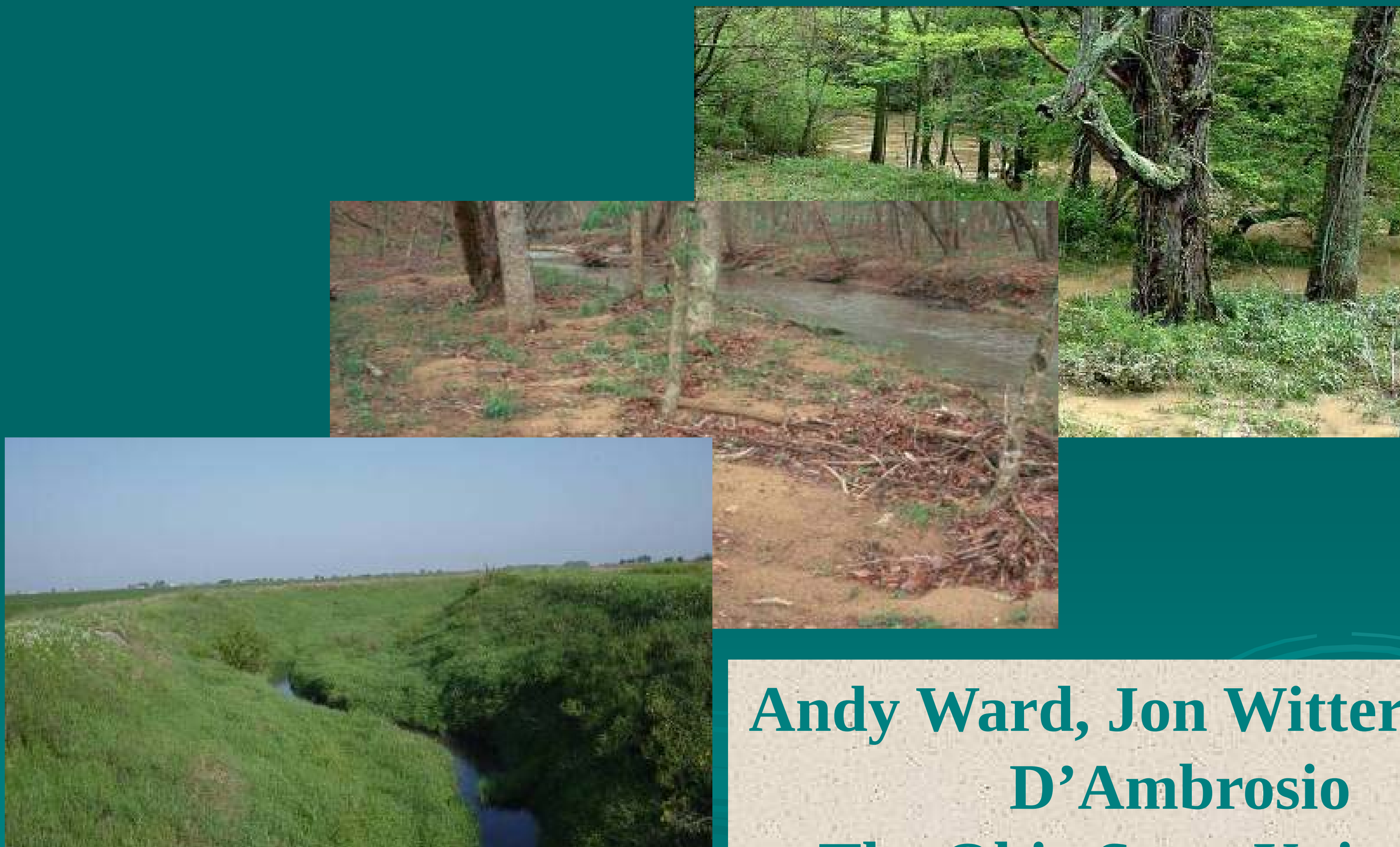
Benefits of Establishing Floodplains in Agricultural Ditches: Two-Stage Ditch Approach

