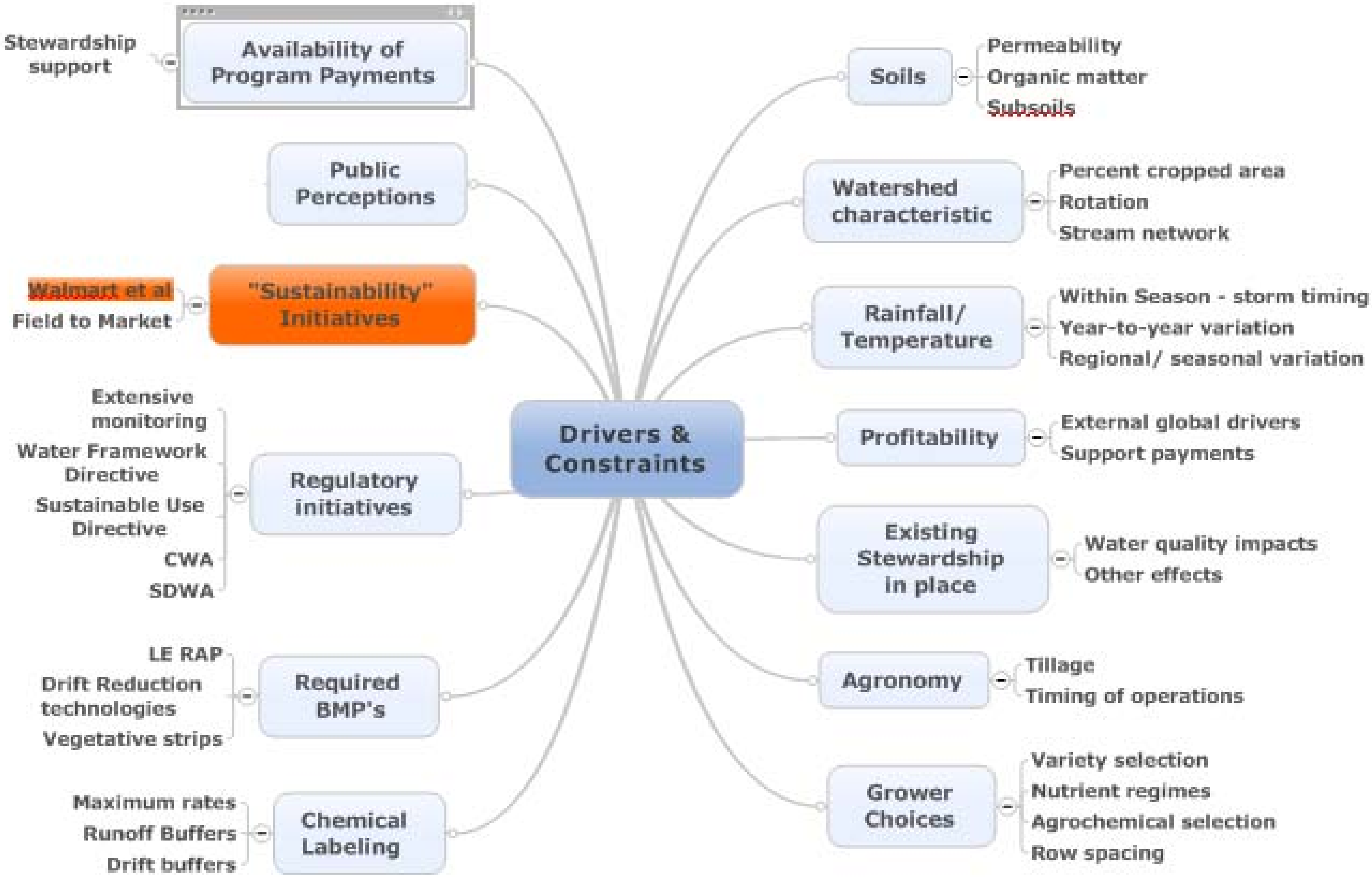
(Sustainable Intensified) Agriculture & Water Quality



Water Quality Challenges – where does Agriculture fit??

General Impairment Name	Impairments Reported	Percent of Reported
SEDIMENT/SILTATION	5876	13.93
PATHOGENS	5530	13.11
METALS	4874	11.55
NUTRIENTS	4697	11.13
ORGANIC ENRICHMENT/LOW DO	4492	10.65
OTHER HABITAT ALTERATIONS	2214	5.25
THERMAL MODIFICATIONS	1962	4.65
PH	1721	4.08
PESTICIDES	1508	3.57
FISH CONSUMPTION ADVIS.	1271	3.01
BIOLOGICAL CRITERIA	1217	2.88
FLOW ALTERATION	975	2.31
NOXIOUS AQUATIC PLANTS	783	1.86
UNIONIZED AMMONIA	743	1.76
PRIORITY ORGANICS	706	1.67
SALINITY/TDS/CHLORIDES	613	1.45
CAUSE UNKNOWN	467	1.11
OTHER CAUSE	361	.86

Agriculture & Water Quality - Drivers and Constraints



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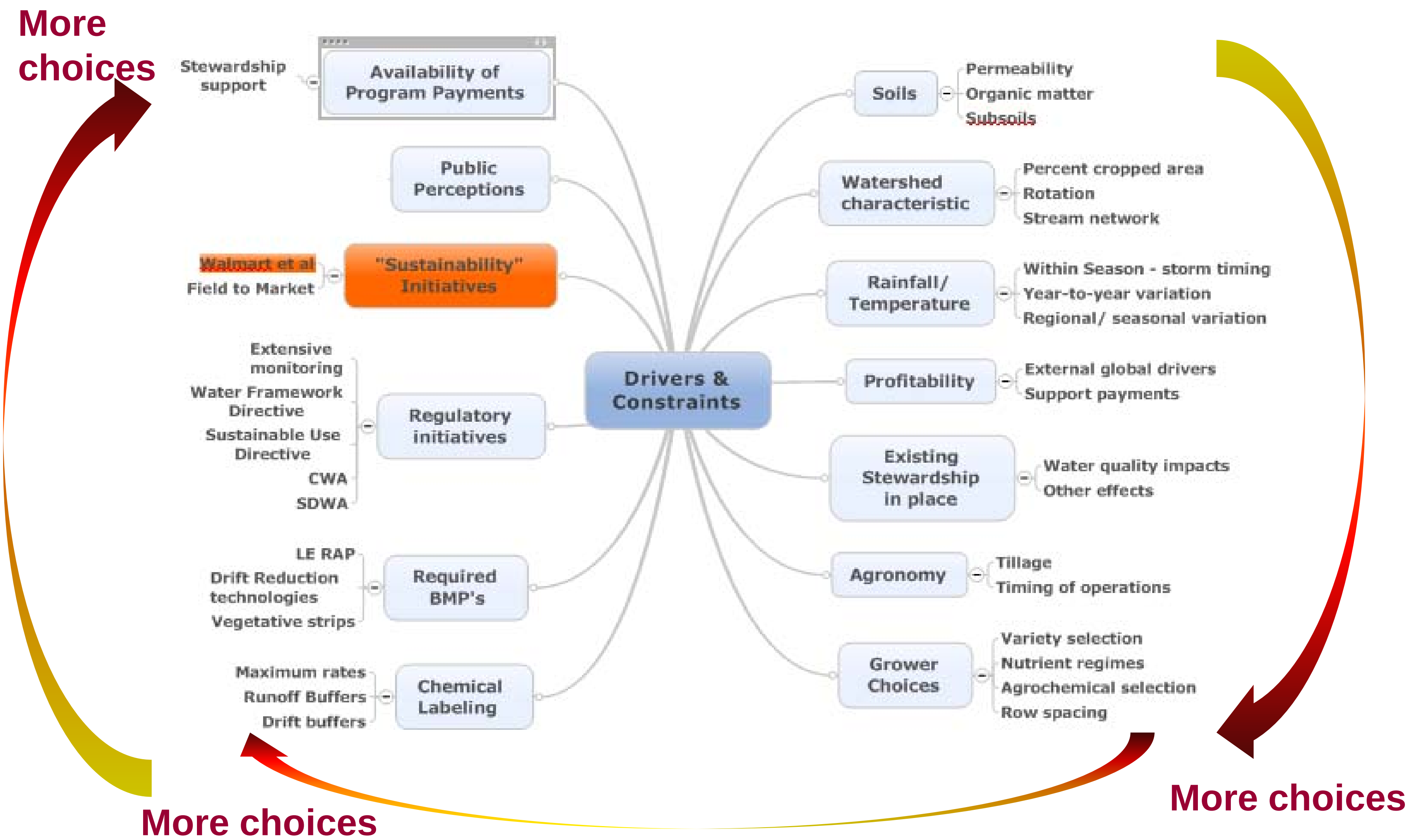
Agriculture & Water Quality – Feasible Stewardship Options



Precision Mitigation Concept

- **Precision farming** focuses on managing production at subfield scale
- **Precision mitigation** focuses on ranking areas that may be contributing to water quality issues in terms of their potential significance.
  - Starts at watershed scale – which merit initial attention?
  - Then WITHIN a watershed – which fields merit initial attention?
  - Then WITHIN a field – what is most efficient mitigation deployment?

Background - Why/how generate data??

Atrazine Monitoring Program - 2003

- *Protection Goal* - Ecological status of small streams
  Assessment criteria – Primary producer eco-community structure
  Measurement Endpoint – Chemograph providing magnitude / duration of exposures
  Uncertainty factors to be included – Multiple years of measurement at many (40) sites representing wide range of environmental conditions, agronomy, weather patterns

- Outputs Required by EPA
  - **HOW MUCH?**
    - What fraction of watersheds (with specified level of confidence) where flowing water bodies may approach or exceed effects-based (primary productivity) thresholds for atrazine
  - **WHAT CHARACTERISTICS / WHERE?**
    - Use knowledge gained from monitoring program to help identify additional watersheds of potential concern

