Conservation Drainage Practices for Agriculture

2009 Minnesota Association of Watershed Districts Meeting

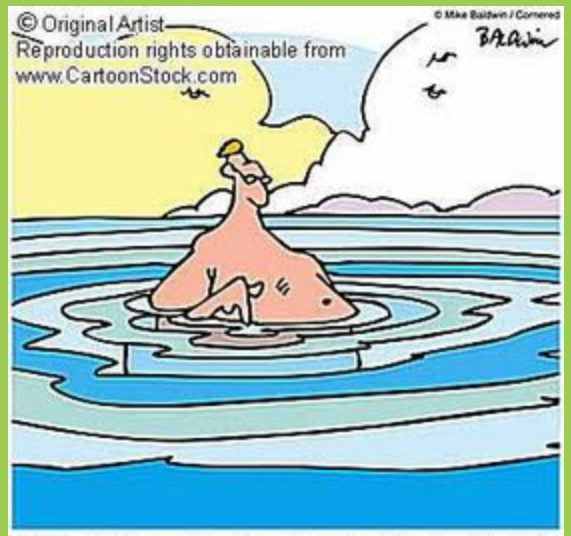
Joel Peterson, PE, PhD, BWSR

Outline

- Setting the context for conservation:
  - Agriculture
  - Drainage
  - Climate
  - Impairments
- Conservation drainage practices

Cause and Effect

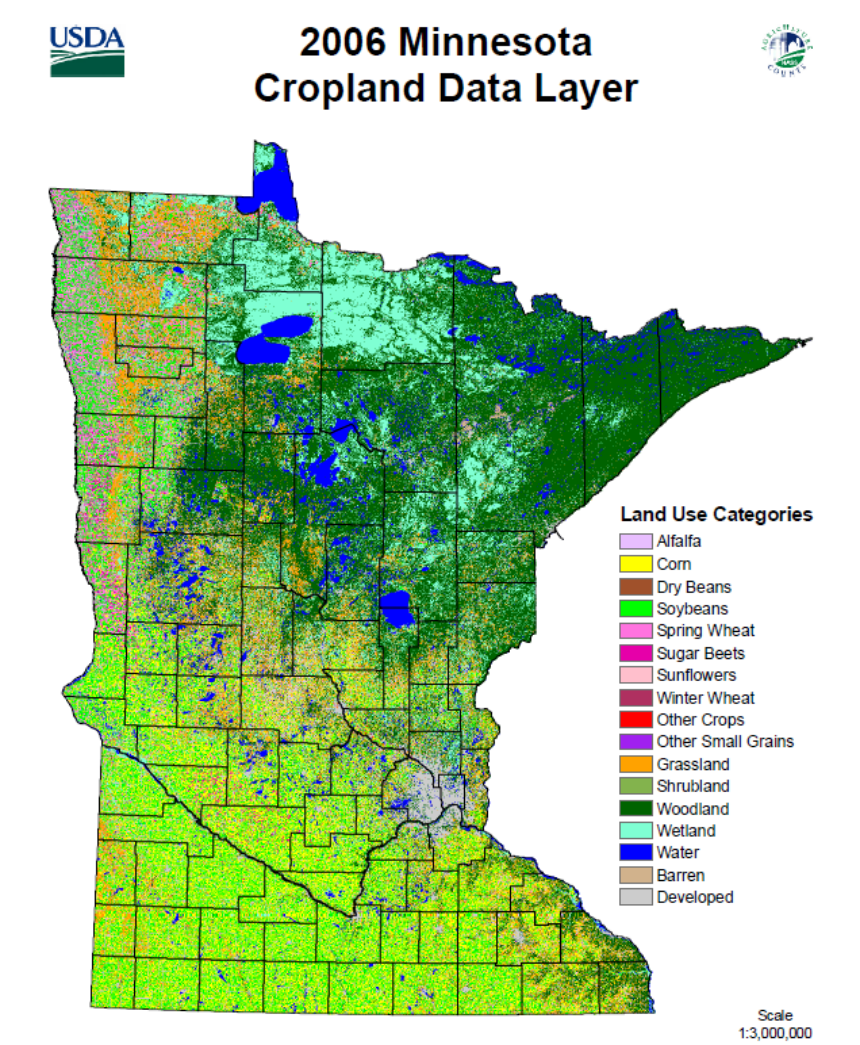
- Cause
  - Land Use
  - Land Management
  - Climate and climate trends
- Effects
  - Gulf Hypoxia
  - Lake Winnipeg Eutrophication
  - Impairments…TMDLs



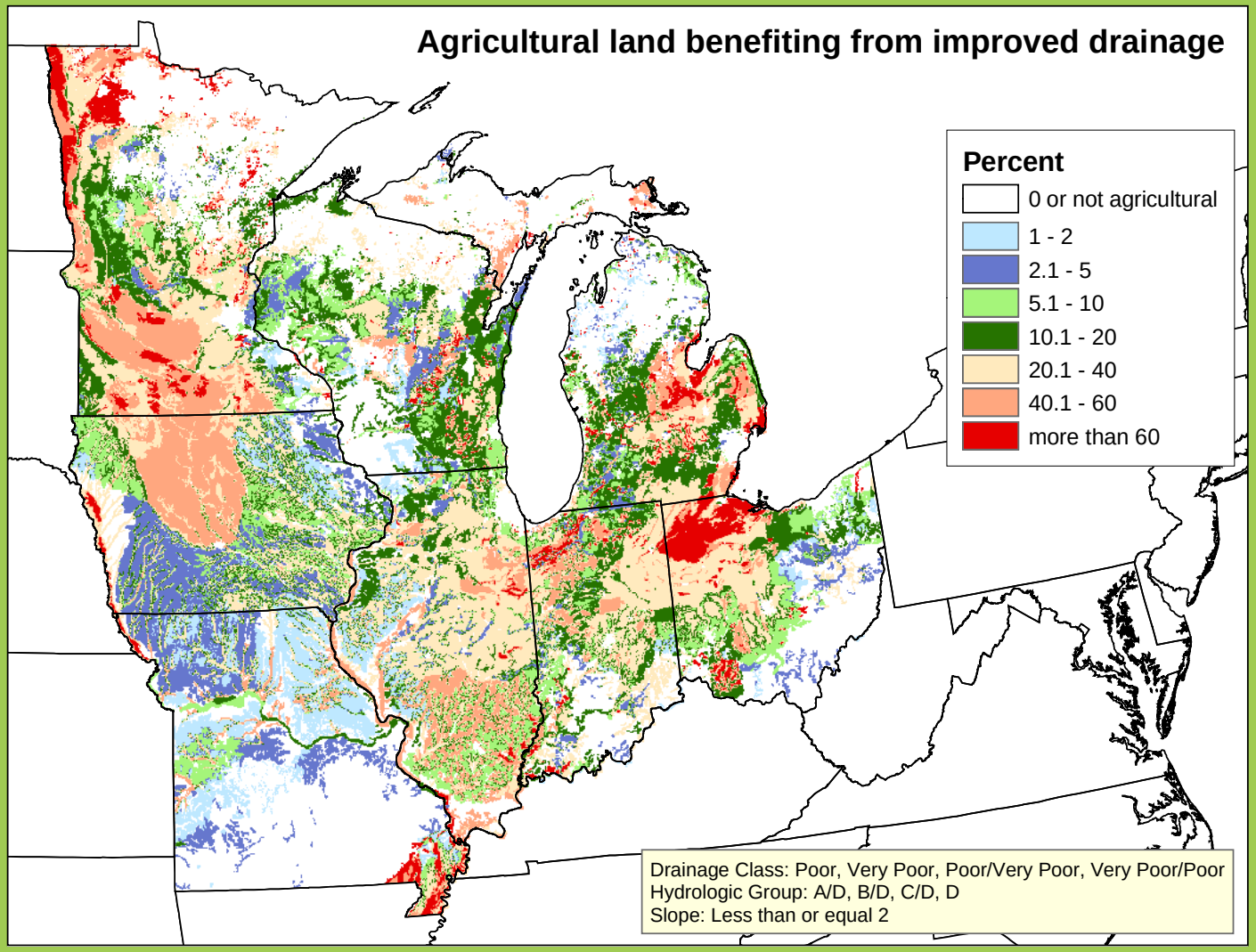
Bob believed in the ripple effect. Which was surprising, given that his own ripple didn't appear to be all that effective.

Minnesota is an Agricultural State

- #7 ag state in nation (USDA, 2007)
  - Corn, #4
  - Soybean, #3
  - Sugarbeets, #1
  - Hogs, #3
  - Turkeys, #1
- 48% total farmed
- 53% land farmed



Midwest Ag Land Benefiting from Improved Drainage



Prairie Pothole Region in Minnesota

Surface Hydrology of Minnesota

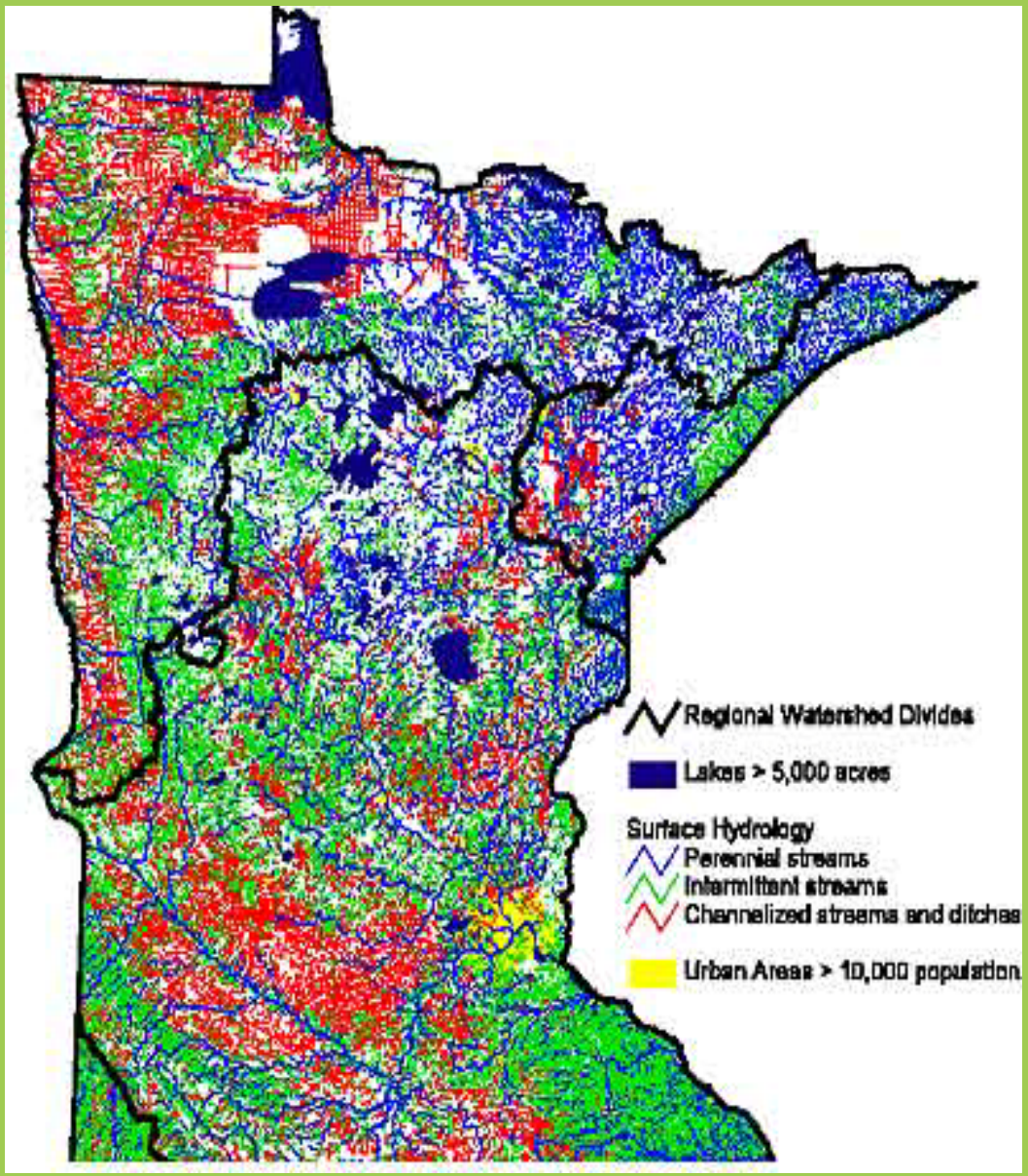
(DNR)

