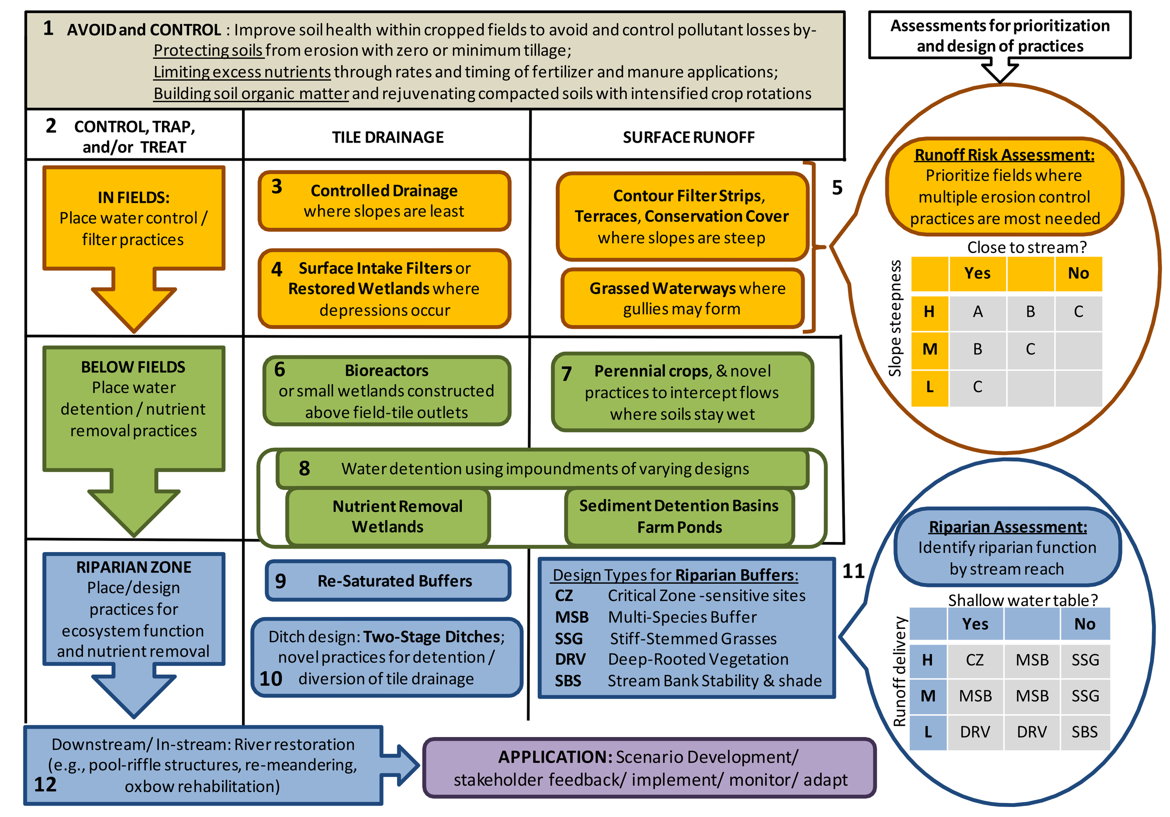
A Framework for Watershed Conservation Planning using Precision GIS Technologies