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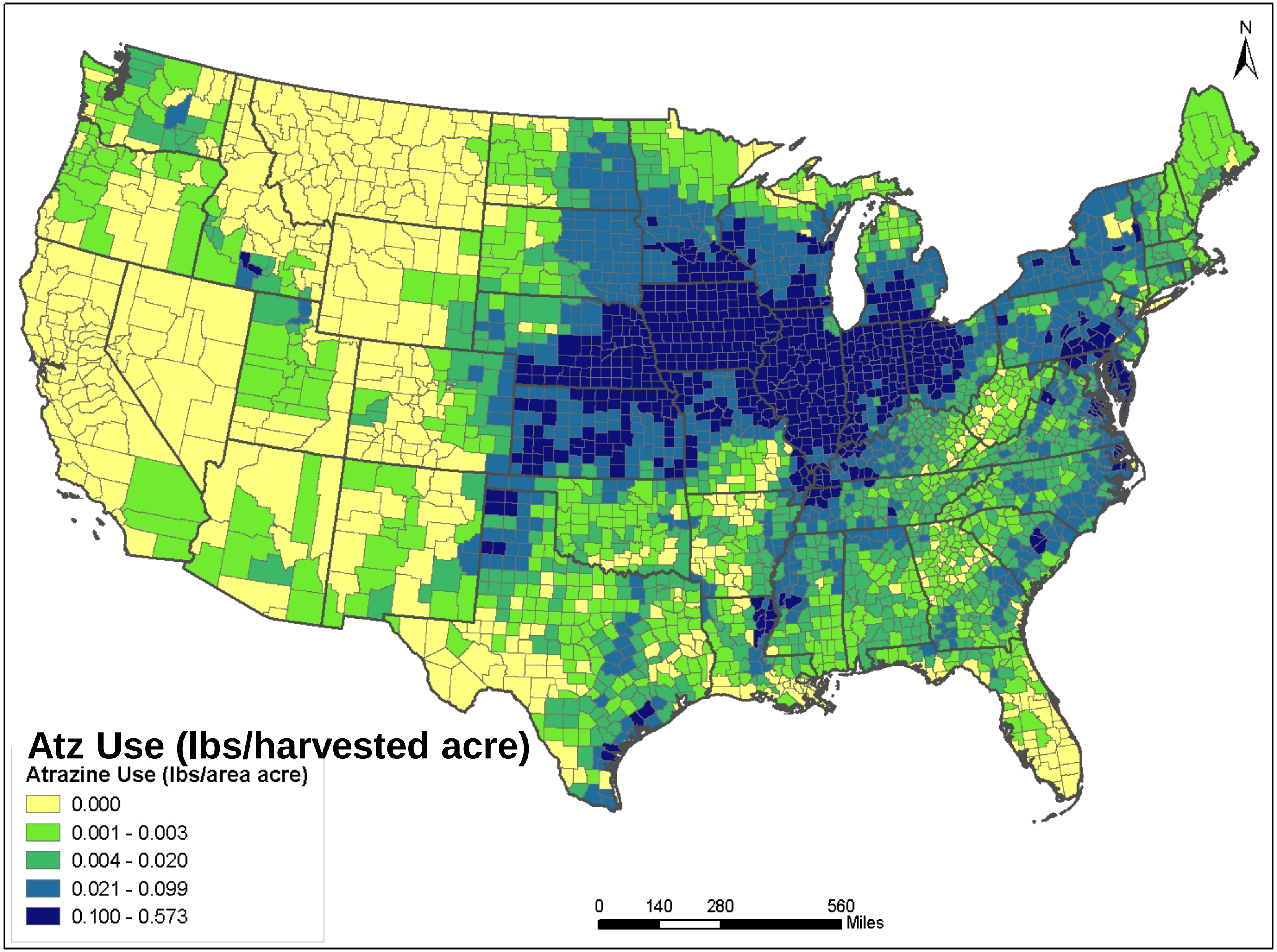
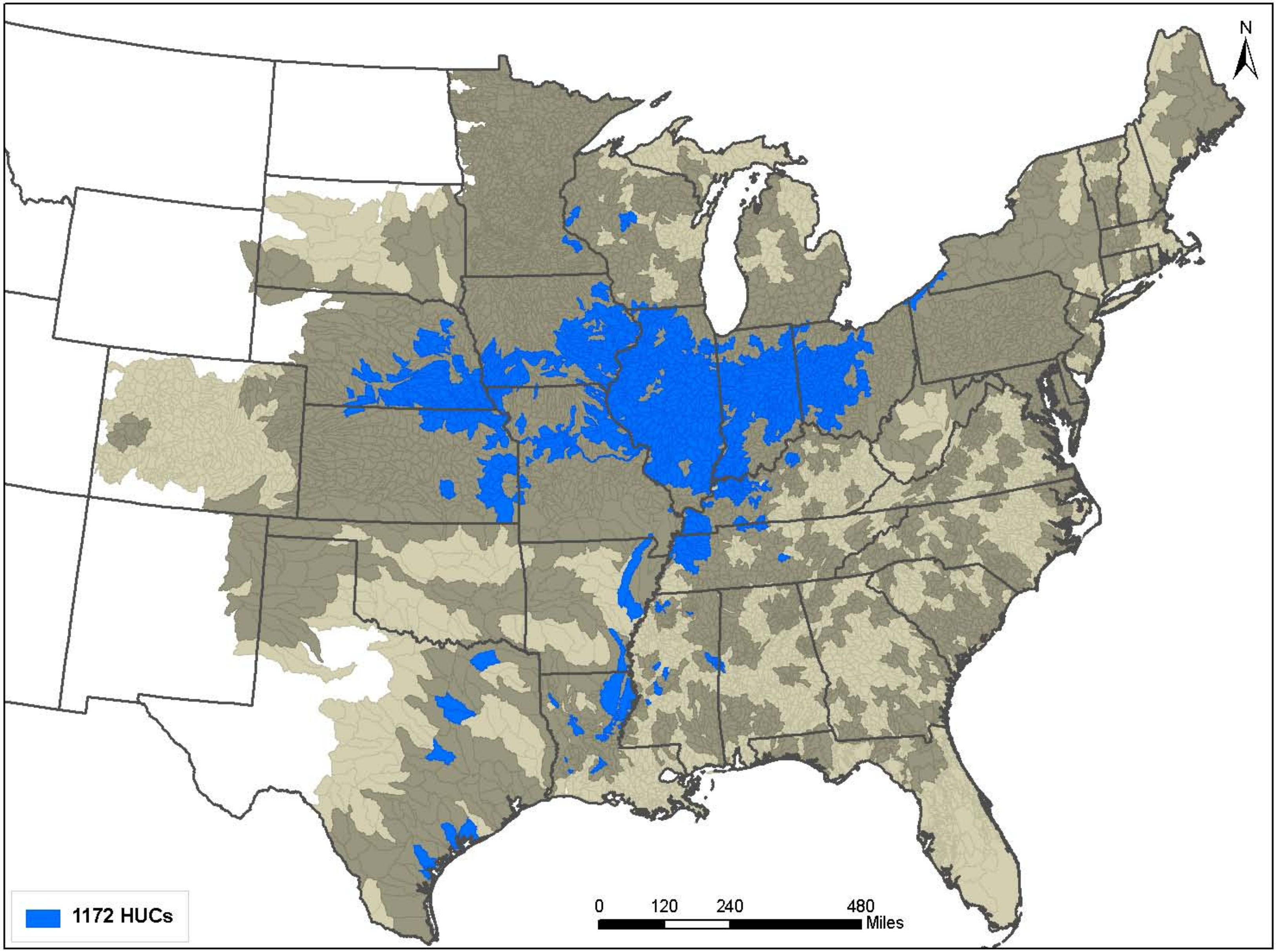
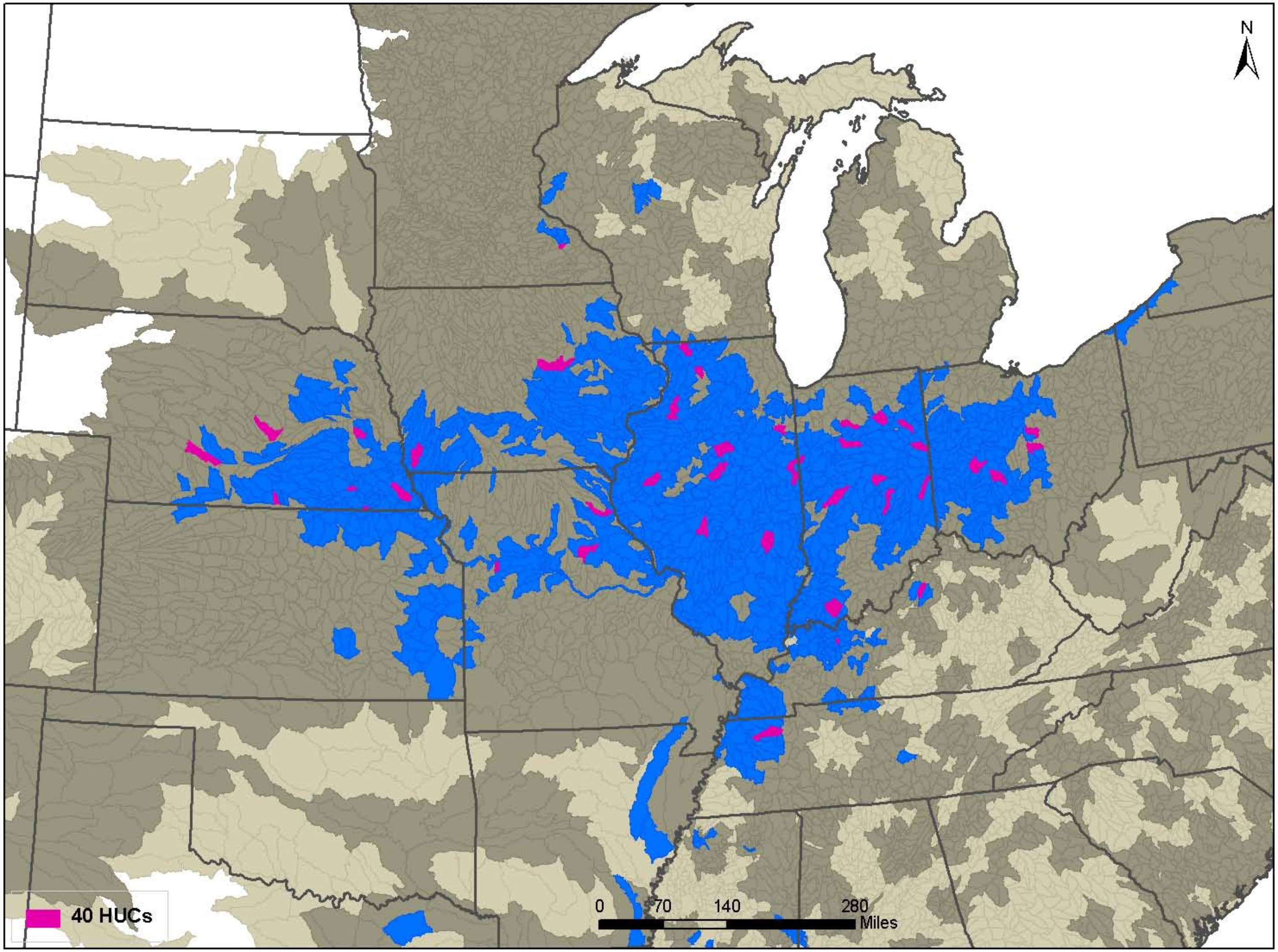
Atrazine Use Areas



1172 HUC10 Watersheds are the upper 20th centile WARP



40 HUC10 Watersheds from Generalized Random Tessellation Stratified (GRTS)



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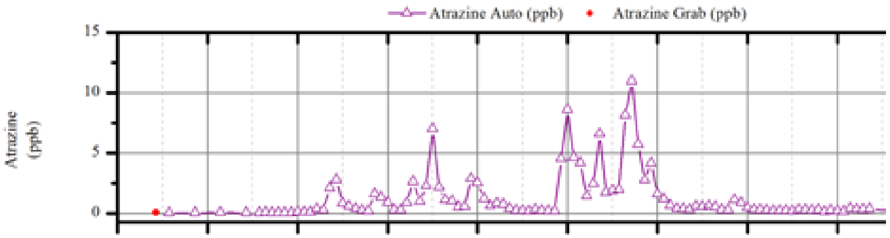
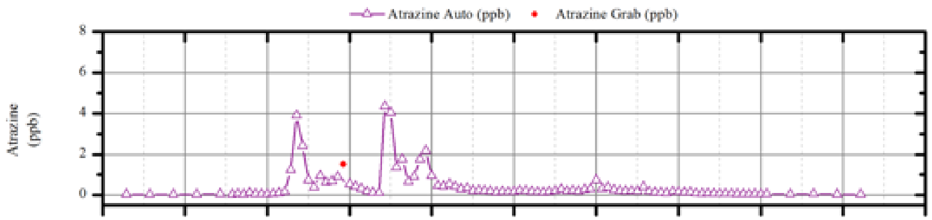
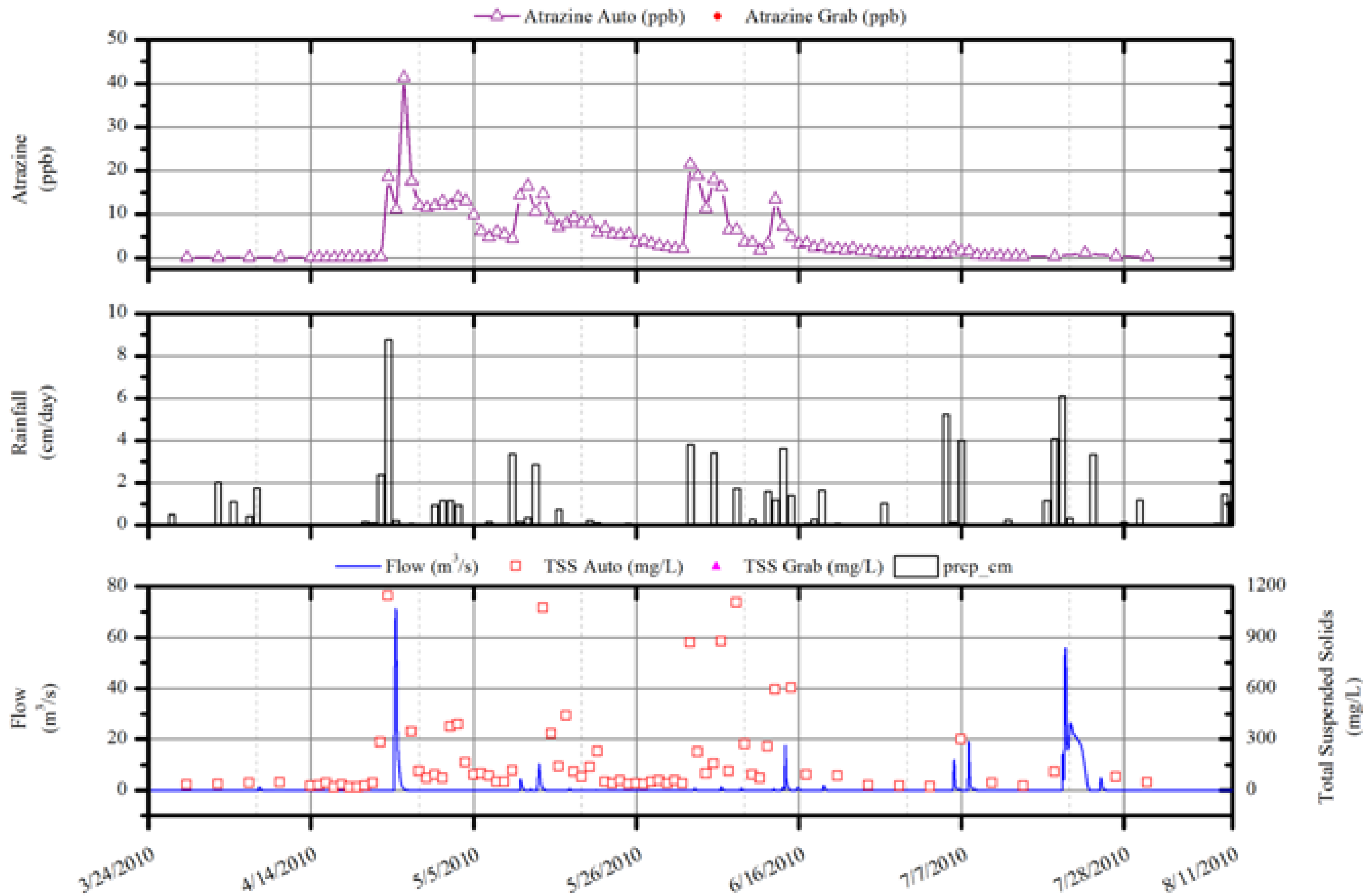
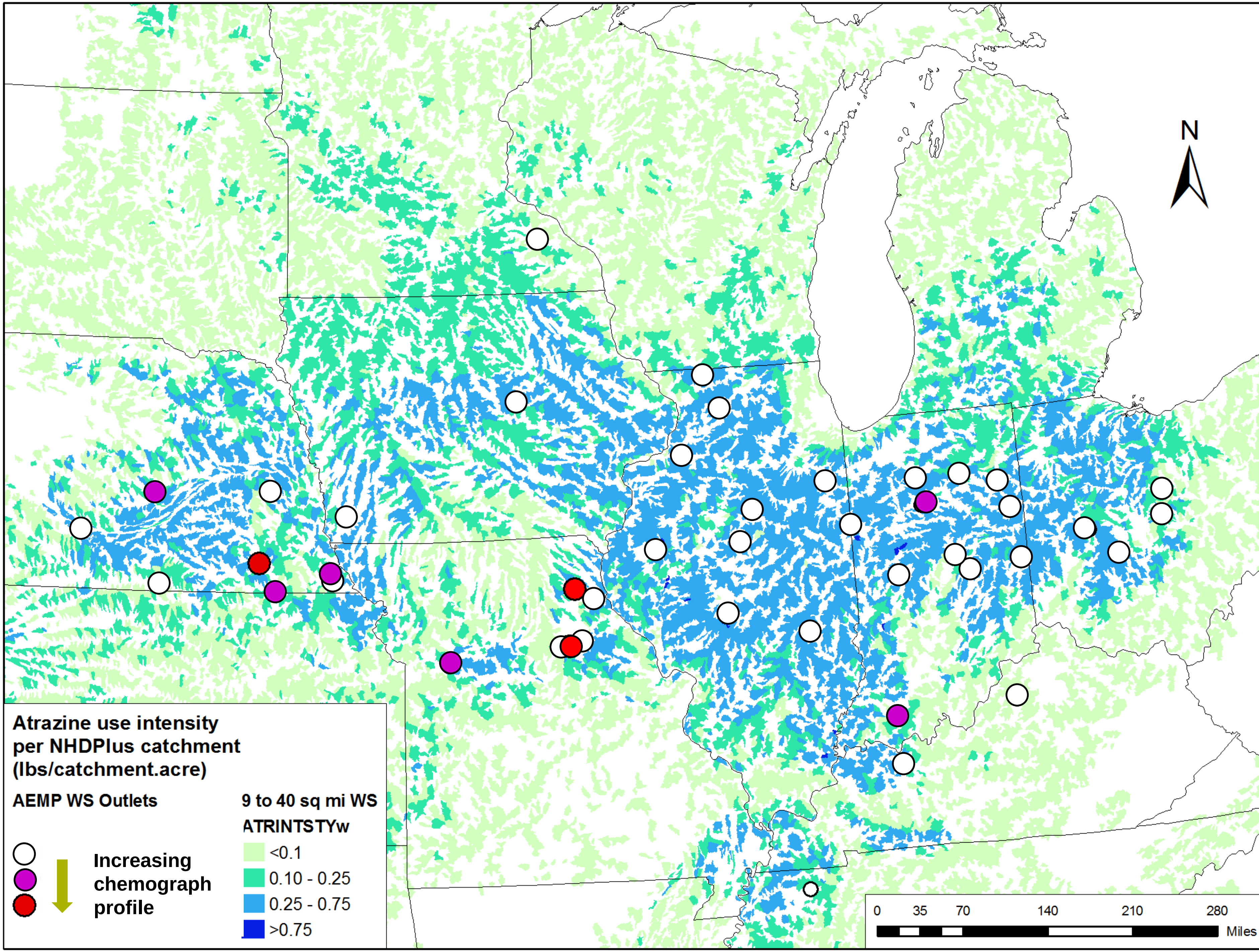
Example Atrazine Chemographs