Blue = Perennial Streams

Green = Intermittent

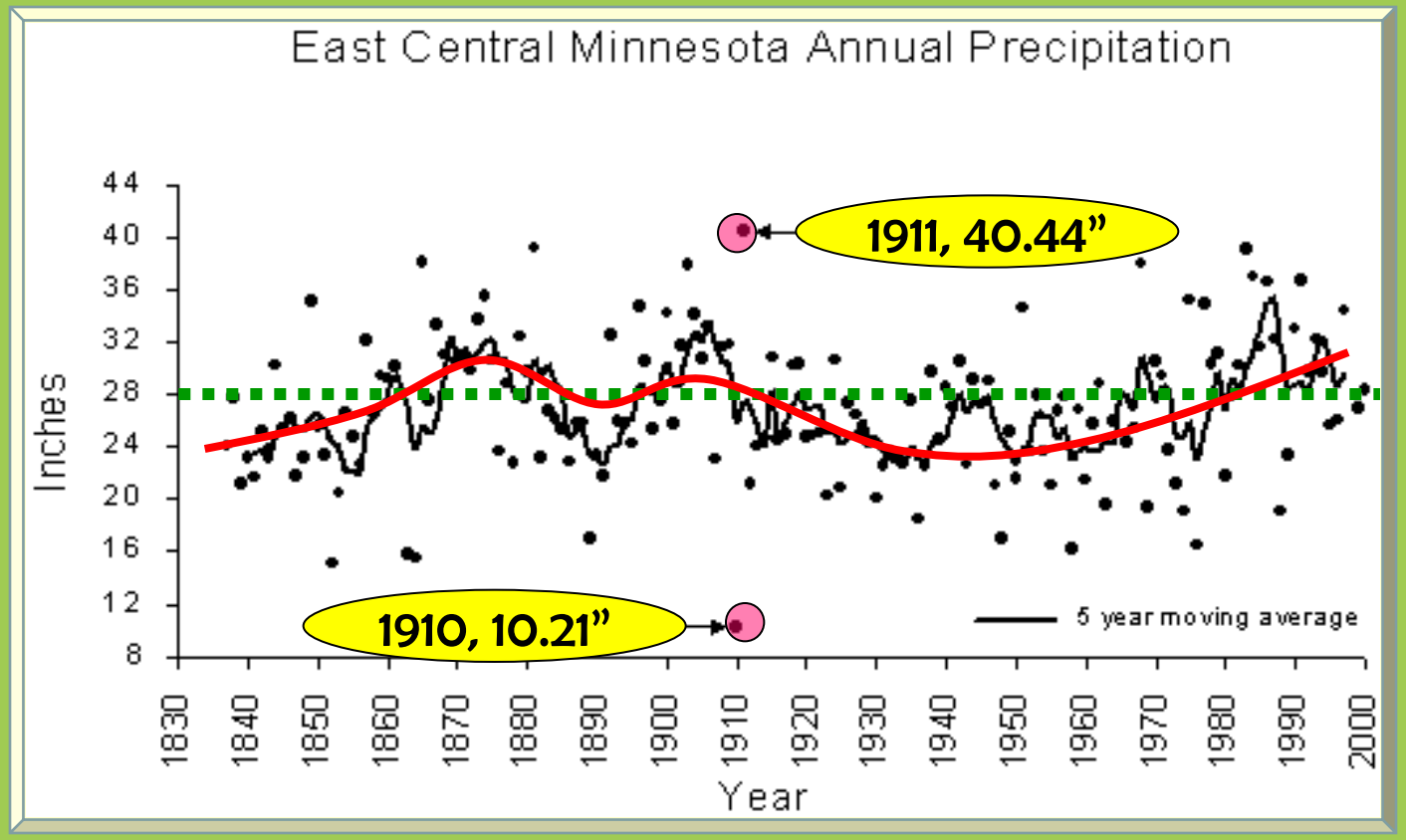
Red = Channelized Streams and Ditches

(Approx. 21,000 miles of public ditches)