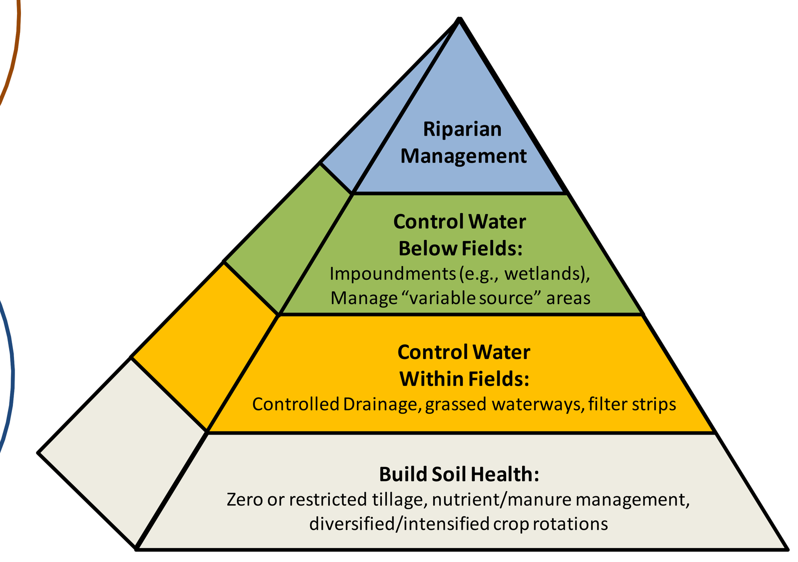
Improving water quality in agricultural watersheds will require comprehensive and adaptive approaches to plan and implement conservation practices. These approaches will need to consider landscape hydrology, distributions of soil types, land cover, and cropping systems in a comprehensive manner. Two big challenges to improving conservation planning capacities will be to ensure consistent and reliable data, and a seamless translation of conservation planning alternatives from watershed to farm and field scales. The translation of scale is required because, while conservation practices can be planned based on a watershed scale framework, they must be implemented by landowners in specific fields and riparian sites. We are developing conservation planning tools using a new framework (shown at right) that leverages high-resolution spatial datasets to identify feasible and specific conservation alternatives for stakeholders to consider. A three-state spatial database of land cover and soils has been developed for more than 4,000 HUC12 watersheds in Iowa, Illinois, and Minnesota to support local application of this framework, which includes data derived from the NASS Crop Data Layer (30m), NRCS SSURGO soils (10m), and from field boundaries publicly released by USDA prior to 2008. Detailed topographic data (1-3m) must be available and processed for local application.

The 12-step planning framework (right) can help identify conservation alternatives and scenarios that inform local stakeholders and allow them to better participate in watershed planning. Results provide a broad range of landscape and field-scale opportunities to address environmental vulnerabilities through specific conservation practices. The framework classifies practices by placement category (i.e., in-field, below-field, or riparian zone) and flow pathway addressed (surface runoff or subsurface tile drainage). Matrices help to: 1) identify where runoff directly enters surface water and runoff control practices are most needed (step 5), and 2) identify where riparian buffers can intercept surface and/or groundwater flows to customize buffer widths and vegetation species according to the landscape setting (step 11). In concept, the framework in based on a conservation pyramid (far right), in which soil management underpins a multi-practice approach to conservation. Details are freely available online: www.jswconline.org/content/68/5/113A.full.pdf+html.

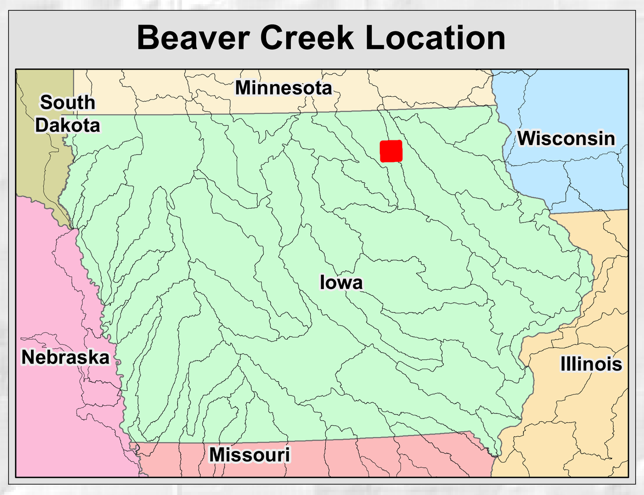
In the example below, the Beaver Creek, Iowa watershed (HUC12) has been analyzed to showcase possible placement scenarios for two conservation practices, Nutrient-Removal Wetlands (step 8) and Re-Saturated Riparian Buffers (step 9).



