Managing Agricultural Drainage Systems
For Water Quality Improvements in the Midwest

Brown, Fausey et al.

USDA ARS

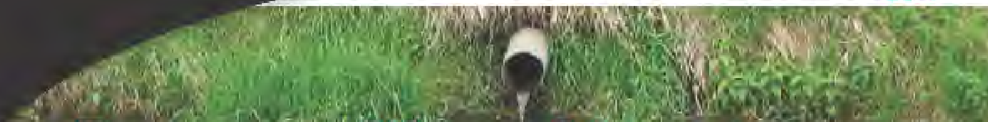
THE OHIO STATE UNIVERSITY

2012 Overholt Drainage School

March 19-23
Paulding County, Ohio

- Laser Surveying/Topographic Mapping
- GPS-RTK Surveying/Topographc Mapping
- Subsurface Drainage: Design, Layout and Installation; Benefits and Impacts
- Drainage Water Management **(*Controlled Drainage*)** Design, Layout, Construction, and Management

WQ-44



Drainage Water Management

for the Midwest

Questions and Answers About Drainage Water Management for the Midwest

Jane Frankenberger, Eileen Kladivko, Gary Sands, Dan Jaynes, Norm Fausey, Matt Helmers, Richard Cooke, Jeff Strock, Kelly Nelson, Larry Brown

Purdue University
University of Minnesota
Iowa State University
University of Missouri
University of Illinois
The Ohio State University
USDA-Agricultural Research Service

Introduction

Subsurface tile drainage is an essential water management practice on many highly productive fields in the Midwest. However, nitrate carried in drainage water can lead to local water quality problems and contribute to hypoxia in the Gulf of Mexico, so strategies are needed to reduce the nitrate loads while maintaining adequate drainage for crop production. Practices that can reduce nitrate loads on tile-drained soils include growing winter forage or cover crops, fine-tuning fertilizer application rates and timing, bioreactors, treatment wetlands, and modifying drainage system design and operation. Drainage water management is one of these practices and is described in this fact sheet. Answers given here apply specifically to Midwest corn and soybean cropping systems, and not to perennial or winter annual crops.

1. What is drainage water management?

Drainage water management is the practice of using a water control structure in a main, submain, or lateral drain to vary the depth of the drainage outlet. The water table must rise above the outlet depth for drainage to occur, as illustrated at right. The outlet depth, as determined by the control structure, is:

- Raised after harvest to limit drainage outflow and reduce the delivery of nitrate to ditches and streams during the off-season. (Figure 1)
- Lowered in early spring and again in the fall so the drain can flow freely before field operations such as planting or harvest. (Figure 2)
- Raised again after planting and spring field operations to create a potential to store water for the crop to use in midsummer. (Figure 3)

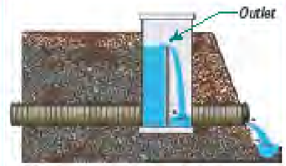


Figure 1. The outlet is raised after harvest to reduce nitrate delivery.

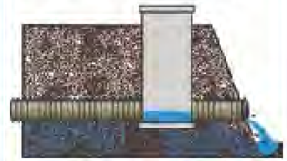


Figure 2. The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.

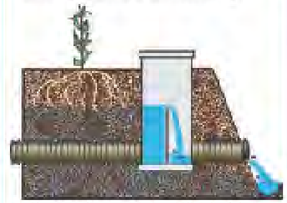
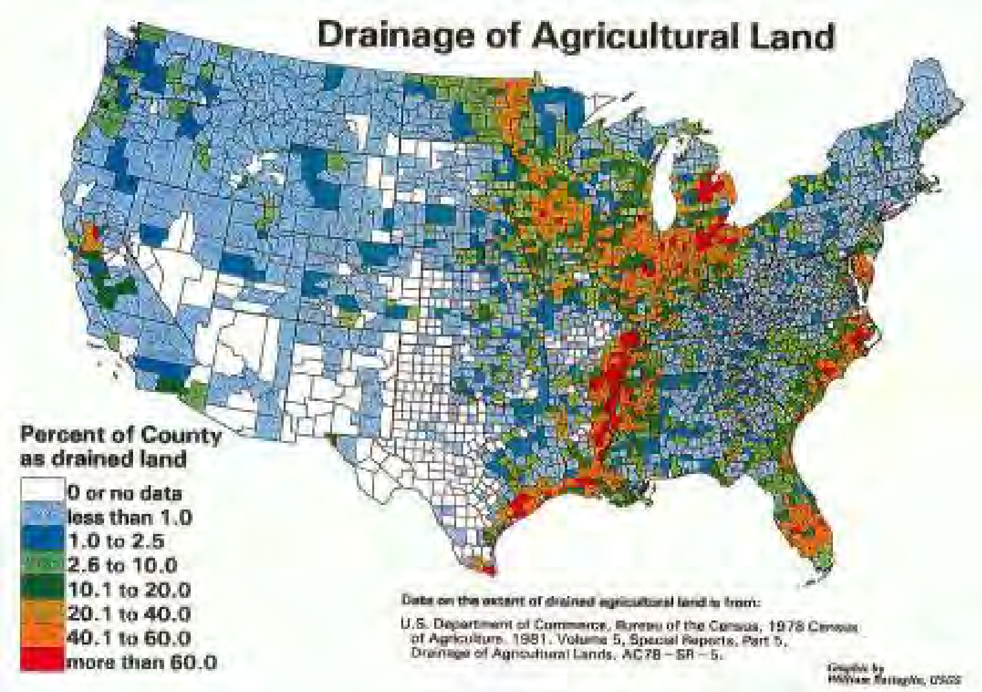


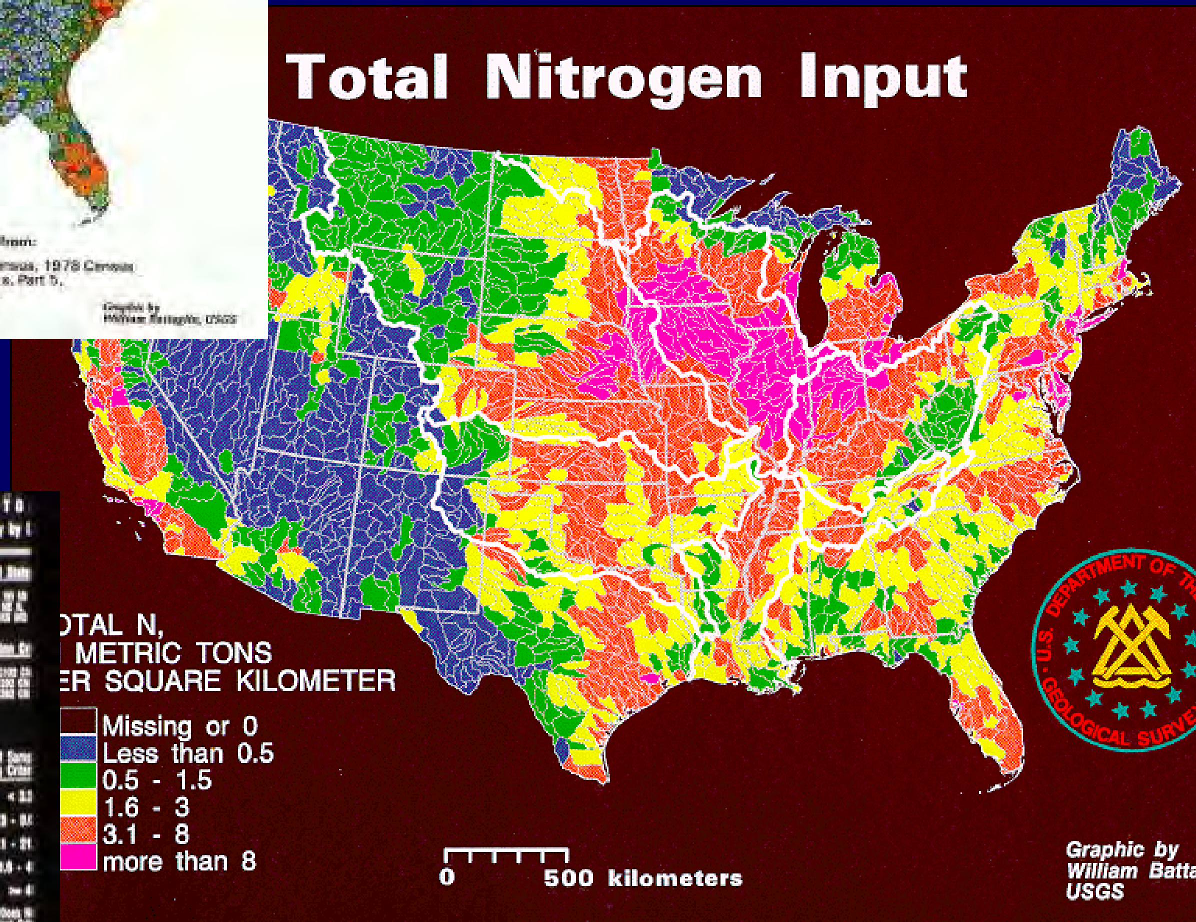
Figure 3. The outlet is raised after planting to potentially store water for crops.

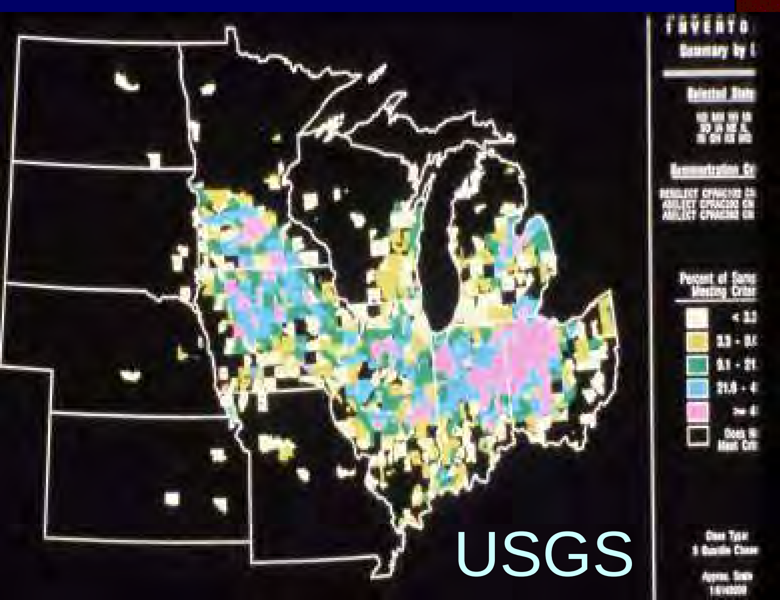
Purdue Extension
Knowledge to Go
1-888-EXT-INFO

Available after Presentation – see me or email brown.59@osu.edu

http://www.ces.purdue.edu/extmedia/WQ/WQ-44.pdf


Drainage of Agricultural Land
Percent of County as drained land
0 or no data
less than 1.0
1.0 to 2.5
2.6 to 10.0
10.1 to 20.0
20.1 to 40.0
40.1 to 60.0
more than 60.0
Data on the extent of drained agricultural land is from:
U.S. Department of Commerce, Bureau of the Census, 1978 Census of Agriculture, 1981. Volume 5, Special Reports, Part 5, Drainage of Agricultural Lands. AC78 – SR – 5.


Total Nitrogen Input
OTAL N,
METRIC TONS
ER SQUARE KILOMETER
Missing or 0
Less than 0.5
0.5 - 1.5
1.6 - 3
3.1 - 8
more than 8
0
500 kilometers
Graphic by
William Batta
USGS


USGS

Source areas of N to Gulf of Mexico and Great Lakes

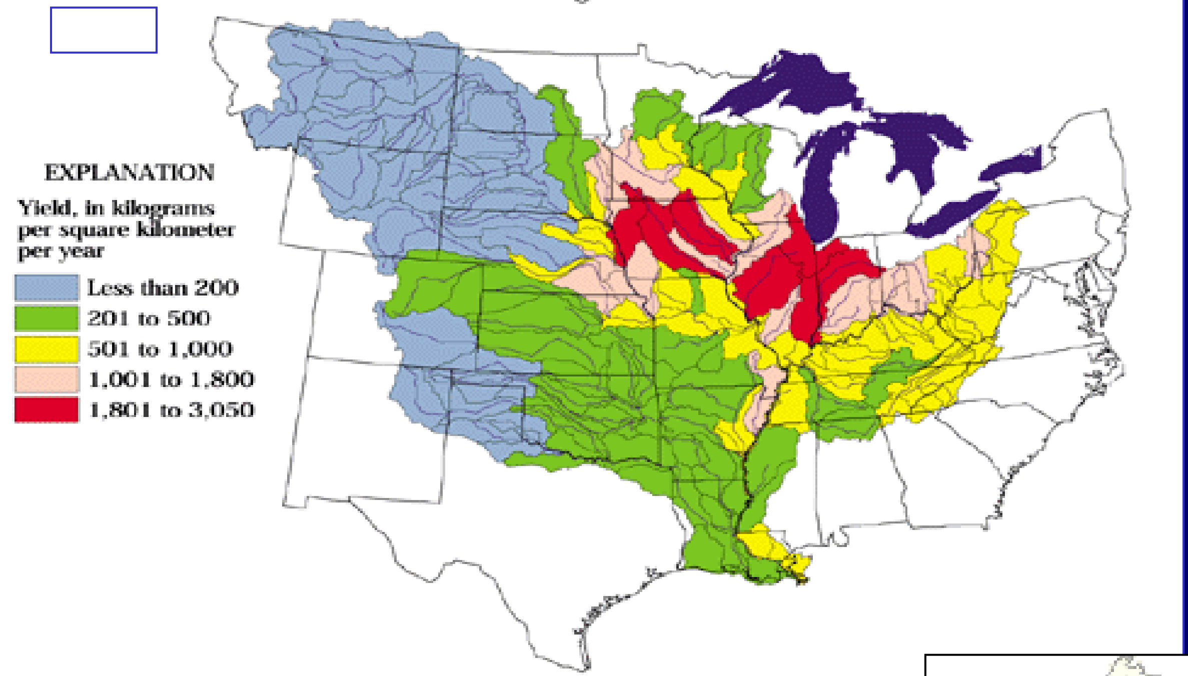
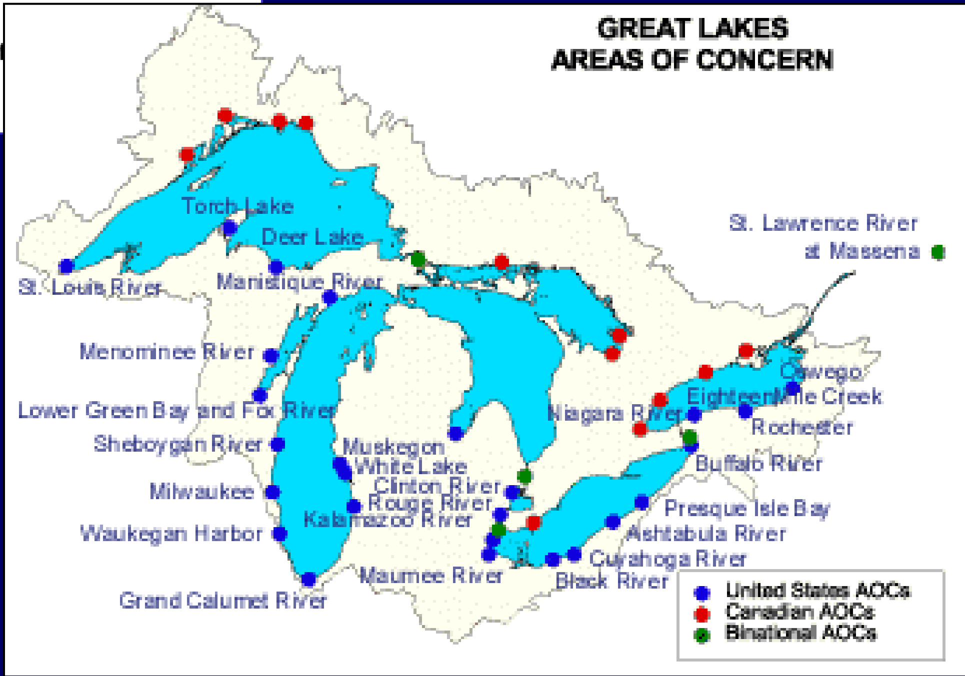


Figure 6. *(A)* **Nitrogen inputs during 1992 and** *(B)* **average annual nitrogen yields of streams for 1980–96 (modified from Goolsby and others, 1999).**



Midwest Agricultural Drainage Systems Management Initiative

- Primarily focused on agricultural subsurface drainage and nitrate-nitrogen loading to surface waters (and now soluble phosphorus)
- Practices include:
  - Controlled drainage (Drainage Water Management)
  - Shallower drains spaced closer together
  - Biofilter drains, Bioreactors, Constructed wetlands, others

http://www.ag.ohio-state.edu/~usdasdru/ADMS/ADMSindex.htm

http://www.admcoalition.com/

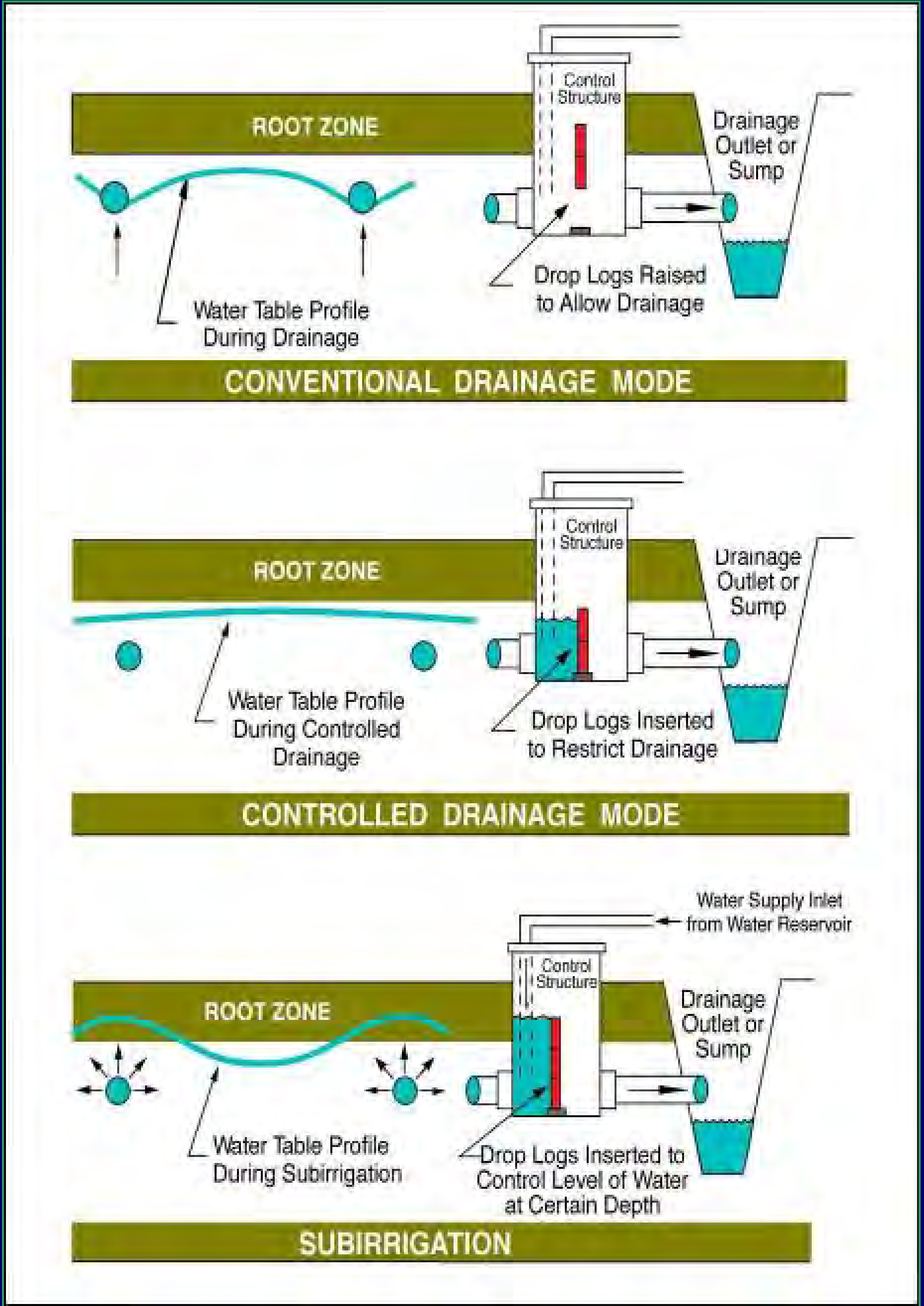
USDA-NRCS Practice Standard 554

Drainage Water Management

(available on NRCS Website)

- National Standard
- Primary focus has been Midwest
- Ohio manure standard addresses drainage water management
- Ohio 554 practice is EQIP practice for buffers in CREP watersheds, Scioto River Basin, Lake Erie Basin, others
- Couples with **Practice Standard 587 Structure for Water Control**

Water Table Management



- Conventional Drainage
- Controlled Drainage
- Subirrigation

Drainage Water Management Implementation in Ohio

- Controlled drainage – been around long time (1950s) – water management for organic soils
- A few cooperators began implementing controlled drainage for water quality and water conservation in early 1990s – slow growth of practice acceptance
- Questions on economic impact, false impression that we want to plug drains
- Current projects to help document economic impact, water quality impacts, operation and management approach, impact on upland areas of zones that are not within the effected area in zone

On appropriate landscapes, we expect up to a 50% reduction in Annual Nitrate Loads, on average, by Managing Agricultural Drainage Systems on appropriate sites in Ohio

"Change in Outflow Volume"
Minimal change in Concentration

Focus on crop yields, economics, soil-water, and nitrate-nitrogen and soluble phosphorus fate, DM-NII Modeling, etc.

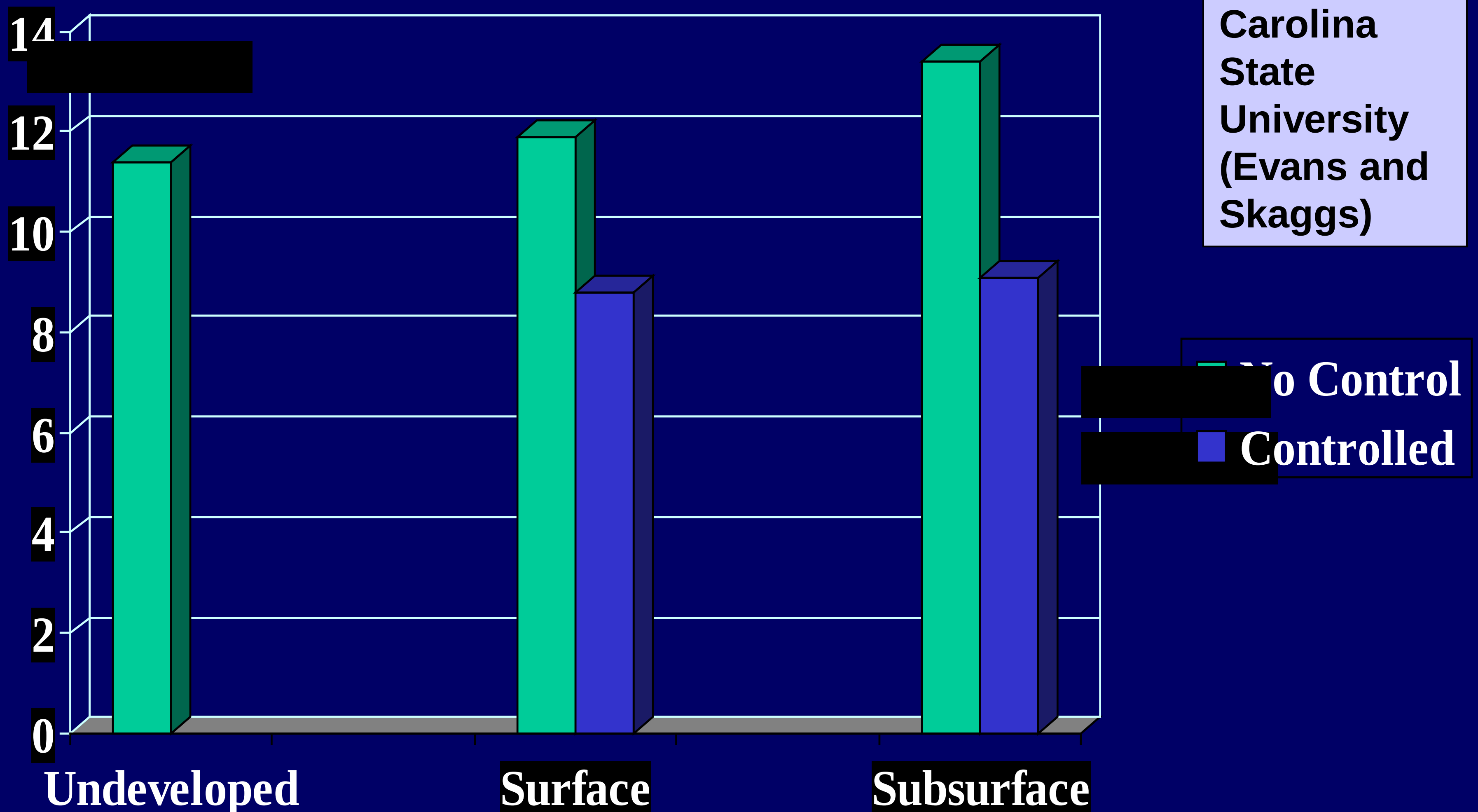
Open Drainage Ditches in North Carolina are on 300’ centers

Many Controlled Drainage applications were on Ditch Channels; In past 20 years, more applications have been on Subsurface Drainage Systems, similar to sites in Ohio.