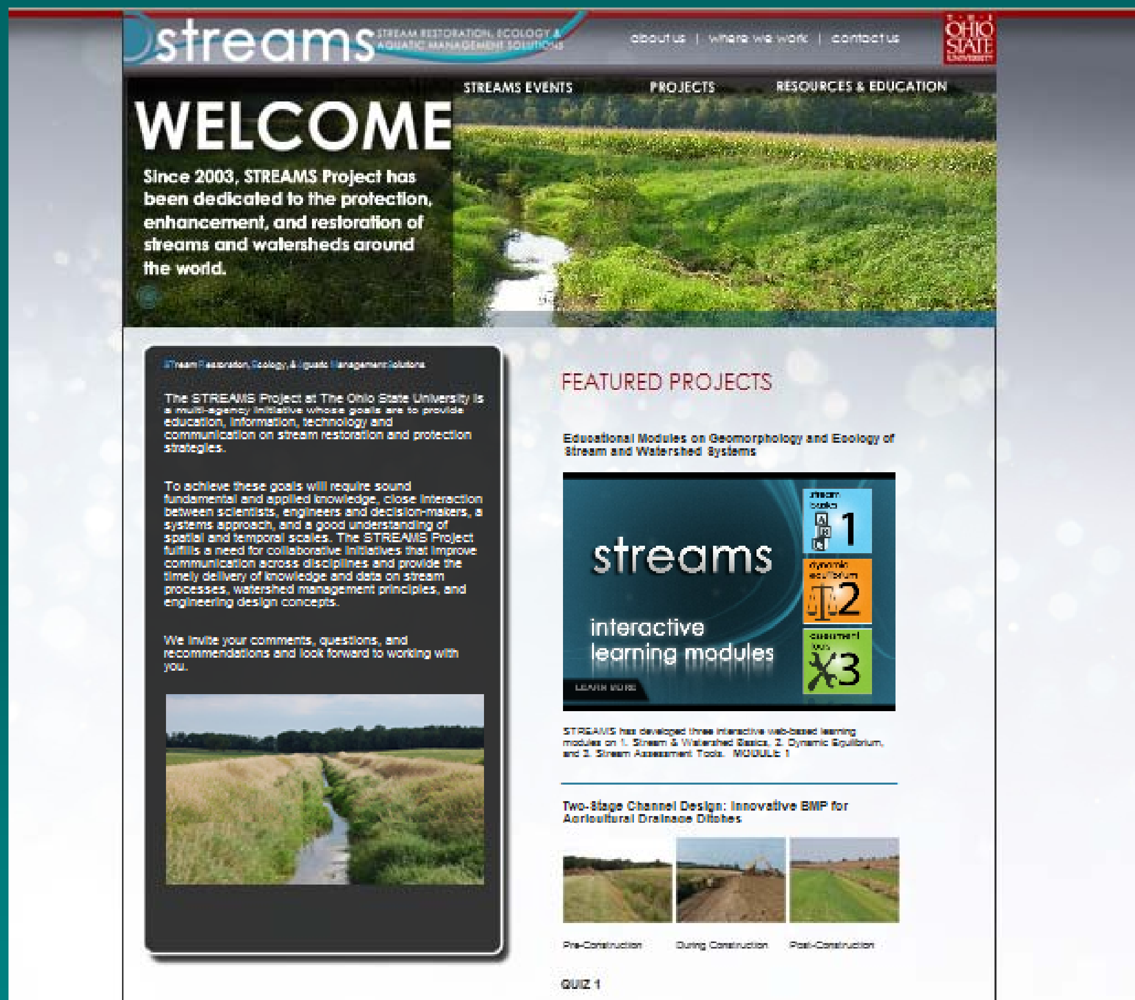


Andy Ward, Jon Witter Jessica D'Ambrosio
The Ohio State University

STREAMS Website

Streams.osu.edu

http://www.twitteringmachineproductions.com/streams2/



Stream Restoration Design

How to use this CD:

Open MAIN-MENU.pdf with Adobe® Reader® (free at www.adobe.com)