Conservation Pyramid:
Conceptual basis for conservation planning emphasizes managing land to improve soil health, and effective use of multiple practices to meet water quality goals.

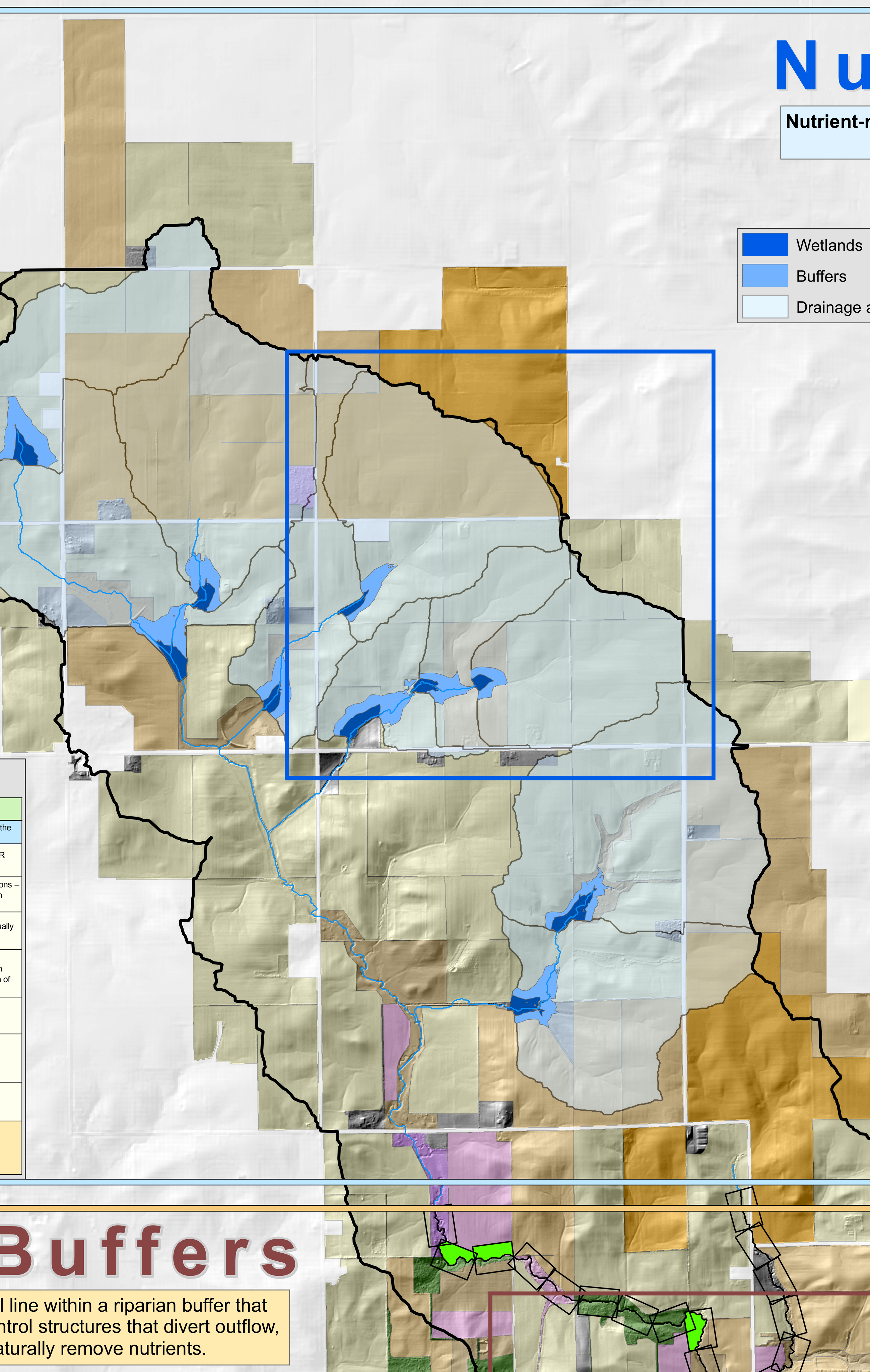


Beaver Creek Location



Beaver Creek Land-Use 2007-2011

- Corn/Soybeans
- CB with Continuous Corn
- Continuous Corn
- Extended Rotation
- Pasture
- Forest
- Mixed
- Unassigned