Annual Outflows (inches) Eastern North Carolina

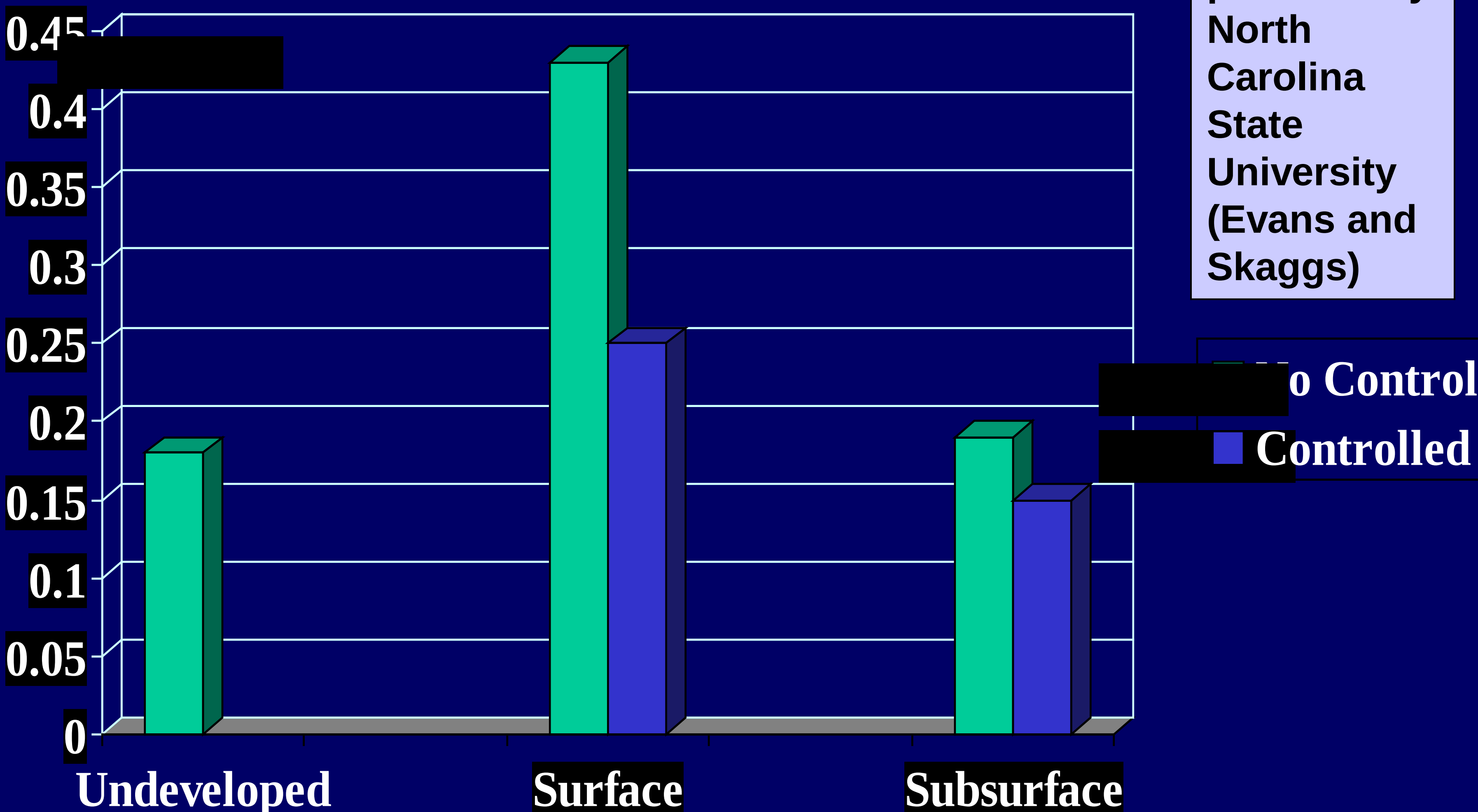
(14 sites/125 site-years of data)

Data provided by North Carolina State University (Evans and Skaggs)

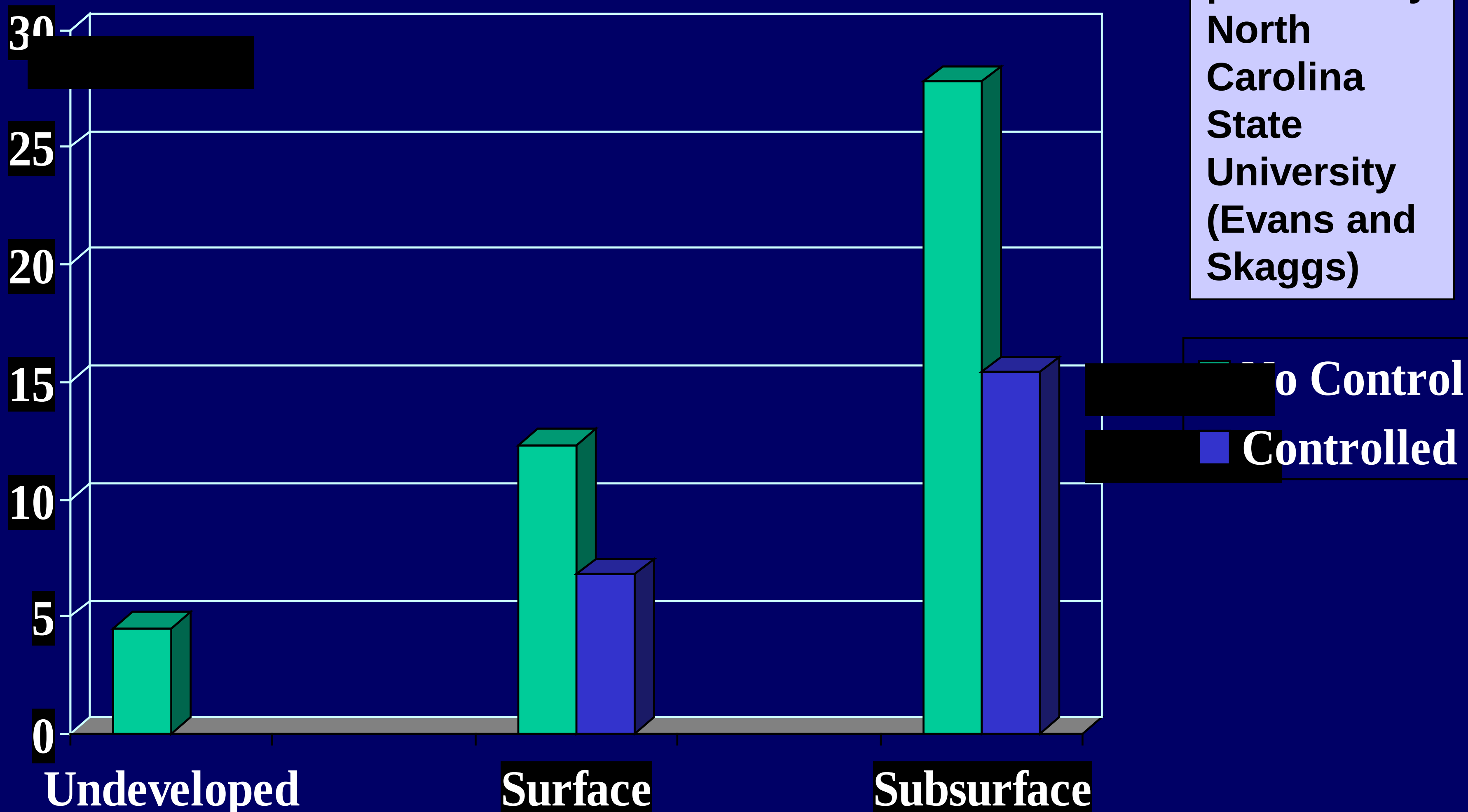


Average Annual TP Transport (#/ac)
12 Eastern NC Soils and Sites

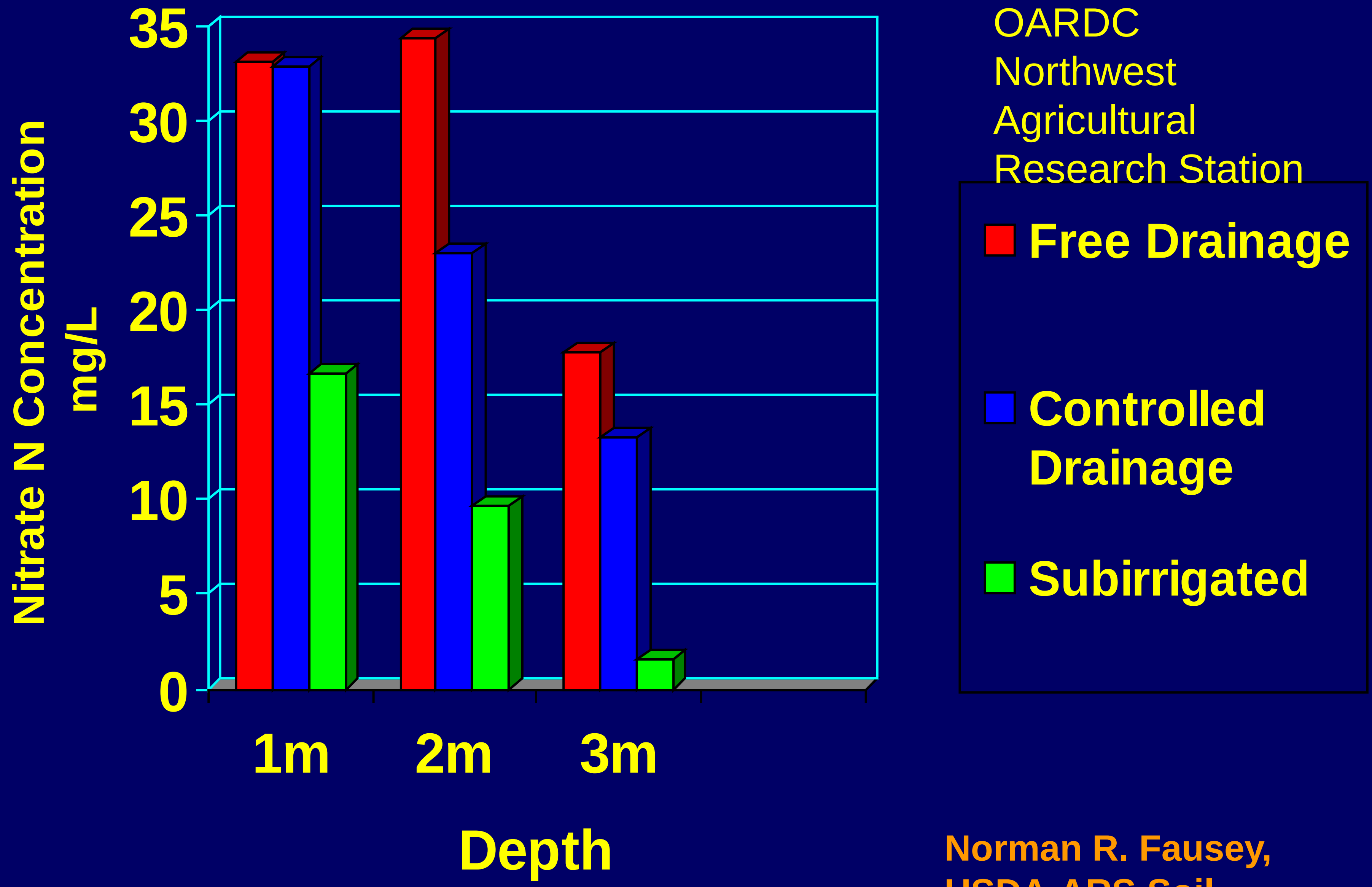
Data provided by North Carolina State University (Evans and Skaggs)



Average Annual TKN & NO3-N (#/ac)
14 Eastern NC Soils and Sites



Data provided by North Carolina State University (Evans and Skaggs)



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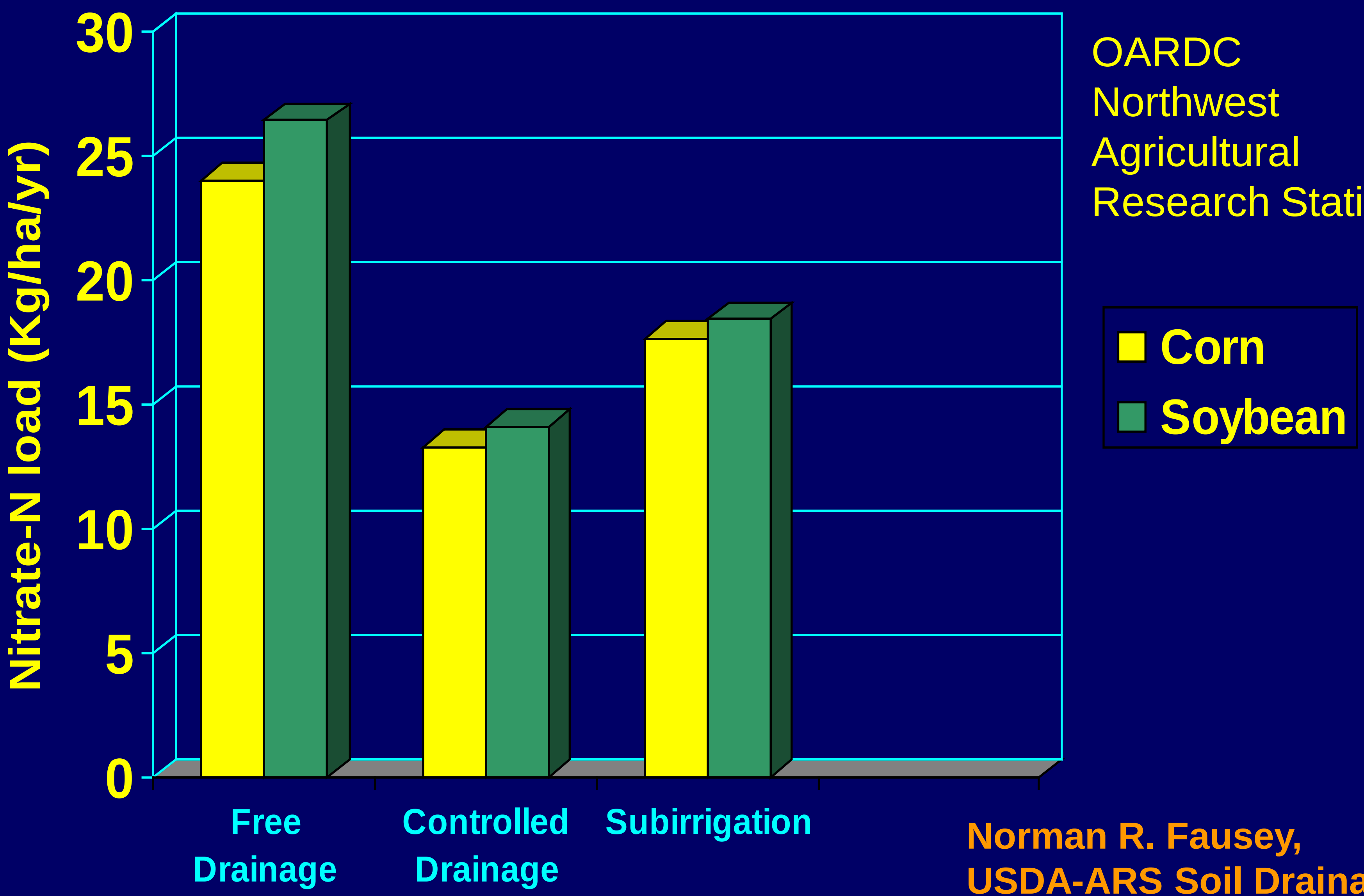
Northwest
Agricultural
Research Station

Norman R. Fausey,
USDA-ARS Soil
Drainage Research Unit



OARDC
Northwest
Agricultural
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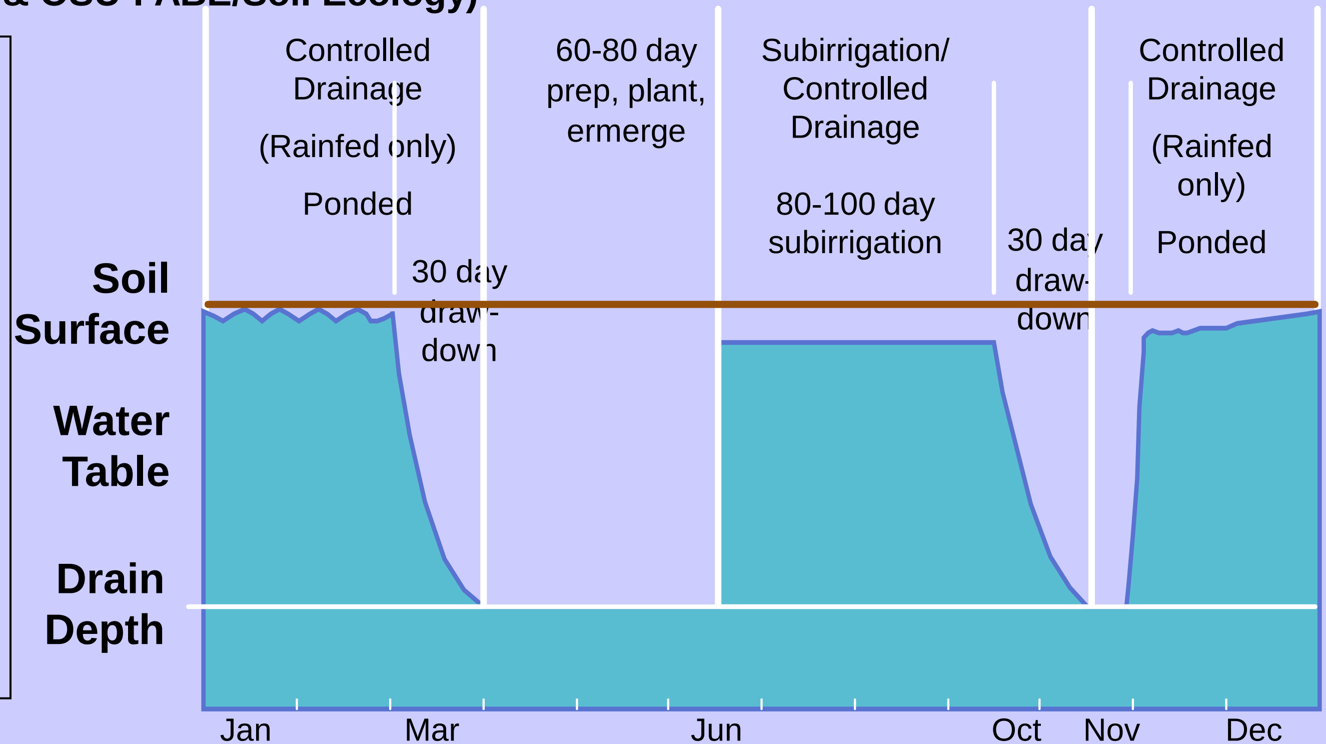
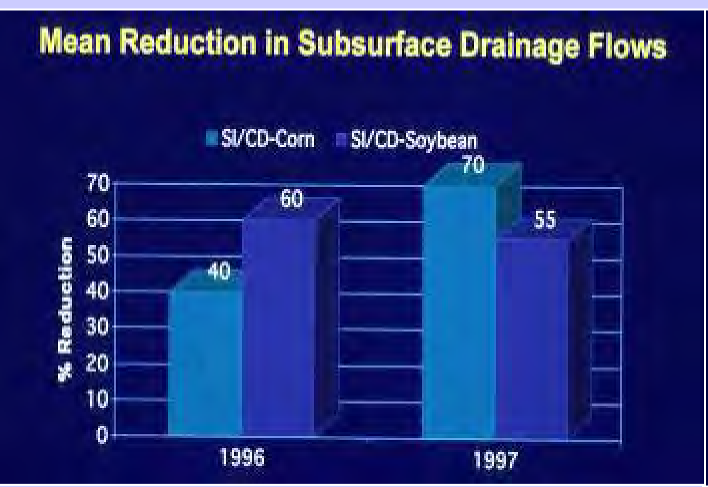
Research Unit

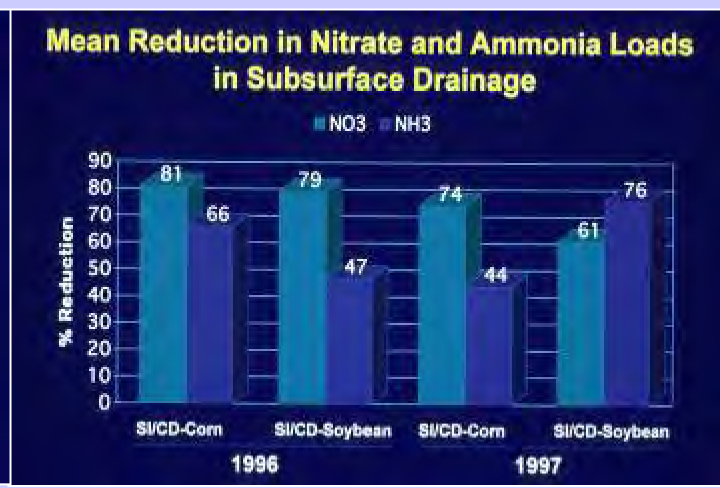
Hydrology of Controlled Drainage/Subirrigated System

(CWAES – USDA-ARS-SDRU & OSU-FABE/Soil Ecology)

- Up to ***40% reduction*** in subsurface drainage flows
- Up to ***80% reduction*** in nitrate loads
- ***30% to 50% improvement*** in crop yields







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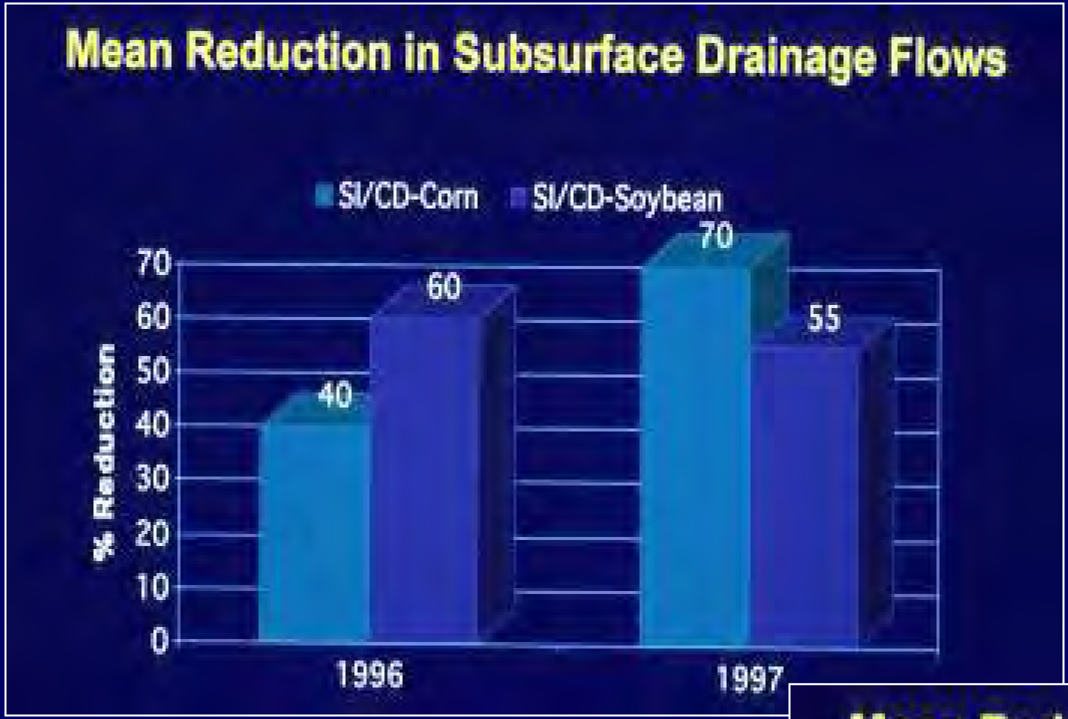
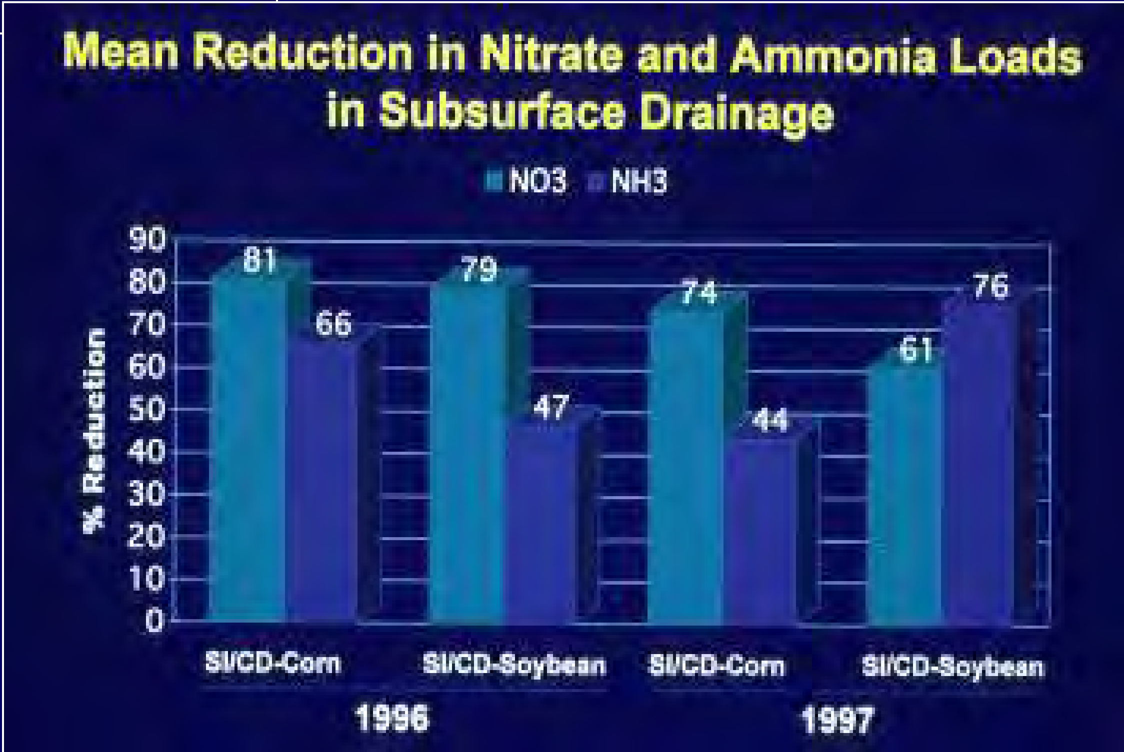
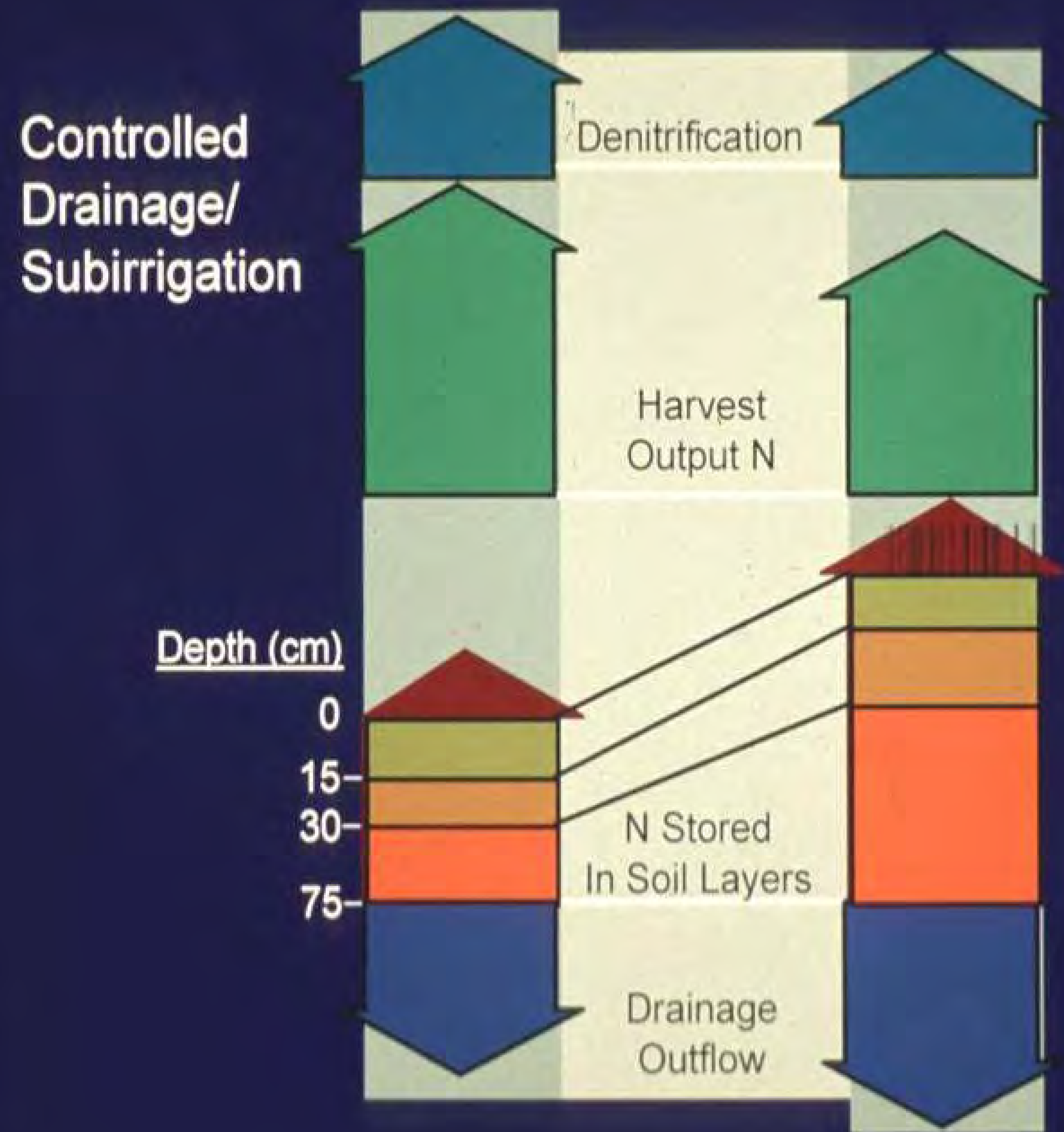