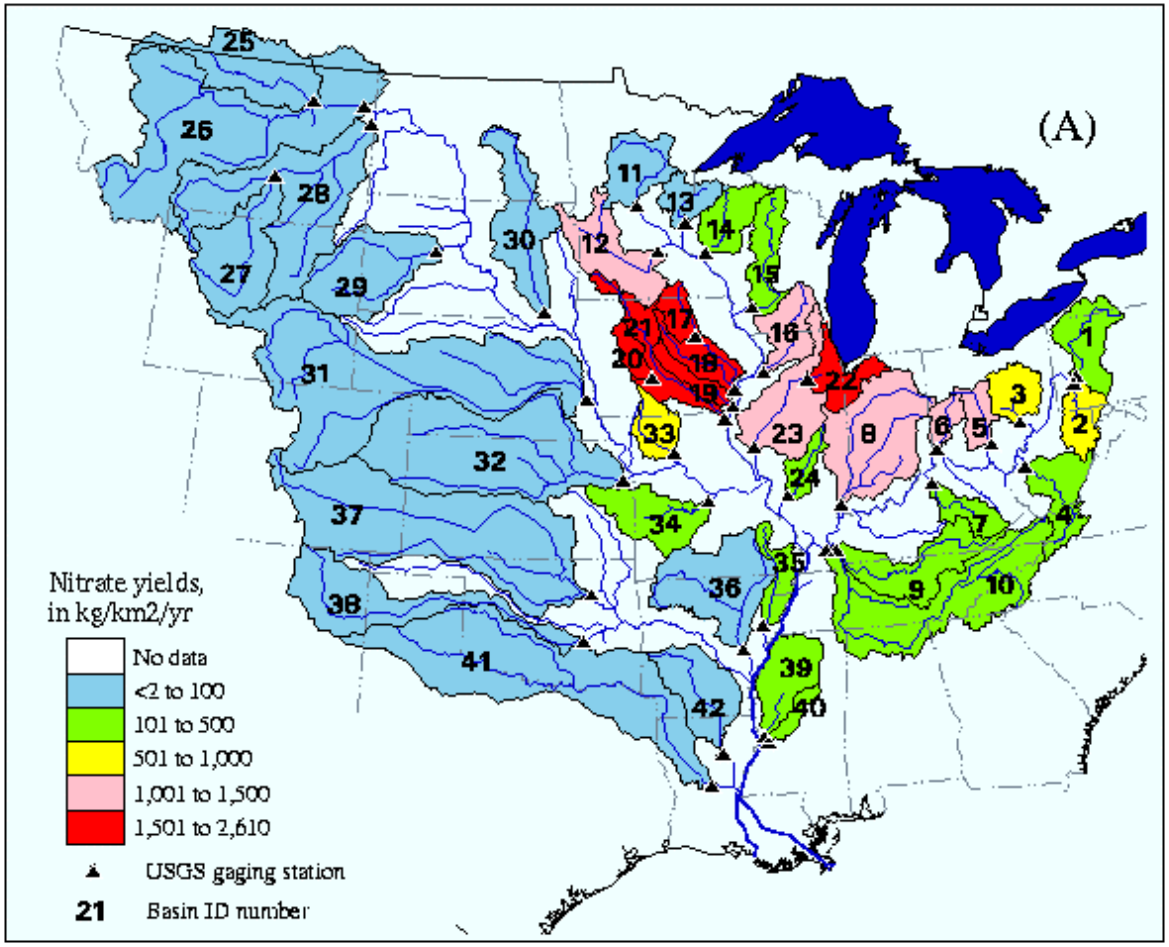


Precipitation Extremes and Trends

Extremes & Trends

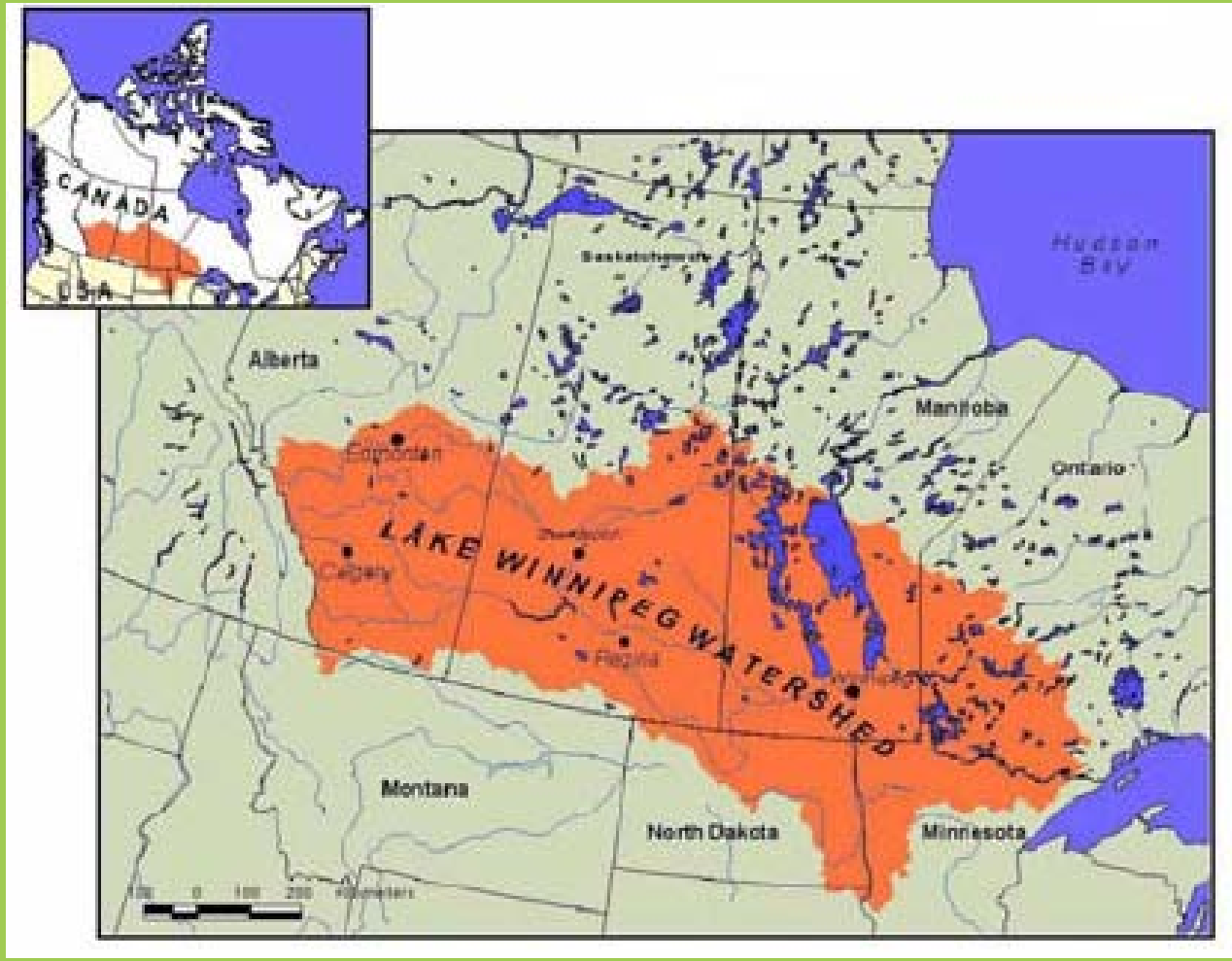


Gulf Hypoxia



Mississippi River Basin Nitrate Yields

Eutrophication in Lake Winnipeg



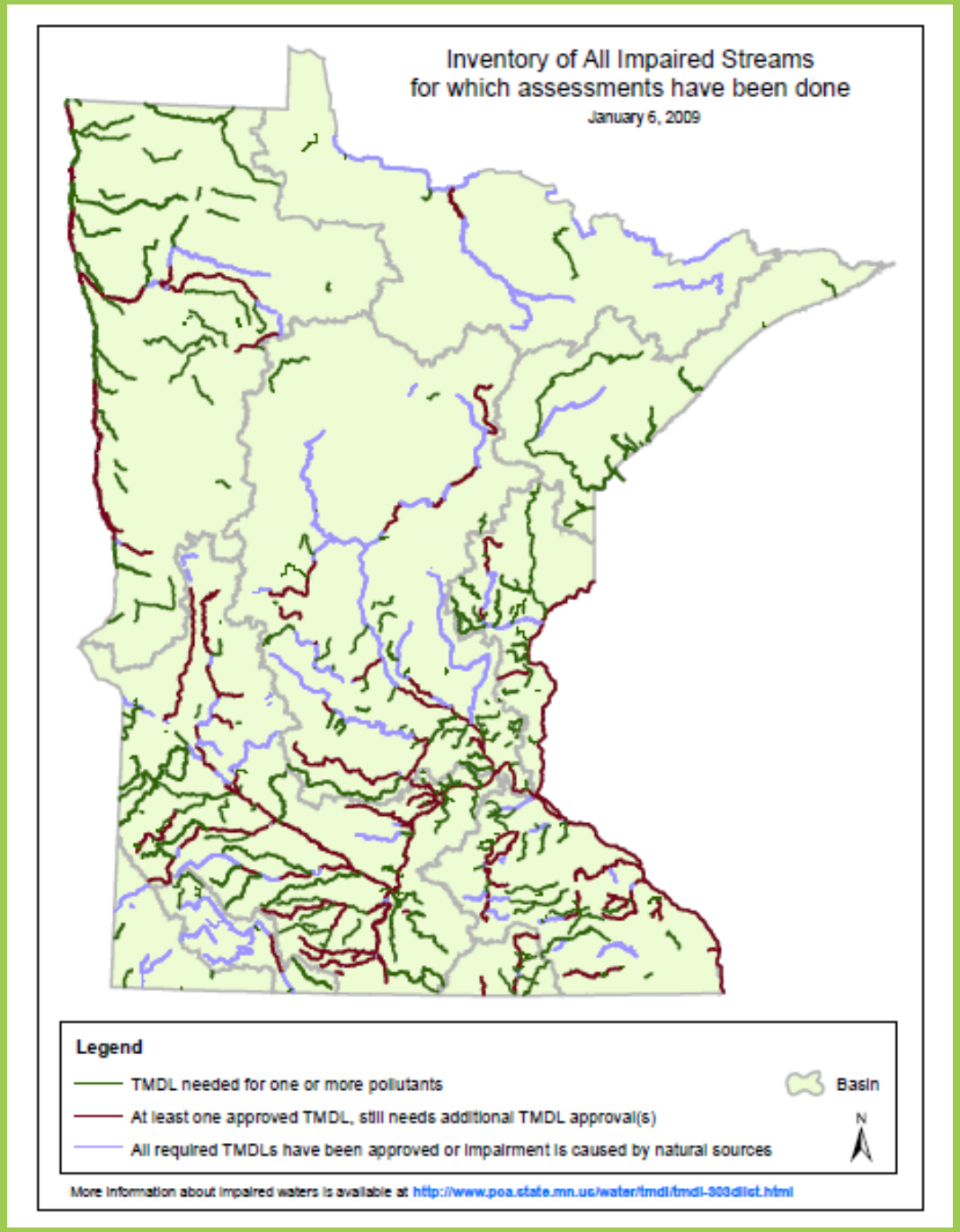
Red River Basin in MN and ND contributes about 30% of Phosphorus and 20% of Nitrogen

Minnesota Board of Water & Soil Resources

Impaired Waters January 2009

Rivers and Streams

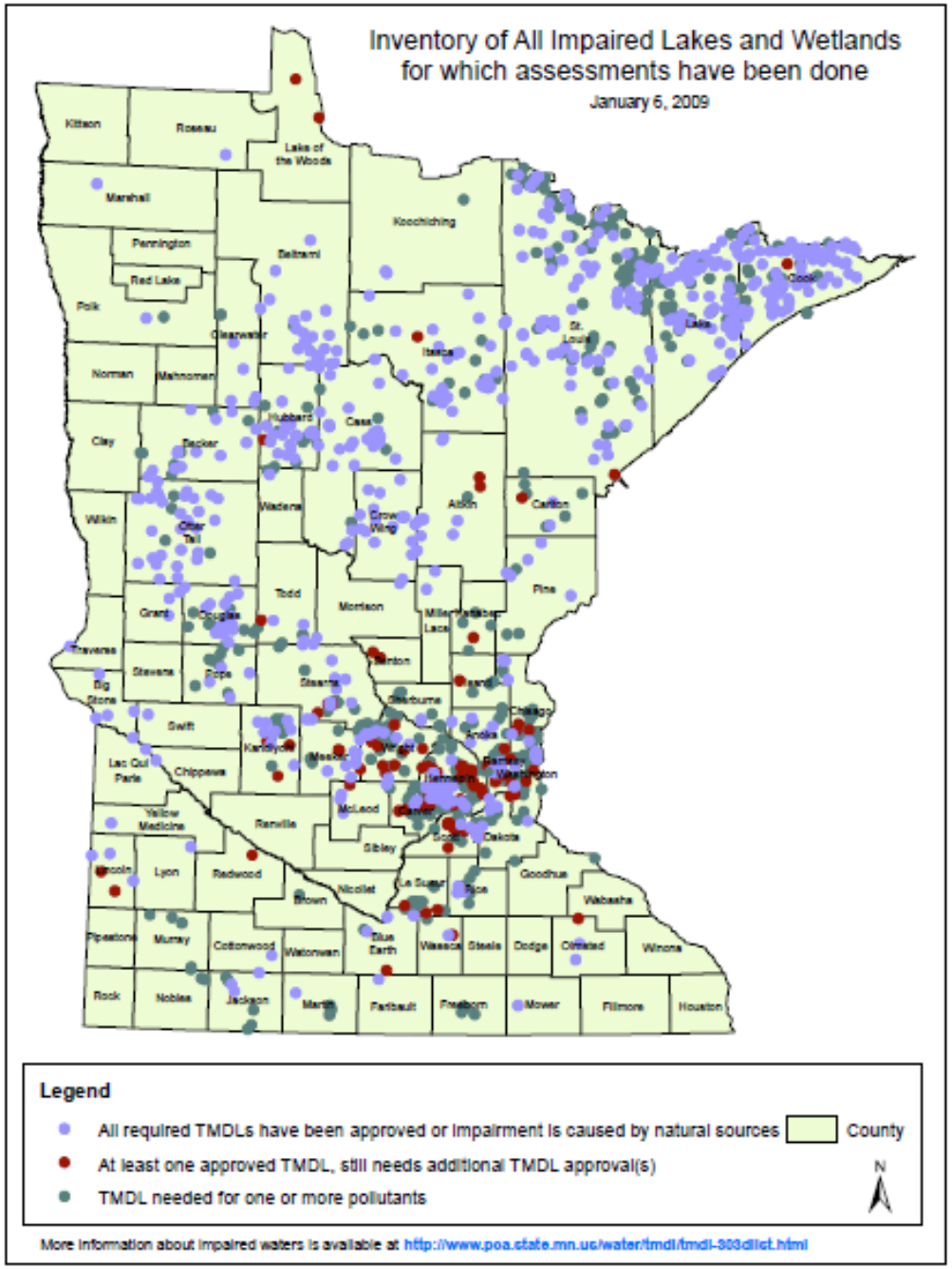
Includes some channelized streams and ditches



Minnesota Board of Water & Soil Resources

Impaired Waters January 2009

Lakes and Wetlands



Pollutants or Stressors Related to Drainage

- Turbidity (erosion & sediment)
- Dissolved Oxygen (erosion & sediment → phosphorus → algae)
- Nutrient / Eutrophication (erosion & sediment → phosphorus → algae)
- Nutrient / Eutrophication (nitrogen → nitrates → groundwater sources and Gulf Hypoxia)

Understandings About Sources of Sediment

Field Erosion

Ravines, Bluffs, Streambanks

% Sediment from non-field sources

Ravens Creek = 70%

Kasota Pond & integrator sites = 60-80%

Lake Pepin = 65%

Event TSS samples = >70%

Slide from Schottler, S (2009)

Fundamental Goals for Conservation Drainage Management

- Maintain agricultural drainage
  - Field trafficability for planting and harvesting
  - Prevent / reduce crop drowning and manage water for crop productivity
- Improve water quality (reduce erosion, pollutant concentration and carrying capacity)
- Reduce flood damages downstream
- Critical common aspect is **hydrology management** (rate, timing and volume of flow)

Conservation Drainage Practices

- Buffer Strips
- Culvert Sizing
- Side Inlet Controls
- Wetland Restorations
- Wood Chip Bioreactors (on tile systems)
- Drainage Water Management (on tile systems)
- 2-Stage Ditch
- Alternative Tile Inlets
- Treatment Wetland (off-channel and on-channel)

Drainage Ditch Buffer Strips

What are they?