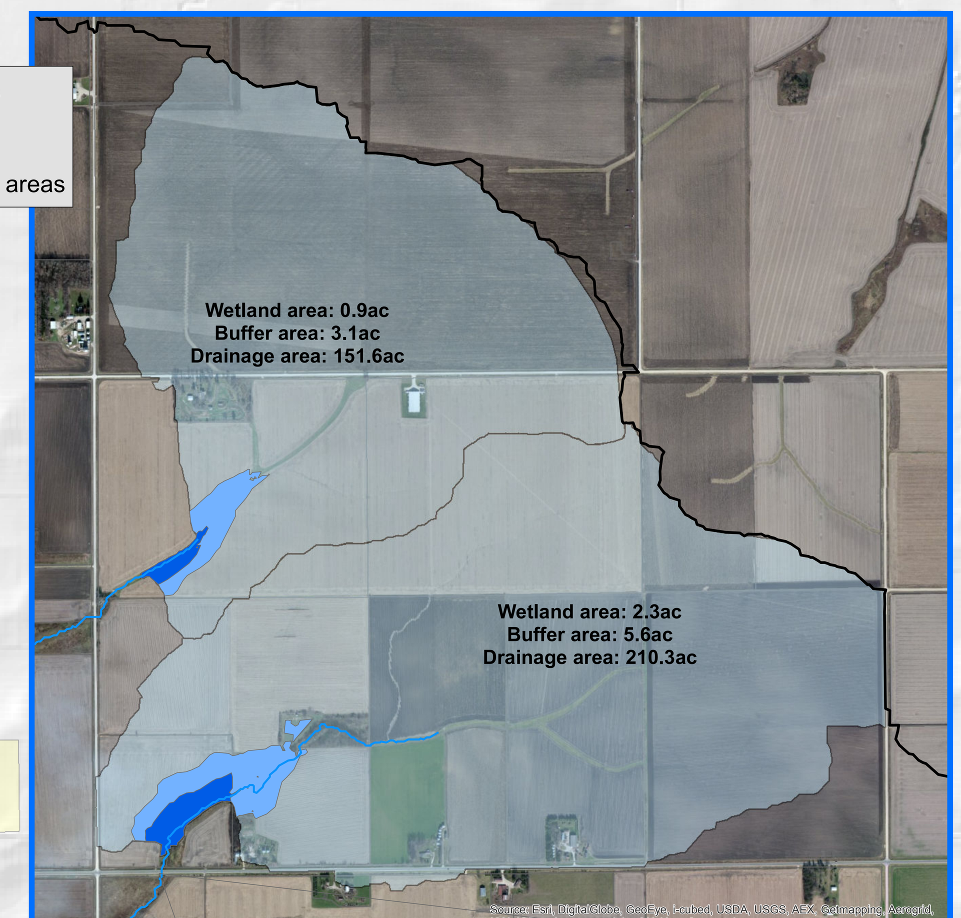


Summary of Conservation Planning Tools

Practice and description for procedure	Description	Spatial Location	Nitrogen Removal Efficiencies
Nutrient-removal wetlands (656, 658)	An artificial ecosystem with hydrophytic vegetation for water treatment.	Edge of field	52% average reduction in nitrate concentration – where the average wetland is .785% of the contributing watershed
Controlled drainage (554)	The process of managing water discharges from surface and/or subsurface agricultural drainage systems by adjusting the elevation of the drainage outlet.	In-field	33% average reduction in **amount** of tile-drained WATER (not N concentration)
Grass waterways (412)	A shaped or graded channel that is established with suitable vegetation to carry surface water at a non-erosive velocity to a stable outlet.	In-field	Up to 25% average long-term reduction in N concentrations – dependent on width, type of vegetation, coordination with other practices.
Riparian buffers (391,393,327)	An area predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies.	Edge of field	91% average reduction in N concentration for water actually passing through the root zone.
Filter strips (393,327)	A strip or area of herbaceous vegetation that removes contaminants from overland flow.	In field	25% average long-term reduction in N concentrations – dependent on width, type of vegetation, coordination with other practices. N reduction directly related to proportion of field removed from production.
Wetland restoration (657,659)	Establish or reestablish wetlands for the benefit of wildlife, to reduce flooding, provide offsite water quality benefits, and increase groundwater recharge.	Edge of field	20% - 40% reduction in N from individual field only
Bioreactors (747)	An excavated trench filled with an organic matter source, such as wood chips, with water table control structures installed at the outlet of the largest subsurface drainage system to enhance denitrification.	Edge of field	26%-43% average reduction in N
Two-stage ditches/ditch modification (new)	Incorporates a floodplain zone, called benches, into the ditch to have more area to spread out on and decreases the velocity - or energy - of the water.	Edge of field	25% reduction in NO3