Mean Reduction in Subsurface Drainage Flows
SI/CD-Corn
SI/CD-Soybean
% Reduction
70
60
50
40
30
20
10
0
40
60
70
55
1996
1997


Mean Reduction in Nitrate and Ammonia Loads in Subsurface Drainage
NO3
NH3
% Reduction
90
80
70
60
50
40
30
20
10
0
81
66
79
47
74
44
61
76
SI/CD-Corn
SI/CD-Soybean
SI/CD-Corn
SI/CD-Soybean
1996
1997



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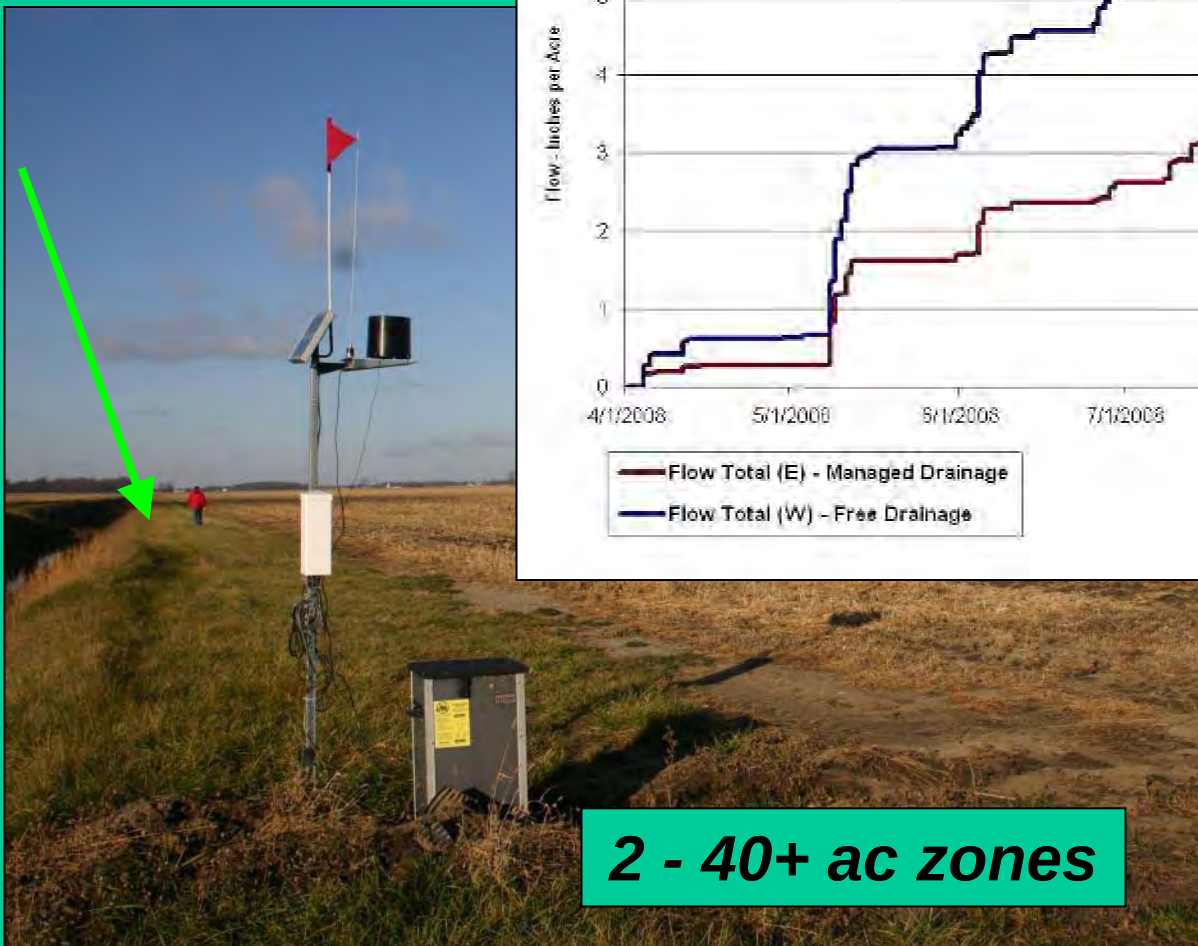

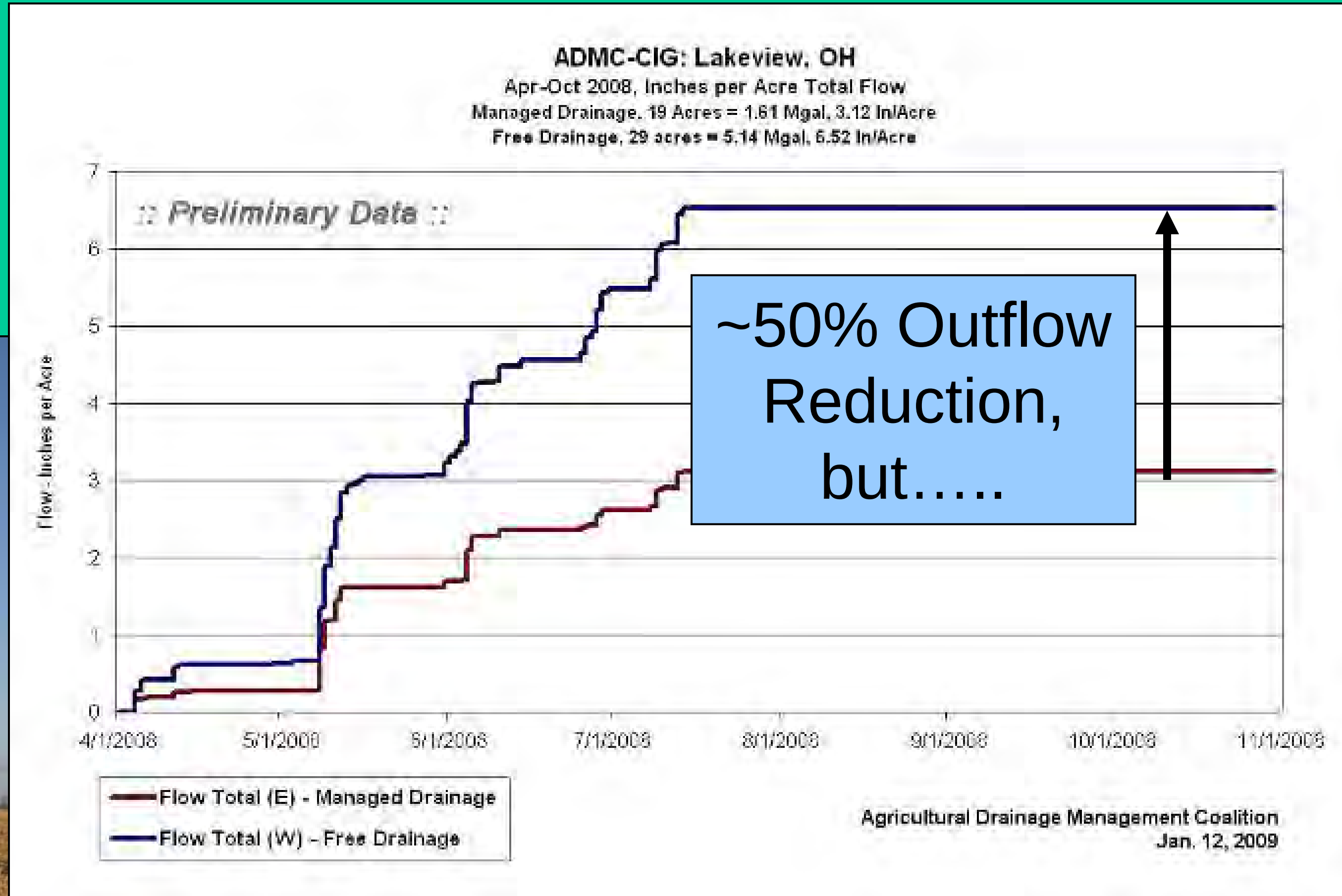

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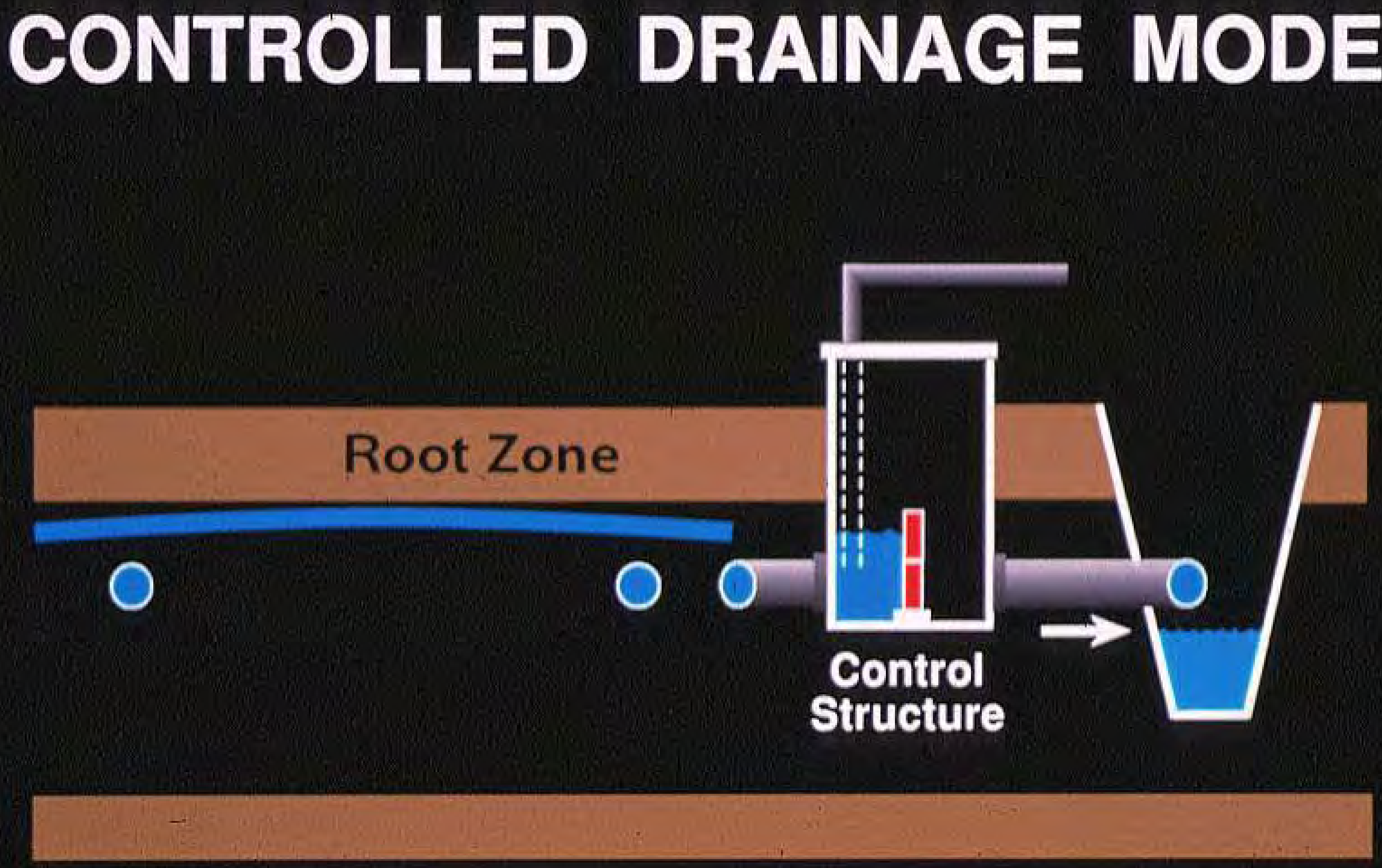
On appropriate landscapes, we expect up to a 50% reduction in Annual Nitrate Loads, on average, by Managing Agricultural Drainage Systems on appropriate sites in Ohio and across the Midwest

"Change in Outflow Volume"

Minimal change in Concentration

We continue to research impacts on crop yields, economics, soil-water and nitrate-nitrogen fate, soluble phosphorus, etc.

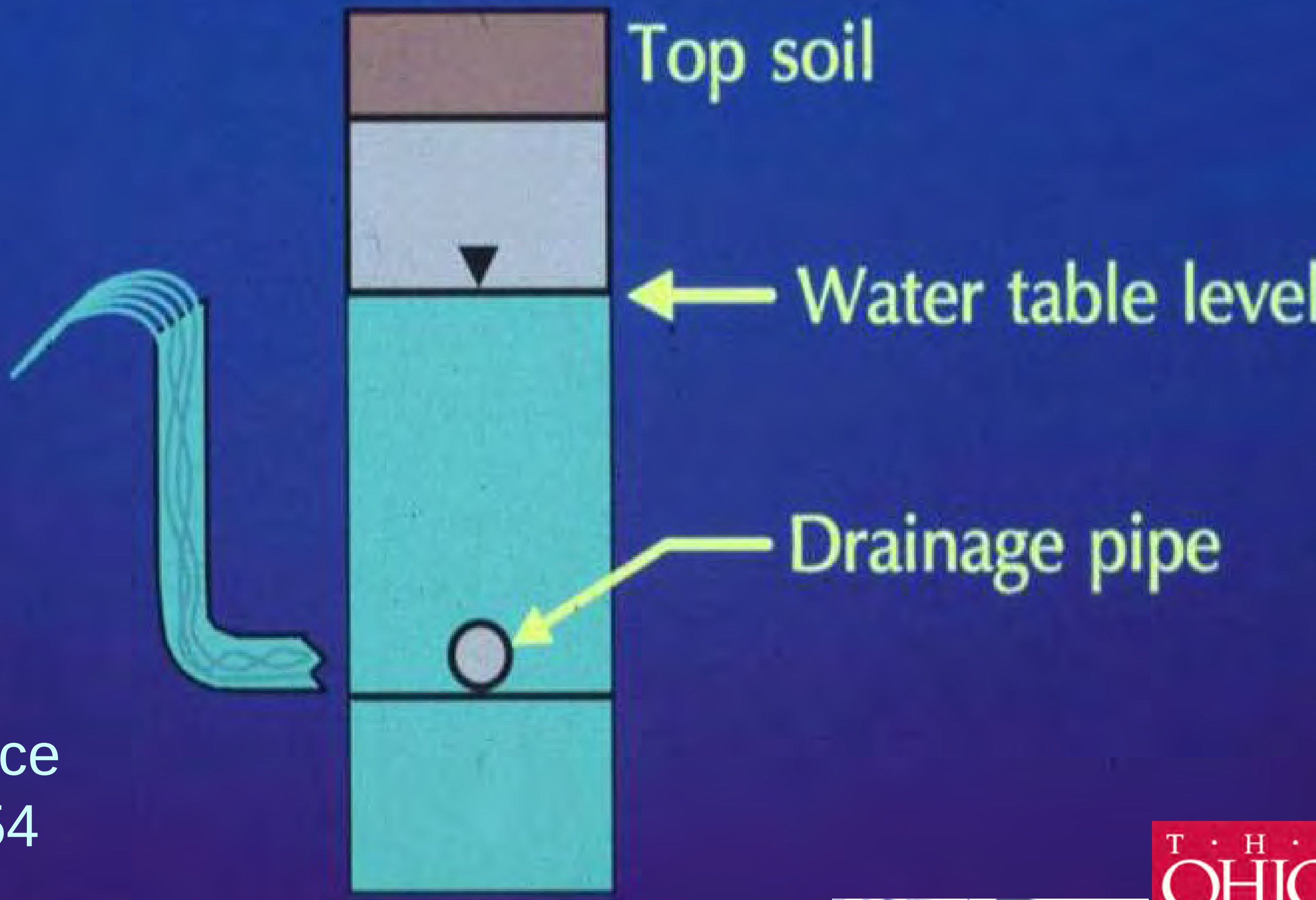
Drainage Water Management



CONTROLLED DRAINAGE

Artificially Raise the Outlet Elevation

We do NOT suggest that you Plug the Outlet!



NRCS Practice Standard 554

Drainage Water Management

Agri Drain Inline Water Level Control Structure™

- Rugged ½" PVC structure.
- Heavy steel lockable top.
- Stainless steel screws and custom anodized aluminum corner extrusions are used for strength and durability.
- 5" & 7" Stoplogs for adjustability.
- Flexible couplers allow PVC, plastic pipe, or other materials to be easily attached. *(Please specify type of pipe when ordering)*
- 5-Year Warranty on all parts.

Please allow up to 2 weeks for shipment.

more info
visit our website

Handle (included) is used to install and remove stoplogs.

INLINE WATER LEVEL CONTROL STRUCTURE

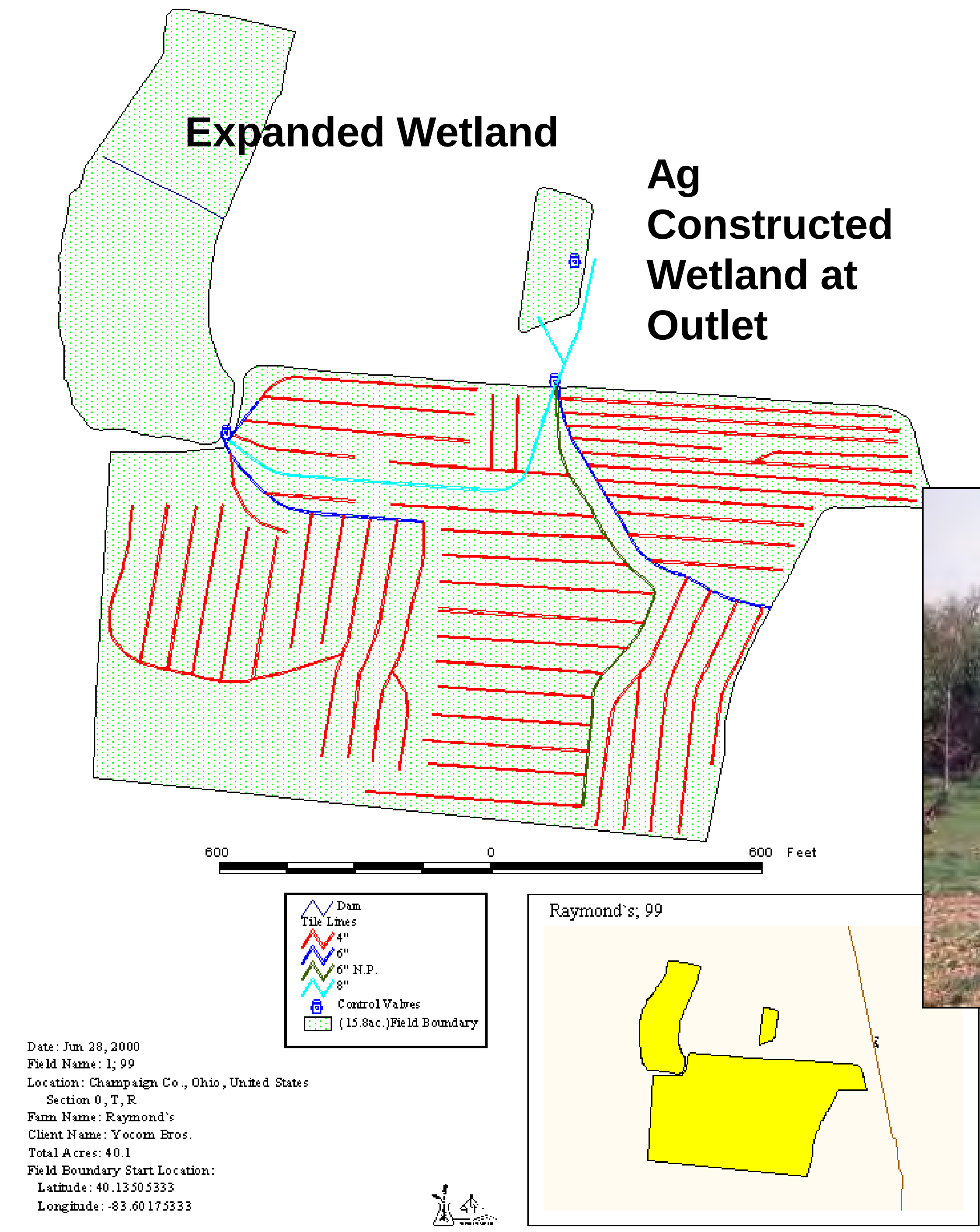
Pipe Size	Inside Dim. Width	Inside Dim. Depth	HEIGHT 2'	3'	4'	5'	6'	8'	10'	12'
4"	8"	10"	$363	$410	$458	$505	$553	$648	$743	$838
6"	8"	10"	$370	$418	$465	$513	$560	$655	$750	$845
8"	12"	12"	$394	$458	$521	$585	$649	$776	$904	$1031
10"	14"	16"	$419	$496	$574	$651	$729	$884	$1039	$1194
12"	16"	20"	$506	$596	$686	$776	$866	$1046	$1226	$1406
15"	20"	24"	$544	$666	$789	$911	$1034	$1279	$1524	$1769
18"	24"	28"	$729	$874	$1019	$1164	$1309	$1599	$1889	$2179
24"	31"	39"		$1100	$1295	$1490	$1685	$2075	$2465	
24"*	31"	39"		$1329	$1524	$1719	$1914	$2304	$2694	

*To fit 24" dual wall polyethylene pipe.

*Larger CMP structures also available– see page 11. Call for details on custom sizes and pricing.

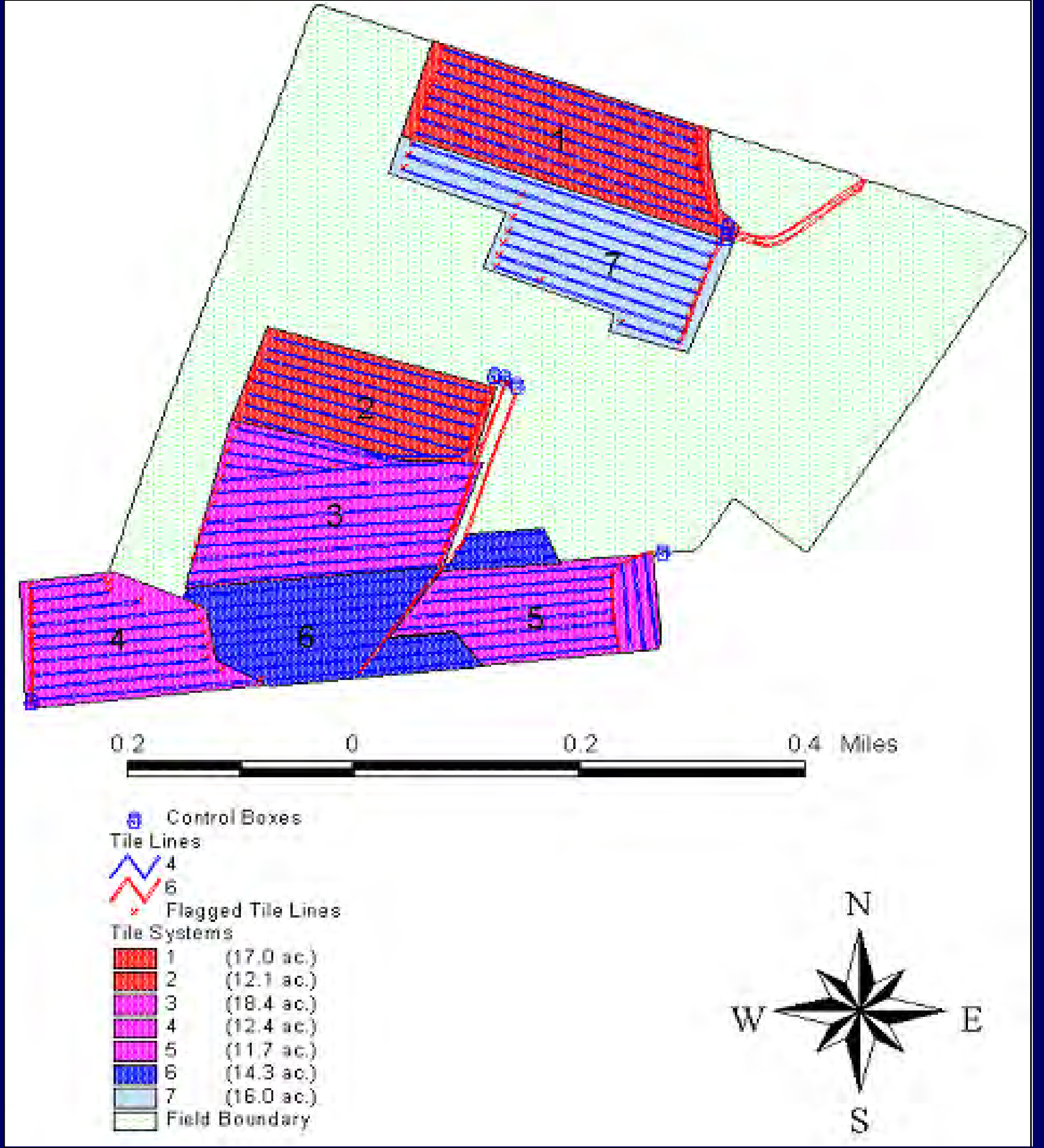



Yocom Farm
Champaign County
Ohio



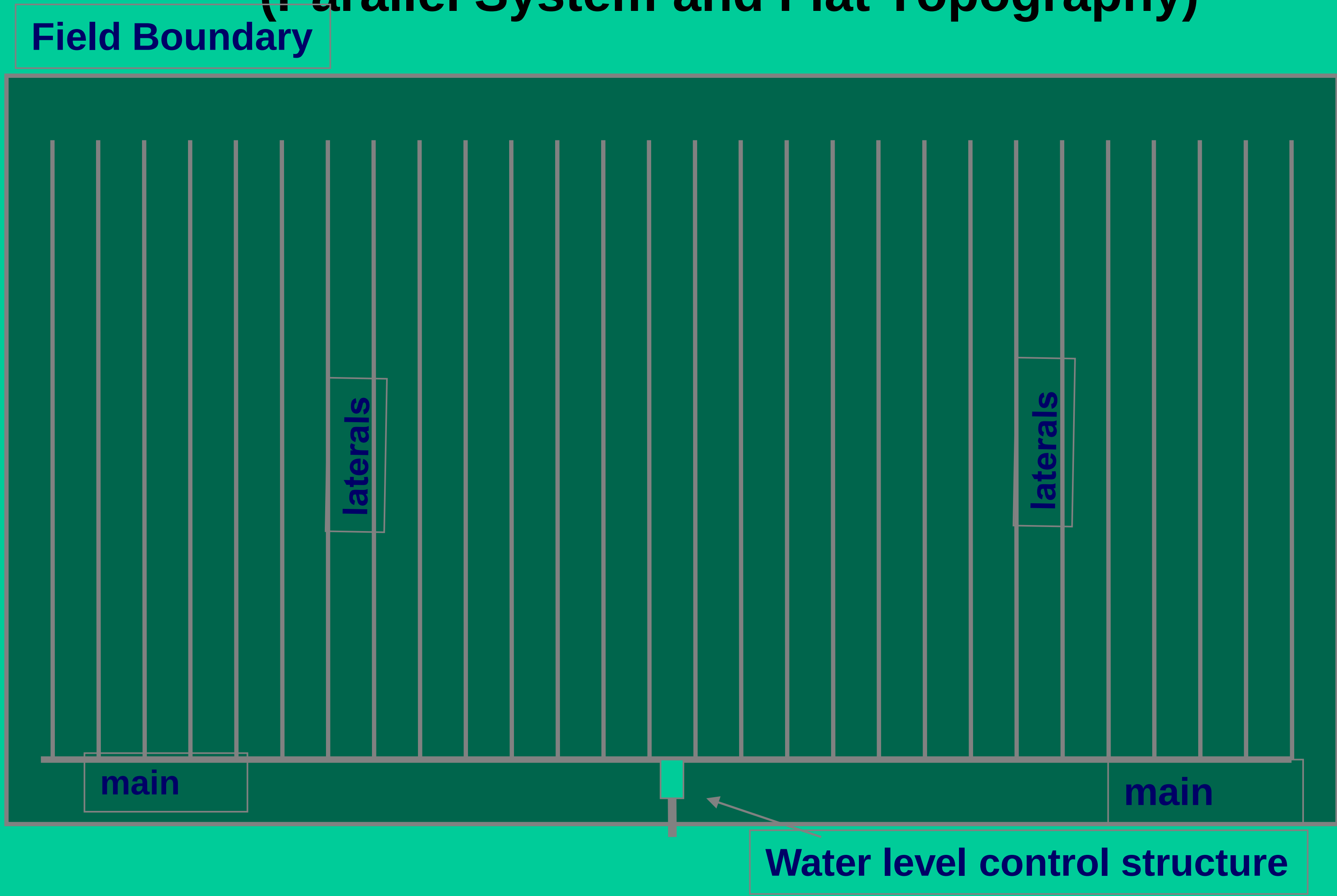
Controlled Drainage Zones

Boeger/Westfall Farm, Madison County

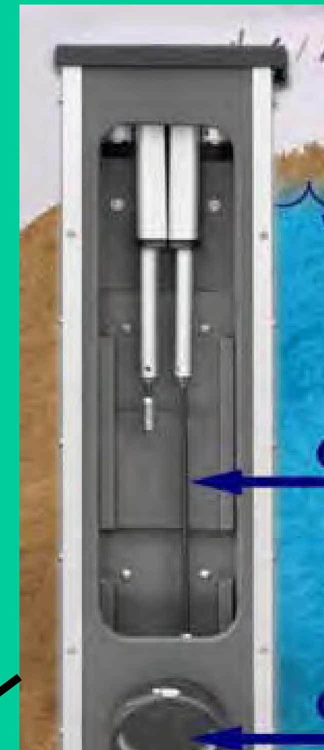


Drainage Management

(Parallel System and Flat Topography)