- Strips of vegetation that filter stormwater runoff
- Small berms on the downstream side can be used to detain water temporarily

Applicability - Drainage Ditch Buffer Strips

- Usually considered as a pre-treatment BMP
- Treatment for small, frequent storms
- Cannot treat high-velocity flows

Benefits - Ditch Buffer Strips

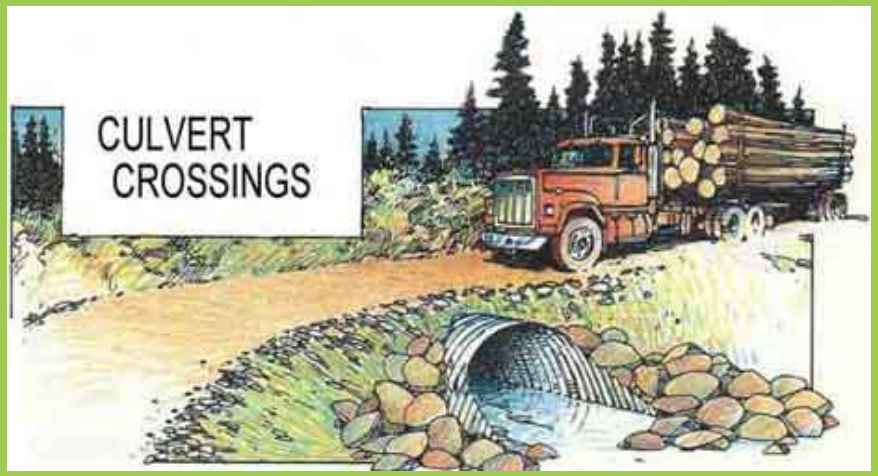
- Increase side slope stability
- 25 to 70% TSS removal for 18 to 50’ buffers
- ~10% TP removal
- ~30% T N

Additional Considerations - Ditch Buffer Strips

- Marginal effect during large events
- Slopes <6%
- Peak velocity less than 1 ft/s
- Desired residence time 9 min
- Mowing removes successional vegetation

Culvert Sizing

- **What is it?**
  - Design culverts at field access and road crossings by:
    - Systematically sizing culverts on a system (subwatershed) to reduce peak runoff rates
    - Retaining water 24-48 hrs

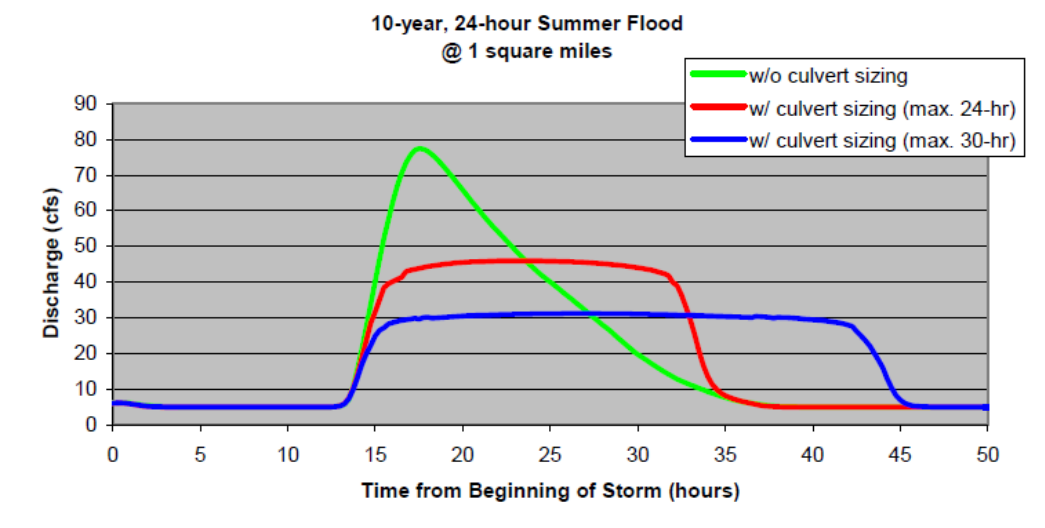


Culvert Sizing - Applicability

- Current designs tend to oversize culverts, especially for smaller drainage areas (< about 30 square miles)
- Many more small drainage areas than large, mainstem drainage areas
- Subwatershed design approach best
- Incremental design approach also addressed in preliminary guidelines

Benefits Culvert Sizing

- Increase short-term temporary storage
- Reduce peak flows
- Reduced velocities,
- Reduce ditch and streambank erosion,
- Reduce downstream flooding, particularly in upstream reaches.



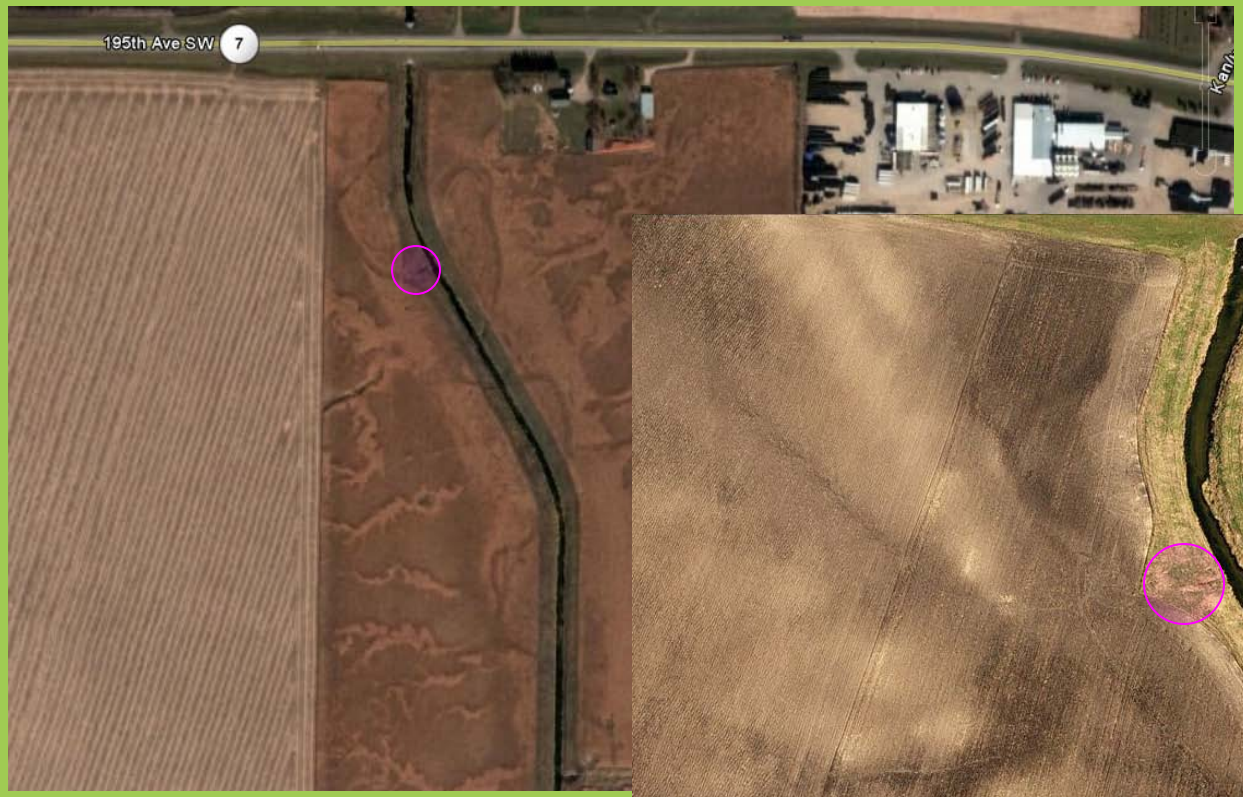
Culvert Sizing
Additional Considerations

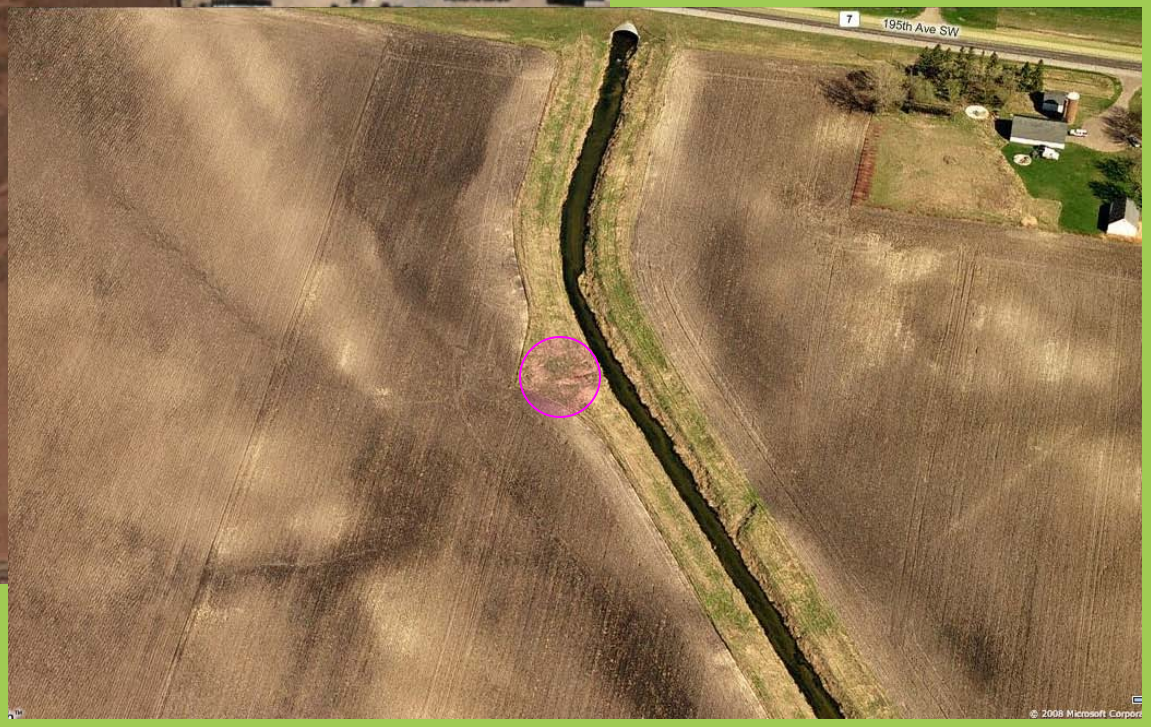
- Culvert Sizing focuses primarily on **removal rate** and **duration** (within 24 – 48 hours), similar to design approach for tile systems (fraction of an inch of runoff per day – drainage coefficient)
- Red River Basin TSAC, Technical Paper No. 15, **Culvert Sizing for Flood Damage Reduction, Phase 1, Preliminary Guidelines, October 2007** **http://www.rrwmb.org/files/FDRW/TP15.pdf**
- Road authorities often reluctant to install smaller culvert than existing (liability issue)
- Fish passage should be addressed