Resaturated buffers (new)	A buffer in which a shallow lateral line intercepts tile lines before they release water into a stream. The lateral line has control structures that raise the water table and slow outflow, allowing the buffers to naturally remove nutrients.	Edge of field	Estimated 820 kg N/km/yr

Nutrient-removal Wetlands

Nutrient-removal Wetland (656) - A wetland that is created by a low impoundment and installed below artificially drained cropland for the purpose of decreasing nutrient concentrations in agricultural subsurface drainage water.



Background/Benefits

Nutrient-removal wetlands comprise a major component of Iowa's nutrient reduction strategy, intended to help mitigate the Gulf of Mexico hypoxic zone. This practice is being encouraged through a partnership between Iowa and the USDA under a Conservation Reserve Enhancement Program (CREP).

❖ Iowa studies have shown that annual nitrate-nitrogen loads in tile drained land are reduced by 30-50% depending on location.

❖ Uses criteria established for the Iowa CREP program, altered to consider watershed sizes as small as 100 ha (250 acres).

❖ Siting criteria includes locating terrain where the wetland impoundment will not inundate significant areas of cropland on near-level landscapes with minimal development of natural stream networks.

Processing Steps

❖ Identify candidate sites for suitability at 100 meter intervals along a drainage network. Sites with larger contributing areas are tested first.

❖ At each site, utilize zonal statistics with LIDAR elevation data to define:
- Channel elevation - minimum value within a 20 meter buffer around test site.
- Bank height – range of values within a 20 meter buffer.
- Bank elevation – maximum value within a 20 meter buffer.

❖ Using candidate site as pour point, delineate upstream drainage area.

❖ Extract LIDAR elevation data to drainage area extent.

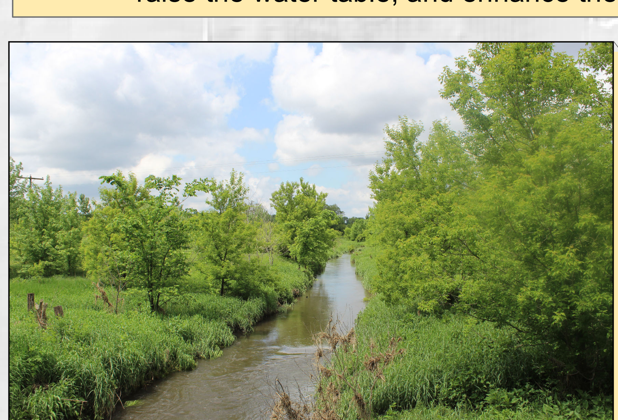
❖ Reclassify elevation data to add wetland and buffer.
- Elevation of wetland pool defined as .9 meters above the bank elevation.
- Elevation of buffer vegetation defined as 1.5 meters above wetland pool.