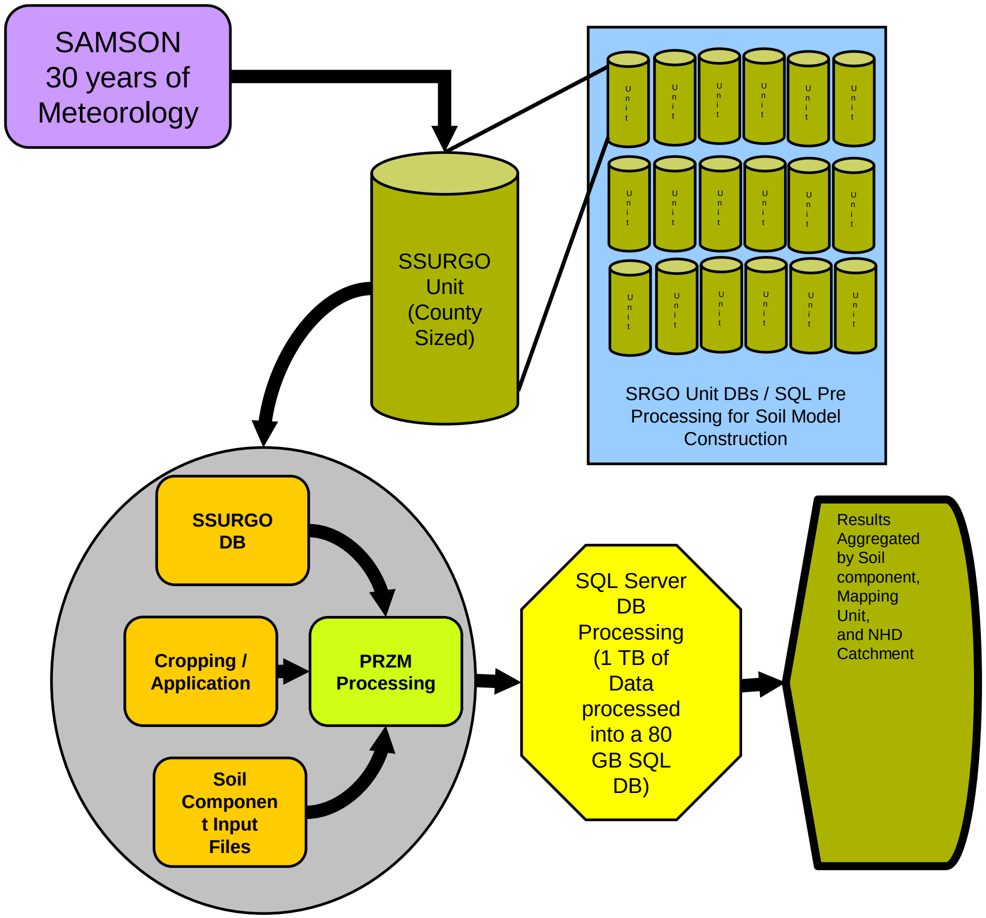



N
Atrazine use intensity
per NHDPlus catchment
(lbs/catchment.acre)
AEMP WS Outlets
Increasing
chemograph
profile
9 to 40 sq mi WS
ATRINTSTYw
<0.1
0.10 - 0.25
0.25 - 0.75
>0.75
0
35
70
140
210
280
Miles

If chemical use does not drive higher runoff – then what does??

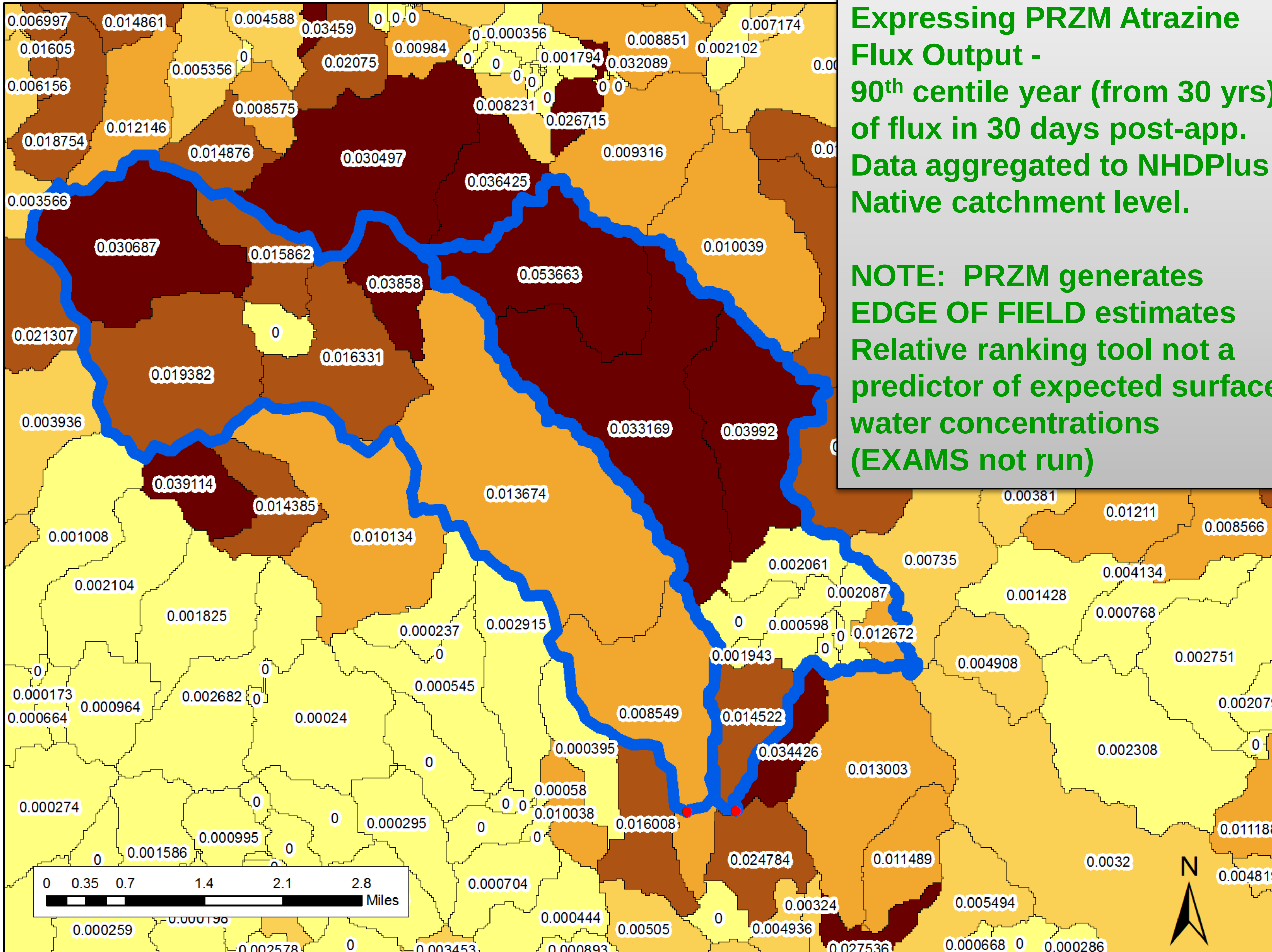
SSURGO-PRZM Atrazine Runoff Modeling Data – USA-wide

- Ranks sites based on classic runoff approaches
- Substantial undertaking
  - 377,000 PRZM runs
    - Across 28 million polygons
    - Area-weighted into 2.6 million NHDPlus native catchments
- Integrates best available data



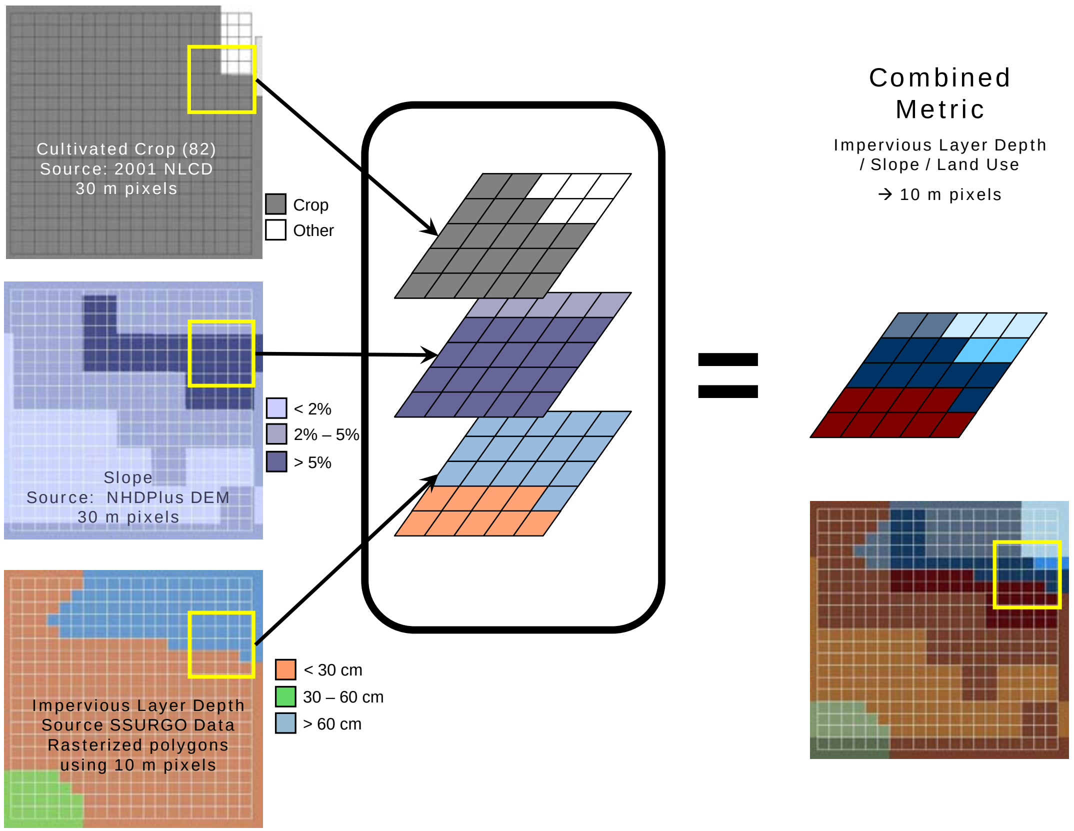
Expressing PRZM Atrazine Flux Output - 90th centile year (from 30 yrs) of flux in 30 days post-app. Data aggregated to NHDPlus Native catchment level.

NOTE: PRZM generates EDGE OF FIELD estimates Relative ranking tool not a predictor of expected surface water concentrations (EXAMS not run)



Characterizing Co-Occurrence of Shallow Impervious Soils with Other Factors across USA

- Best Available Data for
  - Soil, Slope, and Crop
- SSURGO (USDA)
  - Depth to impervious layer
- 30m DEM (from NHDPlus)
  - 10 m grid processing
- Landuse (USDA)
  - Best available reclassed from CDL or NLCD
- Selecting Criteria
  - ≥ 1% slope - Practical hydrology
  - ≤ 30 cm depth to impervious layer
  - K_{sat} <1.25 micron/s



77.8 Billion 10m grid points examined nationwide!

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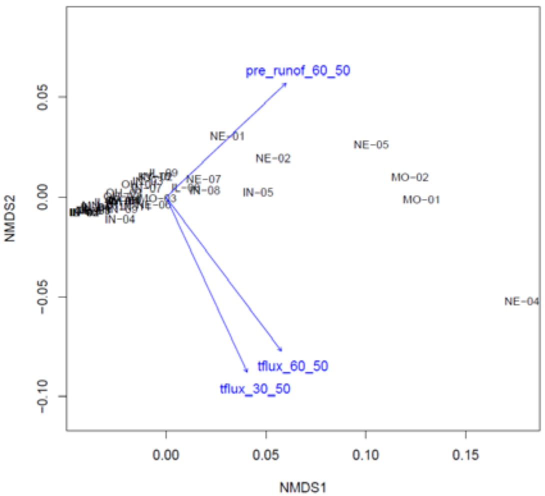
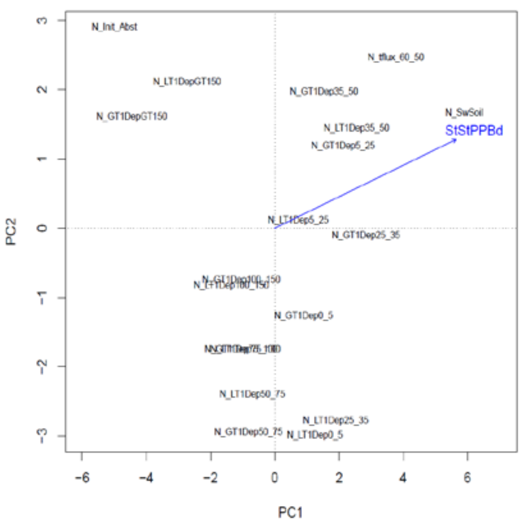
Multi-variate approaches - Key WS scale variables, site year specific





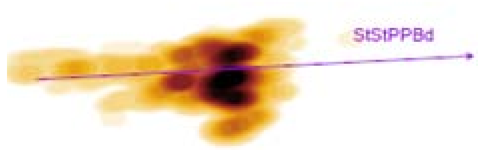
Chemographs >180 site yrs

WS GIS Data >300 variables

Ordination/fitting

PCA based on key env. variables for corn fields in 52 WS & 87 site years

Plot individual WS years into PCA space. Area weight each field



Repeat for other, unmonitored WS

Outcome:

19 factors – 5 groups

Percent area with:

- Slope<1% & Claypan at x-y cm (8 groups)
- Slope>1% & Claypan at x-y cm (8 groups)
- % with shrink-swell soils
- Median PRZM total Atrazine flux in 60 d
- Soil initial abstraction

New PCA on all watersheds at field scale uses key Ag Landscape features

- Depth to shallow claypan by slope
- Shrink Swell soils
- Runoff factors – initial abstraction
- Predicted Atrazine runoff flux