From D. Pitts, NRCS, IL

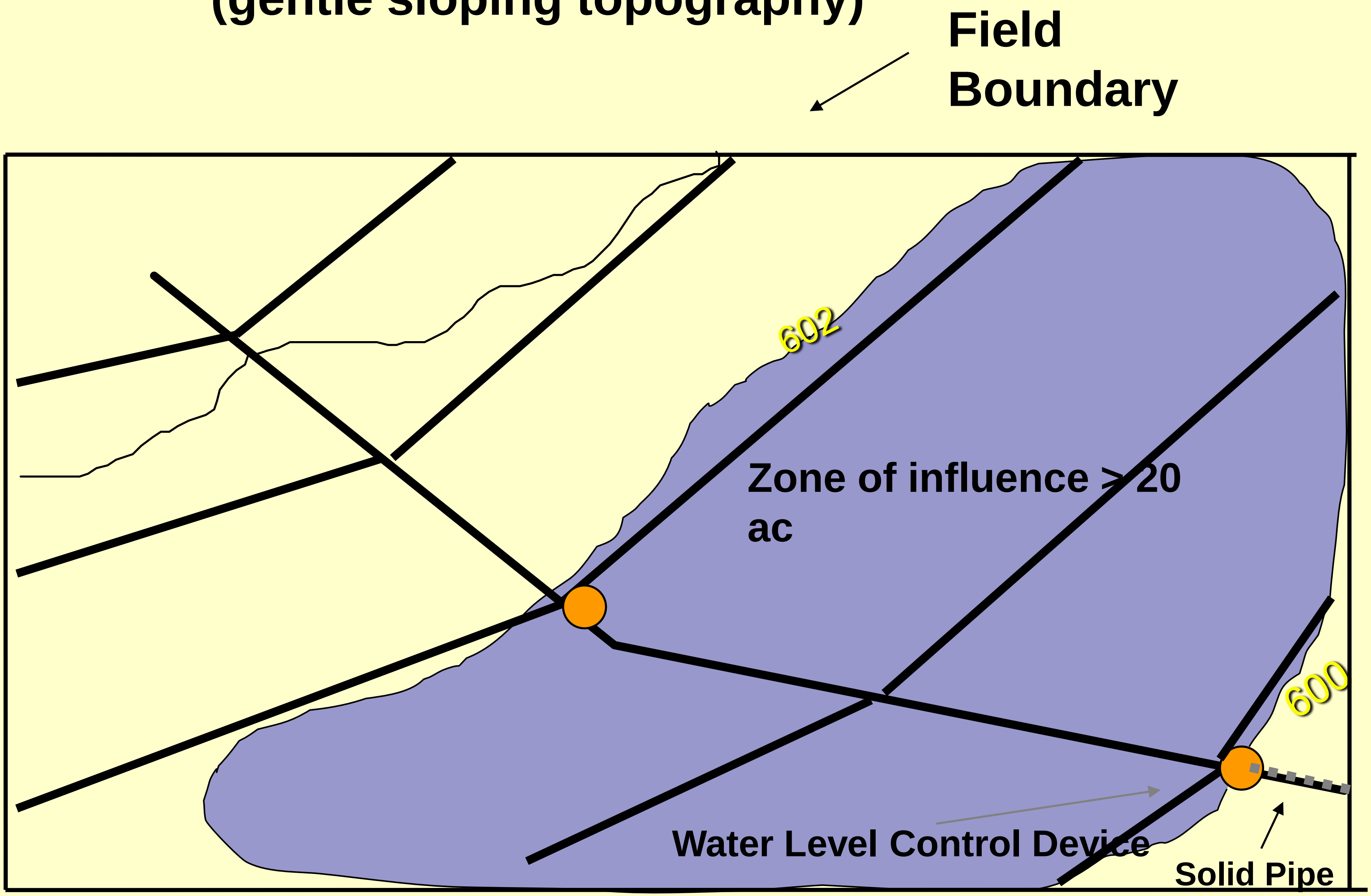


Agri-Drain Smart System

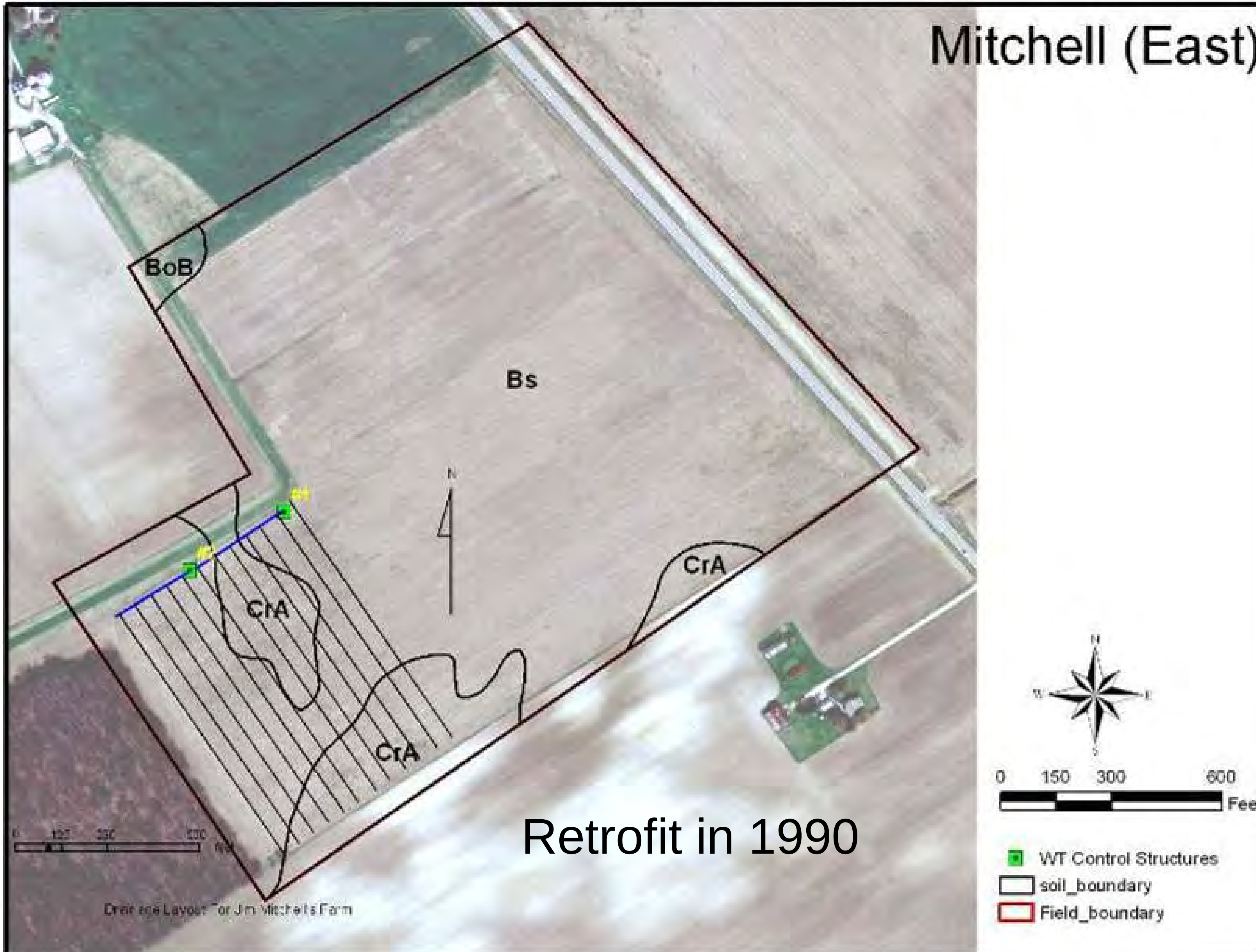
Van Wert County, OH CSP site

Drainage Management System

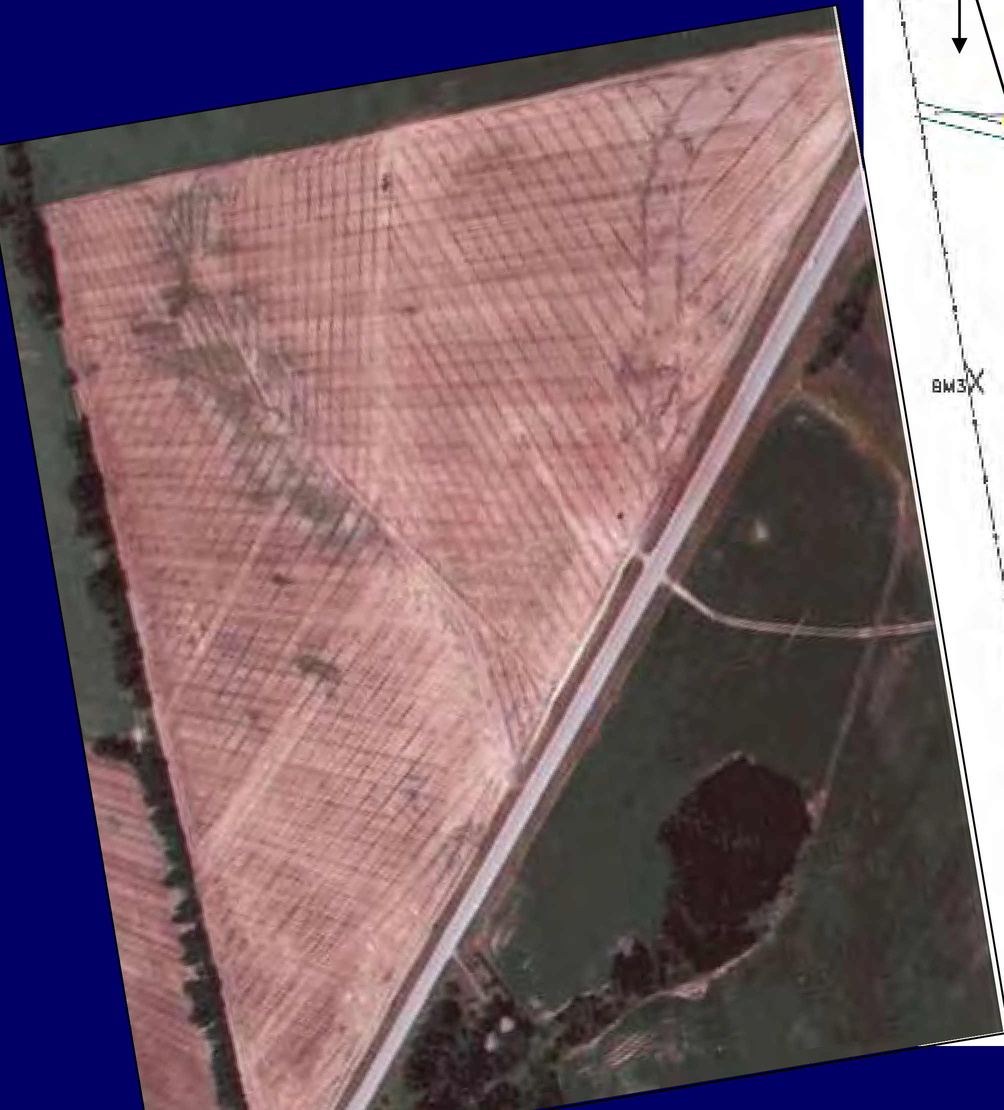
(gentle sloping topography)

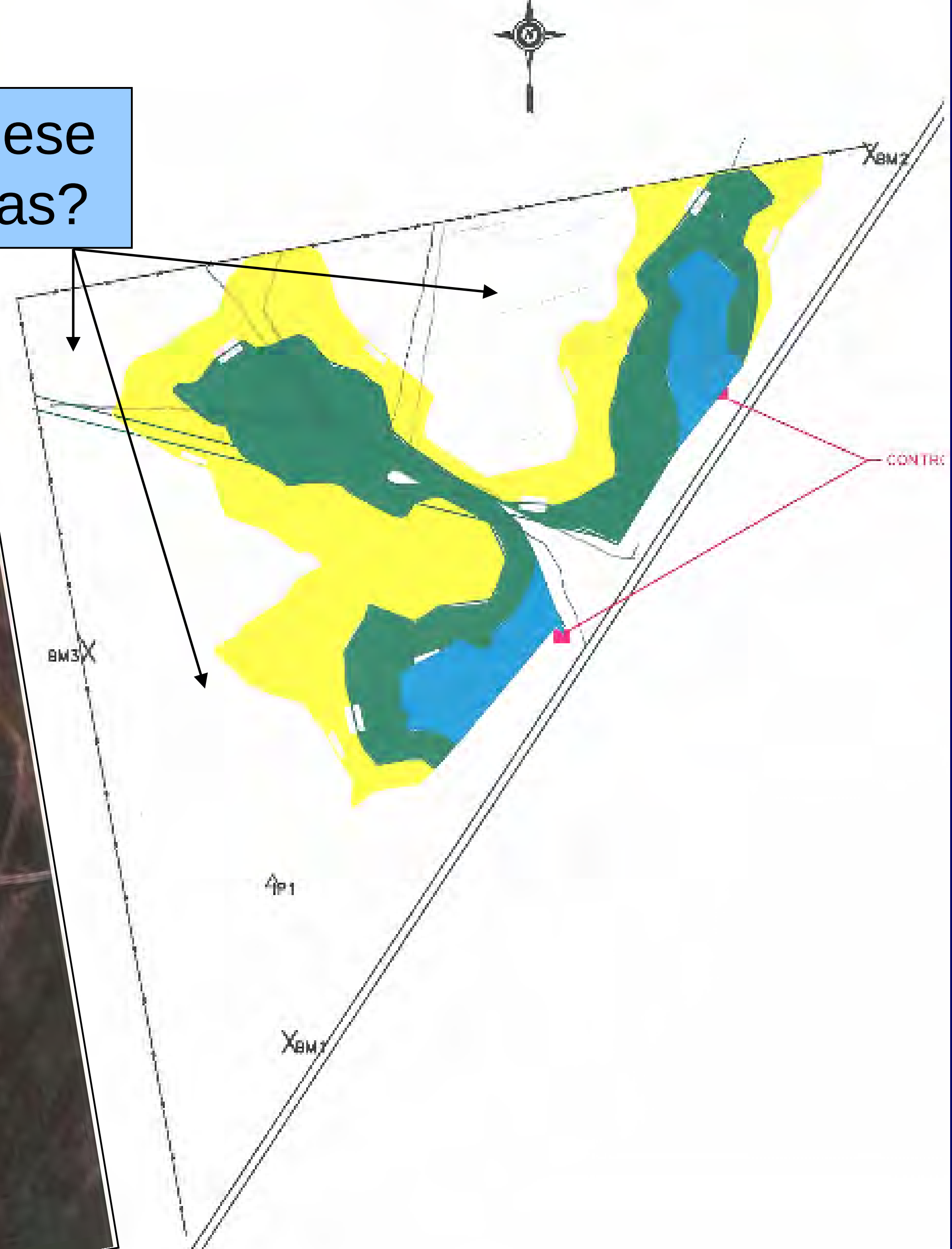


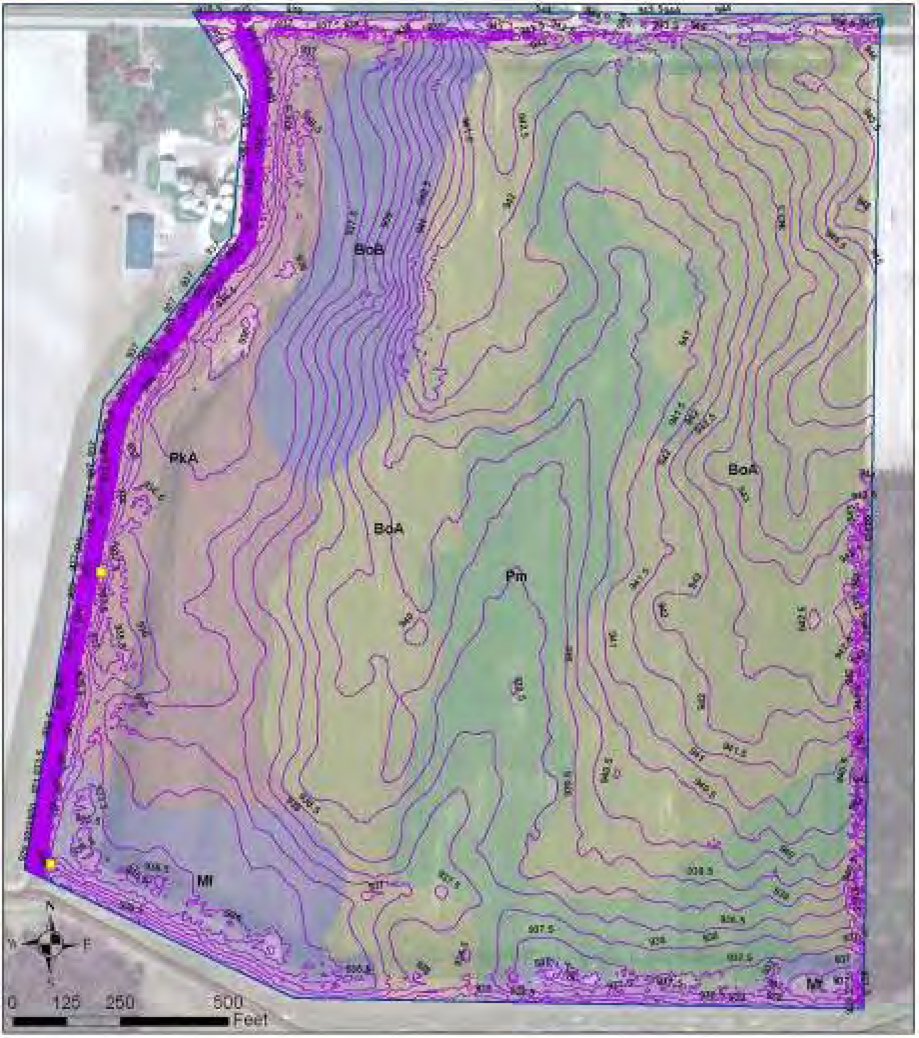
(Modified from D. Pitts, NRCS, IL)

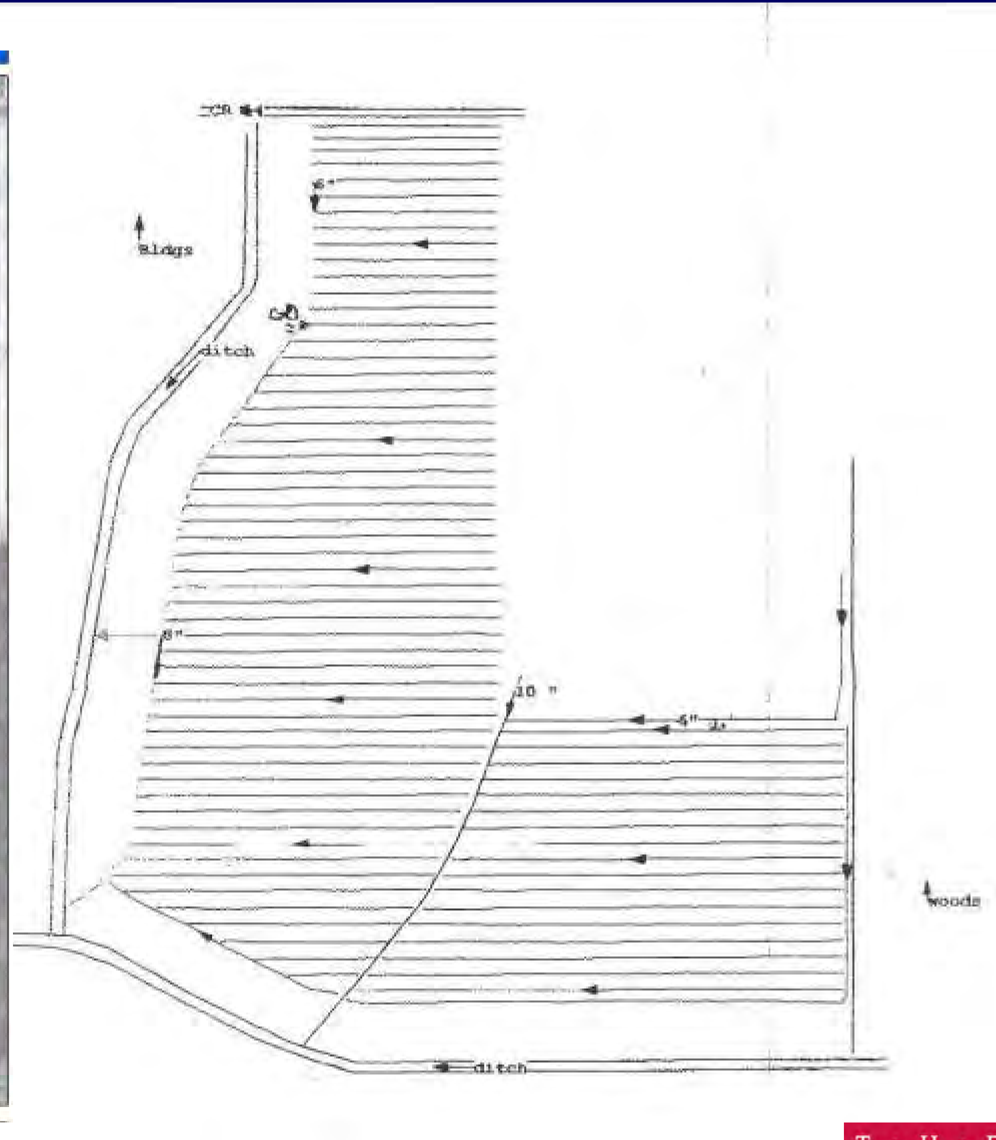

Mitchell (East)
BoB
Bs
CrA
CrA
CrA
Retrofit in 1990
0 150 300 600
Feet
WT Control Structures
soil_boundary
Field_boundary

What is the impact of these upland contributing areas?









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Ohio CIG Regional Project Sites: Location Acreage and Zones of Influence

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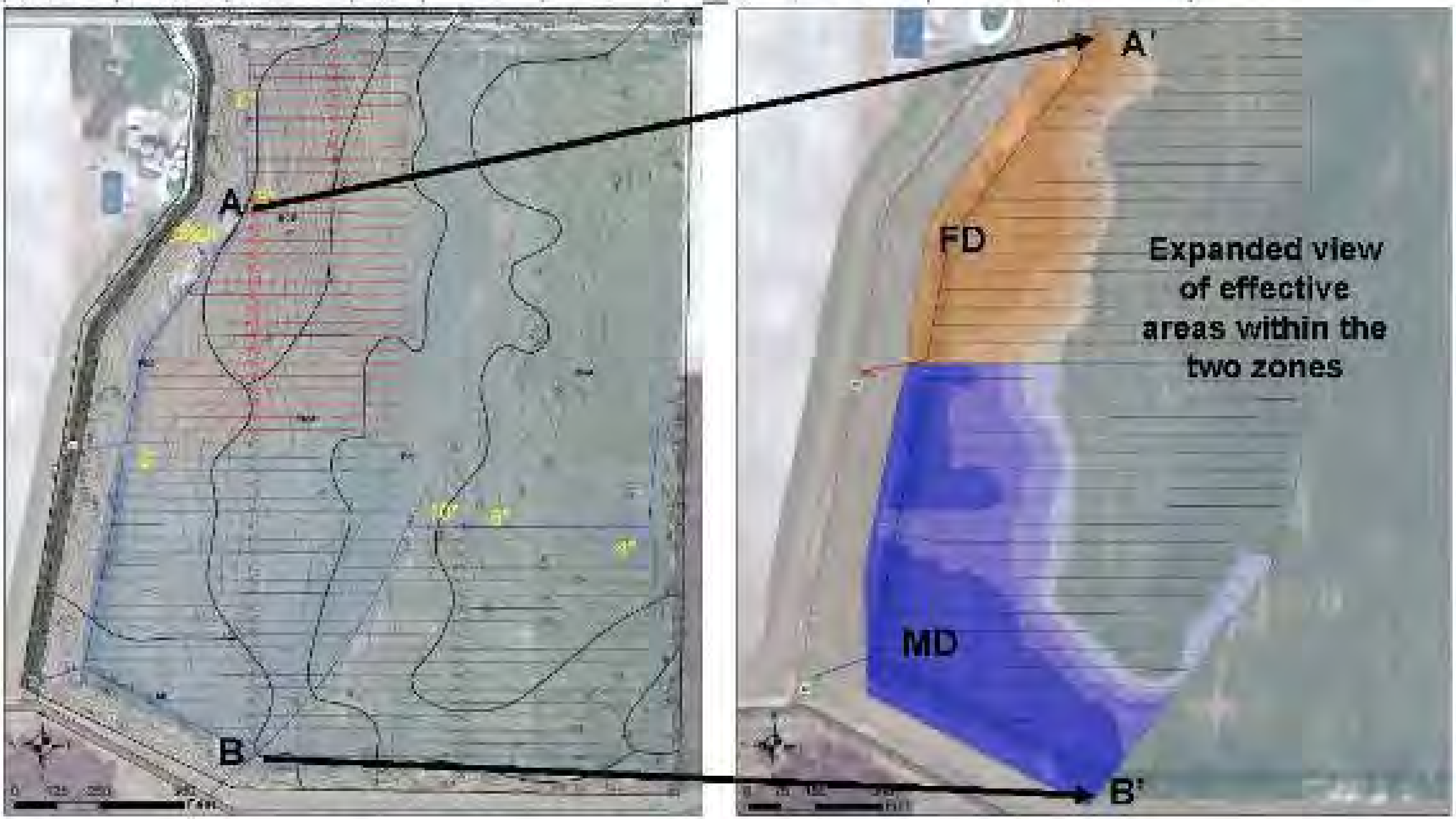
Site	8-Digit Huc W/S	County	Acreage (ac)			Area Under Zone of Influence (ac)		% Area Under Zone of Influence	
			Total Area	CD	FD	CD	FD	CD	FD
Dunkirk	4100007	Hardin	36	20	16	10	5.5	50	34
Lakeview	5080001	Auglaize	48	19	29	19	29	100	100
Napoleon	4100008	Henry	72	37	35	37	35	100	100
Defiance	4100008	Defiance	39	20	19	20	19		