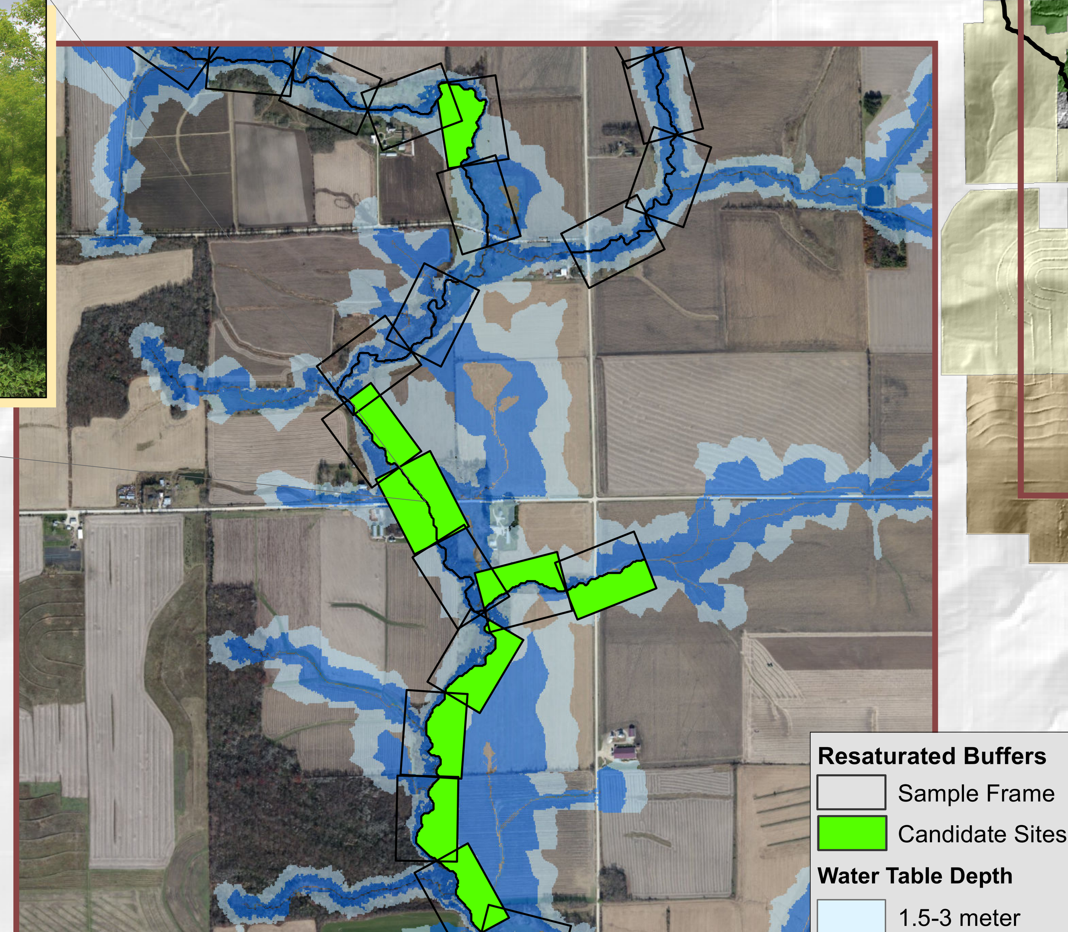
❖ Test site for suitability using criteria established by the Iowa CREP program.
- Wetland-to-Drainage Area ratio must be between .5 and 2%.
- Buffer vegetation cannot be 4 times the size of the wetland.
- Neither the wetland nor buffer intersects a road.