Allows ranking /mapping of potentially vulnerable UNMONITORED watersheds

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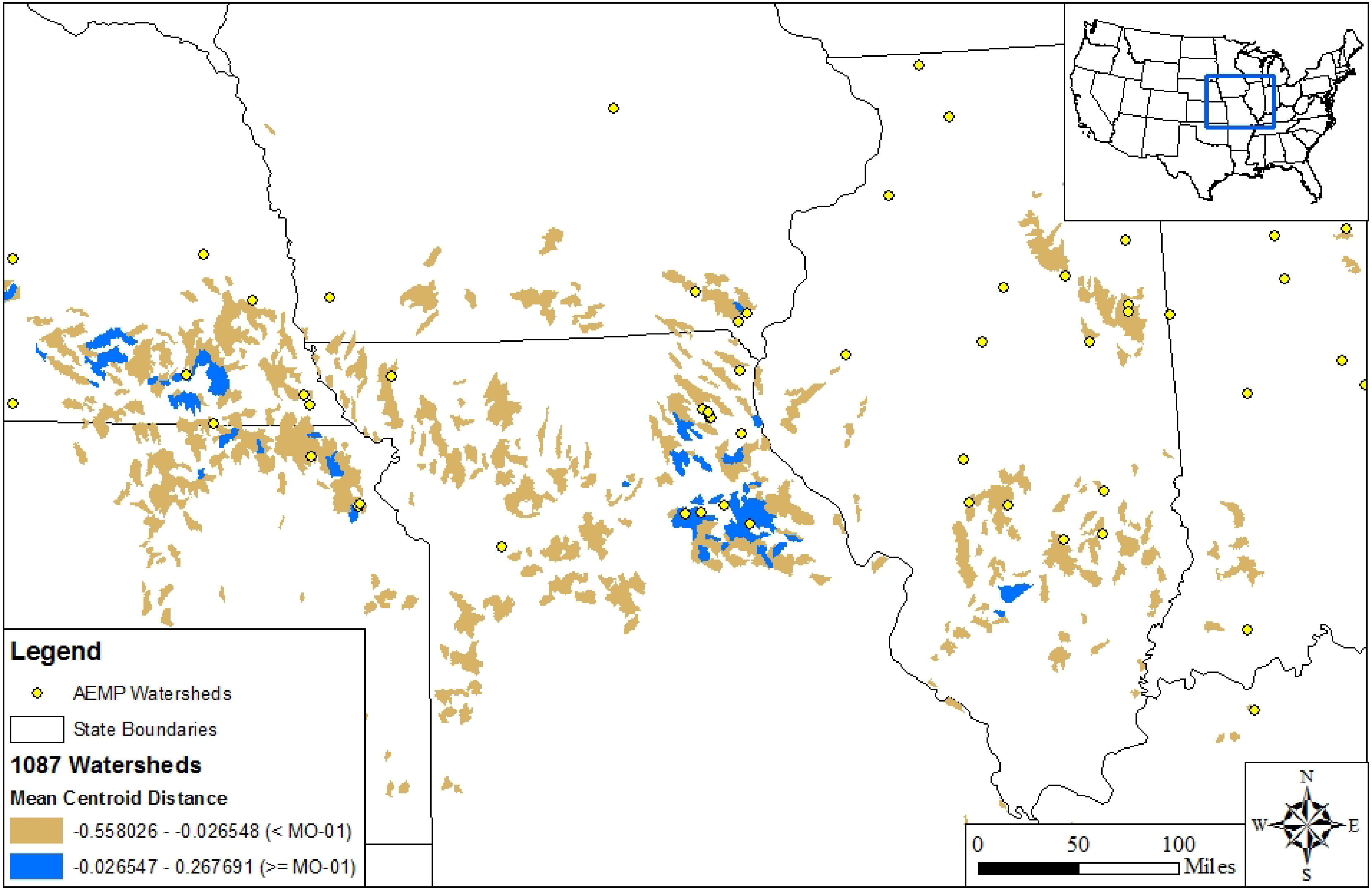
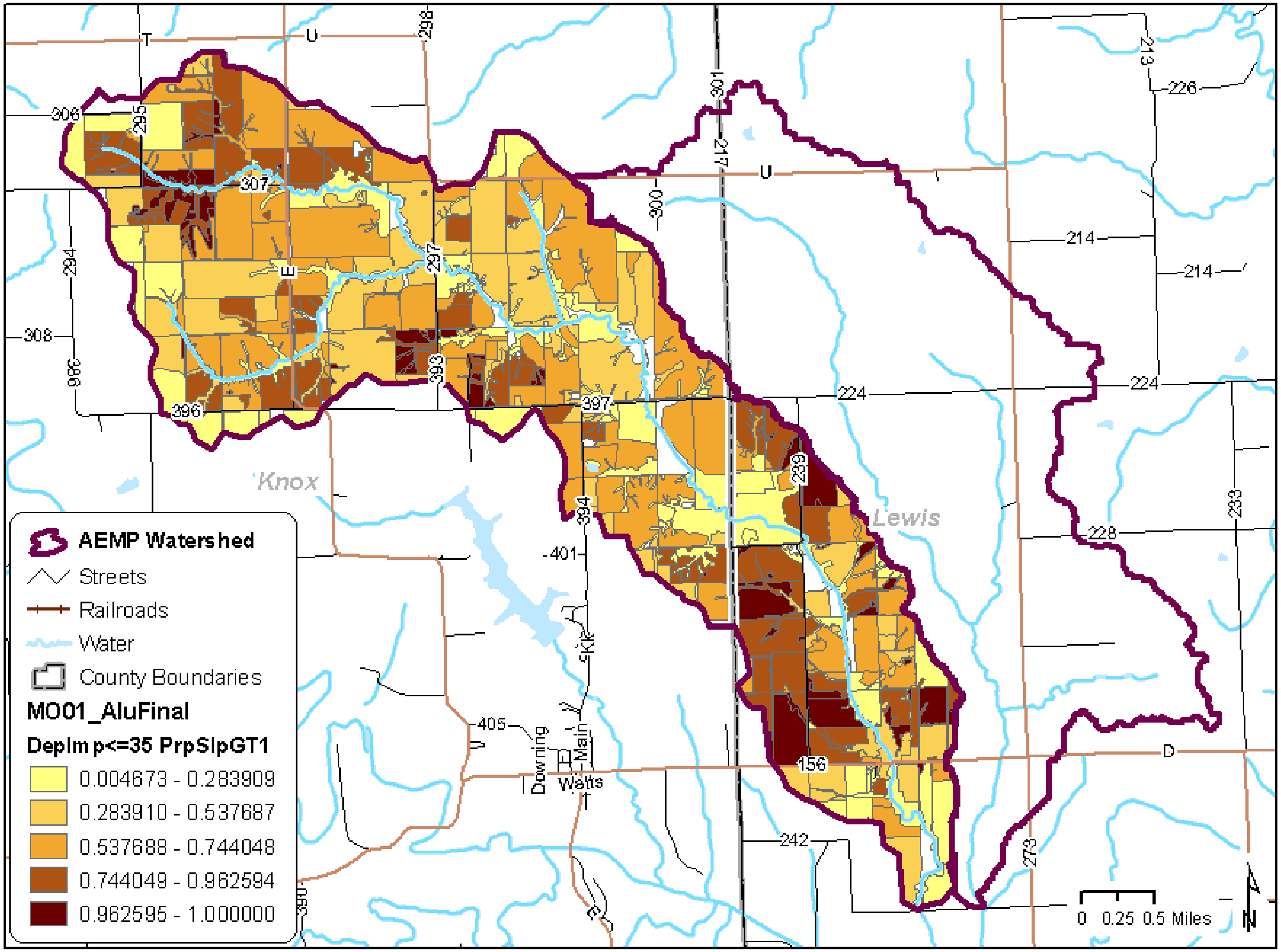
Ranking Can Be Mapped to Identify Other Potentially Vulnerable WS based on Ag Landscape



Site A Fields Ranked by Potential for Extreme Runoff at field scale



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But some sites ranked to have higher runoff potential did not exhibit this across several seasons despite adverse rainfall etc.
Why??
What else was happening in the watershed??

- Use of Remote Sensing and Imagery

Obtained 6 inch imagery to combine with other GIS data.

E.g. Blue line is NHDPlus flowline. This was used to categorize buffer zones with tree and/or grasses as opposed to regular trees and/or grasses while digitizing.

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6 inch imagery

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Process of Structural BMP Identification

- Agricultural signatures identified on high quality true color aerial imagery

- 113 agricultural practice units (APUs) visually interpreted for 19 agricultural practices
  - 18 agricultural practices were observed.
  - 12 of 18 practices considered Best Management Practices.

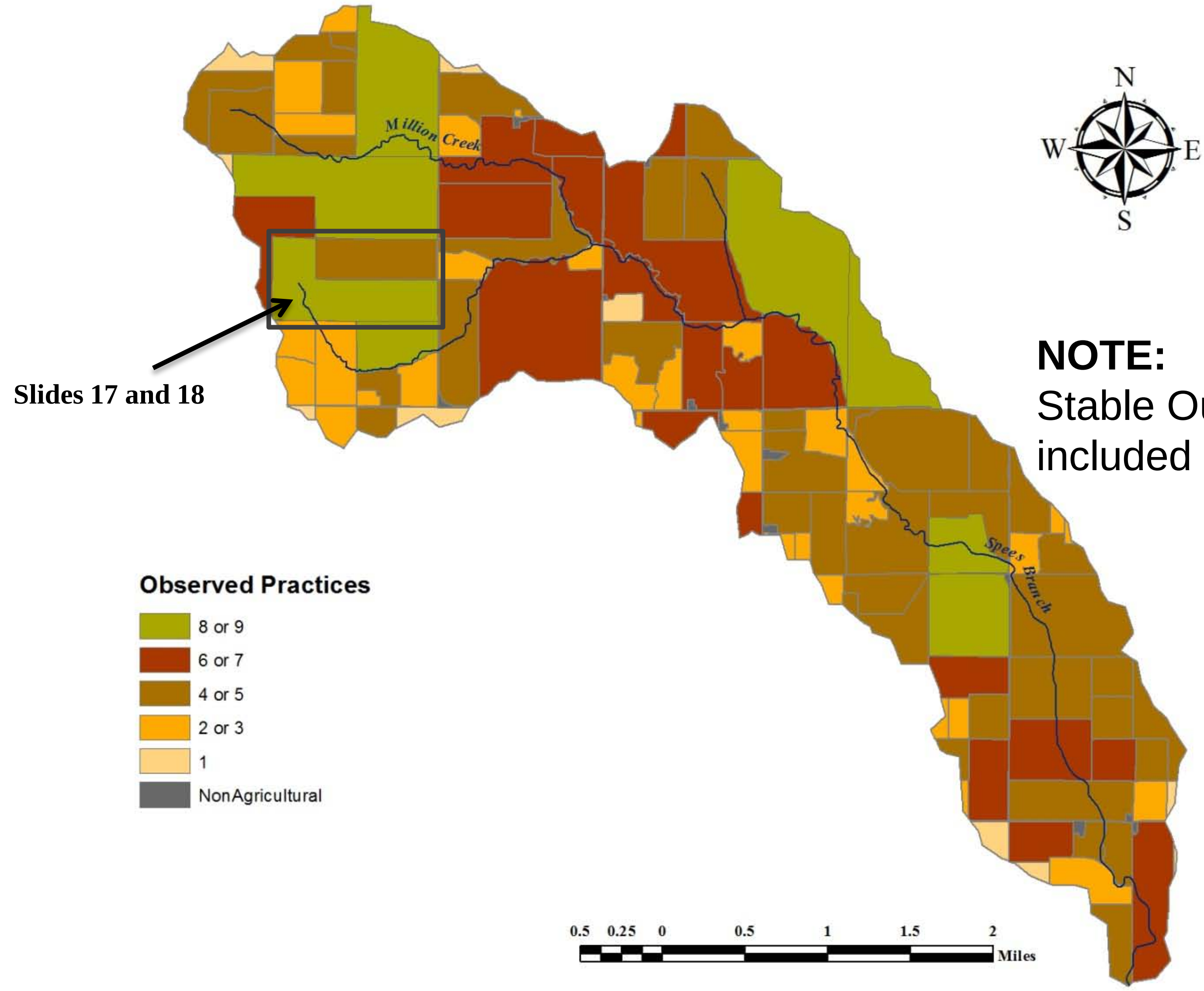
- Field boundaries, water flow outlets and surface drains examined for signs of erosion.
  - Uncontrolled erosion at field boundary defines unstable field outlet.

- “Field vitality” assessed to estimate internal “health” of field.

Agricultural Field Practices (APU) with numbers of practices actually observed

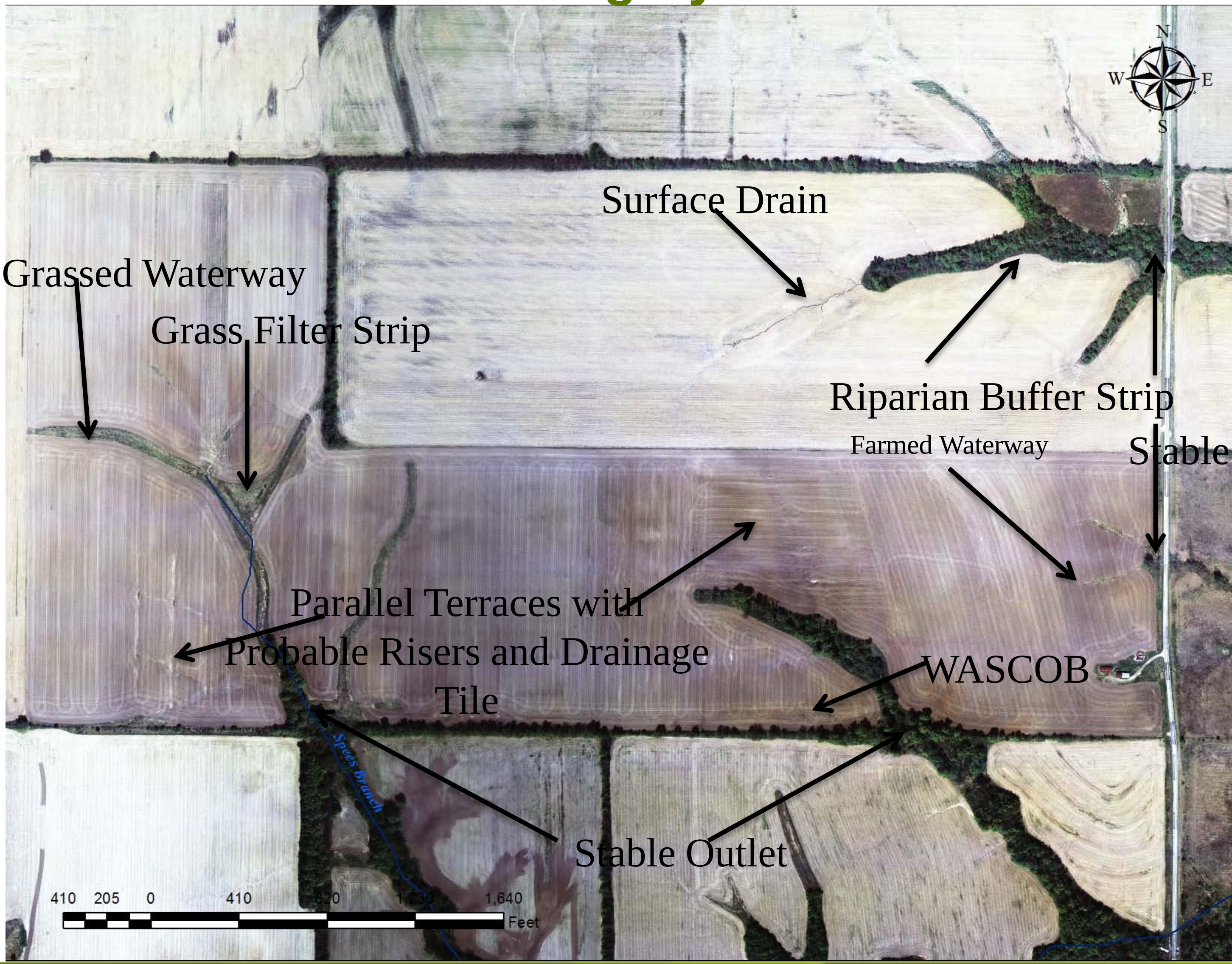
Practice	Obsvd	Practice	Obsvd
Grass Back slope Terraces (BMP)	1	Contour Farming (BMP)	6
Grass Channel Terraces (BMP)	0	Wetland Buffer (BMP)	30
Parallel Terraces (BMP)	10	Farmed Waterway	15
Random Terraces (BMP)	2	Irrigation	3
WASCOB (Water Sediment Control Basin) (BMP)	7	Possible Field Drainage Tiles	33
Grassed Filter Strip (BMP)	26	Possible Risers	16
Grassed Waterway (BMP)	41	Surface Drain/Open Ditch	57
Permanent Grass or Hay (BMP)	37	Confined Animal Feeding Operation (CAFO)	6
Grass Banked Ditch (BMP)	17	Stabilized Outlet (observed feature, not a practice)	112
Riparian Buffer Strip (BMP)	53		