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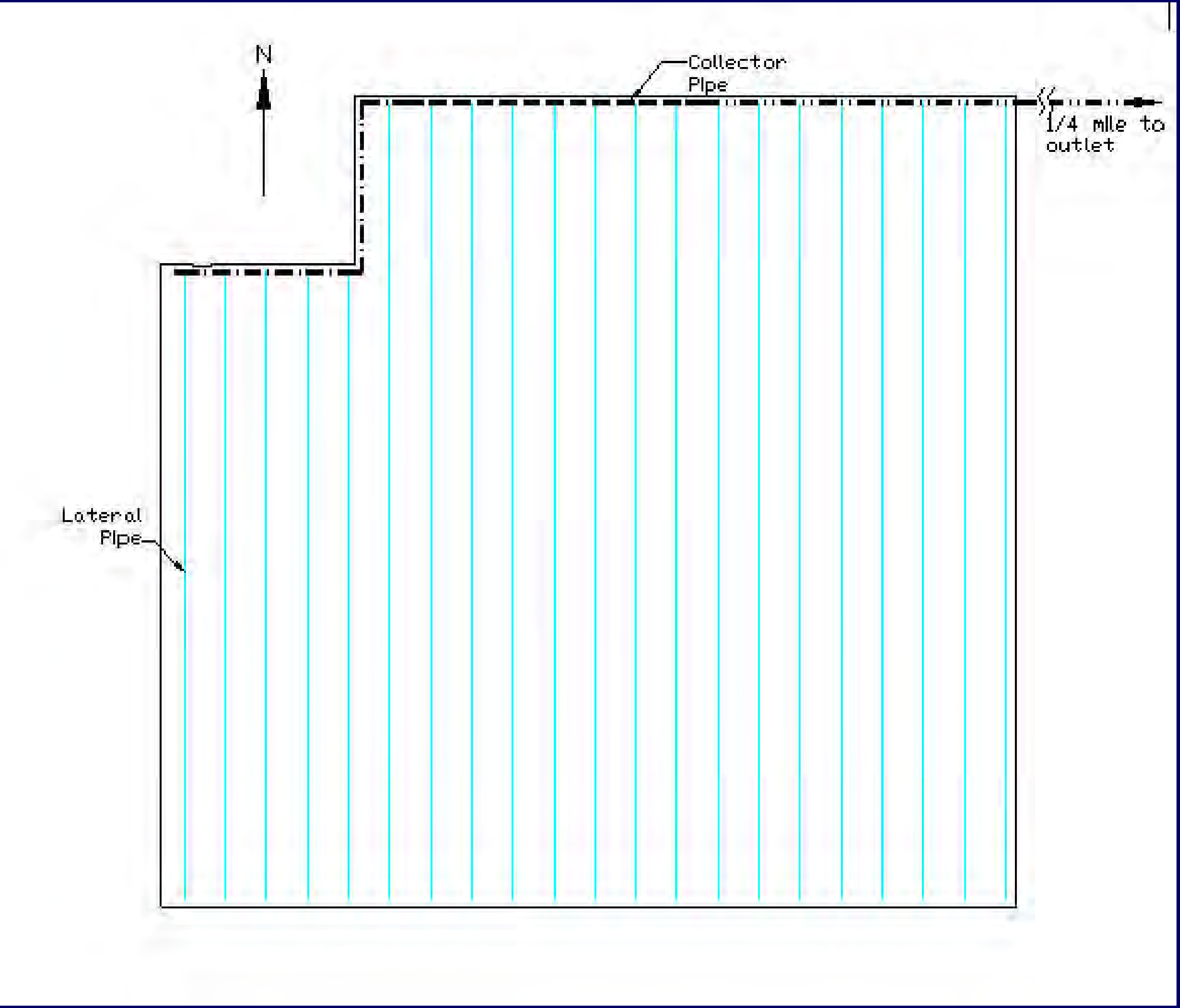
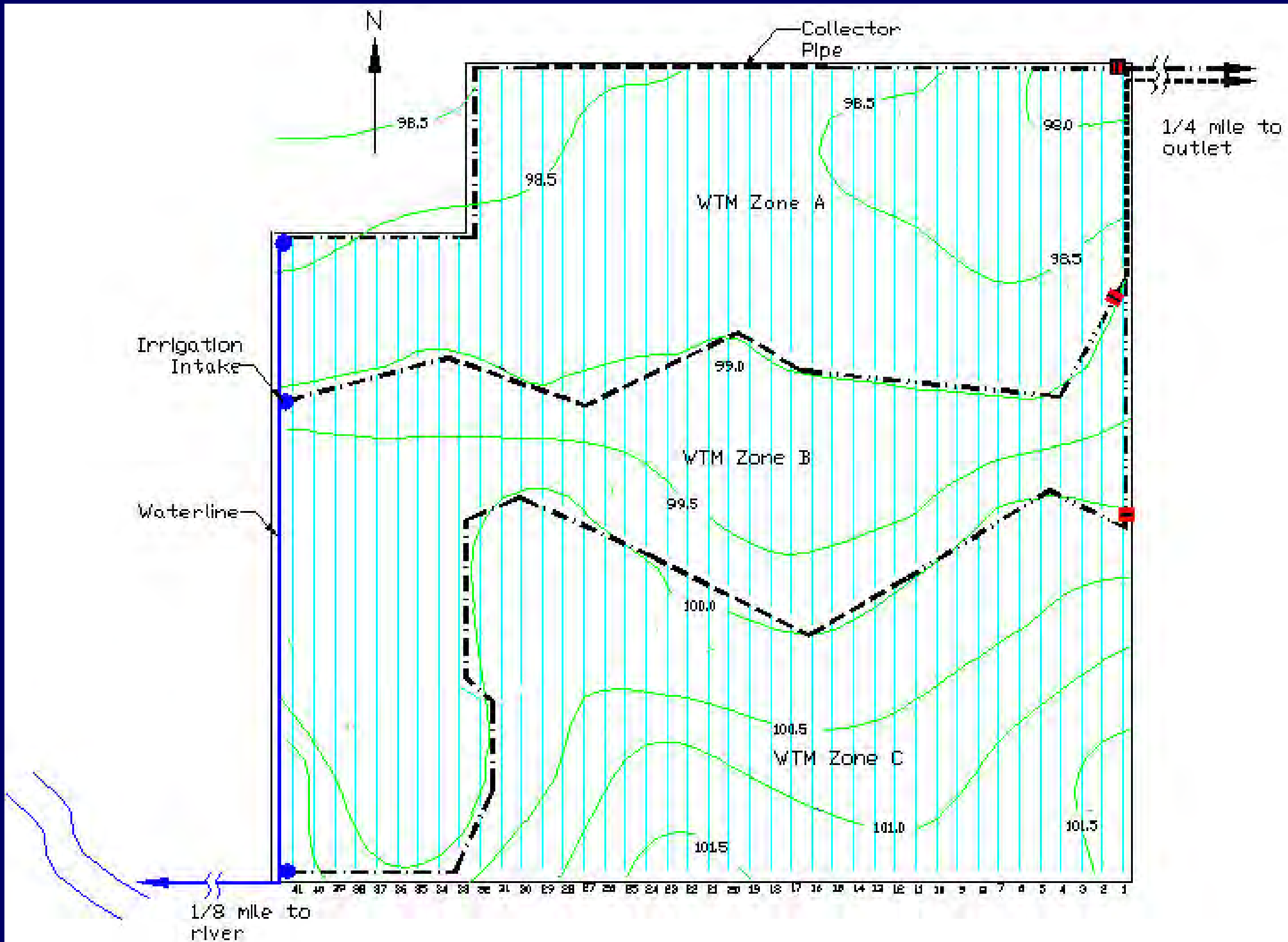
Installation and Maintenance Tips

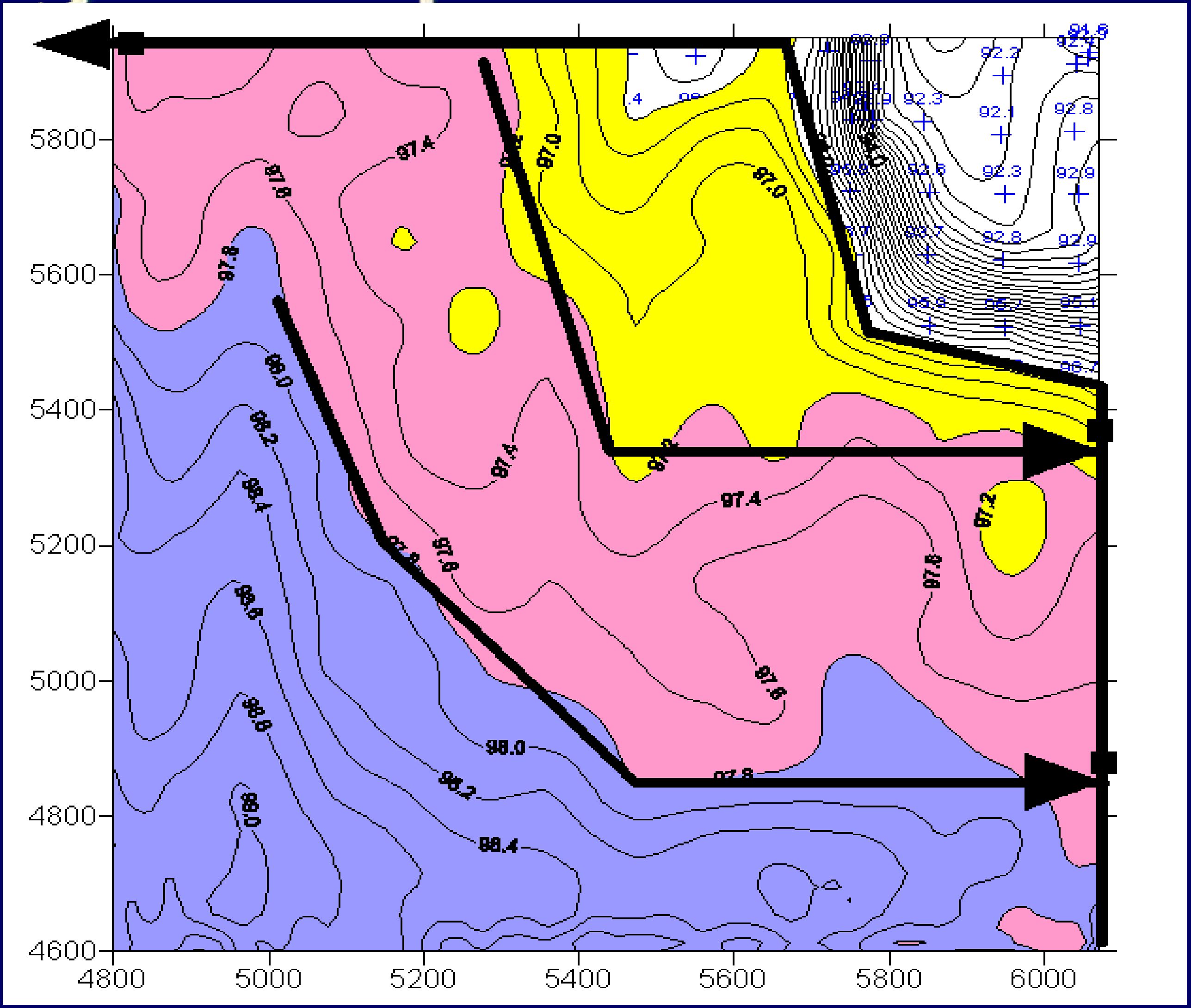
- Structure should be placed on solid, undisturbed earth (no gravel)
- Use anti-seep collar
- Hand backfill; Do not backfill or compact by machine
- Use recommended fittings and pipe; Joints should be water tight
- Use non-perforated pipe on both sides of structure, approx. 20’; no gravel or sand
- Minimal maintenance, but check gaskets on flashboards regularly; Replace gaskets if worn; Grease tracks; Keep flashboards and tool available

Layout and Zoning Examples


N
Collector
Pipe
1/4 mile to
outlet
Lateral
Pipe

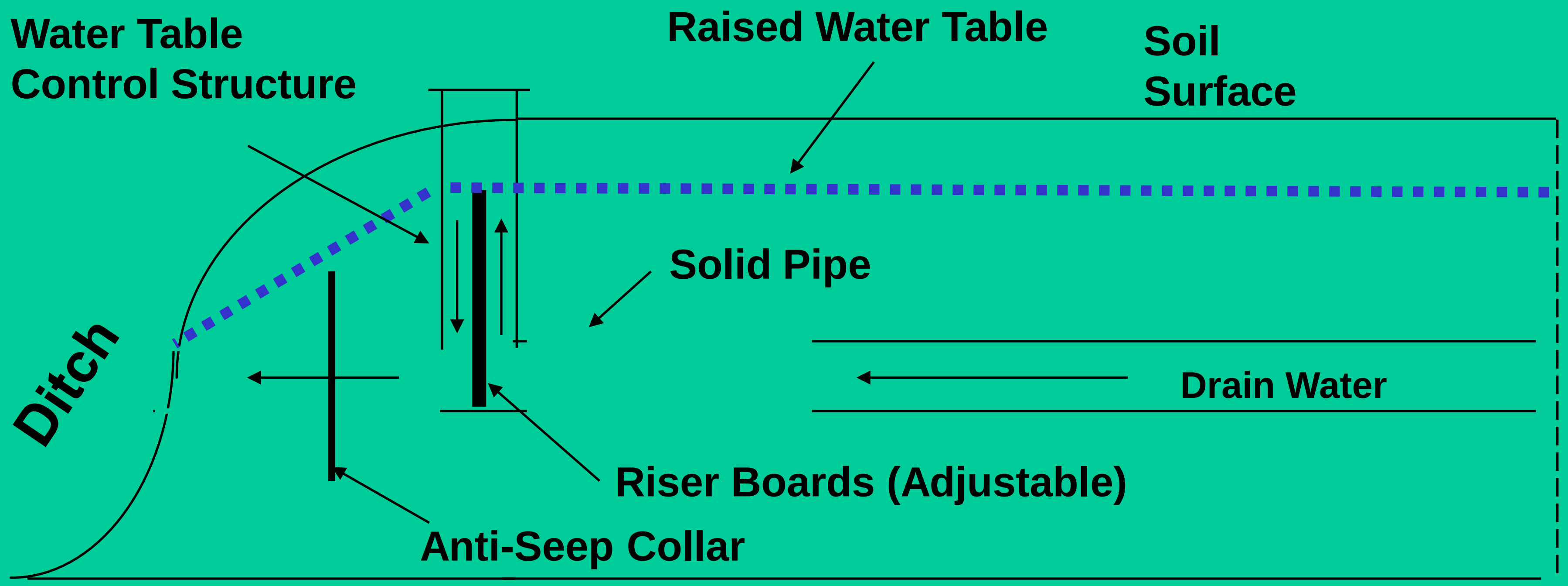

N
Collector Pipe
98.5
98.5
98.5
99.0
1/4 mile to outlet
WTM Zone A
98.5
Irrigation Intake
99.0
WTM Zone B
Waterline
99.5
100.0
100.5
WTM Zone C
101.0
101.5
101.5
1/8 mile to river

Zoning Example



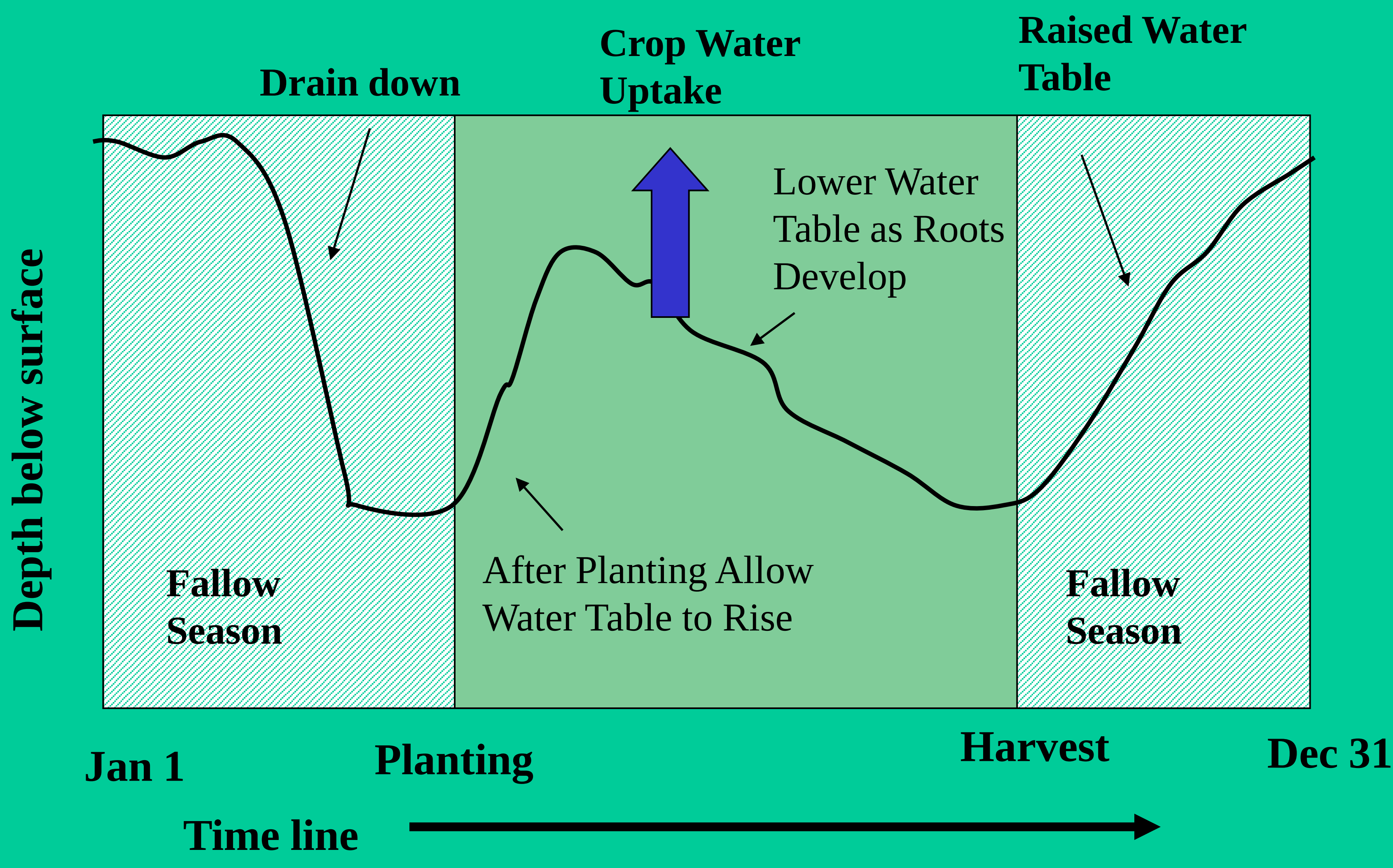
Courtesy of Dr. Bud Belcher

Drainage Water Management
Water Table Control Structure Placed in Drainline
(From D. Pitts, NRCS, IL, Modified by LC Brown)



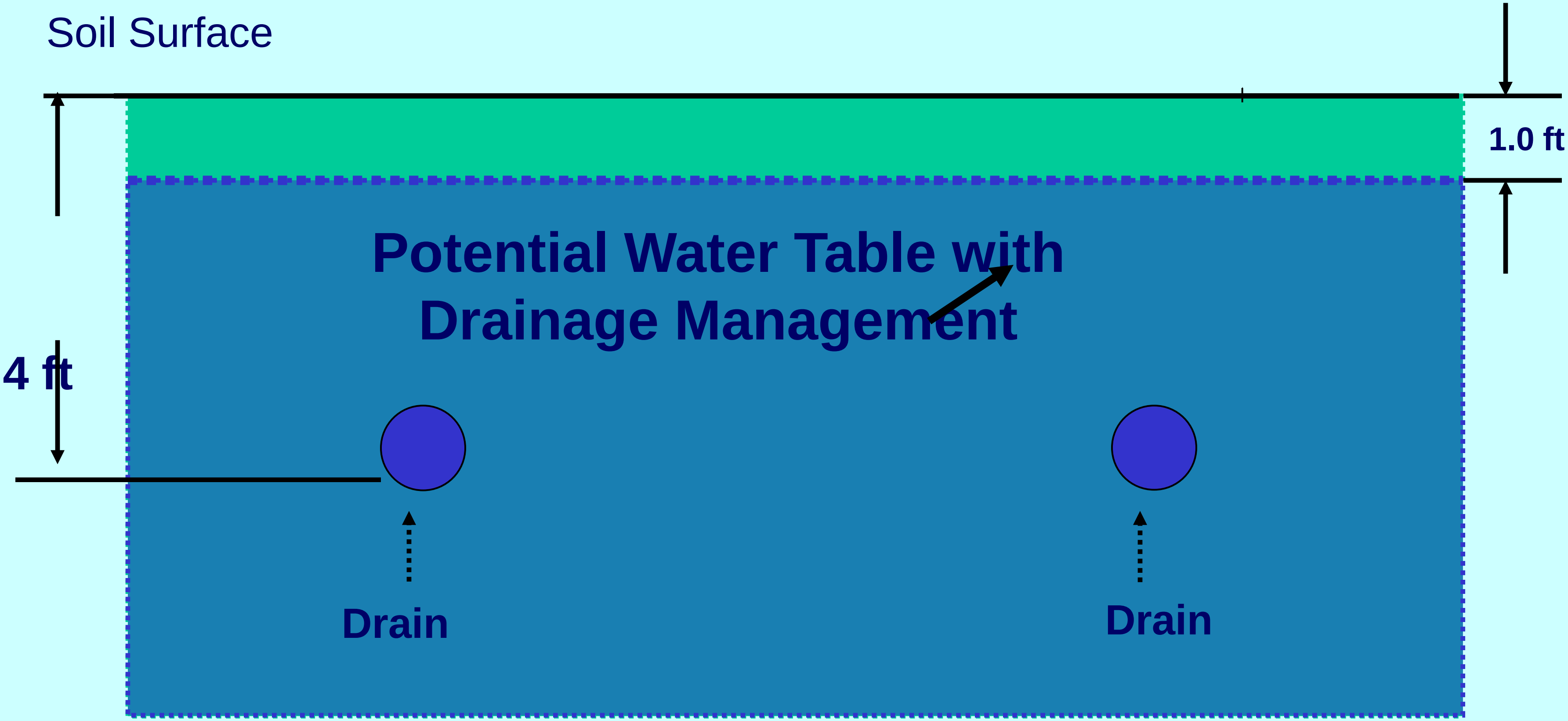
The water table control structure is installed in the main near the outlet, and at various locations within the field depending on topography

Water Table Level with Drainage Management
(from D. Pitts, NRCS, IL)



Fallow Season Drainage Management

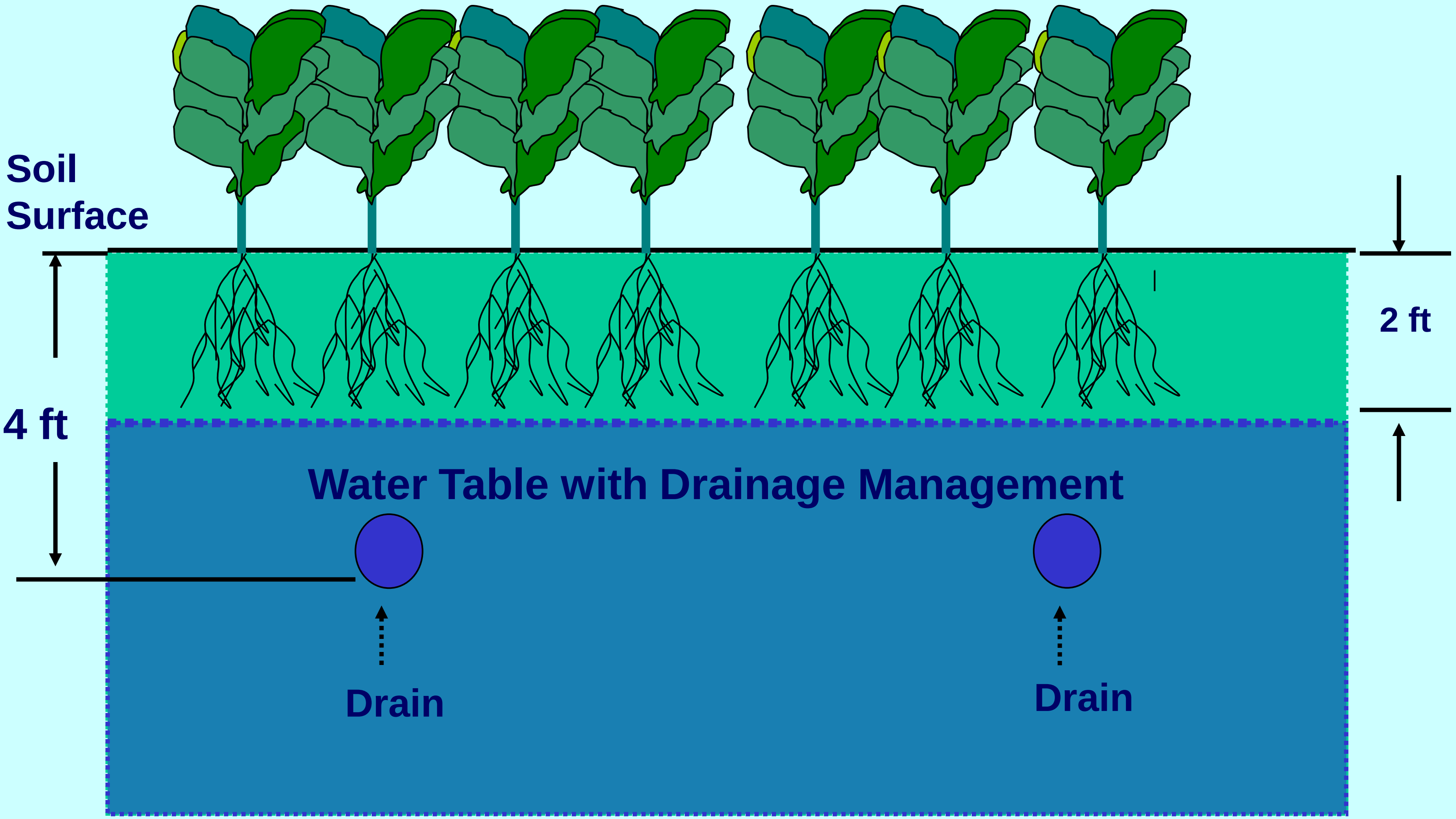
(From D. Pitts, Il NRCS, Modified by LC Brown)



Water Table Control Structure is managed so that water table can rise above drains

Production Season Drainage Management

(when plants are older) (From D. Pitts, Il NRCS)



Water table lowered as root system develops

Water Table Level with Drainage Management
(from D. Pitts, NRCS, IL)