❖ Sample the next upstream site that does not fall within any suitable nutrient removal wetlands and/or buffers.

Resaturated Buffers

Resaturated Buffer- This experimental practice employs a lateral line within a riparian buffer that intercepts a tile above its outlet to a stream. The lateral line has control structures that divert outflow, raise the water table, and enhance the buffers ability to naturally remove nutrients.





Background/Benefits

Agricultural subsurface (tile) drainage used on poorly-drained soils throughout the Midwest convey water directly to streams, bypassing natural opportunities to reduce nutrients in streamside (riparian) settings with organic-rich soils and moist conditions conducive to denitrification. This experimental practice has shown to be:

❖ Inexpensive and can be very efficient for nitrate removal (may be >50%).

❖ Criteria to identify riparian locations
- expected presence of suitable soil and water table conditions,
- tile-drained cropland upslope, and
- minimal surface runoff contributions to flush the system and reduce efficiency.

Processing Steps

Develop a sampling framework consisting of polygons (250 m long x 180 m wide, 90 m on each streamside) along a stream network. Each polygon is split by the stream network centerline in order to analyze each streamside independently.

Extract to each polygon:

❖ Amount of surface runoff delivery to that reach of the stream. Runoff delivery is calculated by summing the runoff at each bank grid cell within a polygon.

❖ Average width of the shallow water table zone. Depth to water table is estimated at each grid cell using surface elevation values, assuming that channel elevation is equal to groundwater depth (Boomer, in press).
- Shallow water table zone (< 1.5 meters).

❖ Average width of high soil organic content zone (> 75th percentile of watershed soil organic content at a depth of 30 to 150 cm).

Identify candidate sites for resaturated buffers using the following criteria:

❖ Width of shallow water table zone is between 25 and 50 meters.

❖ Runoff delivery is not high (High runoff defined as those polygons with the largest runoff volumes that cumulatively account for half of the watershed drainage area).

❖ Width of high soil organic content zone is >= 25 meters.

❖ Sites must include water table depth > 3m

The Future

➢ Test and refine criteria for placement of conservation practices at watershed scale (evaluate and improve upon placement criteria for wetlands, buffers, controlled drainage, and other practices listed in the framework)

➢ Develop criteria for placement of additional alternative conservation practices that can be distributed within watersheds to optimize their environmental performance. This may include development of technical standards for new conservation practices not covered by current USDA technical guidelines.

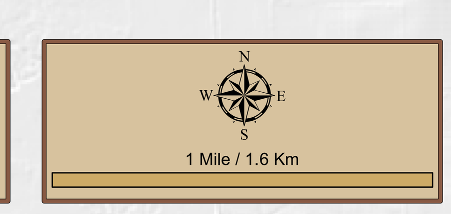
➢ Evaluate conservation practice placement criteria at eco-regional scales to provide advice for adjusting placement criteria based on landscape factors.

➢ Develop tools to estimate nutrient reductions resulting from implementation of conservation planning scenarios at the 12-digit watershed scale.

➢ Develop and test planning tools to evaluate watershed-scale economic (net farm income) and environmental (nutrient load reduction) impacts of alternative conservation scenarios. This will enable the need for conservation incentives to be more clearly quantified.

➢ Convene planning forums in several test watersheds across the Upper Mississippi Basin to demonstrate the value of this approach in engaging stakeholders and optimizing watershed planning.

Data Sources:
Iowa Department of Natural Resources
USDA National Resources Conservation Service
USDA National Agricultural Statistics Service
USDA Farm Service Agency



Authors:
M. D. Tomer - USDA/ARS NLAE
S. A. Porter - USDA/ARS NLAE
D. E. James - USDA/ARS NLAE
E. McLellan - EDF