Agricultural Field Practices



NOTE:
Stable Outlets are included in this number

Agricultural Practices As Seen on 2010 High Resolution Imagery



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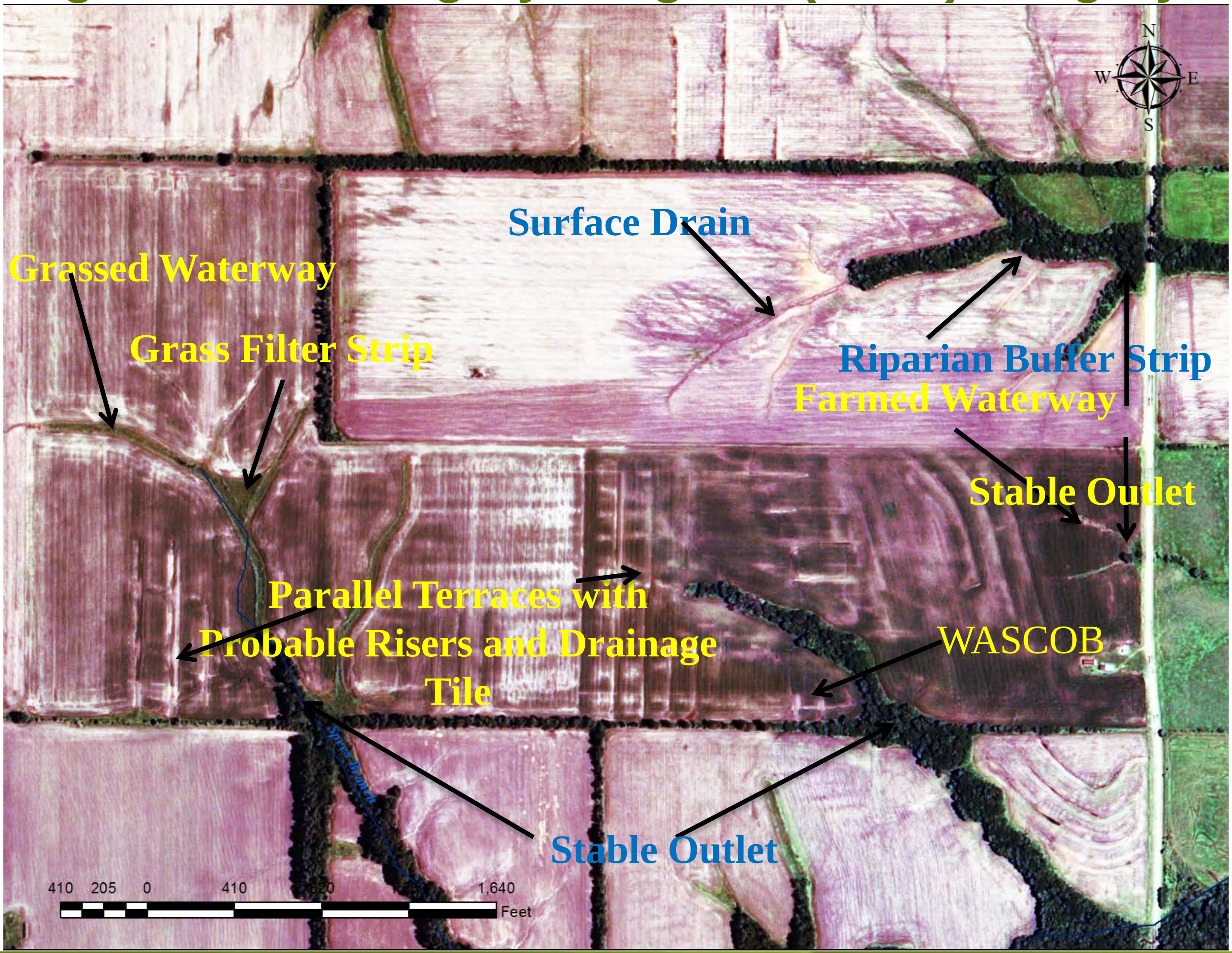
Agricultural Practices As Seen on 2010 National Agricultural Imagery Program (NAIP) imagery

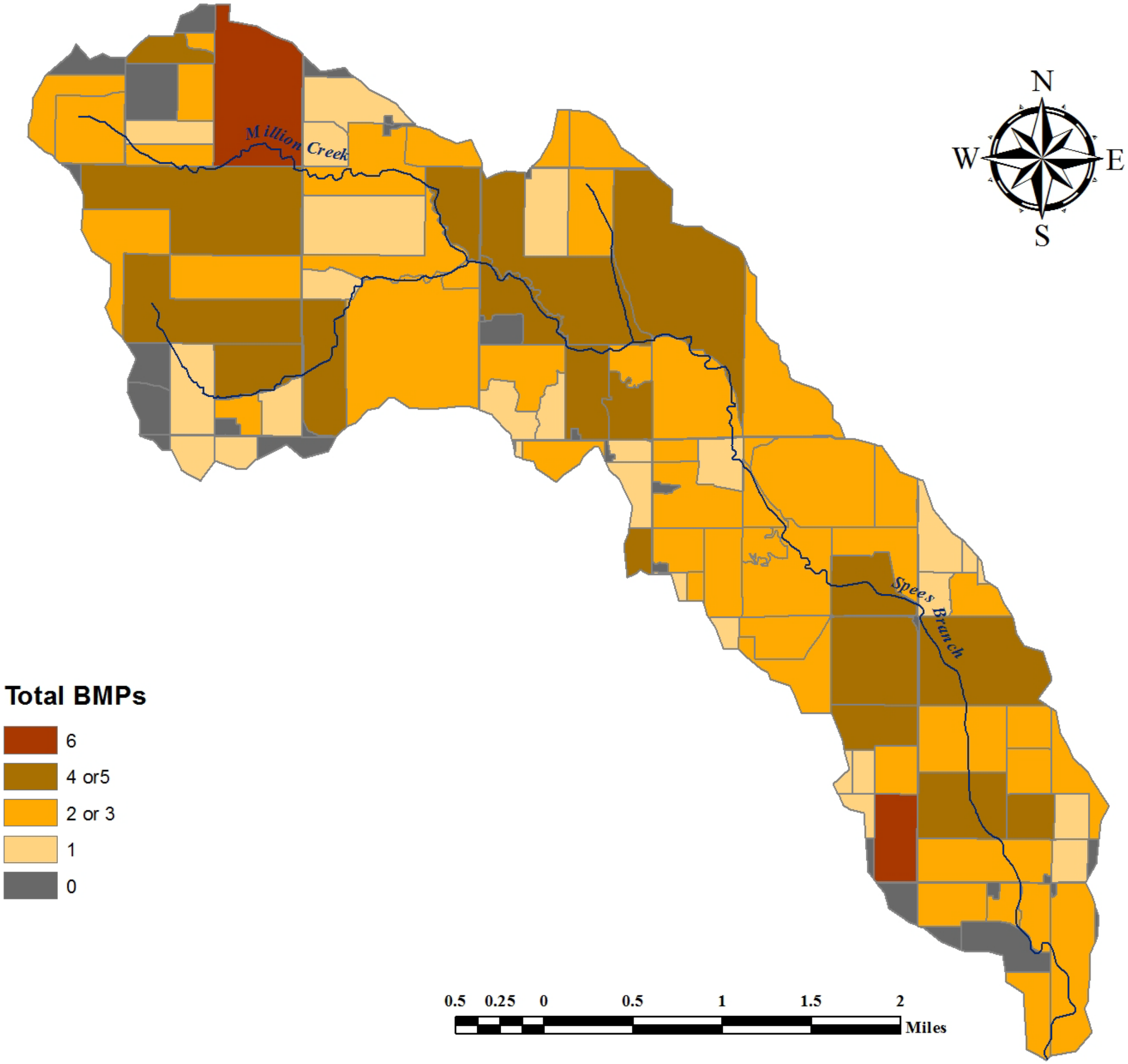


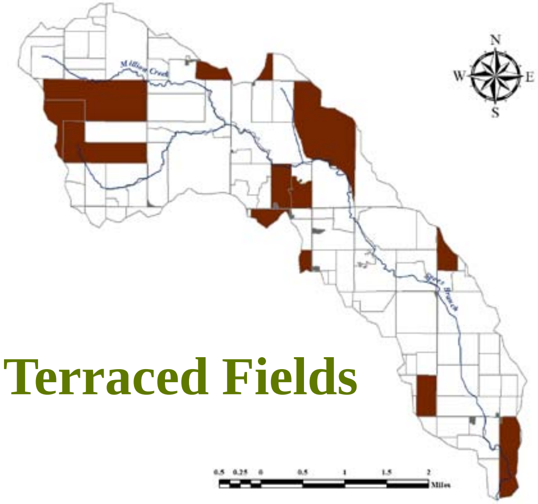
tlet,
d
ble

Best Management Practice Summary Table

Best Management Practice	Observed
Terraced (includes Grass Back Slope, Grass Channel, Parallel, Random Terraces, and WASCOBs)	20
Filter Strips (includes: Grass Filter Strips, Riparian Buffers and Grass Banked Ditches)	96
Permanent Grass or Hay	37
Grassed Waterway	41
Contour Farming	6
Wetland Buffer	30

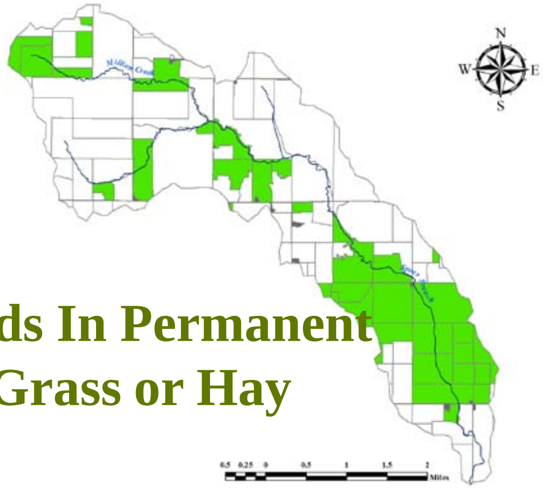
Best Management Practices



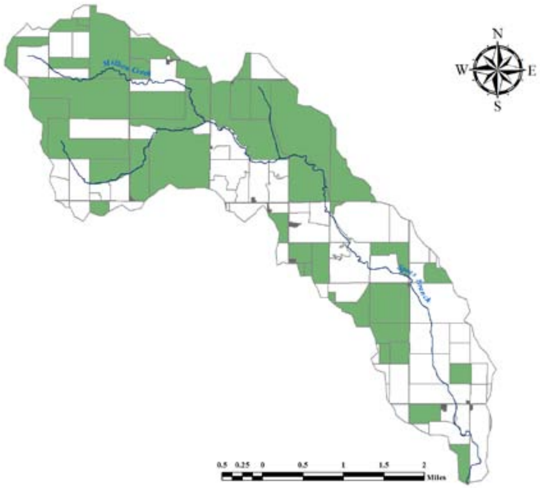


Terraced Fields

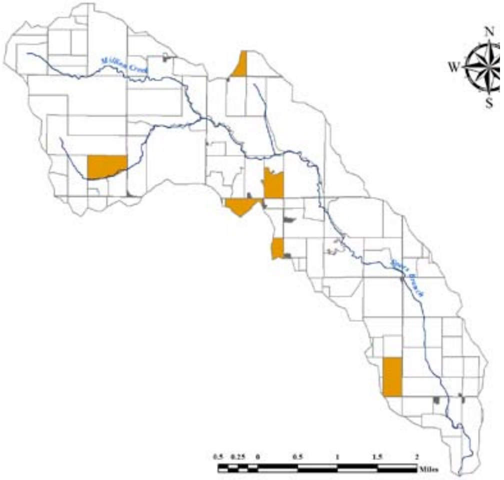
Fields With Filter Strips



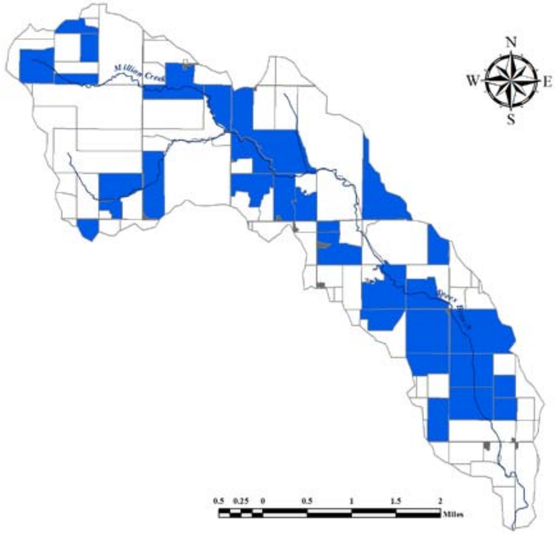
Fields In Permanent Grass or Hay



Fields With Grassed Waterways



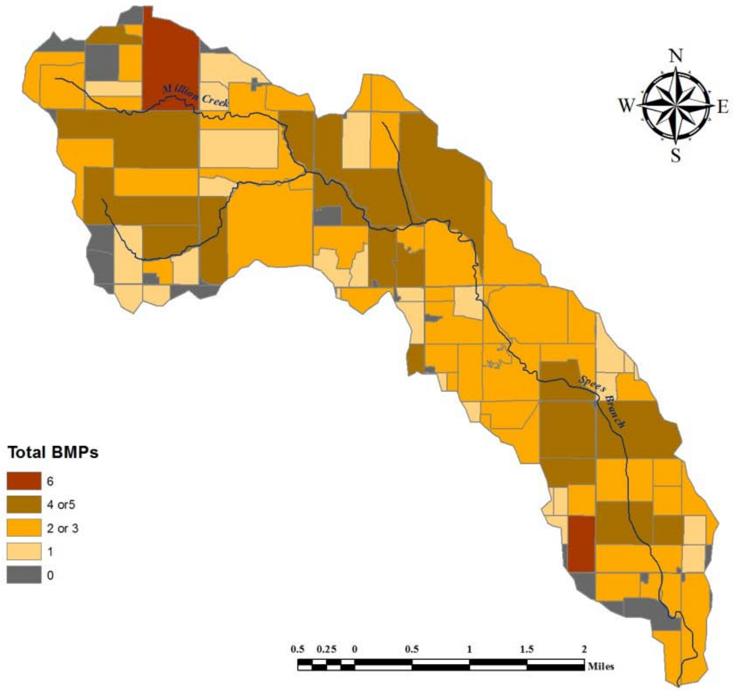
Fields With Contour Farming



Fields With Wetland Buffers

Comparing Extent of Installed “Engineering” BMP’s Can Help Explain Runoff Findings