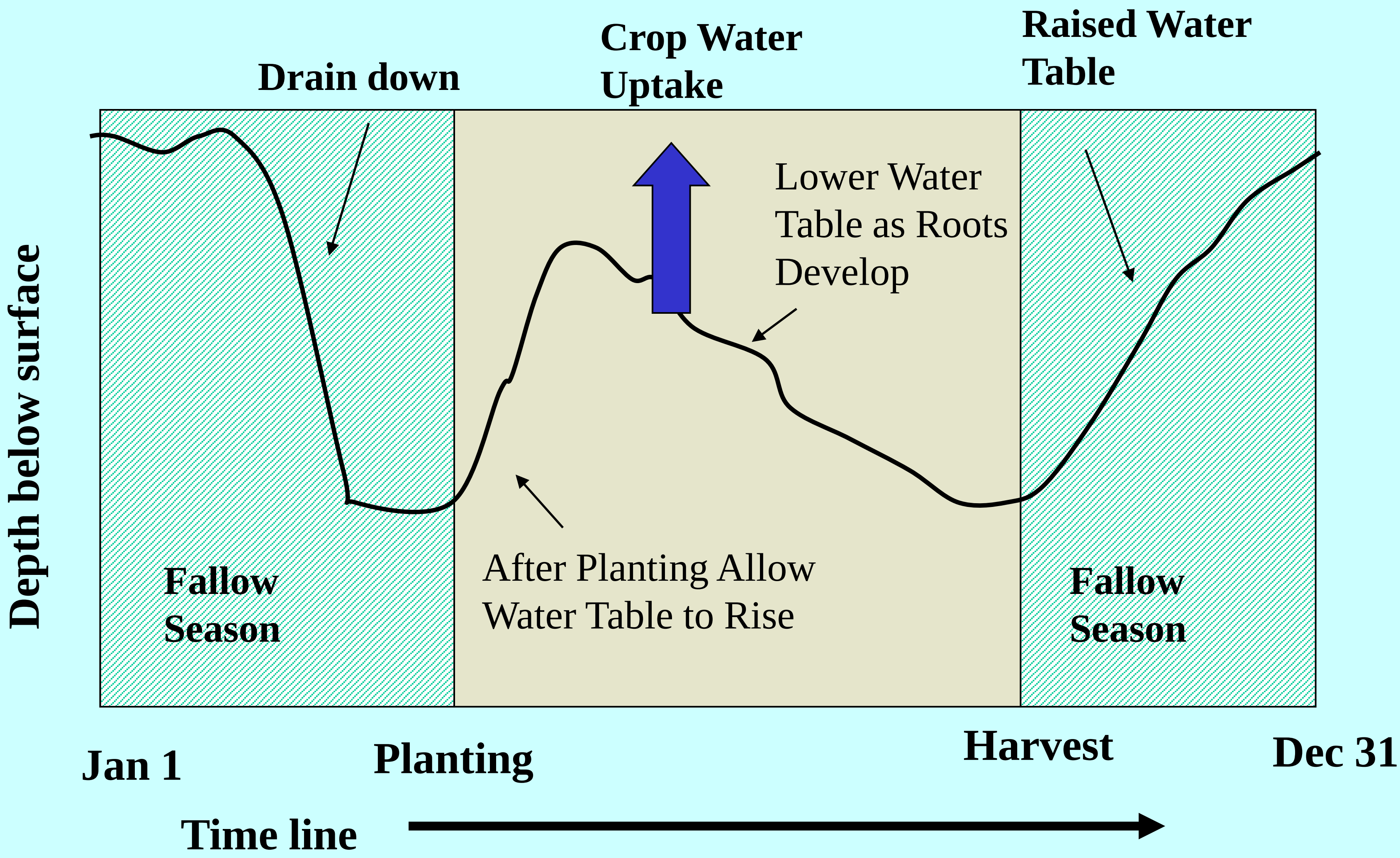
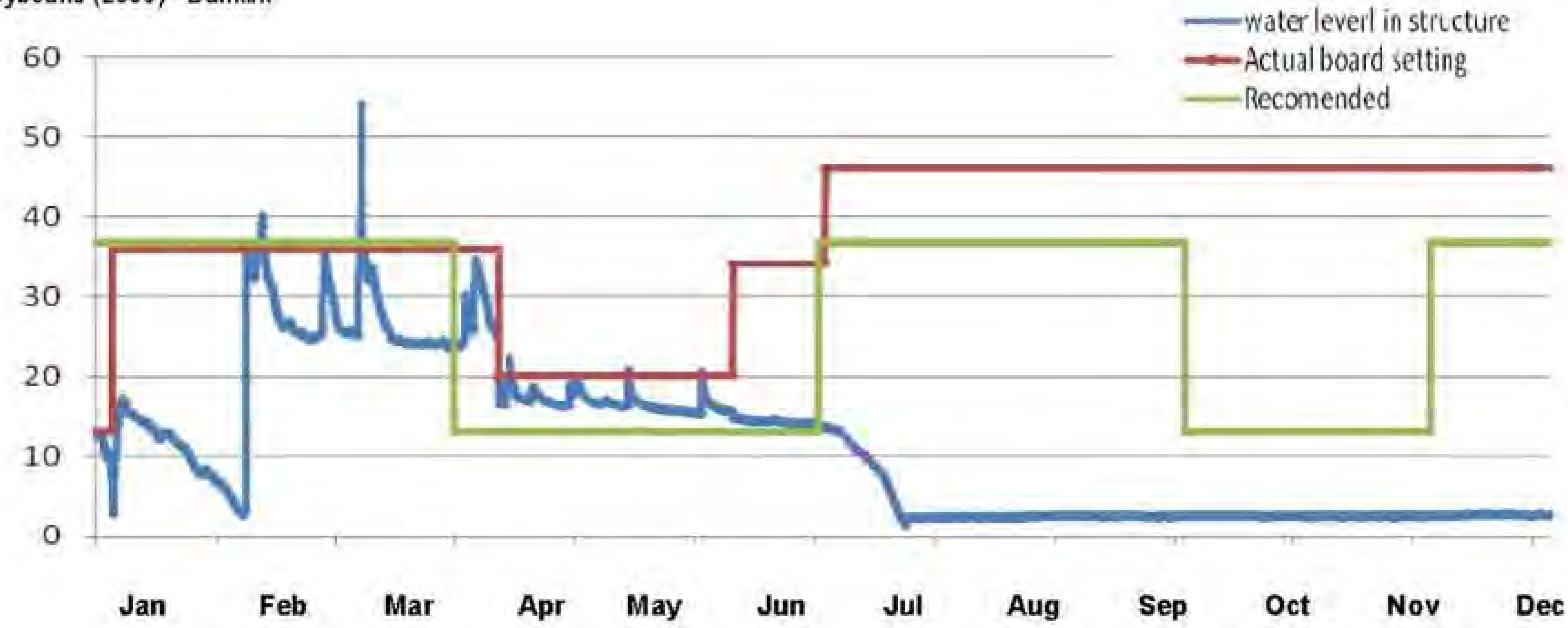


Figure 19b. Actual Control Plan and Water Table for DWM in 2009 (depth from bottom of structure in inches) – Dunkirk.

Note: Top board is a 12" V board, with a depth of 4" V cut and the depth of the top board is 8" to the v-point.

Actual Setting	Soybeans (2009)											
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	36"	36"	36"	36"	20"	20"	46"	46"	46"	46"	46"	46"
2	36"	36"	36"	36"	20"	34"	46"	46"	46"	46"	46"	46"
3	36"	36"	36"	20"	20"	34"	46"	46"	46"	46"	46"	46"
4	36"	36"	36"	20"	20"	34"	46"	46"	46"	46"	46"	46"

Soybeans (2009) - Dunkirk



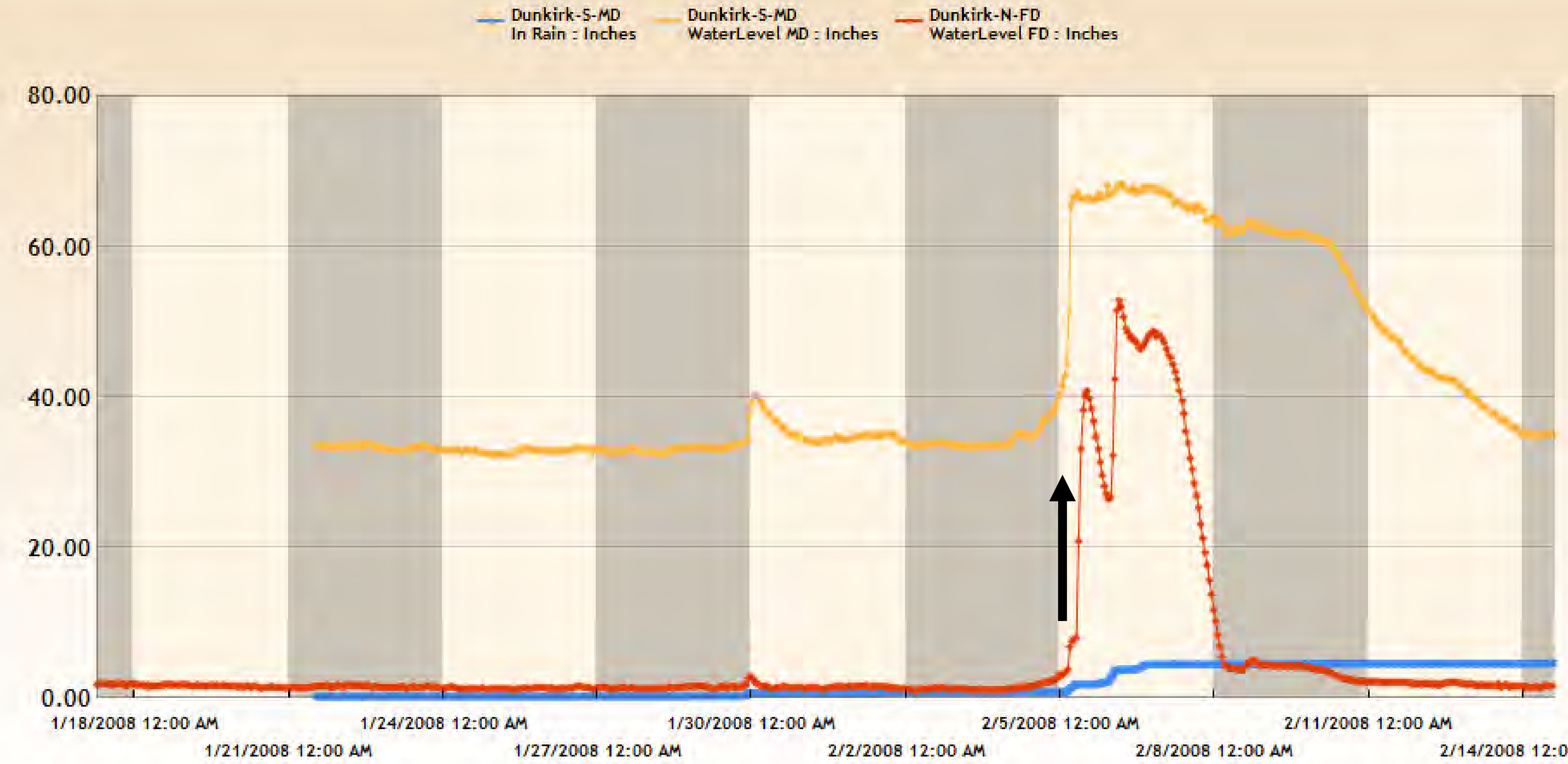
Comments:

Winter 2008

Yellow – Controlled Outlet

Red – Free Drainage Outlet

Blue – Cumulative Rainfall



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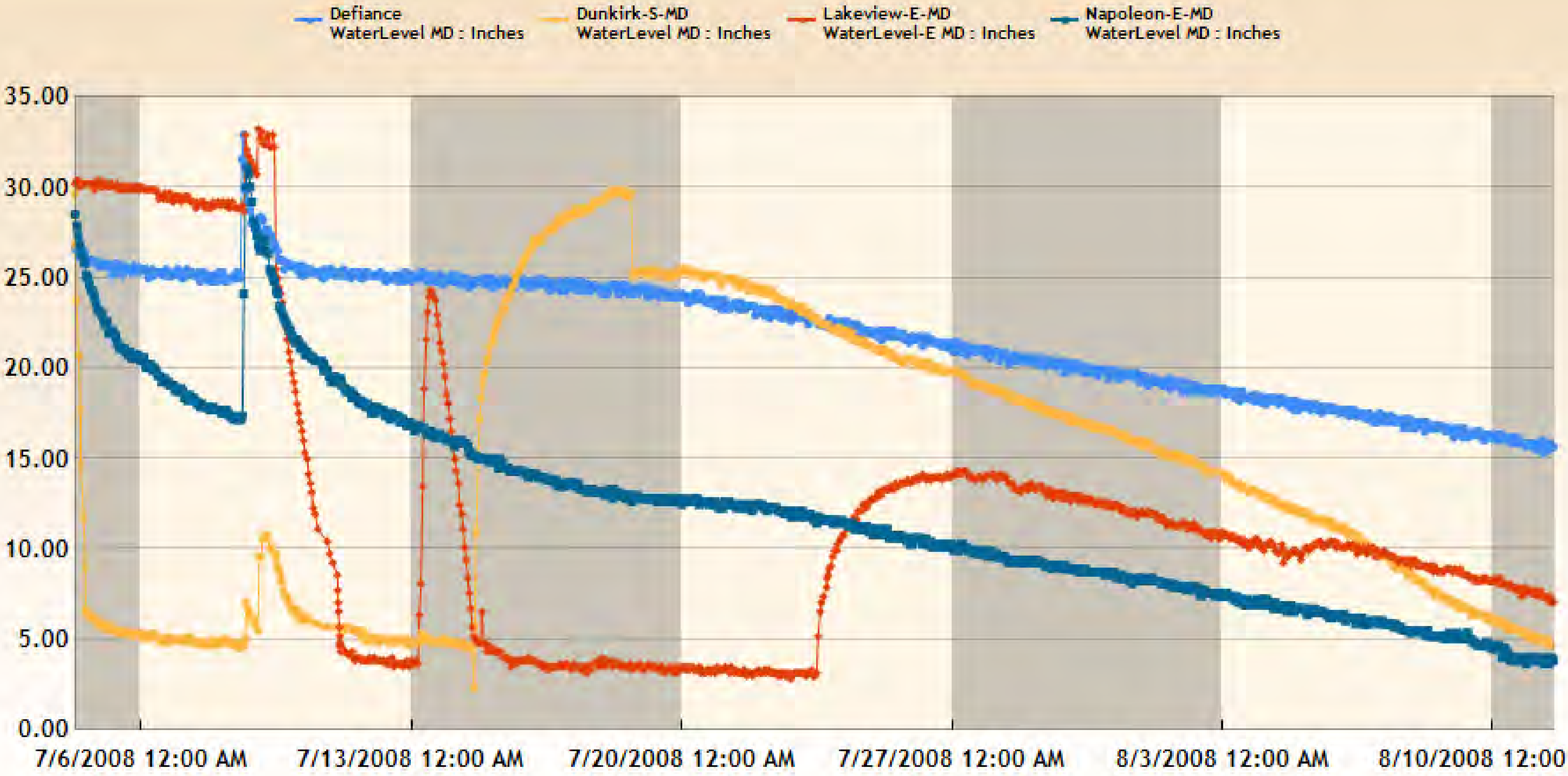
Summer 2008 – 4 Sites NW Ohio



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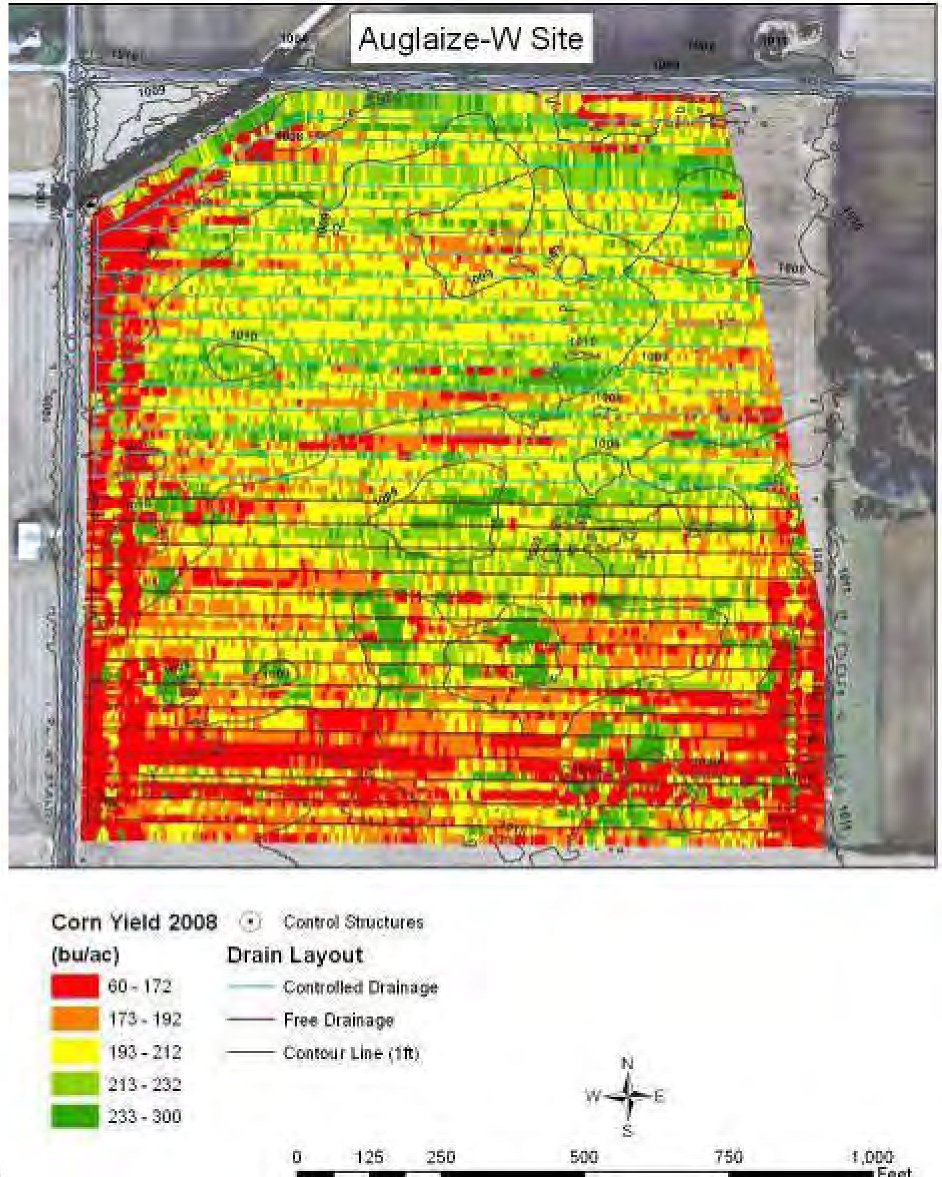
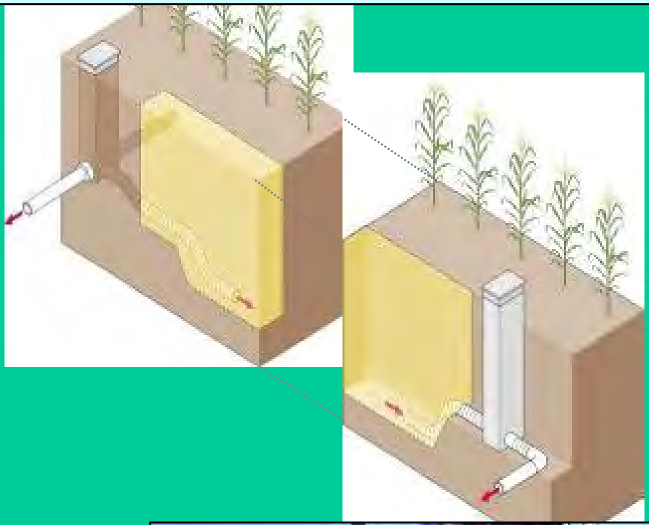
Auglaize-W Site
Control Structures
Drain Layout
Controlled Drainage
Free Drainage
N
W
E
S
0 125 250 500 750 1,000
Feet


Auglaize-W Site
Corn Yield 2008
(bu/ac)
60 - 172
173 - 192
193 - 212
213 - 232
233 - 300
Control Structures
Drain Layout
Controlled Drainage
Free Drainage
Contour Line (1ft)
N
W
E
S
0 125 250 500 750 1,000
Feet

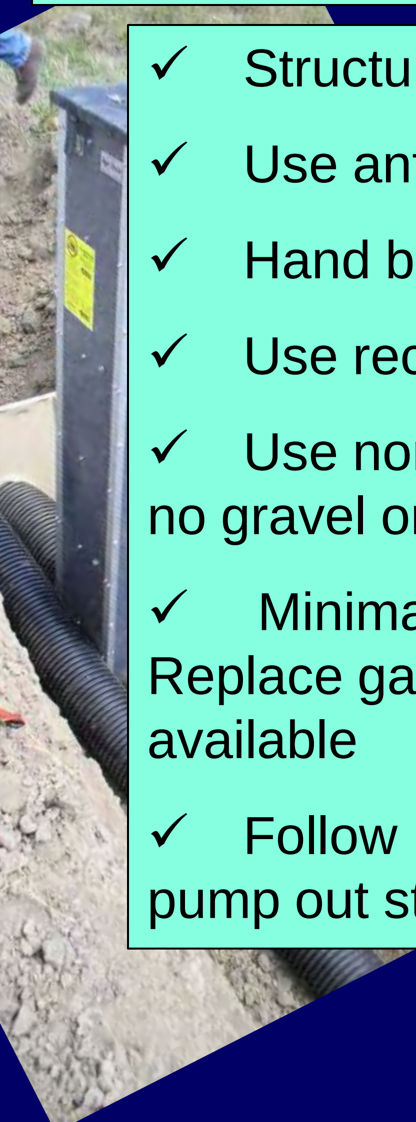
Bio-Reactor approach modeled after research by Dr. Richard Cooke, UII

Application of Drainage Water Management and Bio-Reactors for Liquid Manure Application on Subsurface Drained Cropland, and Milking Center Wastewater





For Land Application of Liquid Manure using Drainage Water Management, Proper Installation and Maintenance is even more Important!



- ✓ Structure placed on solid, undisturbed earth (no gravel)
- ✓ Use anti-seep collar
- ✓ Hand backfill; Do not backfill or compact by machine
- ✓ Use recommended fittings and pipe; Joints water tight
- ✓ Use non-perforated pipe on both sides of structure, approx. 20’; no gravel or sand
- ✓ Minimal maintenance; Check gaskets on flashboards regularly; Replace gaskets if worn; Grease tracks; Keep flashboards and tool available
- ✓ Follow NRCS design recommendations for observation and pump out storage

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Study by Professor G.O. Schwab et al.

Undrained → Surface → SubSurface → Combination

Year-to-year yield stability increases
as drainage intensity increases.

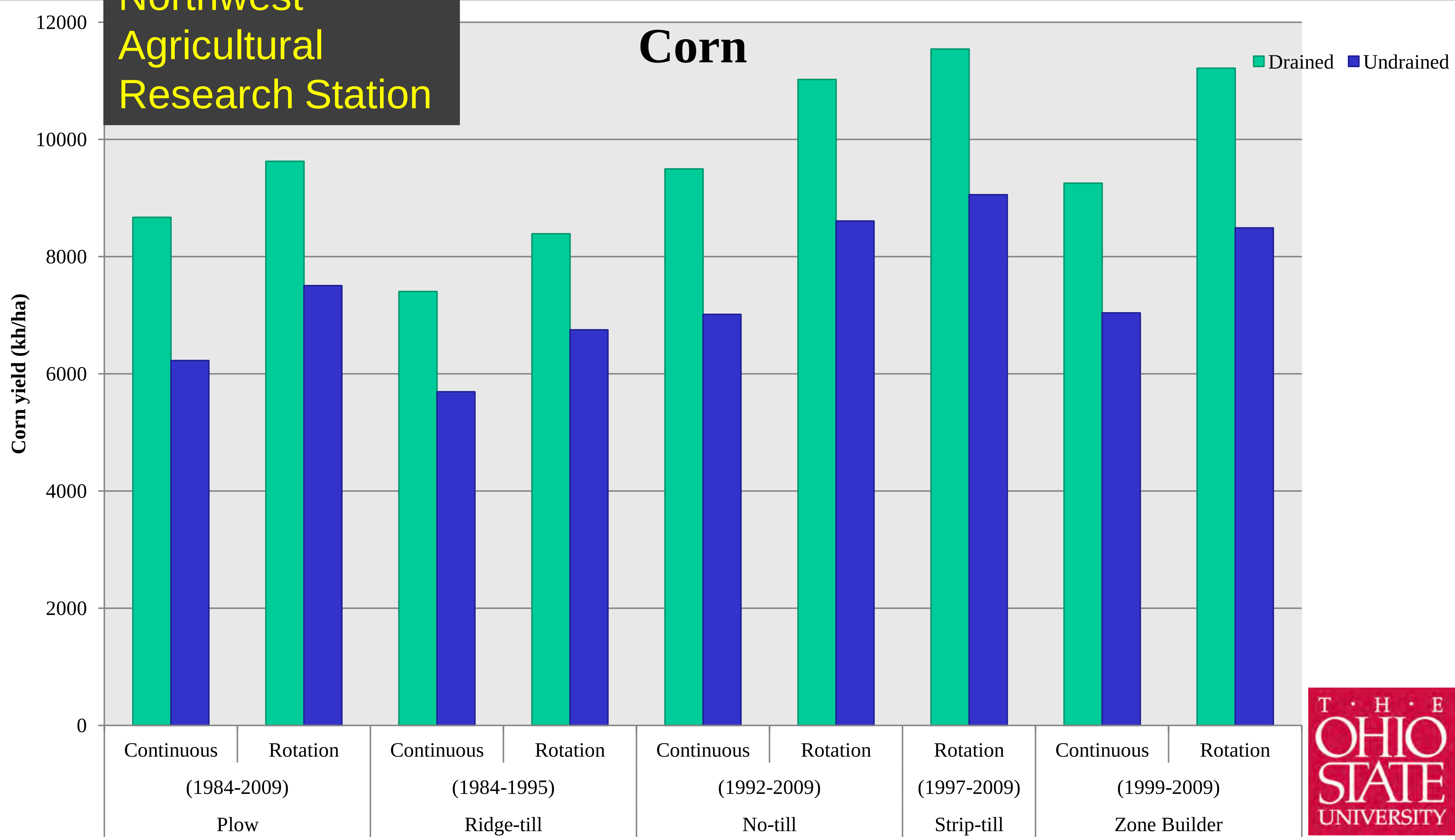
- Toledosiltyclay
- 20-year study
- Crop yields, water qality, soil properties
- North Central Branch Station, OARDC

Contact L.C. Brown brown.59@osu.edu for Data Summary

Subsurface Drainage and Crop Yields - Corn

OARDC
Northwest
Agricultural
Research Station

Increase 24 to 39%



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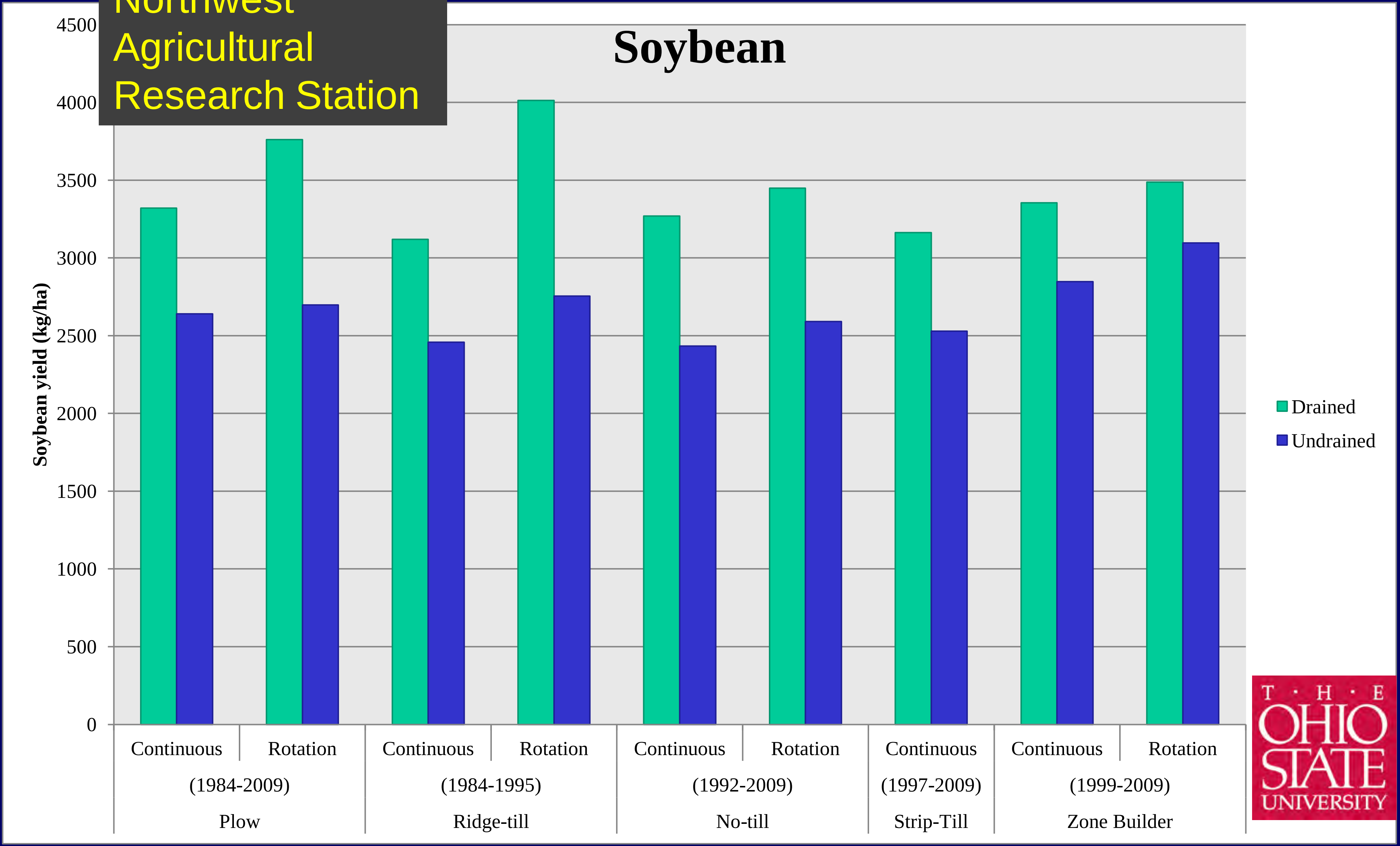
Subsurface Drainage and Crop Yields - Soybean