Side Inlets are Located Adjacent to Ditches

- Low points along ditches

Side Inlets Act as Tributaries





Side Inlets Contribute Water, Sediment, and Nutrients to Ditches

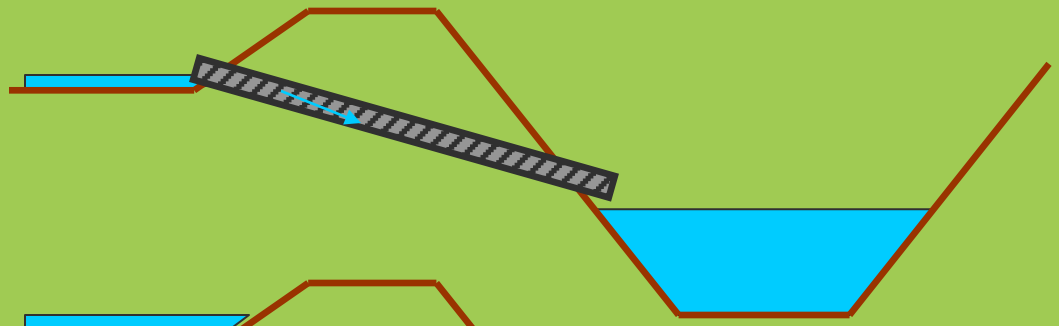
1. Sediment affects water quality, maintenance, nutrients
2. Additional flow contributes to downstream flooding and baseflow

Failures Lead to Increased Expenses to:

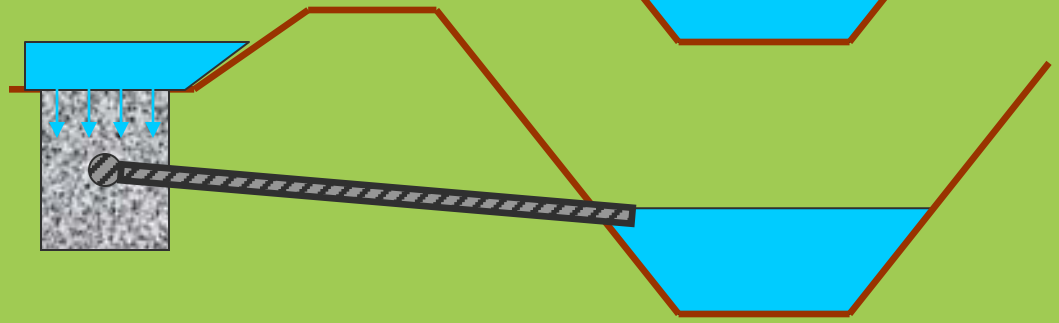
1. Ditch Authority – All being assessed
2. Landowner, potentially
3. Downstream Resources – TMDLs

Types of Side Inlets

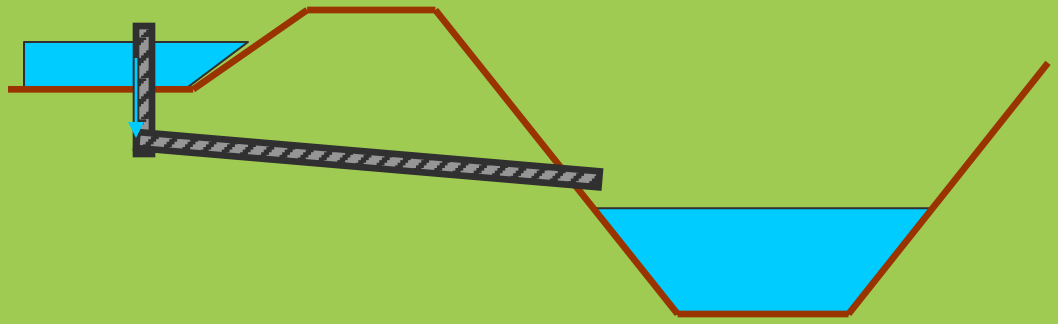
Typical



Rock Inlet

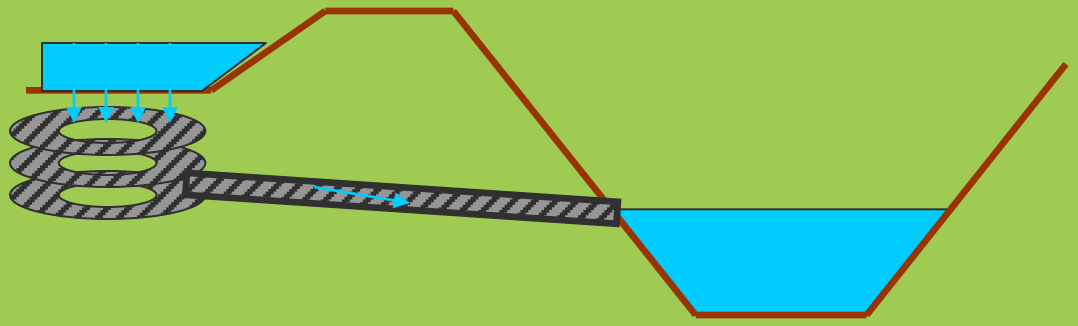


Drop Inlet
(Standpipe)

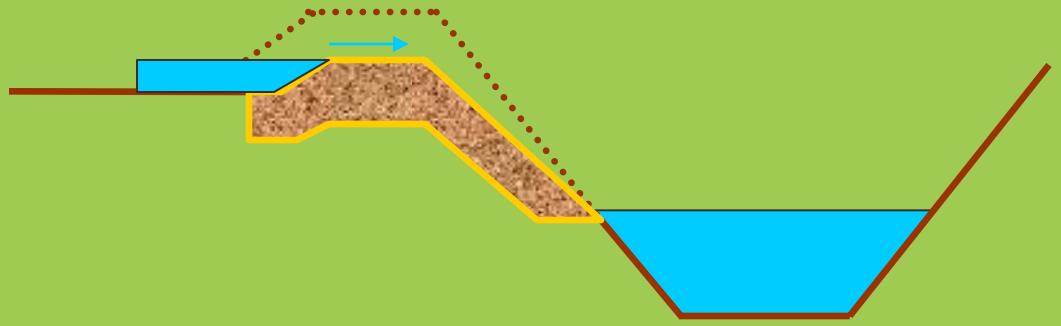


Types of Side Inlets…cont

Coil Tile Inlet



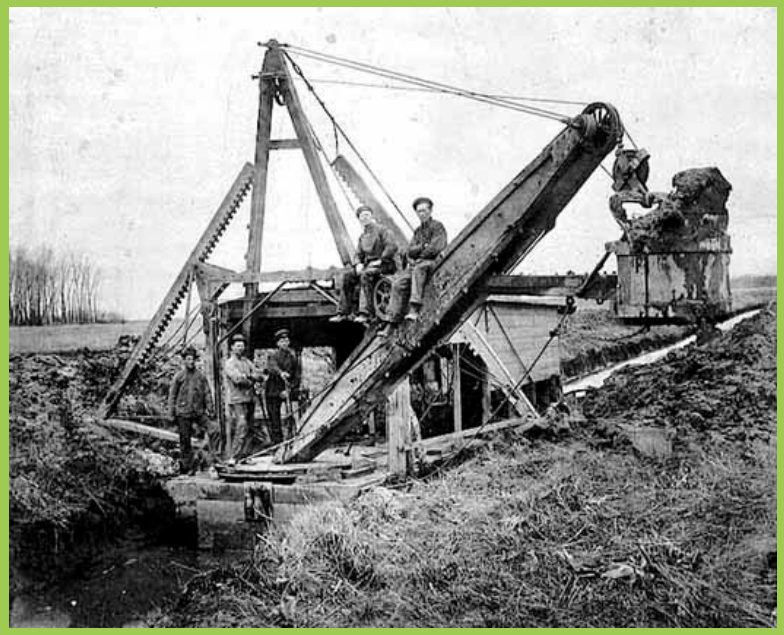
Rock Weir



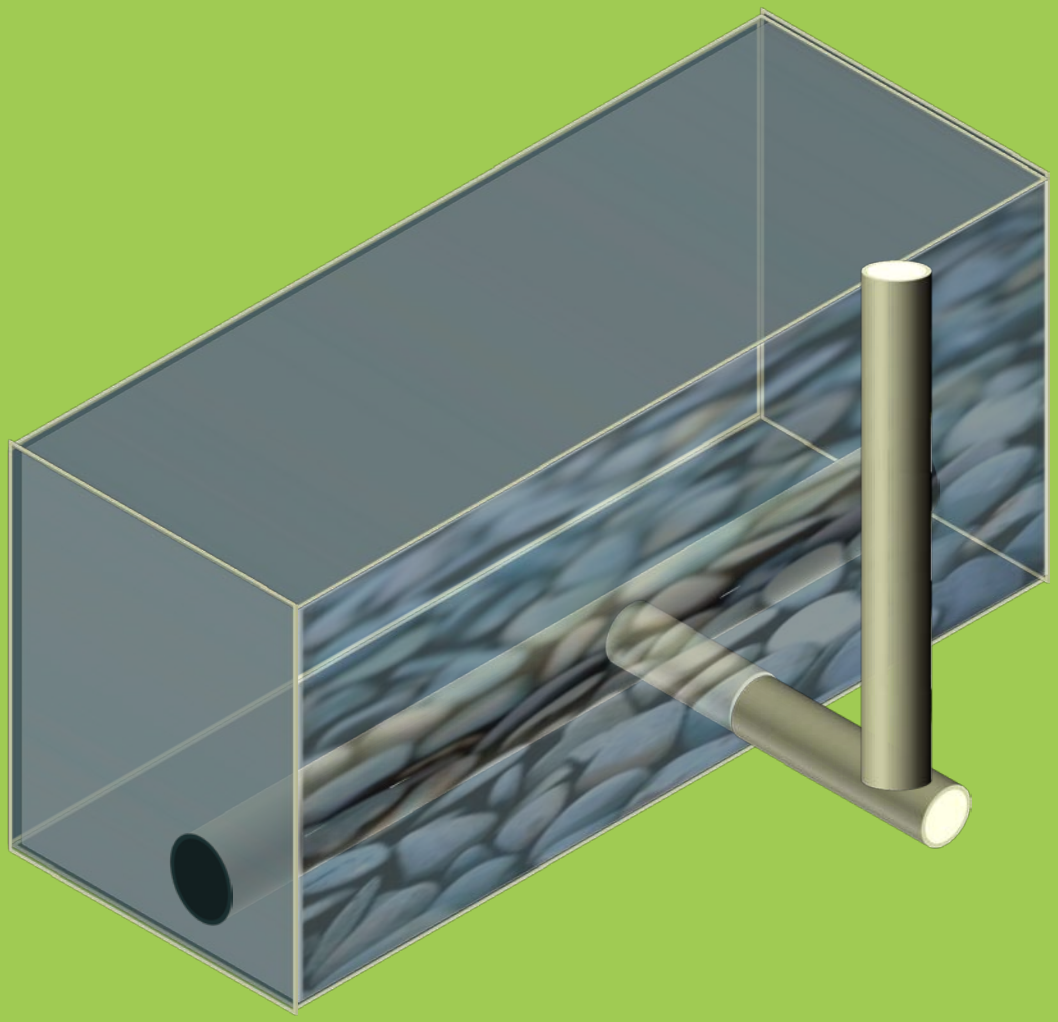
Side Inlet Controls Address:

1. Peak Flows – water temporarily stored on the land
2. Sediment Delivery – sediment allowed to settle
3. Nutrients – Reduced with sediment
4. Reduced stream erosion associated with flow reduction

…all while preserving productivity



Rock Inlet and Seepage Trench



Benefits of Side Inlet Controls

- Erosion control at side inlet location
- Create short-term ponding at multiple locations along drainage ditches for:

  1) sediment and phosphorus trapping

  2) reduced peak flows and velocities in the drainage system and downstream
- BWSR received EPA 319 grant to study importance of side inlets and develop better designs

Side Inlet Controls, Additional Considerations

- 103E.021, Subd. 6 added in 2008 – Drainage authorities can install buffer strips and side inlet controls where needed using repair funds
- Federal EQIP and State Cost-Share Program can provide financial and technical assistance (Practice Std. 410 Grade Stabilization Structure)

Wetland Restoration

- In drained wetlands
- Used tile breaks/plugs for hydrology

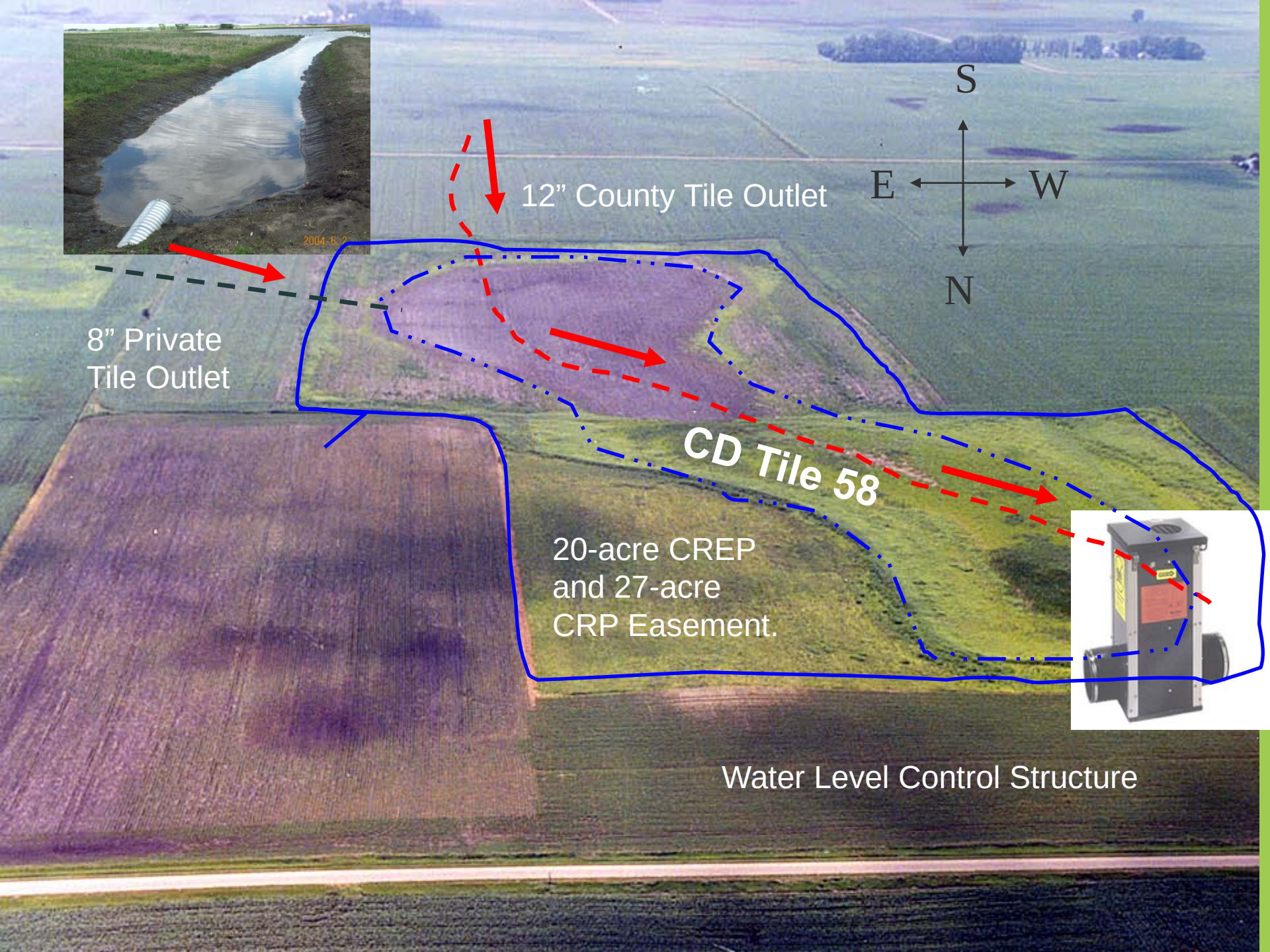
Nicollet County Site 3 Wetland Restoration

BEFORE

AFTER

Seven Mile Creek Watershed Project

Brown Nicollet Cottonwood Water Quality Board

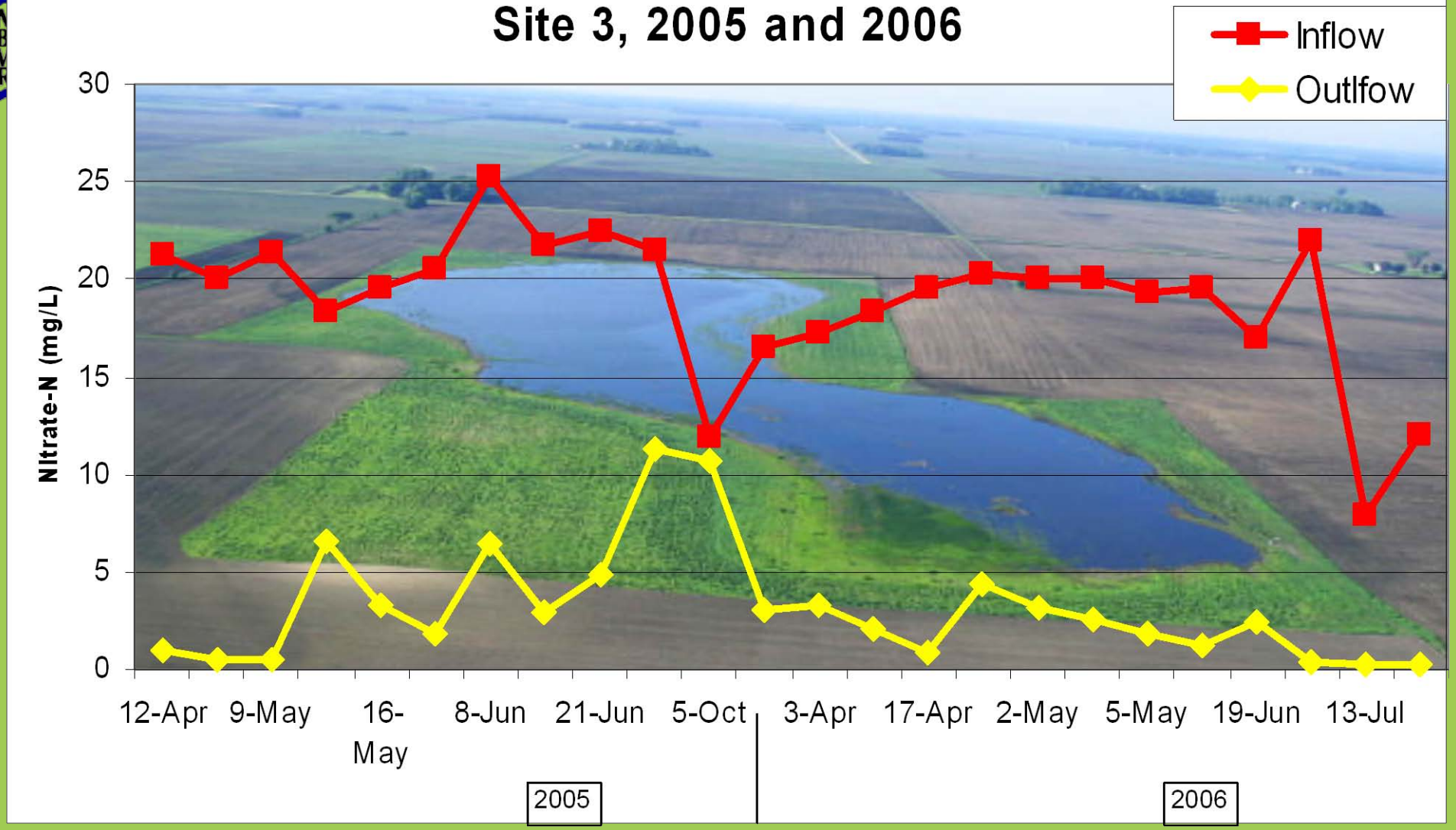

S
E
W
N
12” County Tile Outlet
8” Private
Tile Outlet
CD Tile 58
20-acre CREP
and 27-acre
CRP Easement.
Water Level Control Structure