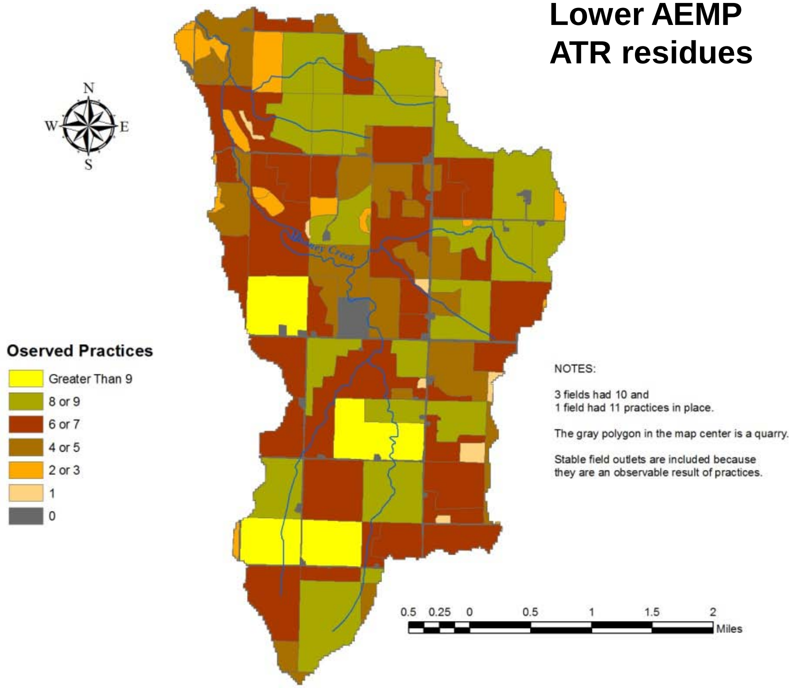
MO-01 30.7 km^2



Best Management Practice	Observed
Terraced (includes Grass Back Slope, Grass Channel, Parallel, Random Terraces, and WASCOBs)	20
Filter Strips (includes: Grass Filter Strips, Riparian Buffers and Grass Banked Ditches)	96
Permanent Grass or Hay	37
Grassed Waterway	41
Contour Farming	6
Wetland Buffer	30

KS-02 27.0 km^2

Ranked more vulnerable. Lower AEMP ATR residues

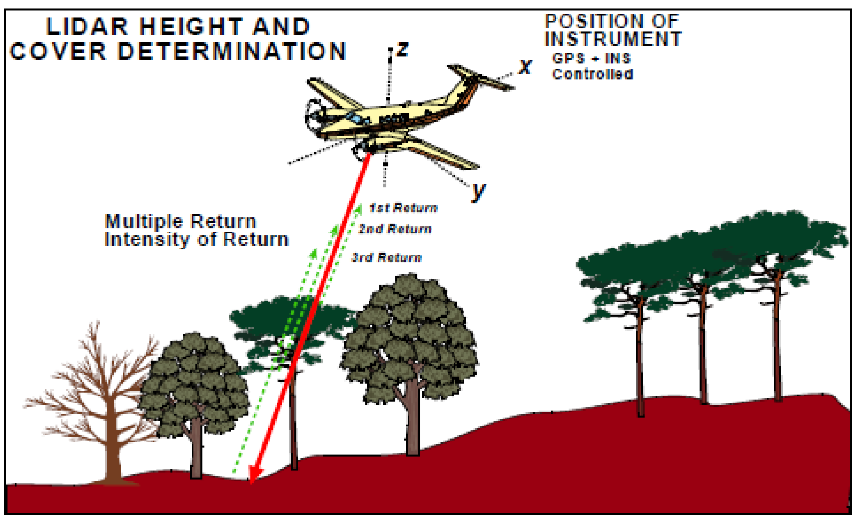


Best Management Practice	Observed
Terraced (includes Grass Back Slope, Parallel, Random Terraces, and WASCOBs)	107
Filter Strips (includes: Grass Filter Strips, Riparian Buffers and Grass Banked Ditches)	82
Permanent Grass or Hay	28
Grassed Waterway	50
Contour Farming	34
Wetland Buffer	32

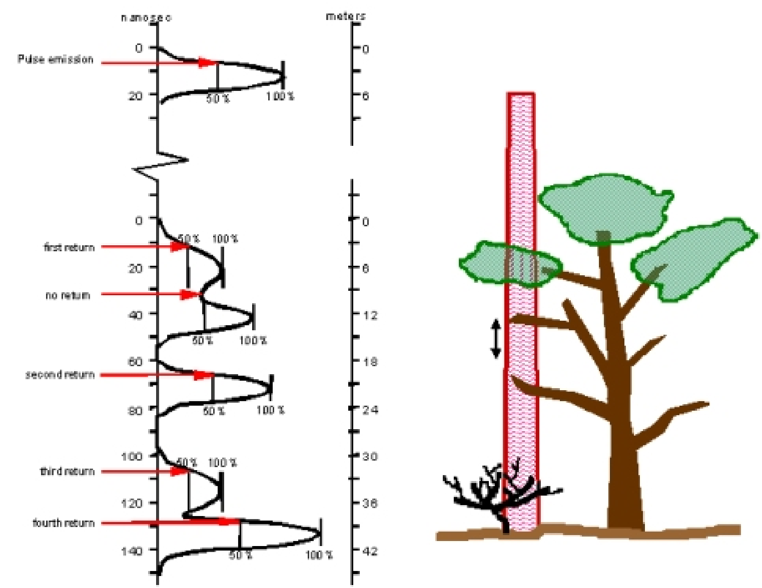
Other relevant technology advances
- LIDAR – Understanding Riparian Habitats

LiDAR (Light Detecting and Ranging) Application for Vegetation Characterization

- LiDAR laser pulse is a beam of light comprised of a continuous electromagnetic waveform
- LiDAR laser pulse enables to measure canopy height, canopy density, and % canopy closure, which are good indicators for vegetation diversity
- Buffer relationship to contours, upslope runoff area to buffer area ratio, and buffer width in areas of concentrated flow can be also used for describing relationship of buffer to agriculture fields



In this example, the first return measurement is a range value of the tree top; the last return is the ground. Lidar systems can return up to four range values and three intensity values for ground and above-ground elevation data from a single flight.



Information & Images Courtesy of: Penn State GEOG497D, ASPRS, & http://www.fugroearthdata.com/pdfs/FCT_Lidar-Educational_11-07.pdf

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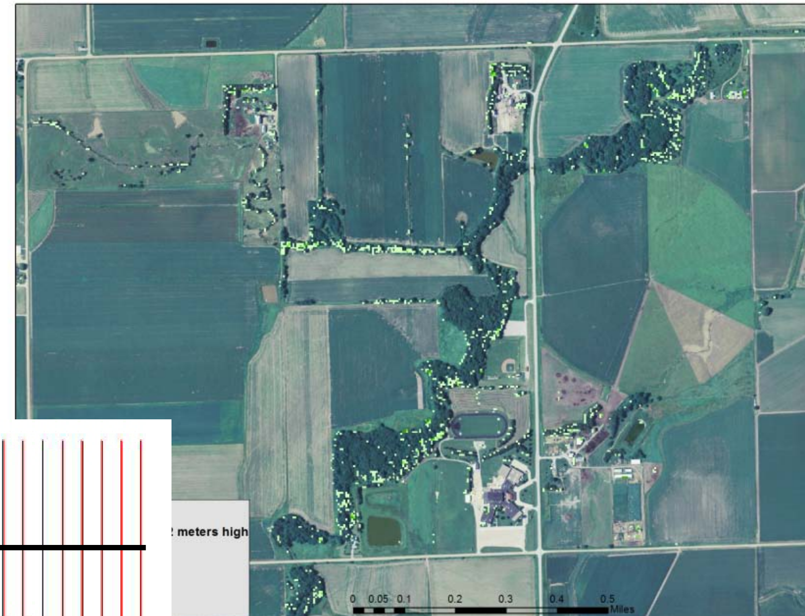
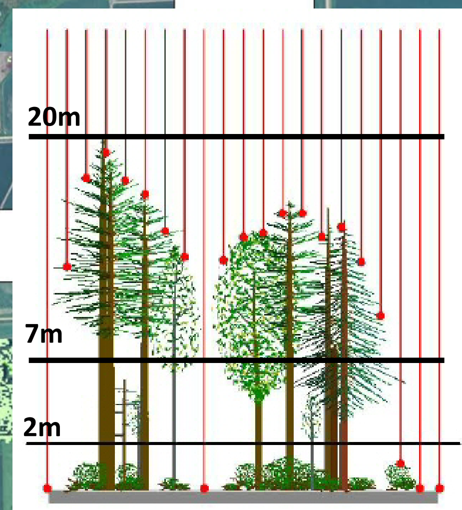
An Example of Riparian Buffer Composition characterized by LiDAR Data

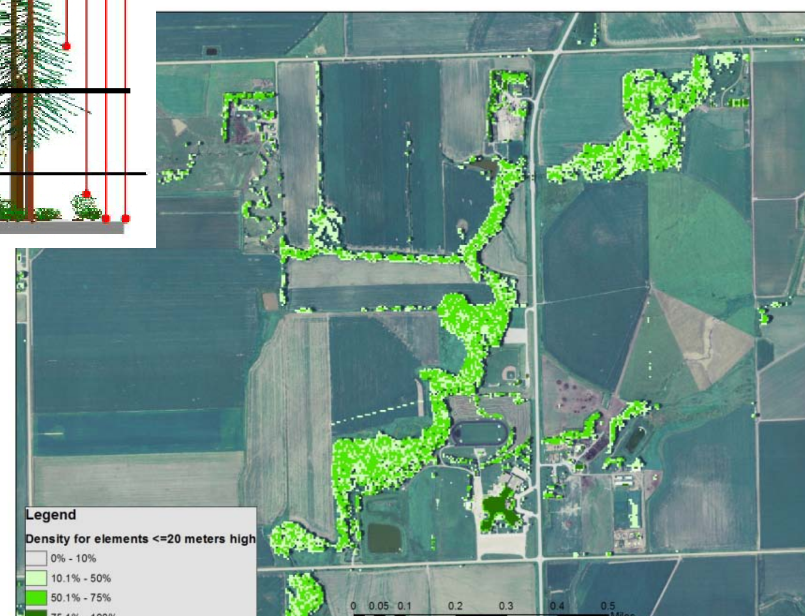
Density for any height strata



Density for height strata less than 2 meters



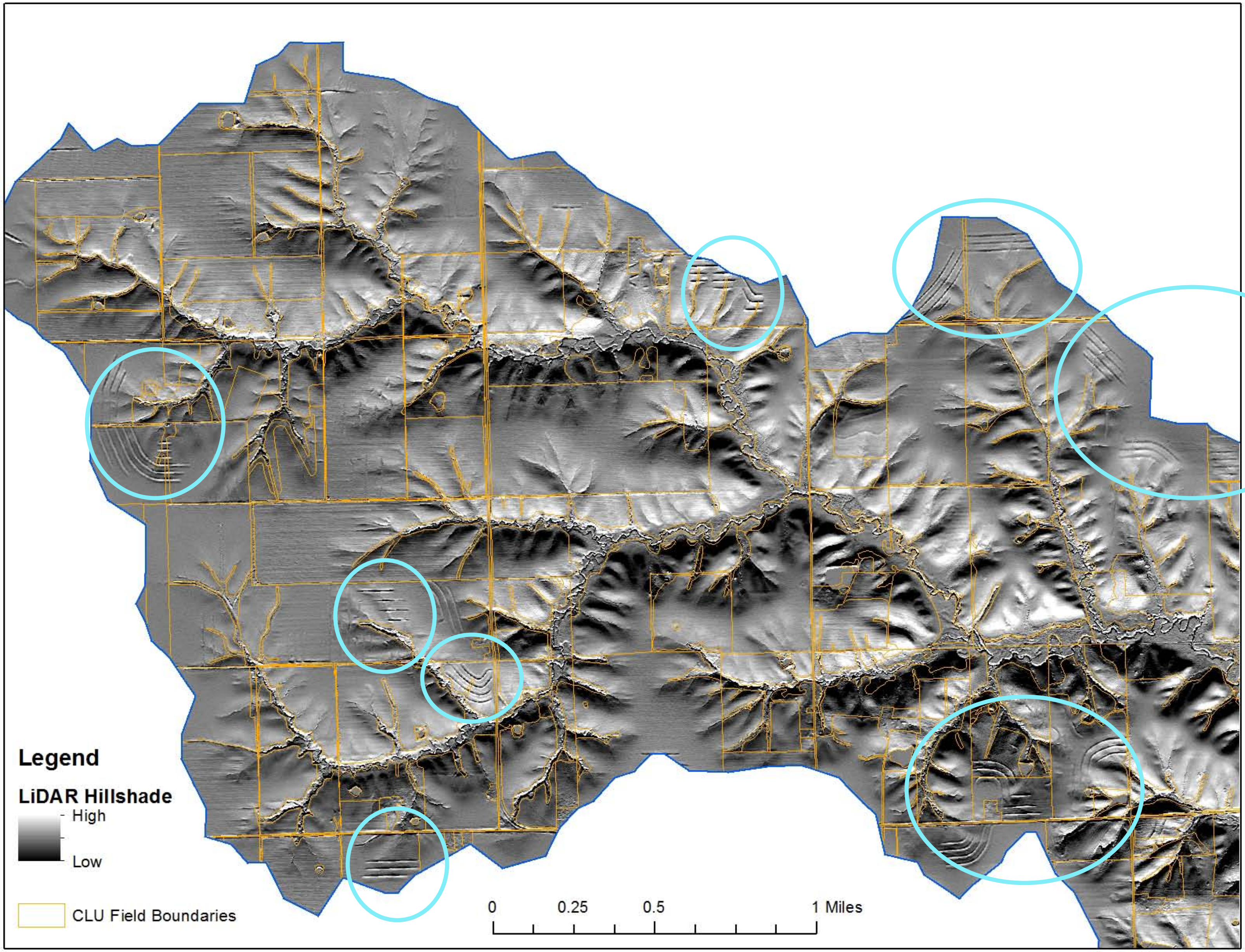
Density for height strata less than 7 meters