OARDC
Northwest
Agricultural
Research Station

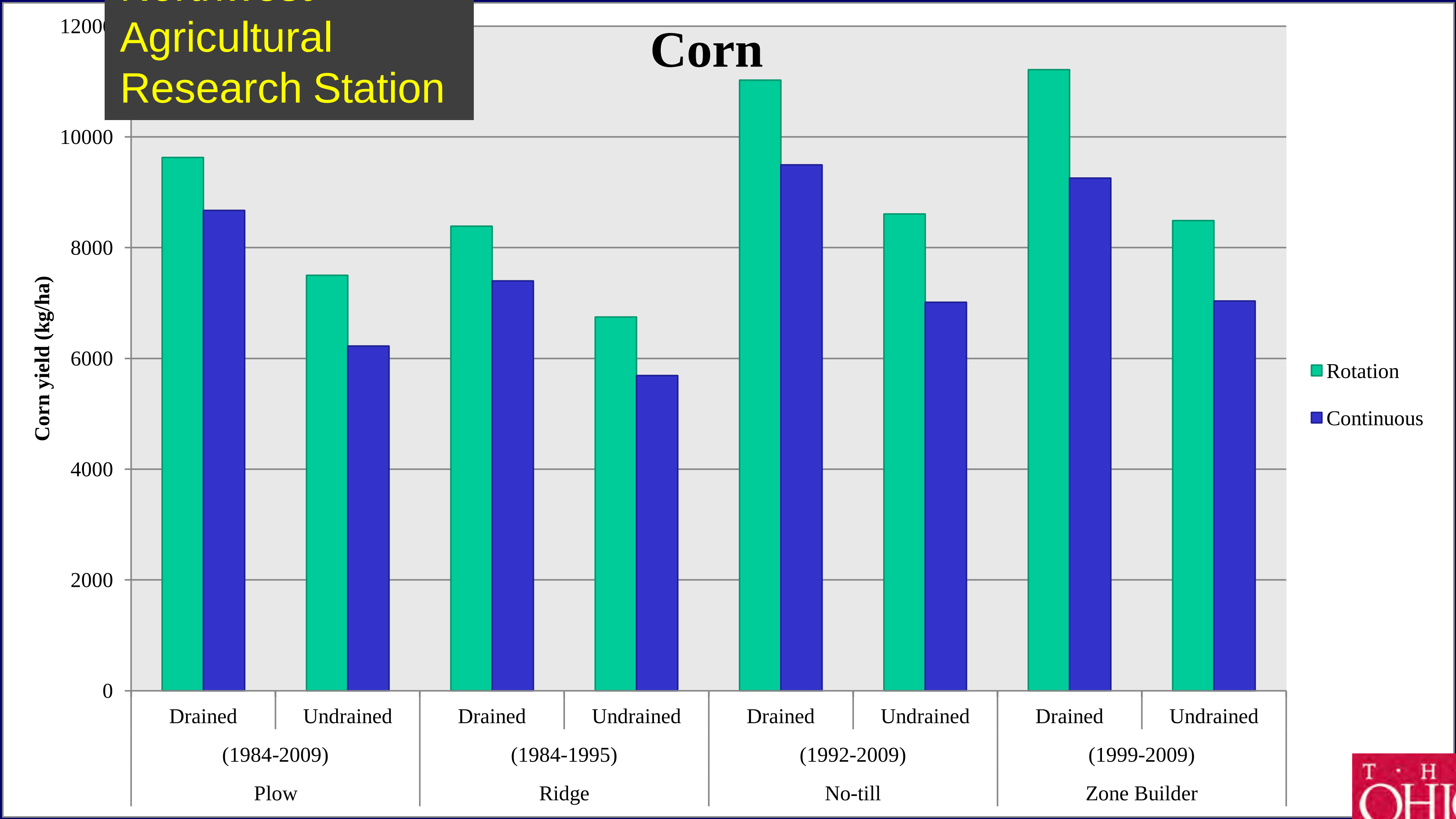
Increase 13 to 46%



Subsurface Drainage and Crop Yields - Rotation

OARDC
Northwest
Agricultural
Research Station

Increase 11 to 23%



email brown.59@osu.edu for copy of paper

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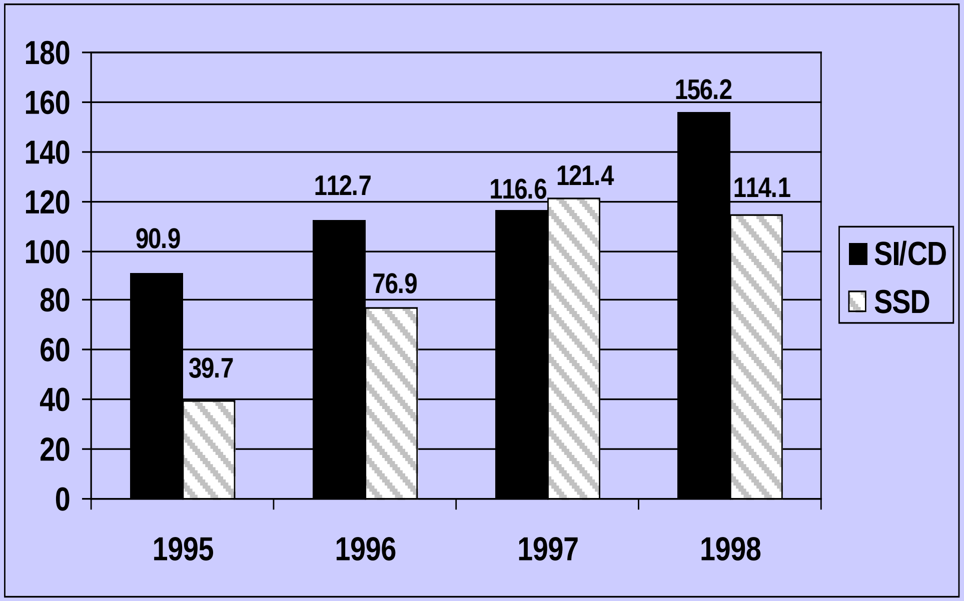
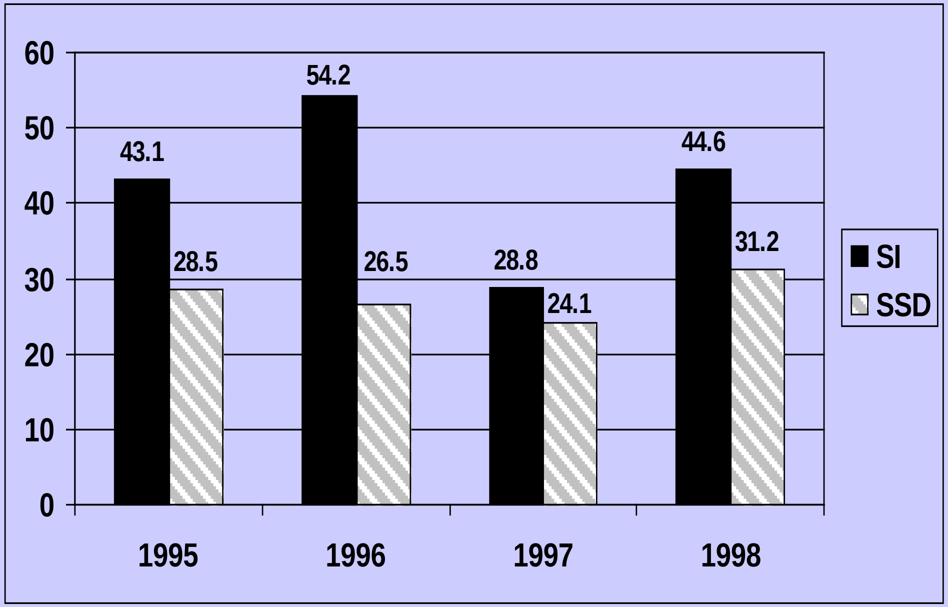
Crop Yields with Water Table Management (Subirrigation/Controlled Drainage)

Brown, Fausey, Bierman, Workman, Subler





Corn

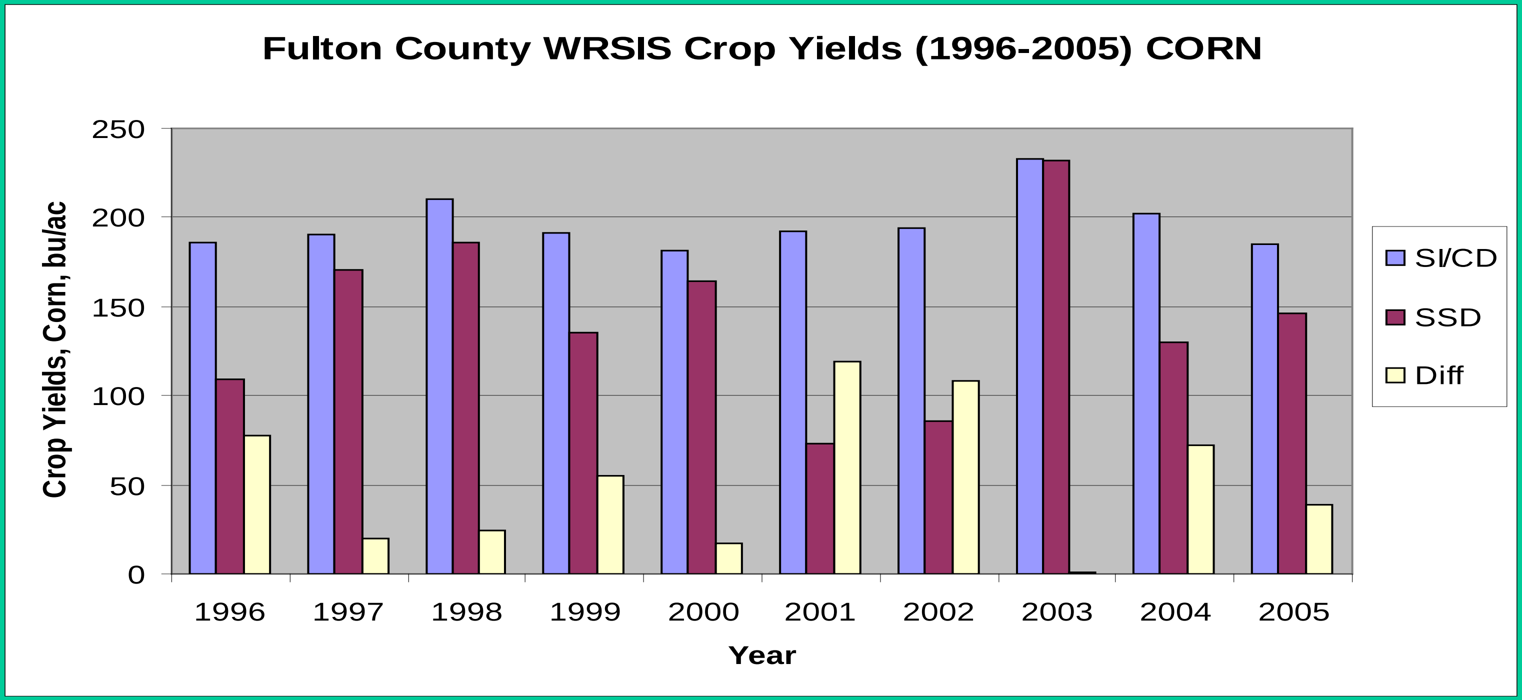
Soybean

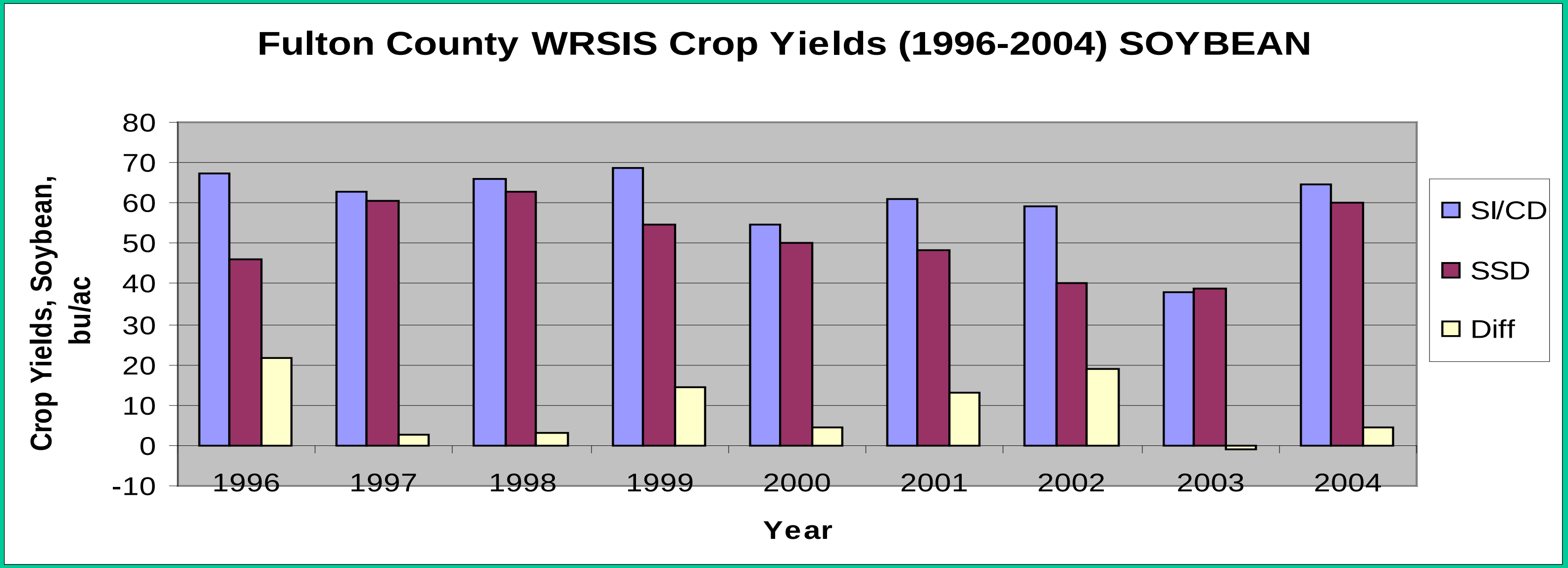
Partial-season subirrigation in 1995 and 1998
Full-season subirrigation in 1996 and 1997

7.7 in precipitation during subirrigation period in 1996
13.1 in precipitation during subirrigation period in 1997

CWAES @ PREC, Pike County

Corn and Soybean Yields Fulton County WRSIS Site





Over 10 Years, SI/CD Yield Advantage was 53 bu/ac for Corn; 9 bu/ac for Soybean

Yield and Grain Quality Improvement possible with Subirrigation and Proper Management

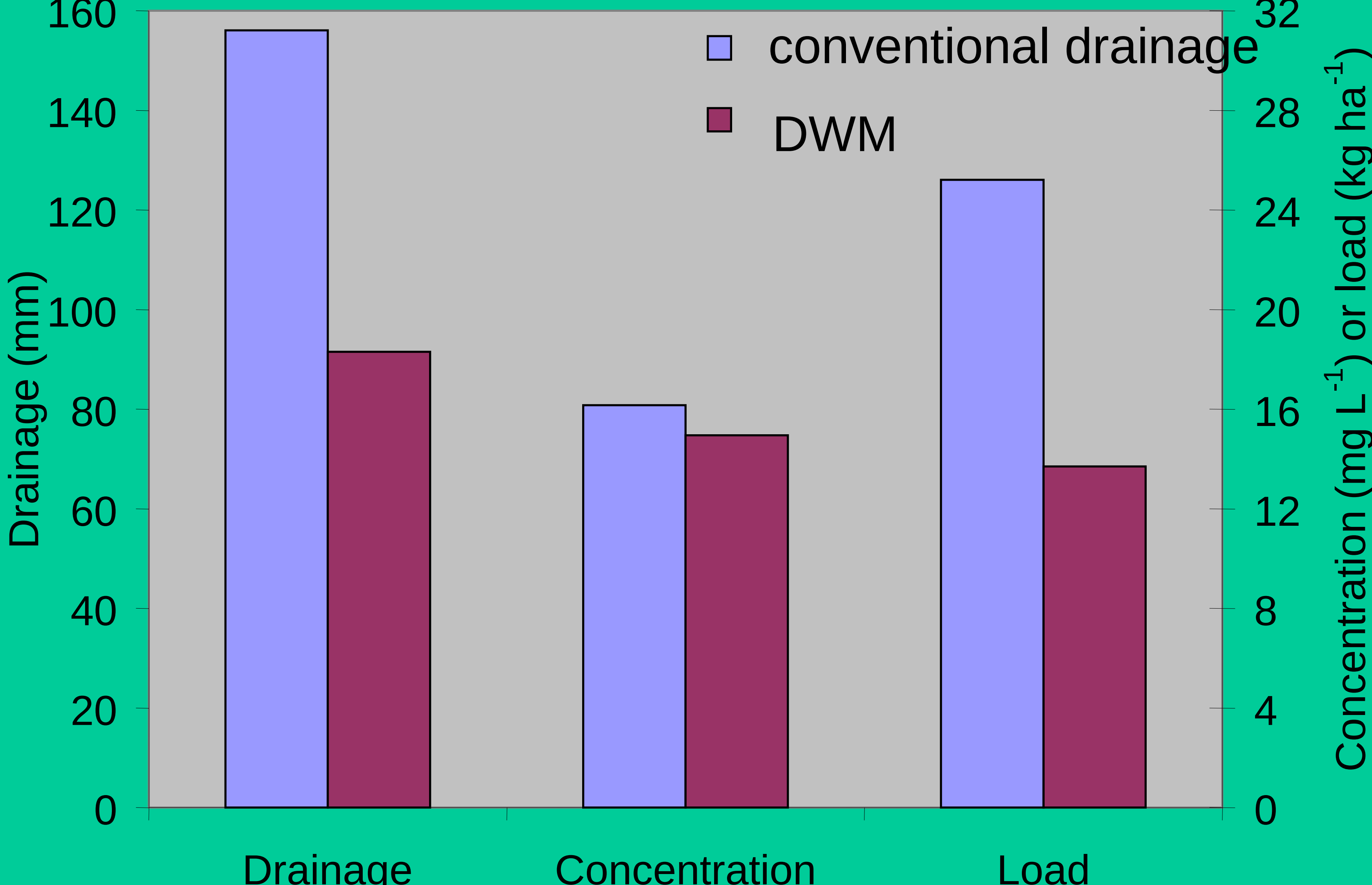
Shininger Farm, Ear Comparison
Fulton County
(left SI; right SSD)
Photo by Greg La Barge, 2001

For Many of Ohio's Poorly Drained, and Somewhat Poorly Drained Soils:

- Compared to lands with adequate surface drainage,
  - Subsurface drainage improvements may increase yields by 25-30 bu/ac for corn and 3-12 bu/ac for soybean
- Compared to lands with adequate subsurface drainage, and where conditions are appropriate,
  - Controlled drainage may increase corn and soybean yield on average by 7.0% and 3.6%, respectively.
- Compared to lands with adequate subsurface drainage, and where conditions are appropriate,
  - Subirrigation/controlled drainage may increase yields by 25-60 bu/ac for corn and 9-12 bu/ac for soybean

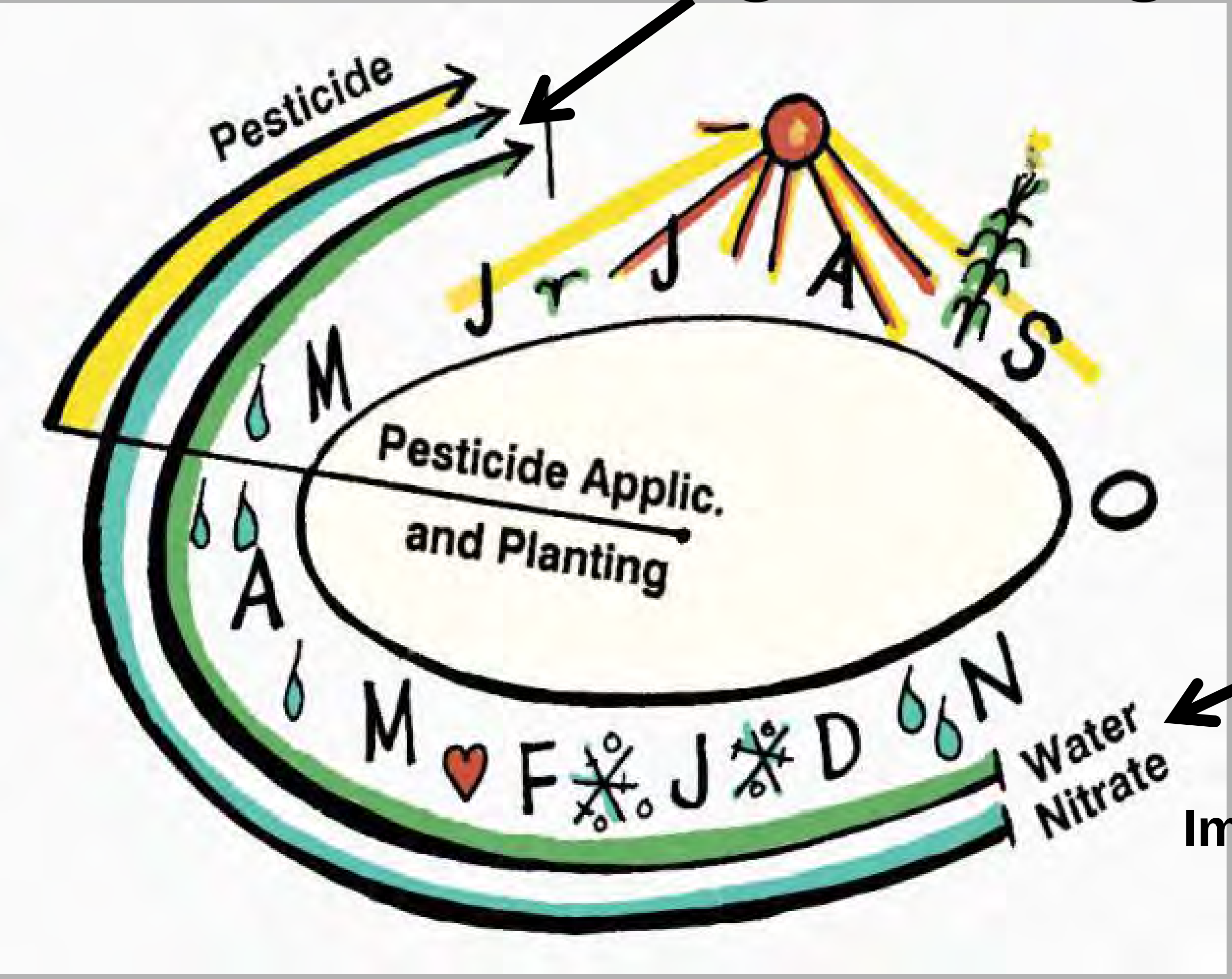
Ohio State University/USDA-ARS Crop Yield Data

4-yr Average Water and Nitrate-N Losses in Ohio



Data from N. Fausey, 2005

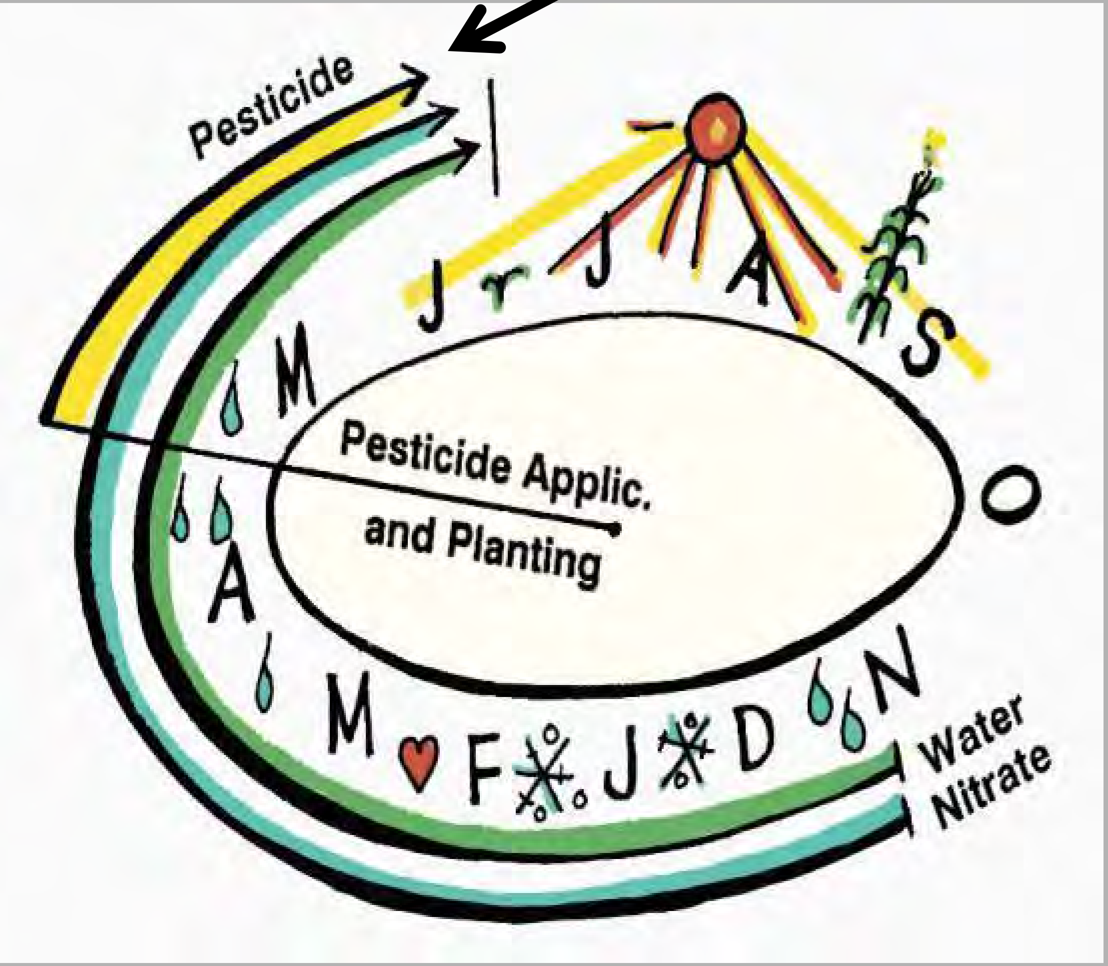
Consider that anytime the drains are flowing, there is most likely some nitrate-nitrogen being exported.