Wetland Restoration Benefits

- Peak flow reduction
- Nitrate removal
- TSS removal
- Habitat

Nitrate Treatment Effectiveness

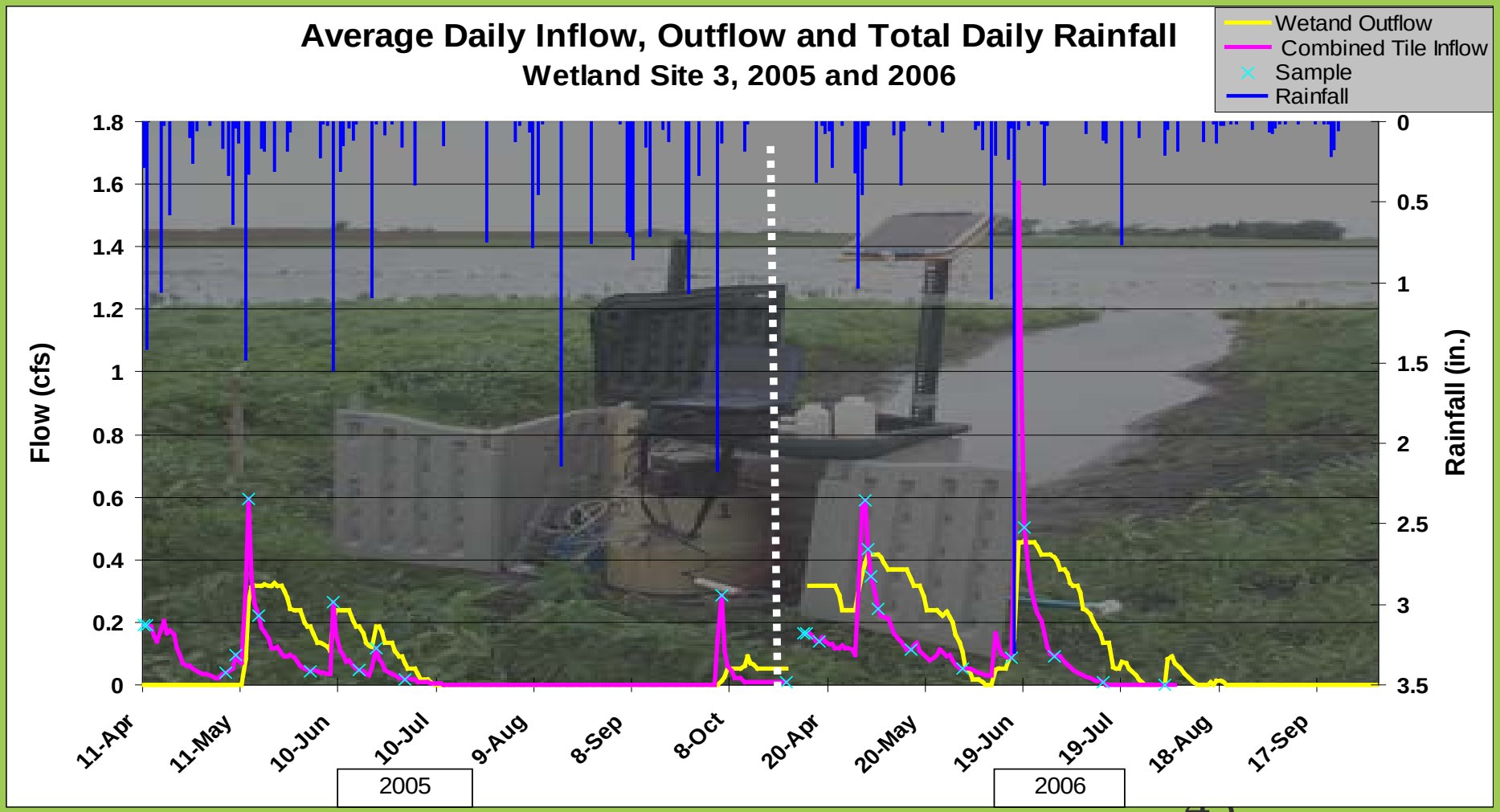
Site 3, 2005 and 2006



82% Average Reduction

19.6mg/l ⟶ 3.6 mg/l

Nicollet County Wetland Site 3 Hydrologic Effects

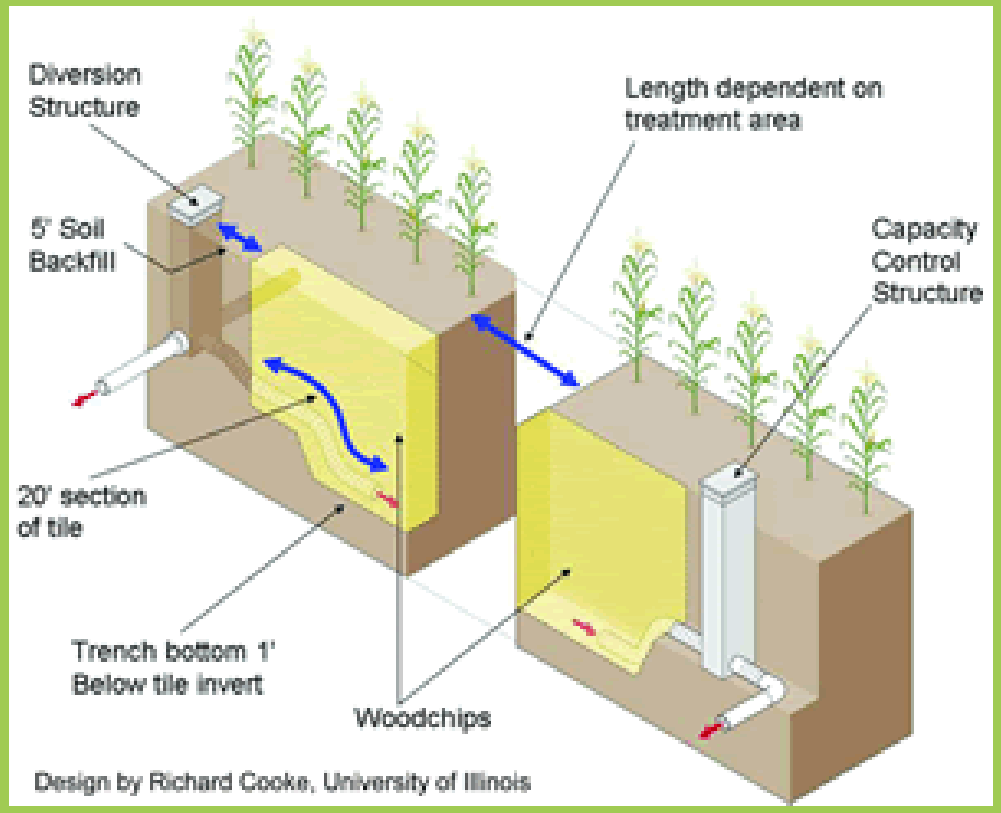


Wetland Restoration – Other Considerations

- Impacts to roads, drainage infrastructure
- Soil P levels may result in short-term net increase

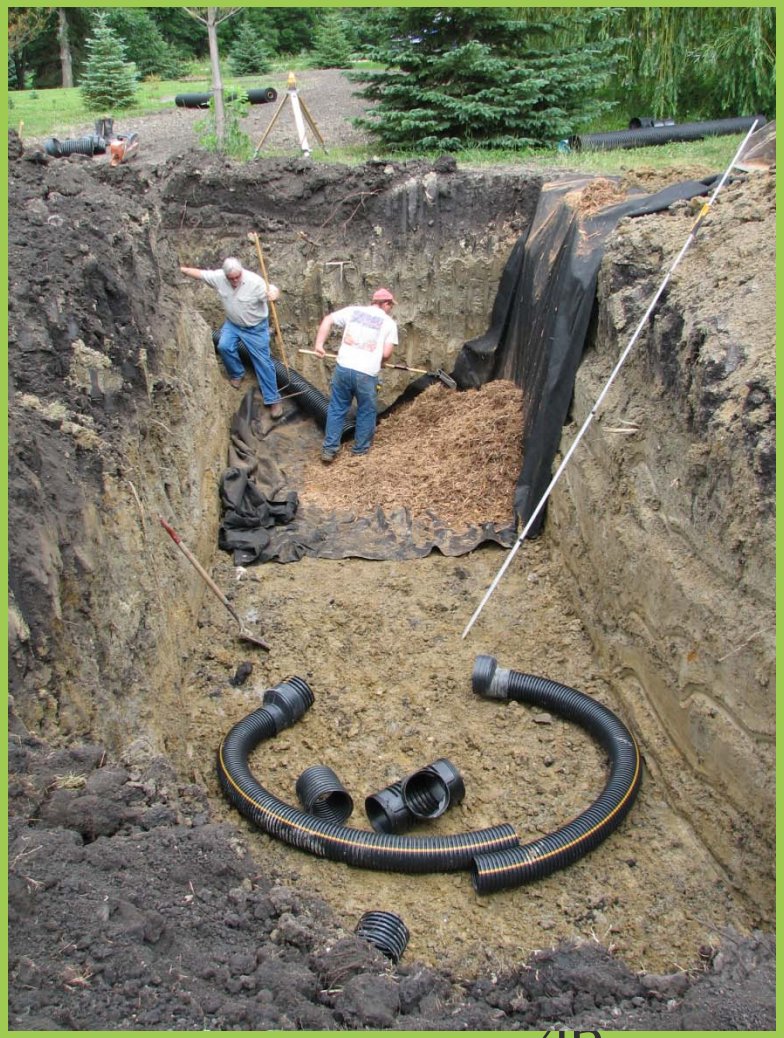
Bioreactors in Tile Systems

- **What is it?**
  - Tile water is fed through a bed of wood chips
  - Microbes use wood chips as a carbon sources, reduce nitrate



Tile System Wood Chip Bioreactor

- Applicability
  - Drainage areas > 10 acres
  - Avoid areas of heavy traffic
  - Woodchips should be saturated



Tile System Wood Chip Bioreactor

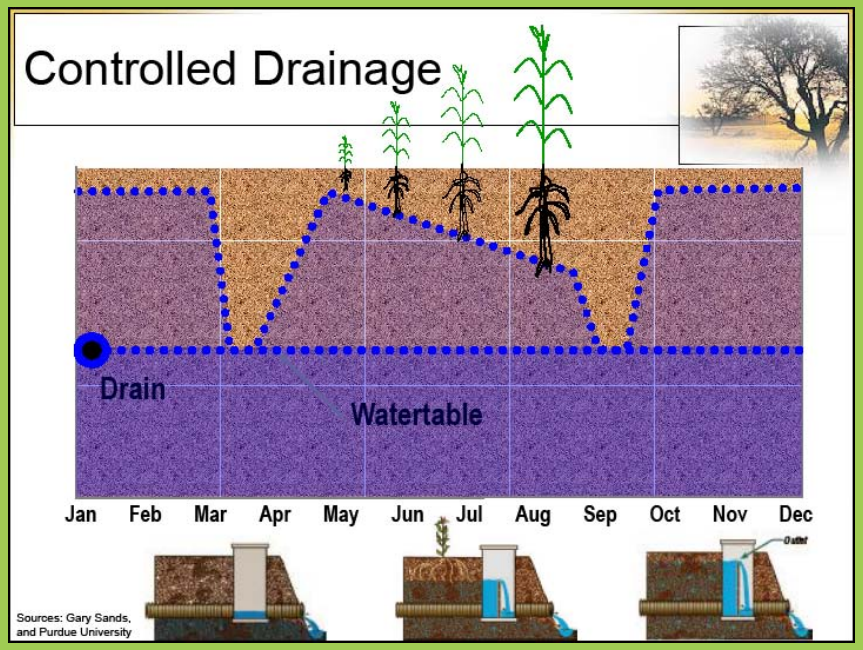
- Benefits
  - Nitrate removal, 40 – 50%
  - TSS removal, ~70%
  - Tot P removal, 20 – 50%
  - Ortho P removal, 25 – 55%

(Moncrief et al., 2009)

Wood Chip Bioreactor – Additional Considerations

- 15-20 year life
- May produce nitrous oxide (greenhouse gas)
- Residence time should be > 10 hrs

Drainage Water Management



- What is it?
  - Permit farmers to control and adjust water levels
  - Use control structures
  - Research dates back to the 1920's in MN

Drainage Water Management - Applicability

- Works best for land slope < 0.5% (up to 1%)
- Minimize number of control structures by installing tile on the contour
- Agricultural Drainage Mgmt. Coalition (ADMC) and MN Dept. of Ag leading 4 demos in MN
- UMN leading research demo at farm near Southwest Research and Outreach Center

Drainage Water Management Tile on the Contour

- Benefits
  - Reduced water outflow (amount depends on moisture conditions)
  - Reduced nitrate loss
  - Increased yield?