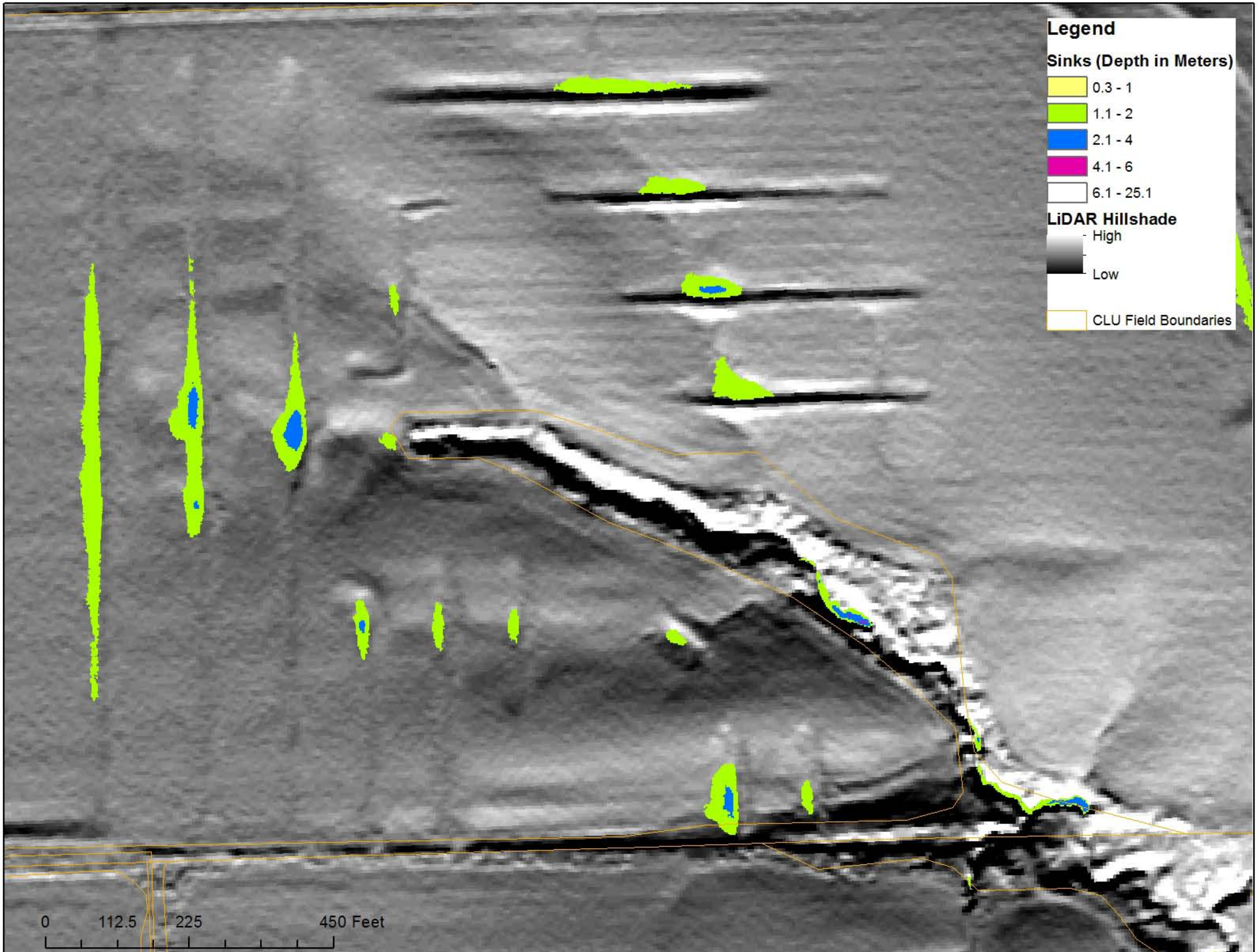
Density for height strata less than 20 meters

Using LIDAR for mitigation identification & placement

- LIDAR flights over example watersheds
  - Detailed exploratory processing to highlight
    - Sinks
    - Flow paths
- Combined with aerial imagery for identification of tile terrace areas
- Flow path data used to decide on optimal placement of Vegetative Filter Strips



Rapidly Locating Linear Features (Terracing or Contour Plowing) in LIDAR


Legend
Sinks (Depth in Meters)
0.3 - 1
1.1 - 2
2.1 - 4
4.1 - 6
6.1 - 25.1
LiDAR Hillshade
High
Low
CLU Field Boundaries
0
112.5
225
450 Feet

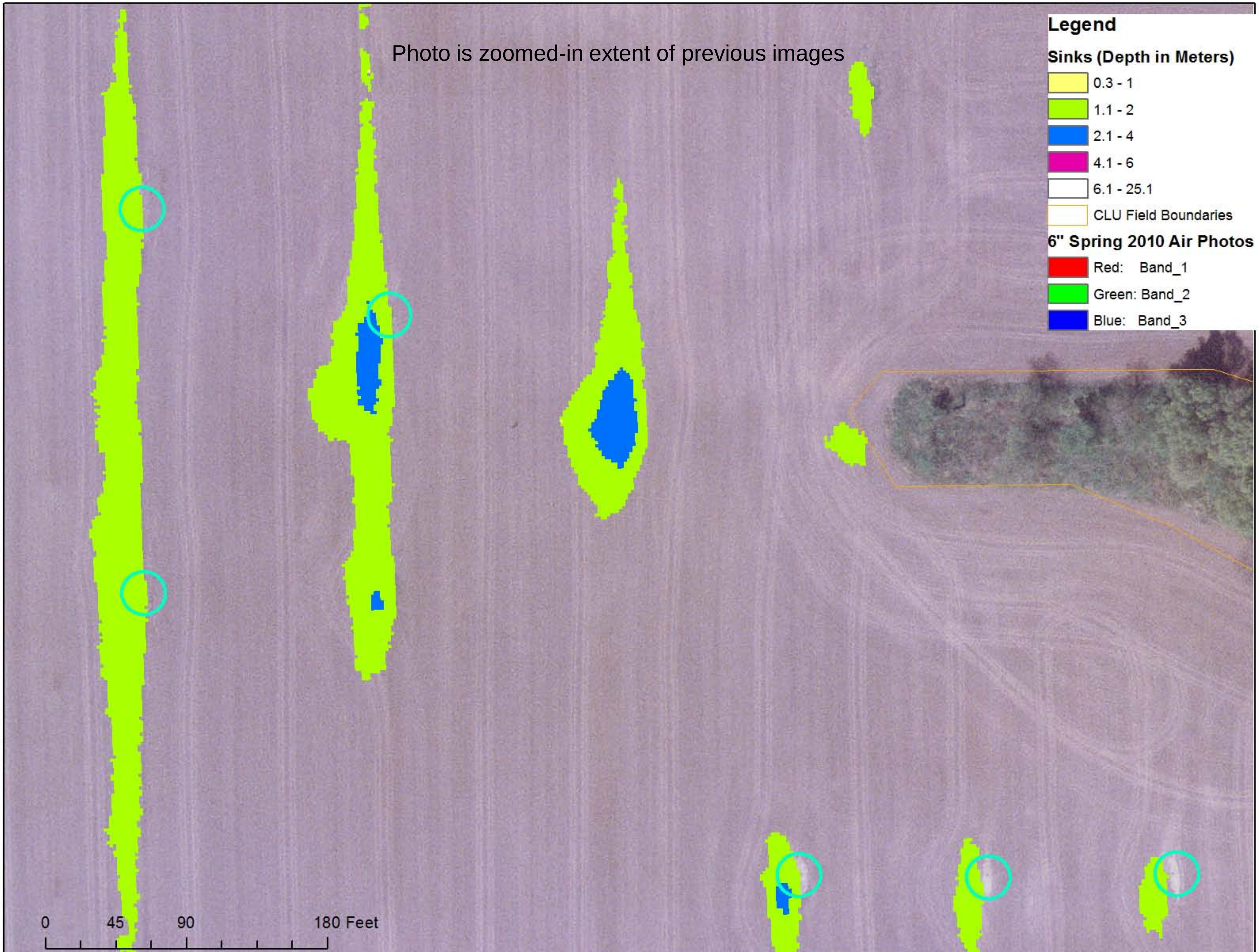
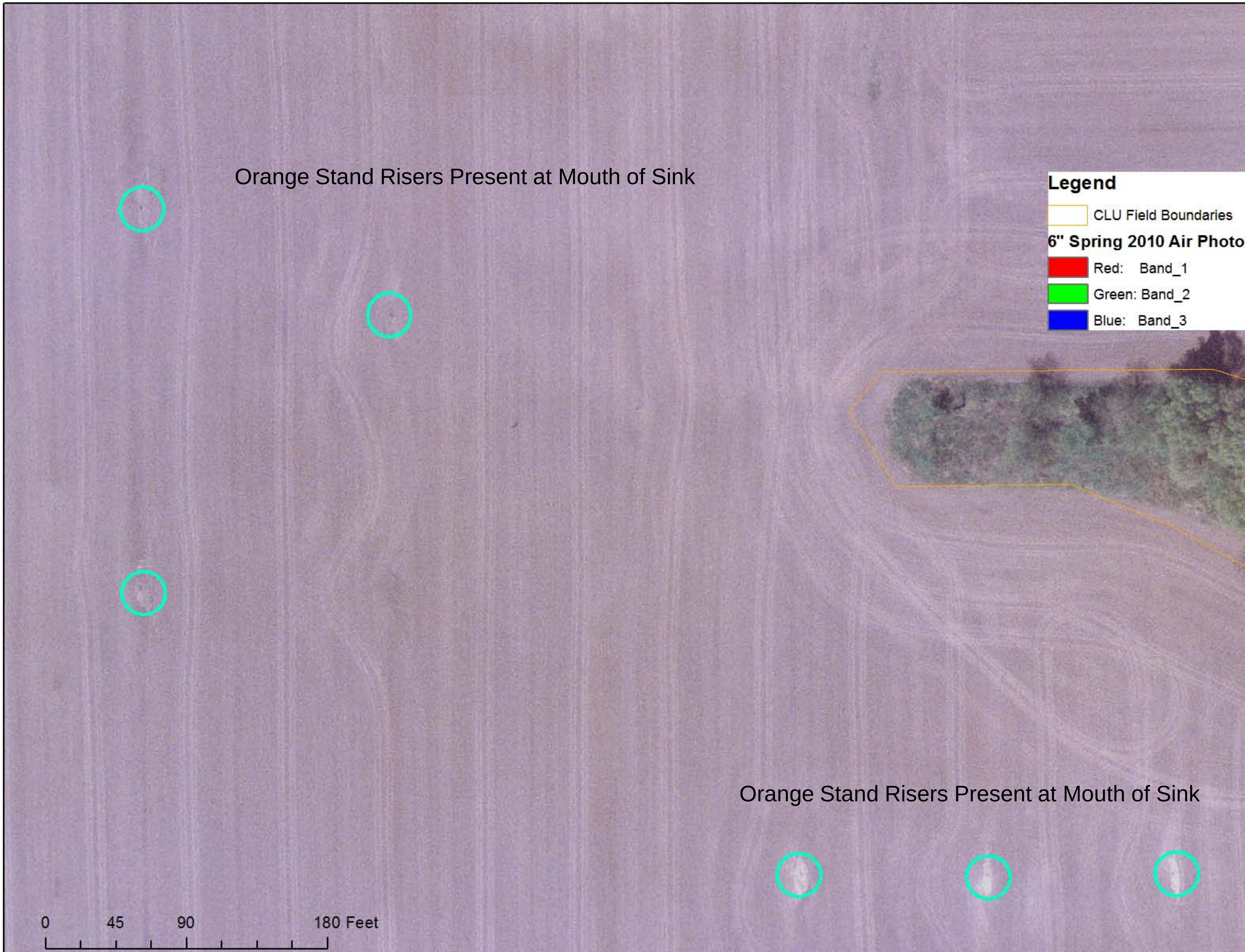
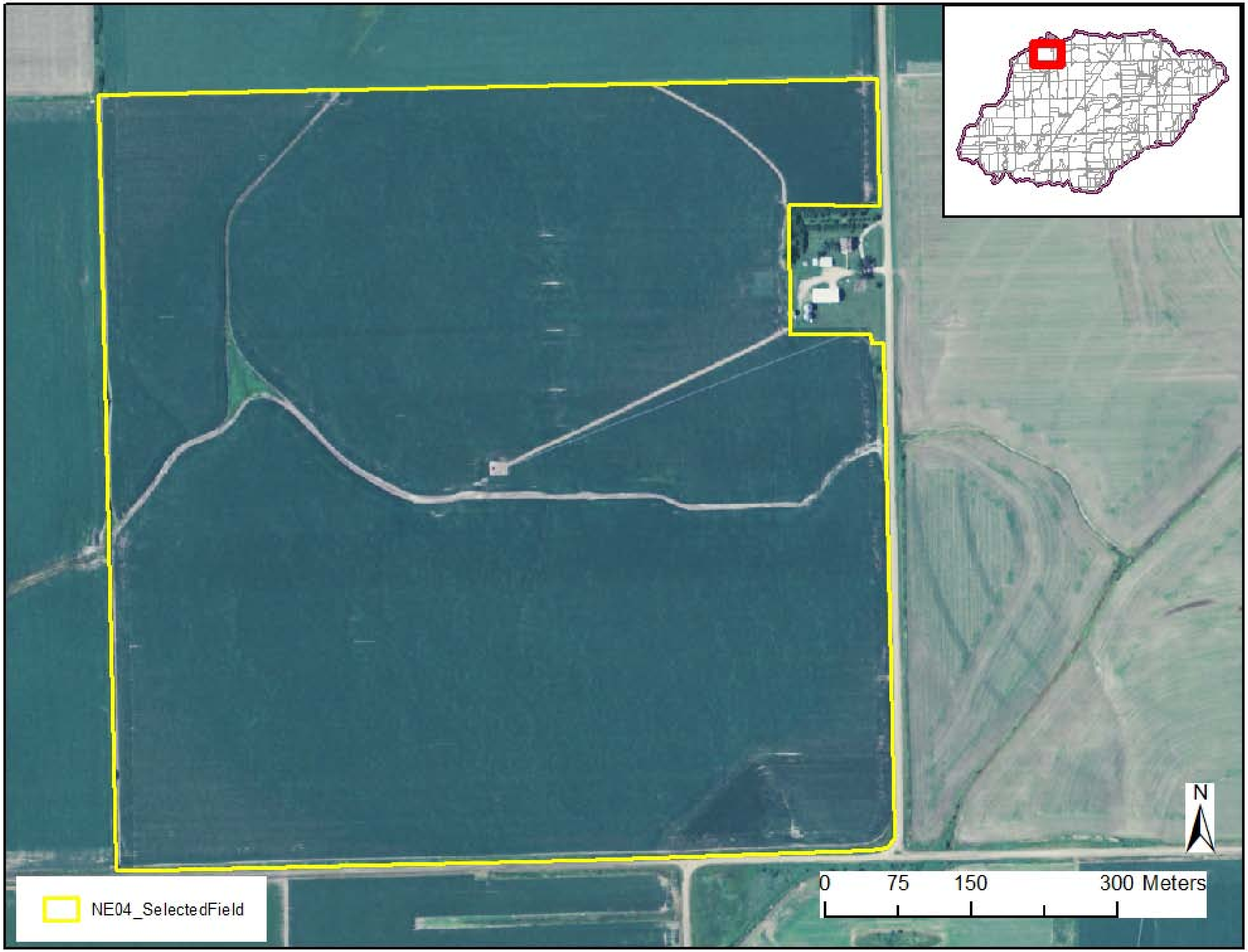


Photo is zoomed-in extent of previous images
Legend
Sinks (Depth in Meters)
0.3 - 1
1.1 - 2
2.1 - 4
4.1 - 6
6.1 - 25.1
CLU Field Boundaries
6" Spring 2010 Air Photos
Red: Band_1
Green: Band_2
Blue: Band_3
0
45
90
180 Feet


Orange Stand Risers Present at Mouth of Sink
Legend
CLU Field Boundaries
6" Spring 2010 Air Photos
Red: Band_1
Green: Band_2
Blue: Band_3
Orange Stand Risers Present at Mouth of Sink
0 45 90 180 Feet