Helping People Help the Land

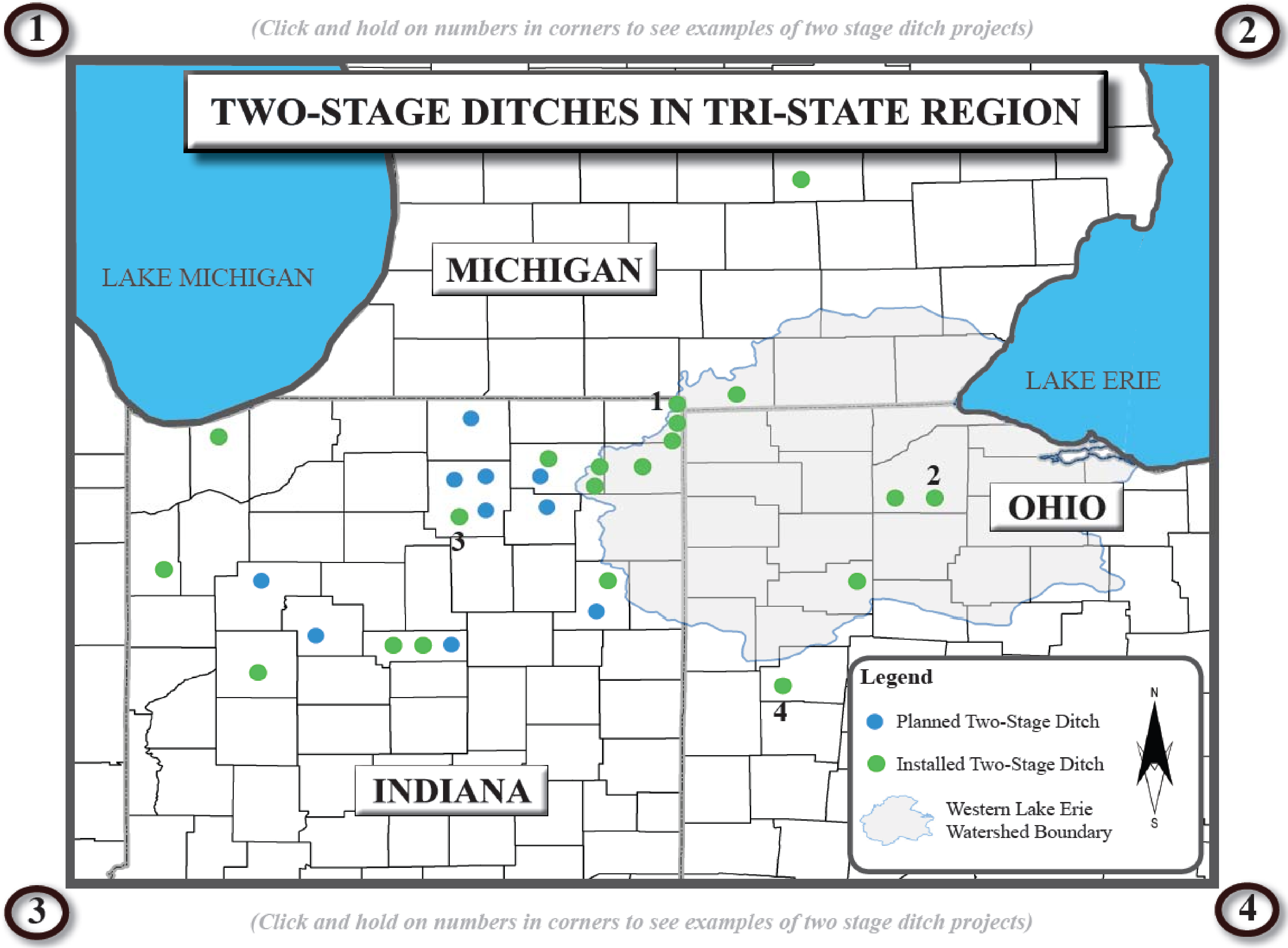
USDA Natural Resources Conservation Service

www.nrcs.usda.gov

NRCS

National Engineering Handbook Part 654 August 2007 (NEH-654)

(Click and hold on numbers in corners to see examples of two stage ditch projects)



(Click and hold on numbers in corners to see examples of two stage ditch projects)

To Build a Better Ditch

http://vimeo.com/7901535

What is Dynamic Equilibrium?

- Dynamic equilibrium is a self-maintaining state that balances stream power with the discharge of bed material sediment.
- The stream system transports its sediment load without aggrading or degrading while maintaining its dimensions, meander pattern, and profile.

Equilibrium States of Stream Systems

A stream can be failing, recovering, in a quasi-state of equilibrium, or in dynamic equilibrium.

Failing streams down-cut or get wider or both.

Equilibrium State

Recovering Streams

Recovering streams build features such as point bars, benches, and floodplains. Often they will also be getting narrower.