Photo Courtesy L. Binstock, ADMC

Two-Stage Ditch, What is it?

- A constructed ditch that seeks to mimic the function of natural channels

Maintenance Issues

- >21K miles in Mn
- Blue Earth County
  - $650K in 2005
  - $1.2M in 2006
- Ohio
  - $450/mi/yr

Important Features

Benefits of 2-Stage Ditches

- Reduce maintenance via improved ditch bank stability and sediment transport
- Can provide riffle and pool aquatic habitat in low flow channel
- Increased habitat on vegetated benches
- Increased in-channel temporary storage, if culverts at roadways control peak flows
- Remove nitrogen via plant uptake

A recently completed example

- U of MN
- Nature Conservancy
- Mower SWCD
- BWSR
- MPCA

Construction of the Ditch

Construction of the Ditch

Construction of the Ditch

Construction of the Ditch

Construction of the Ditch

Construction of the Ditch

Two Stage Ditch – Additional Considerations

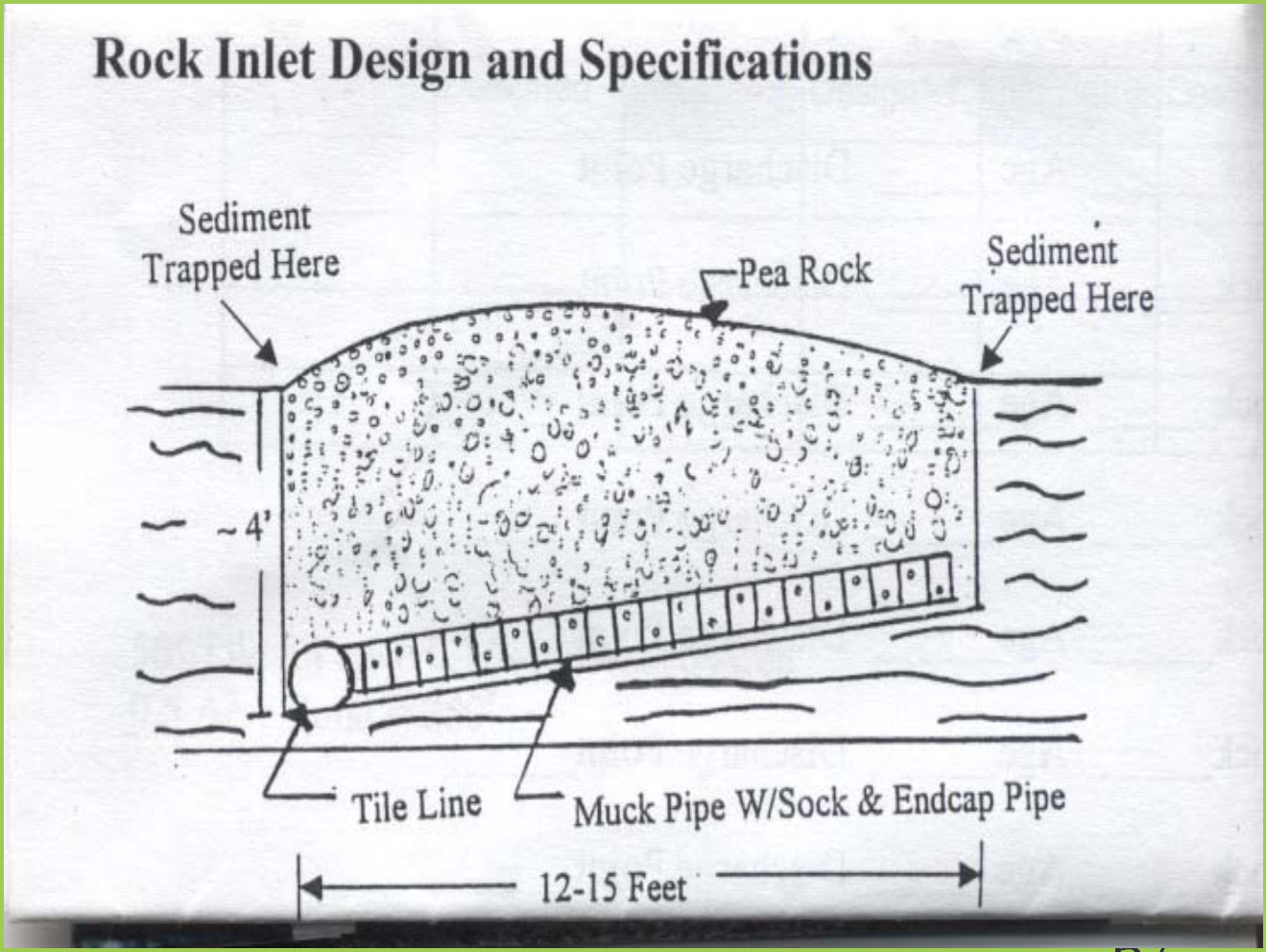
- Construction cost
- Additional land requirements
- Change in conveyance..Improvement
- More info at: http://streams.osu.edu/naturalchannel.php
- Nature Conservancy video of 2-stage in IN at http://www.vimeo.com/7825713

Tile Inlets – Alternatives to Open Surface Inlets

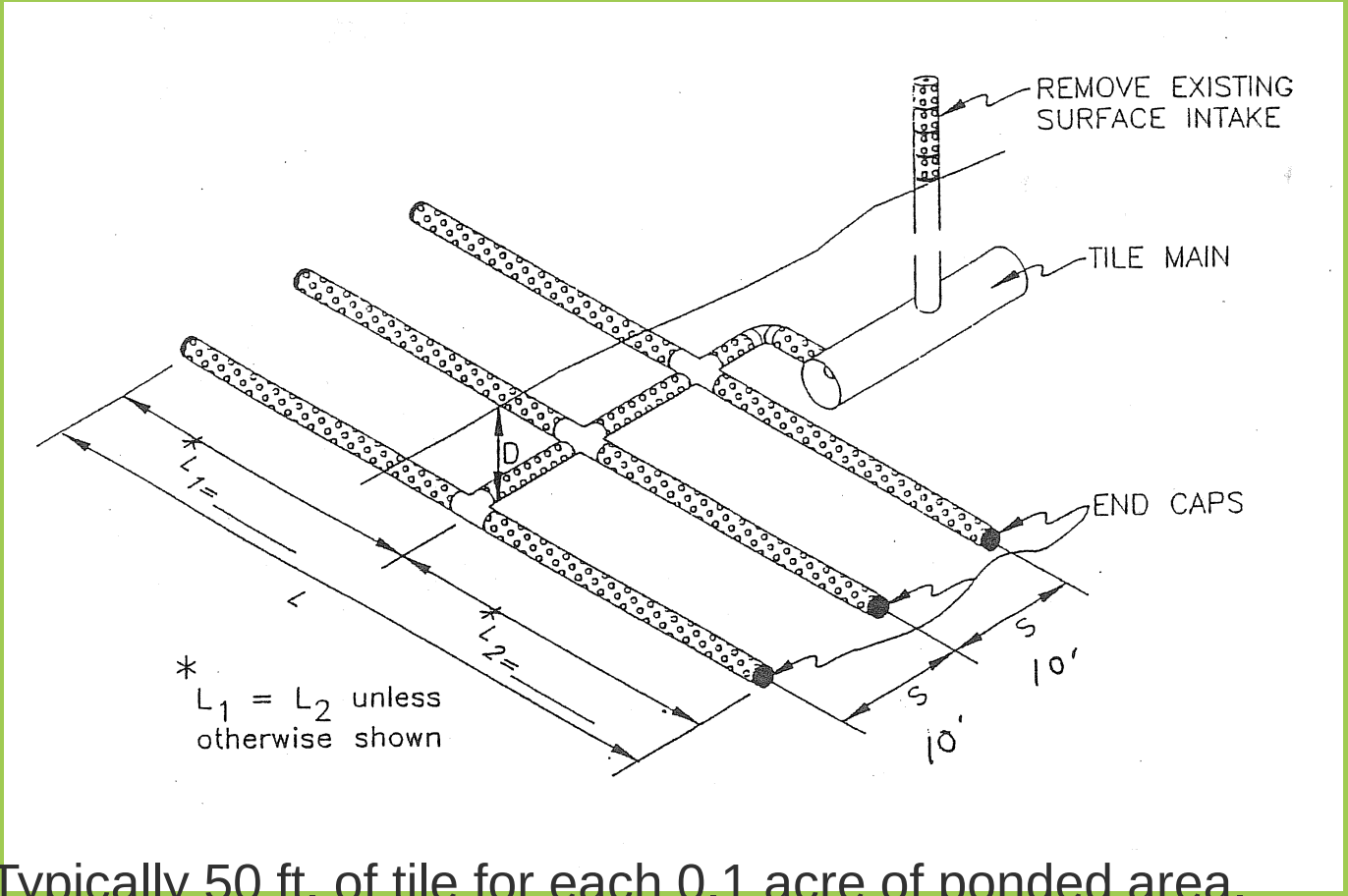
Hickenbottom Perforated Riser

Gravel Tile Inlet

Gravel Tile Inlet Design



Dense Pattern Tile to Replace Surface Intake



Typically 50 ft. of tile for each 0.1 acre of ponded area.

Alternative tile intakes

- Benefits
  - Sediment trapping: 70 – 95% (Wilson et al., 1999)
  - Associated P removal
  - Potentially reduce peak flows leaving system
- Other Considerations
  - Plugging/lifespan

Surge Pond Demonstration Goals

- Initiated by MDA
- Reduce peak flows
- Reduce sediment and nutrient loads downstream
- Evaluate / develop cropland watershed to basin area ratio
- Evaluate effectiveness

Surge Pond Demonstration
Mower County, Site 1

Photo Courtesy M. Dittrich, MDA

Surge Pond Demonstration
Mower County, Site 2

BWSR Conservation Drainage

- $200k in FY 10 and $330k in FY 11
  - Implement conservation drainage pilot projects
  - On existing drainage systems
  - Priority given to sediment/phosphorus
- $130k in FY10 used for match in EPA 319 grant to investigate:
  - Persistence of side inlets
  - Effect of side inlets on water q/q
  - Develop design guidance
    - Mower SWCD, Hawk Creek Watershed, BNCWQB, Sand Hill River WD

Summary

- Agriculture important to MNs economy
- Agriculture benefits from drainage
- Many practices that work in drained, agricultural landscape to improve quality/quantity issues
- BWSR working to develop guidance, knowledge and mechanism for implementation

Minnesota Board of Water & Soil Resources

Questions?

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