Nitrate and subsurface drainage

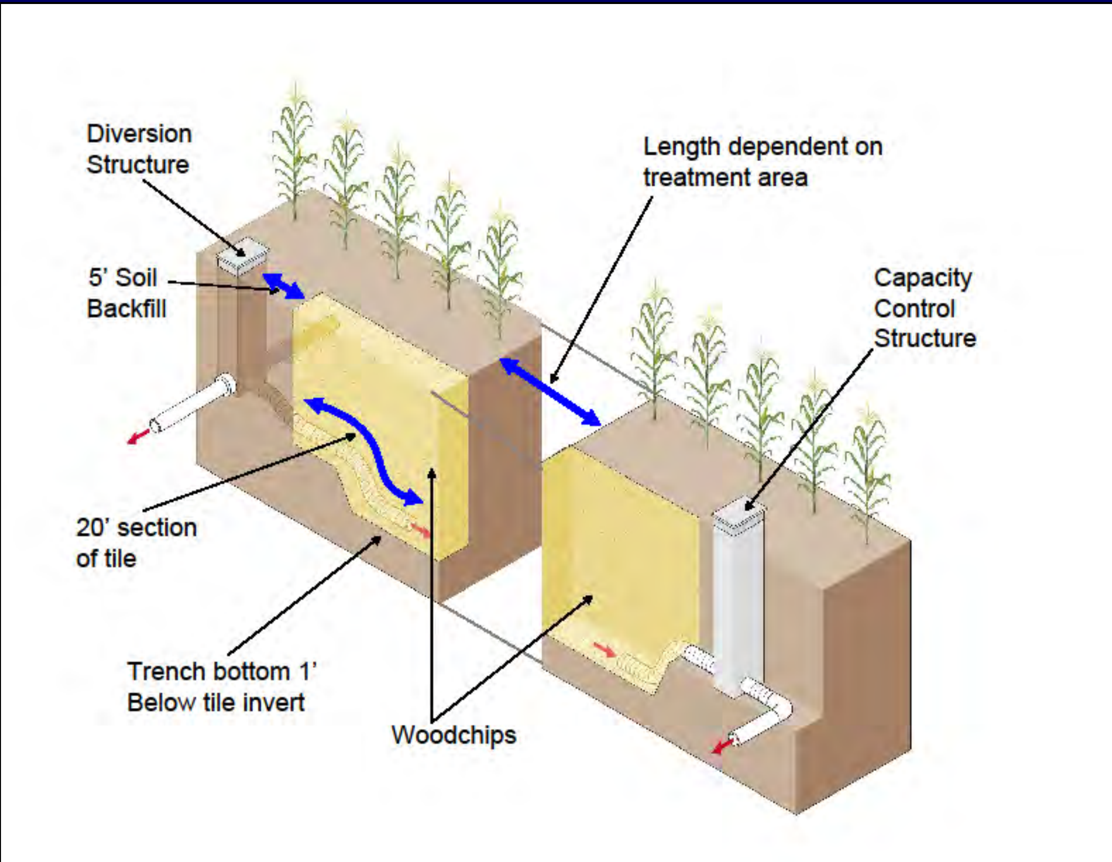
Image from E. Kladivko – Purdue University

Consider that pesticides have the greatest potential to be exported through subsurface drains to surface waters soon after application in the spring.



And,,,, When surface inlets discharge into subsurface drainage systems, or subsurface drainage system is not maintained, blowholes or other short-circuiting mechanisms are present.

Opportunities


Diversion
Structure
5' Soil
Backfill
Length dependent on
treatment area
Capacity
Control
Structure
20' section
of tile
Trench bottom 1'
Below tile invert
Woodchips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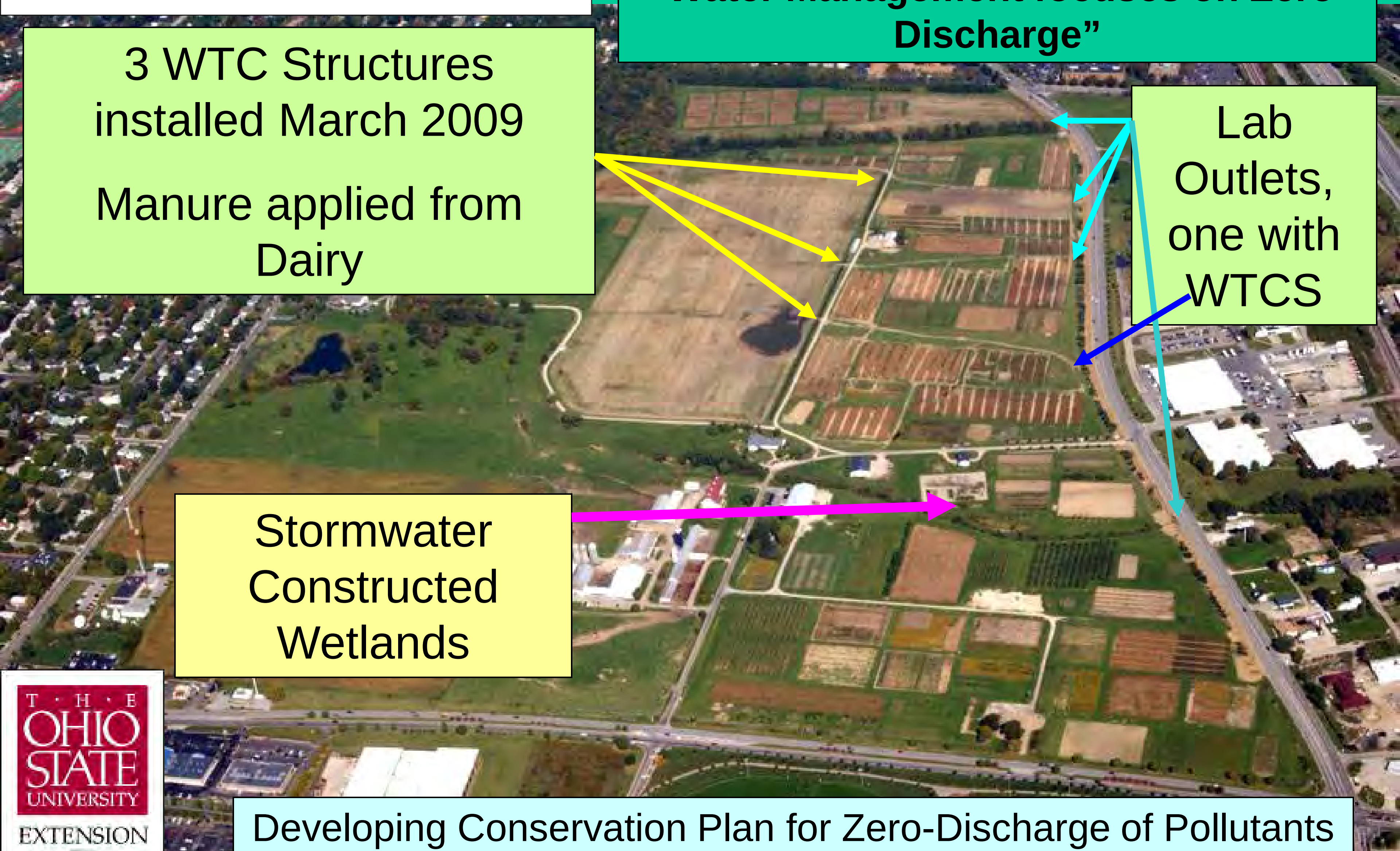
Waterman Agricultural and Natural Resources Lab
"Water Management focuses on Zero-Discharge"

3 WTC Structures installed March 2009

Manure applied from Dairy

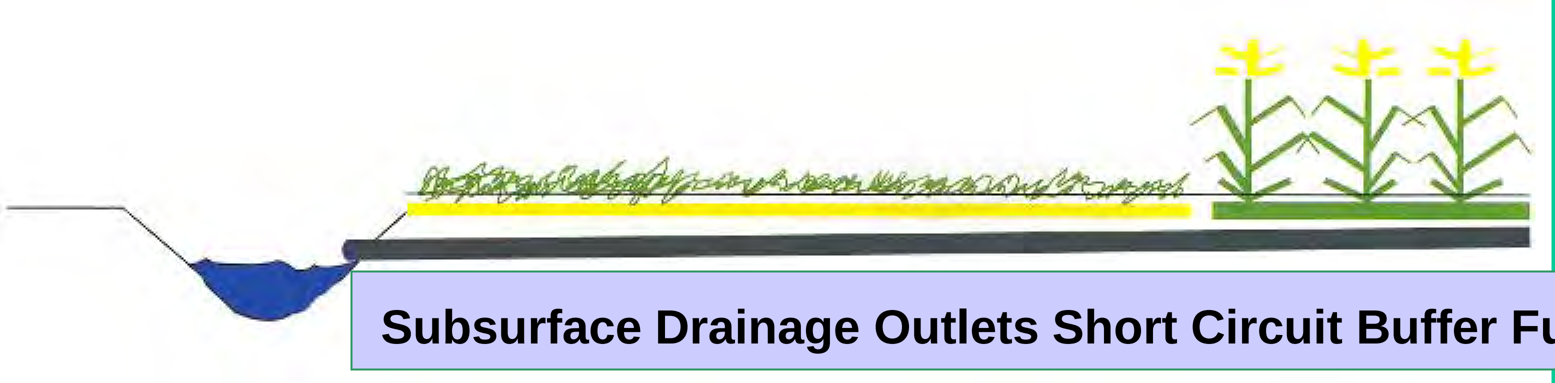
Lab Outlets, one with WTCS

Stormwater Constructed Wetlands



THE OHIO STATE UNIVERSITY EXTENSION OARDC

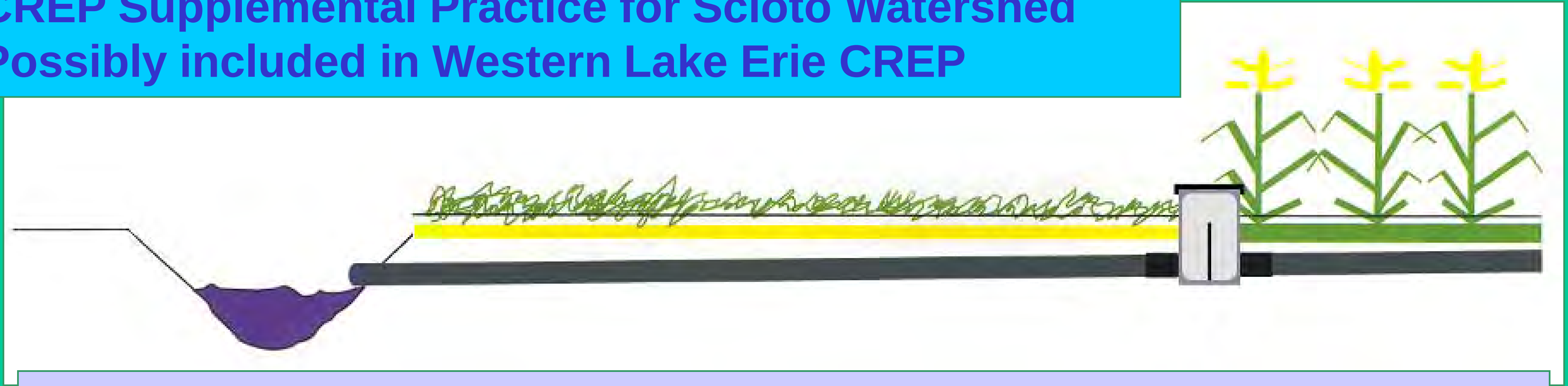
Developing Conservation Plan for Zero-Discharge of Pollutants



Subsurface Drainage Outlets Short Circuit Buffer Function

Conservation Buffers w/Controlled Agricultural Drainage

(Drainage Water Management NRCS 544)
CREP Supplemental Practice for Scioto Watershed
Possibly included in Western Lake Erie CREP



Buffer and Cropland with Subsurface Drainage and Outlet Control Structure

Seeking support to verify impact of this practice

Fulton County WRSIS Site, Shininger Farm – August 1996

- Soil predominantly Nappanee loam
- 1 - 8.1 ha (20 ac) subirrigated field. Drain spacing is 4.6 m (15 ft)
- One 8.1 ha (20 acre) field with conventional subsurface drainage. Drain spacing is 13.7 m (45 ft)
- Wetland: 0.57 ha (1.4 ac) area and 3,790 m^3 (1.0 million gal) capacity
- Reservoir: 0.64 ha (1.57 ac) area and 8,706 m^3 (2.3 million gal) capacity
- Stream provides additional water supply

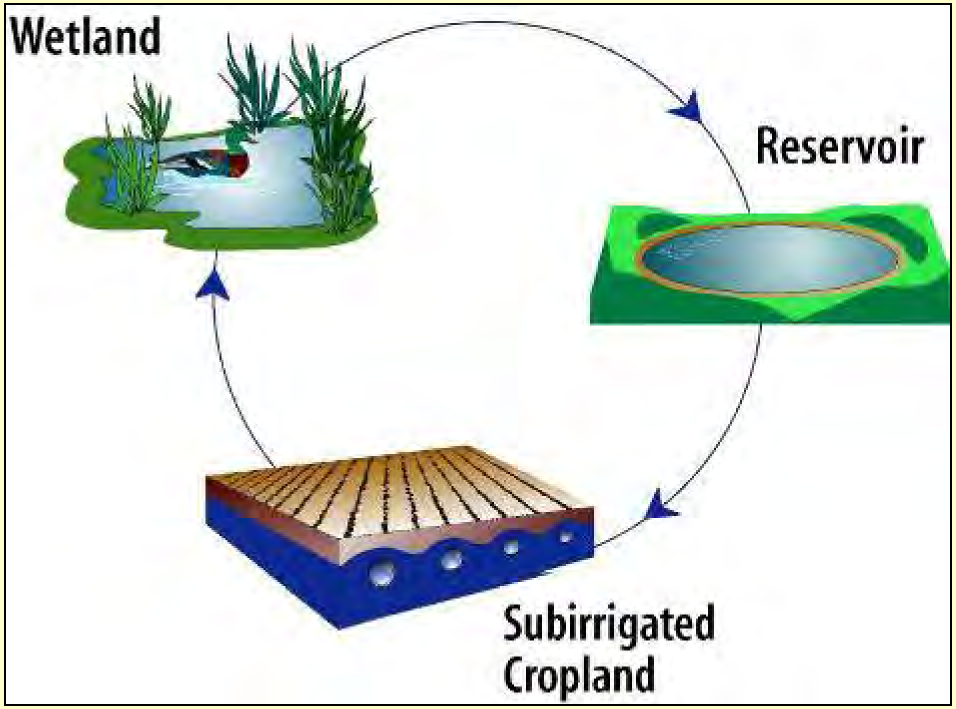
Ohio WRSIS

Photo Courtesy of USDA-NRCS-MVRC&D

Wetland-Reservoir-Subirrigation-Systems (WRSIS)

Agricultural Drainage Water Harvesting, Treatment, Storage, and Recycling for Irrigation Water Supply, Crop Yield Increase and Water Quality Improvement

- ***Increased*** **wetland acres on farmland**
- ***Improvement*** **in wetland vegetation and wildlife habitat**
- ***Significant increase*** **in crop yields**
- ***Significant improvement*** **in water quality**
- ***Potential*** **to provide** ***only clean water*** **leaving the farm**
- **Goal was not restoration, but integrating constructed wetlands within farming systems – "Agricultural Constructed Wetland"**
- ***Technology extended*** **to Ontario, Michigan, Illinois, Indiana, China**



Collaboration w/USDA-NRCS; ODNR-DSWC; producers; others

Brown, Allred, Fausey et al.

USDA ARS

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2012 Overholt Drainage School

March 19-23

Paulding County, Ohio

- Laser Surveying/Topographic Mapping
- GPS-RTK Surveying/Topographc Mapping
- Subsurface Drainage: Design, Layout and Installation; Benefits and Impacts
- Drainage Water Management **(*Controlled Drainage*)** Design, Layout, Construction, and Management

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College of Food, Agricultural, and Environmental Sciences

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Agricultural Water Management

www.ag.ohio-state.edu/~agwatmgt/

AWM

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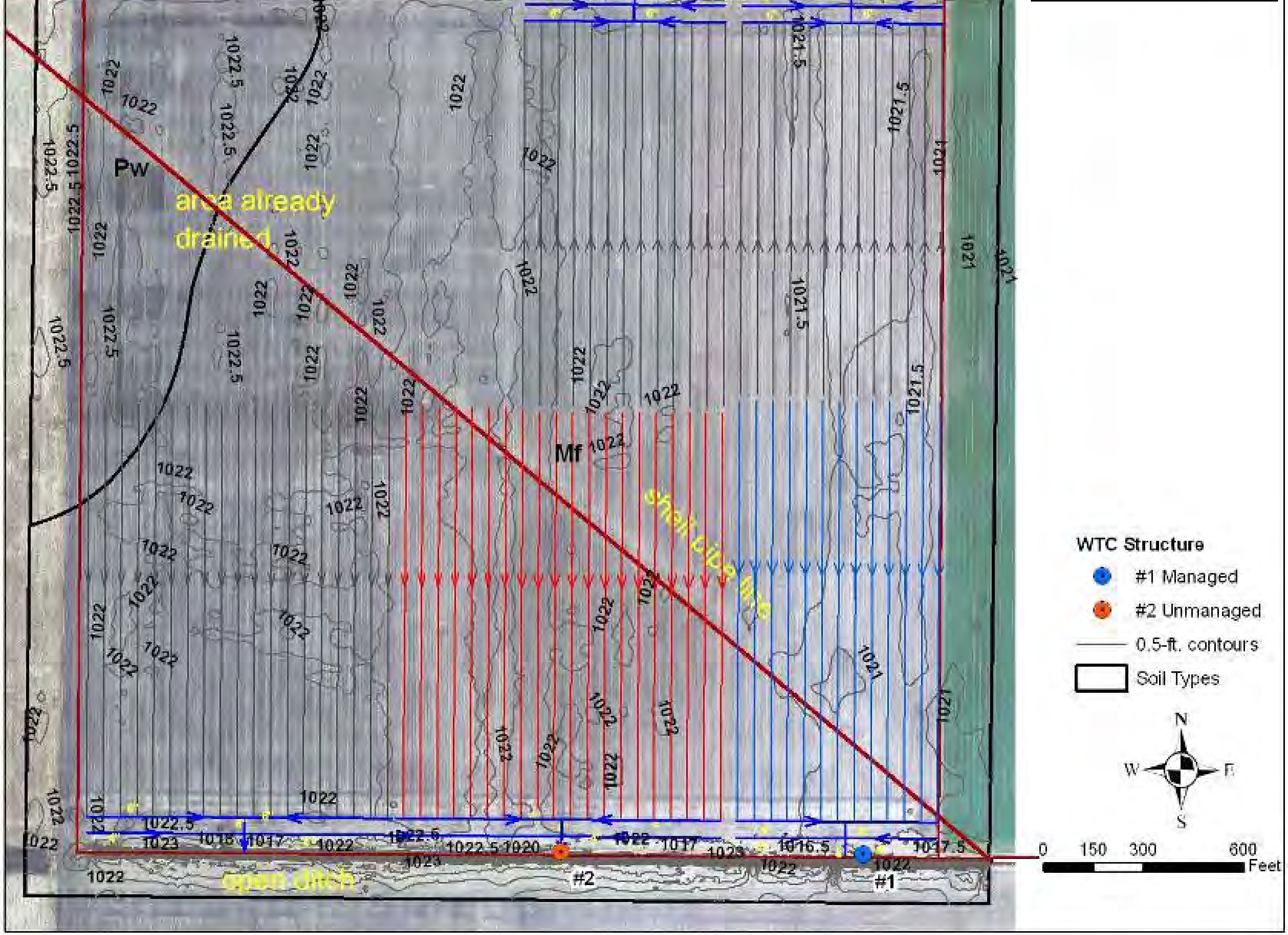
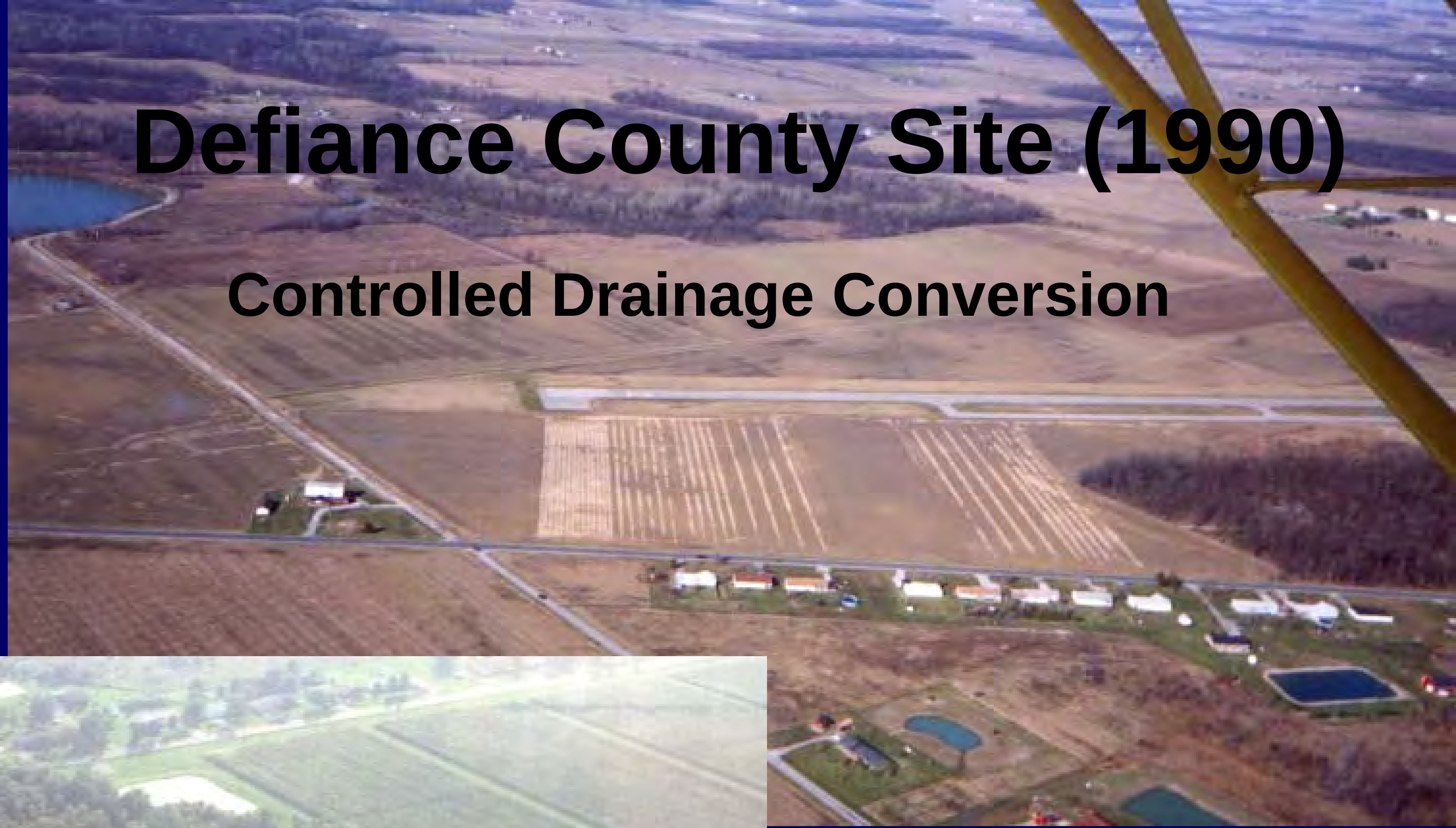
Lakeview



open ditch
area already drained
Pw
Mf
shell pipe line
open ditch
#2
#1
WTC Structure
#1 Managed
#2 Unmanaged
0.5-ft. contours
Soil Types
N
W
E
S
0
150
300
600
Feet

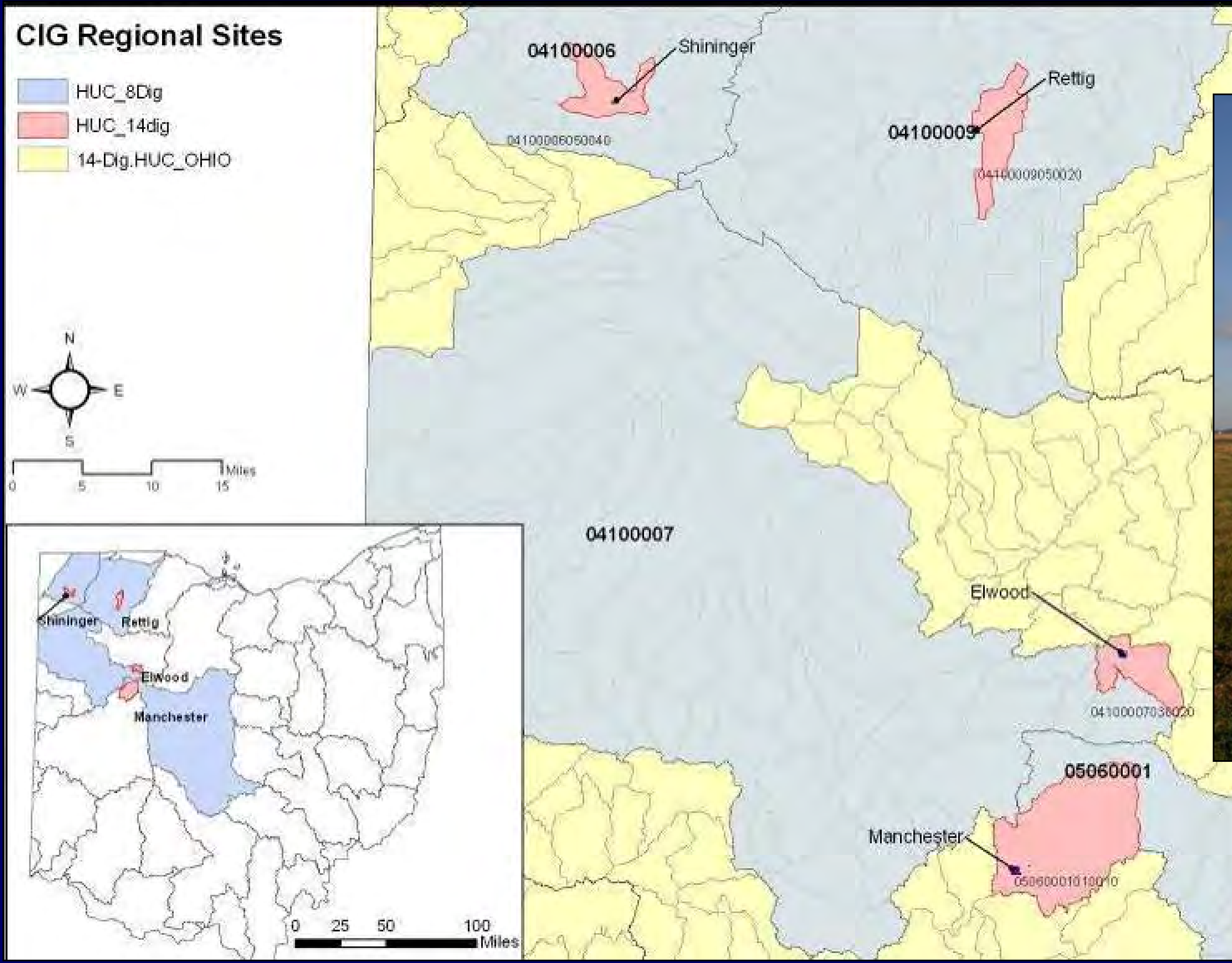
Defiance County Site (1990)

Controlled Drainage Conversion



Defiance County WRSIS Site 1998

WRSIS Ohio Sites in Fulton, Defiance, Van Wert counties



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Pressure Transducer – Senses Height of Water in Structure

Brown, Fausey et

V-Notch Weir

With Pressure Transducer We Can Estimate Flow Rate

Brown, Fausey et