A selected field in a Nebraska watershed



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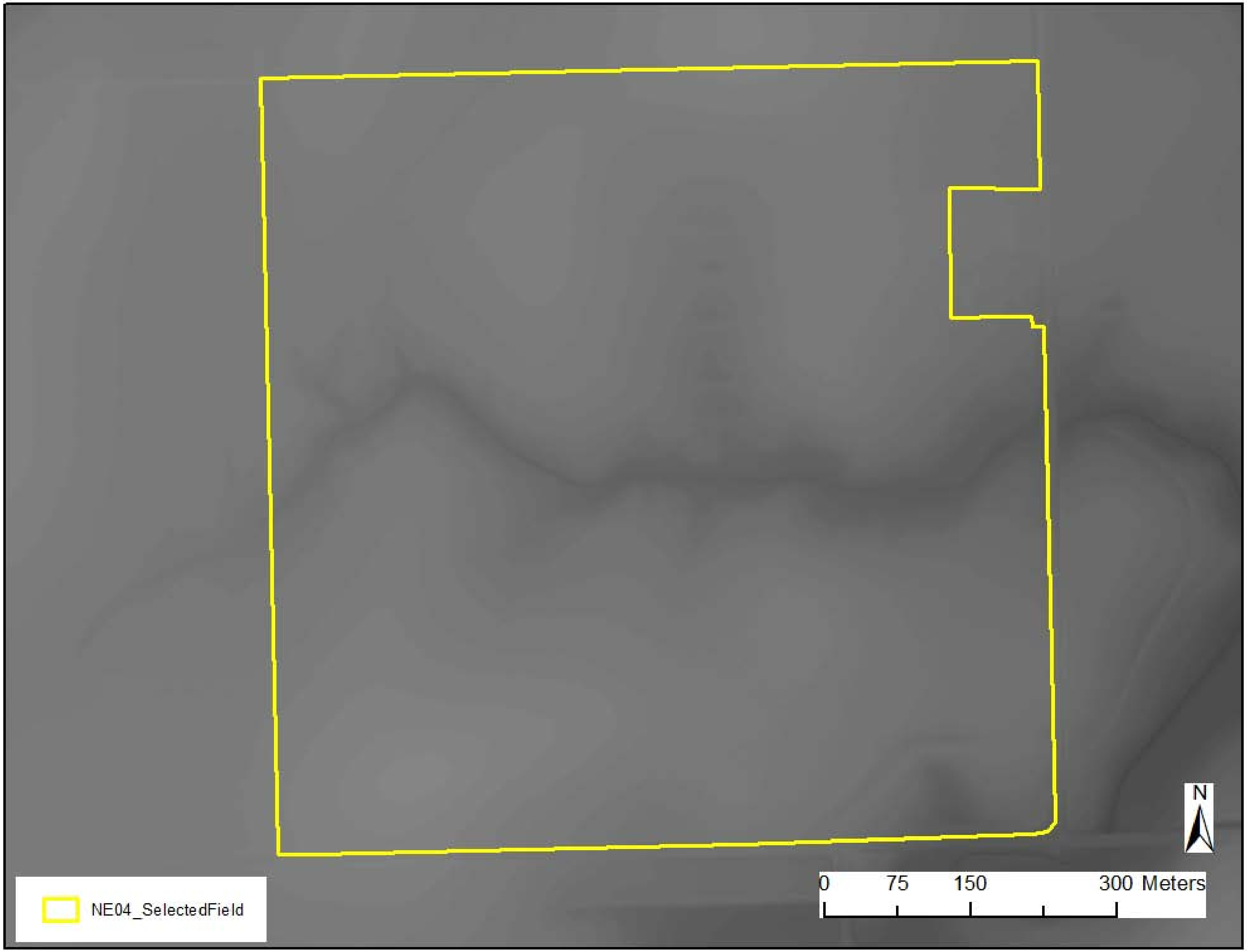
DEM of the selected field



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Flow accumulation derived from DEM

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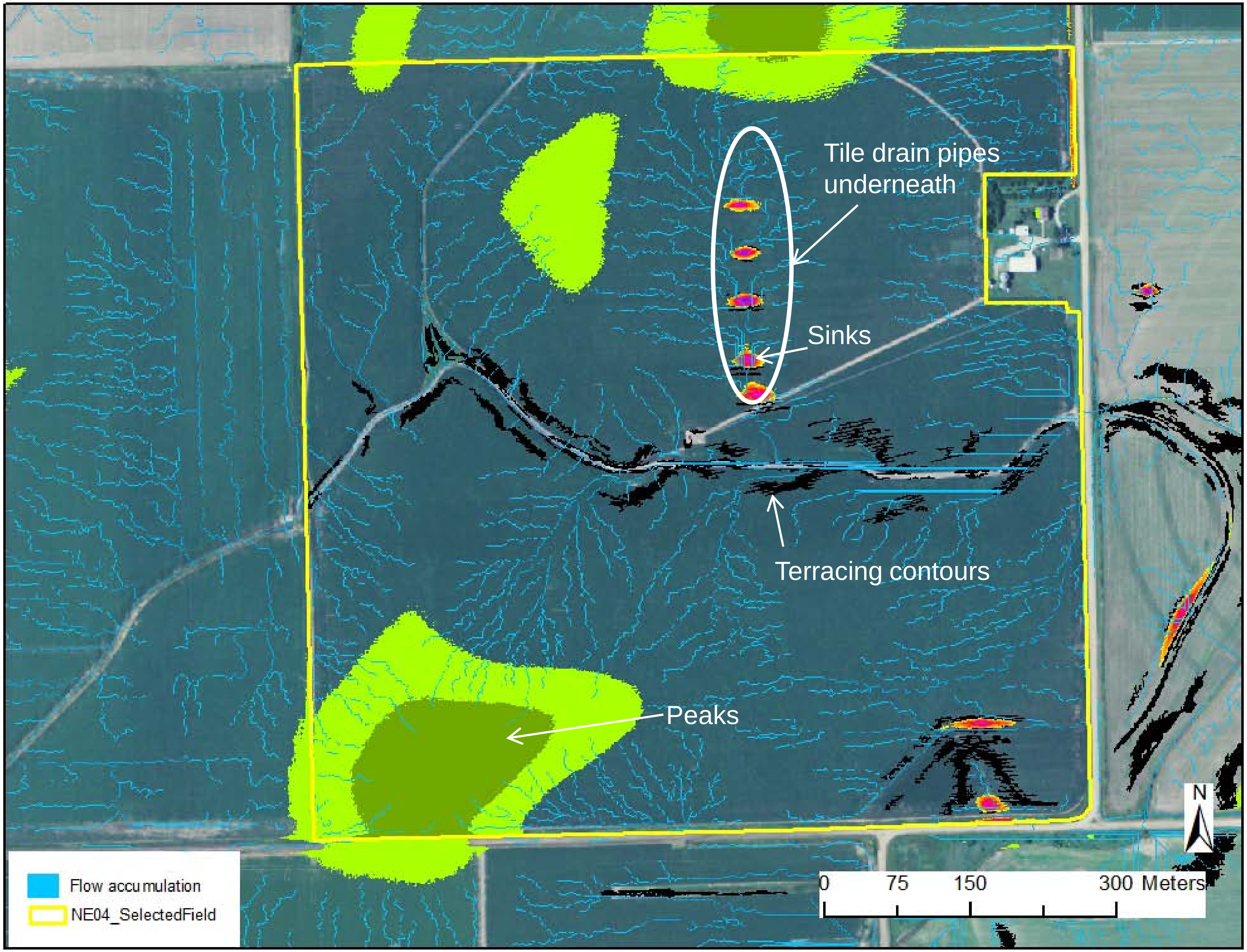
Identified peaks, sinks, and terracing contours



Possible locations for buffer strips (~ 60 ft wide)

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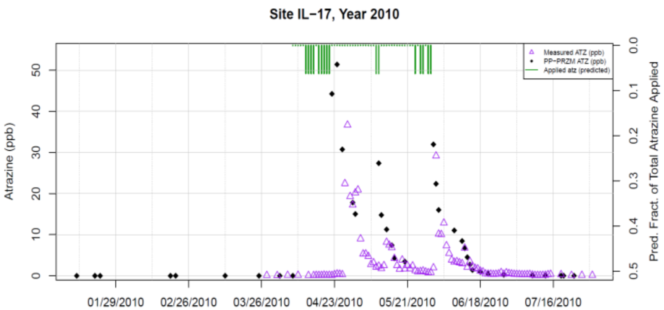
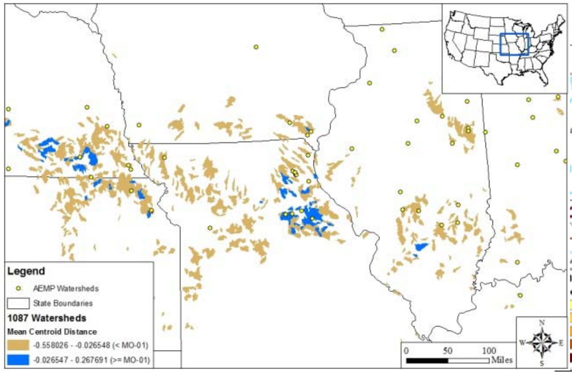
Drawing it together – Watershed behavior

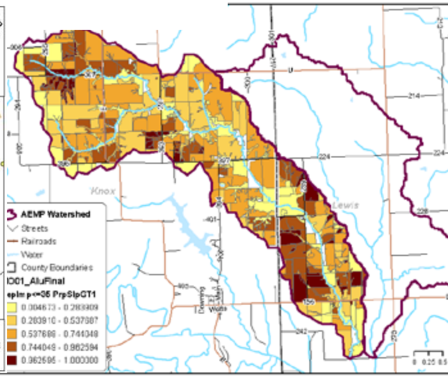
Tools Developed

- WS Pesticide Transport reflecting application & rainfall co-occurrence

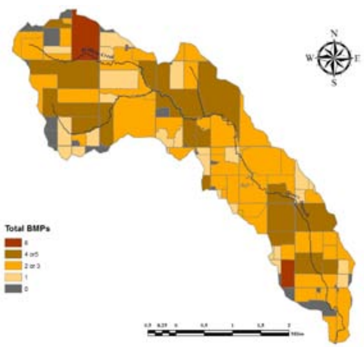


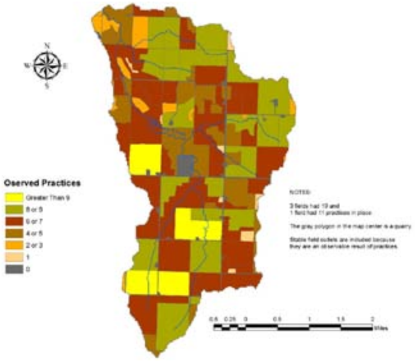
- High resolution real time rainfall





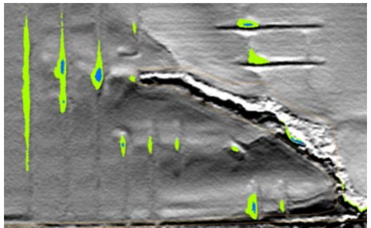
- Relative intrinsic environmental vulnerability of WS
    - WS & Field scales





- Relative occurrence of engineering BMP’s

- LIDAR high resolution drainage/buffer analyses



Potentially Vulnerable Watersheds Can Be Compared

"Engineering"

Watershed Runoff = *Fn* (Landscape), *Fn*(Timing/rain), *Fn*(Stewardship)

Grower Choices

1. Watershed Landscape Factors
   - Soils, Cropping, Slopes, Shallow claypan etc

2. Rainfall intensity/timing vs. applications - explains annual runoff variation
   - Temporal distribution of applications across watershed is key

3. Stewardship Factors
   - Effect of installed "engineering" mitigations – terraces, sediment basins
     - Permanent features designed to reduce water/sediment losses from fields and improve water quality
   - Grower choices – have significant stewardship impacts
     - Stewardship - buffers, set backs….
     - Agronomic – contouring, tillage, fertilizer…
     - Crops – type, location, planting timing, agrochemical regime/rates…

How can this help reduce agricultural impacts on WQ?

- **Precision mitigation** focuses on ranking areas that may be contributing to water quality issues in terms of their potential significance.
  - Starts at watershed scale – which merit initial attention?
  - Then WITHIN a watershed – which fields merit initial attention?
  - Then WITHIN a field – what is most efficient mitigation deployment?
- Provides ability to quantify and thence rank watersheds & fields
- Provides focus for efficiently using limited funds – precision placement
- Provides credit to growers/regions already heavily invested in stewardship
- Provides insights for WQ metrics to add to “sustainability indices”
- **ALSO** Provides data for large numbers of other stakeholders
  - E.g. Habitat analyses, crop modeler support, precision planting

Interacting with Stakeholders for Effective Stewardship

Working with stakeholders

- "Lunch and learn"
  - Before and after season timings
- Bring together growers and potential advisors
  - Extension
  - Dealers
  - Granting bodies
  - Land grant scientists
- Talk about watershed issues
  - Provide data from monitoring or new science
- Show maps, discuss pesticide labels
  - Alert growers to mitigation support options
  - Provide take-home materials
- Listen and answer questions

EDUCATIONAL MATERIALS

Trees Forever

Protecting and enhancing stream quality in Iowa and Illinois…

- 270 demonstration projects in Iowa and Illinois
- Over 1.5 million trees planted
- 5900 acres of land planted with trees shrubs and native plants
- 130 miles of stream banks buffered
- 37,000 community service hours donated

Did you know…?
Buffers reduce sediment in surface runoff by 60-70% in the first 10 feet, and by 70-90% in the first 15-18 feet.

Buffers benefit the watershed by:

- Slowing runoff from fields
- Reducing soil erosion
- Filtering and purifying water (reduced pesticide runoff)
- Creating wildlife habitat
- Providing wind and visual screens

OPERATION Pollinator

Positive Action for Pollinators

Transporting and Supporting important initiatives

Operation Pollinator:
Building Farm Habitat for Pollinators

syngenta

MICHIGAN STATE UNIVERSITY

UC DAVIS UNIVERSITY OF CALIFORNIA

UF UNIVERSITY of FLORIDA IFAS

National Fish and Wildlife Foundation

Applewood Seed Co.

Providing information to significant new "players" in Agricultural Sustainable Production

The Sustainability Consortium

www.sustainabilityconsortium.org/

SUSTAINABILITY CONSORTIUM

Administered by Arizona State University & University of Arkansas

- Most significant initiative in the marketplace

Food, Beverage & Ag Sector Members:

Founder (Walmart)

SC Johnson A Family Company, defra, Tyson, Campbell's, Walmart, Safeway, Cargill, United States Environmental Protection Agency, MillerCoors, Unilever, Tetra Pak, Kellogg's, Marks & Spencer, Darden Restaurants, Ahold, PepsiCo, Syngenta, General Mills, ASDA, Monsanto, BASF The Chemical Company, DMI Dairy Management Inc.

List continues to grow --- reaching critical mass?

Conclusions

- Sustainable Intensification of Agriculture is necessary
- Growers are stewards of land
- Stewardship impacts production – tools needed to maximize efficiency
- Data exist to categorize watershed vulnerability and sustainable status
- “Precision” deployment of mitigation elements feasible with newer tools
  - Leaching issue as well as surface water
- High resolution Ag-related data have many uses & potential stakeholders
- BUT Stewardship happens one field at a time – technological solutions must be linked with developing trust/respect across stakeholders

Thank you!