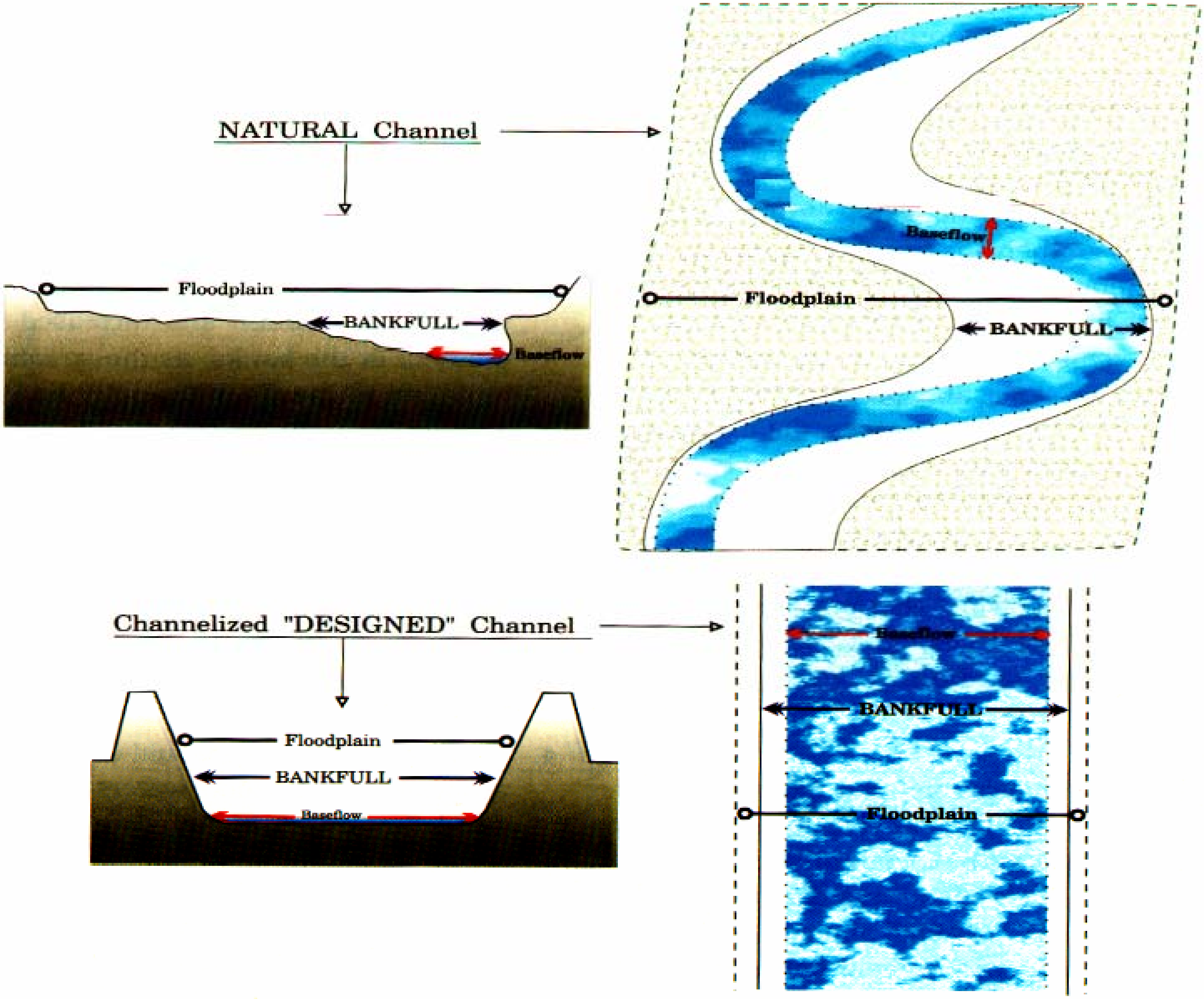
What are Channel-Forming Discharges?

Channel-forming discharges are the range of flows that shape the channel, bars, benches, and the active floodplain elevation associated with dynamic equilibrium.

Incised Channels

Subsurface Drainage

A Natural Stable Stream vs A Designed Stream



Main Channel Meandering And A Bench Forming

Why Is Bench Formation Associated with Low Energy Channel Forming Discharges?

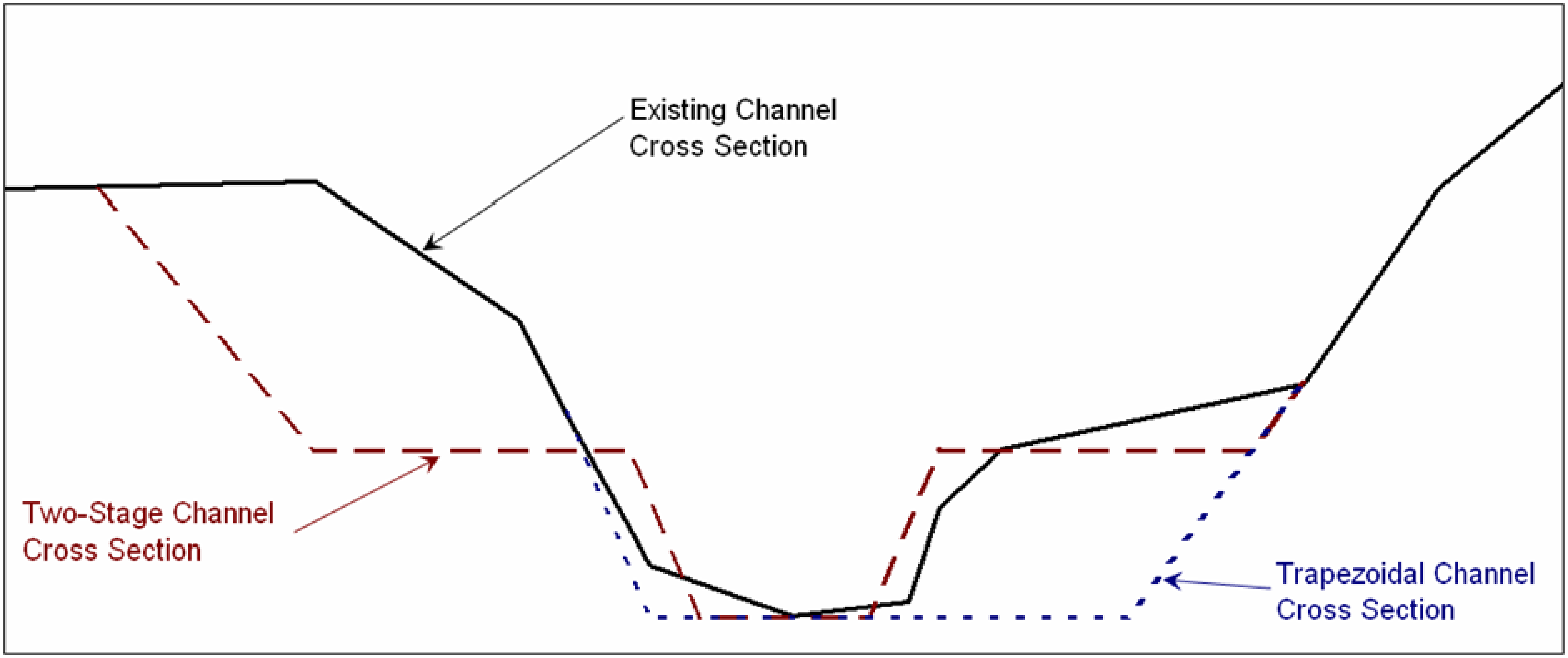
- There is an available supply of fine material at the bottom of the ditch
- Sediment from bank instability
- The dominant flow is subsurface drainage
- Most of the flow entering the ditch contains very little sediment
- Grass rapidly stabilizes the benches


Taiwan
Illinois
South Africa
Mississippi
Ohio
Minnesota
Ohio
Michigan
Ohio

Maintenance Often Removes Fluvial Benches That Will Rebuild Again

Removal of Stable Benches in a Minnesota Ditch

Two-Stage Channel Design



Jin-Mei Creek, Taiwan

Natural Floodplain within a 200 year flood levee

Constructed Terrace within a 200 year flood levee

Sizing Two-Stage Channels

1. Project Identification
2. Data Collection
3. Data Analysis
4. Channel Sizing
5. Hydrologic Evaluation
6. Project Assessment
7. Final Sizing and Design
8. Construction
9. Monitoring and Performance Evaluation

1. Project Identification

- Problem Identification
- Project Situation
- Watershed conditions
- Channel Failures
  - Bank instability
  - Cut banks
  - Sediment deposition
  - Restricted drainage outlets
  - Inadequate subsurface drainage
  - Insufficient capacity

2. Data Collection

3. Data Analysis

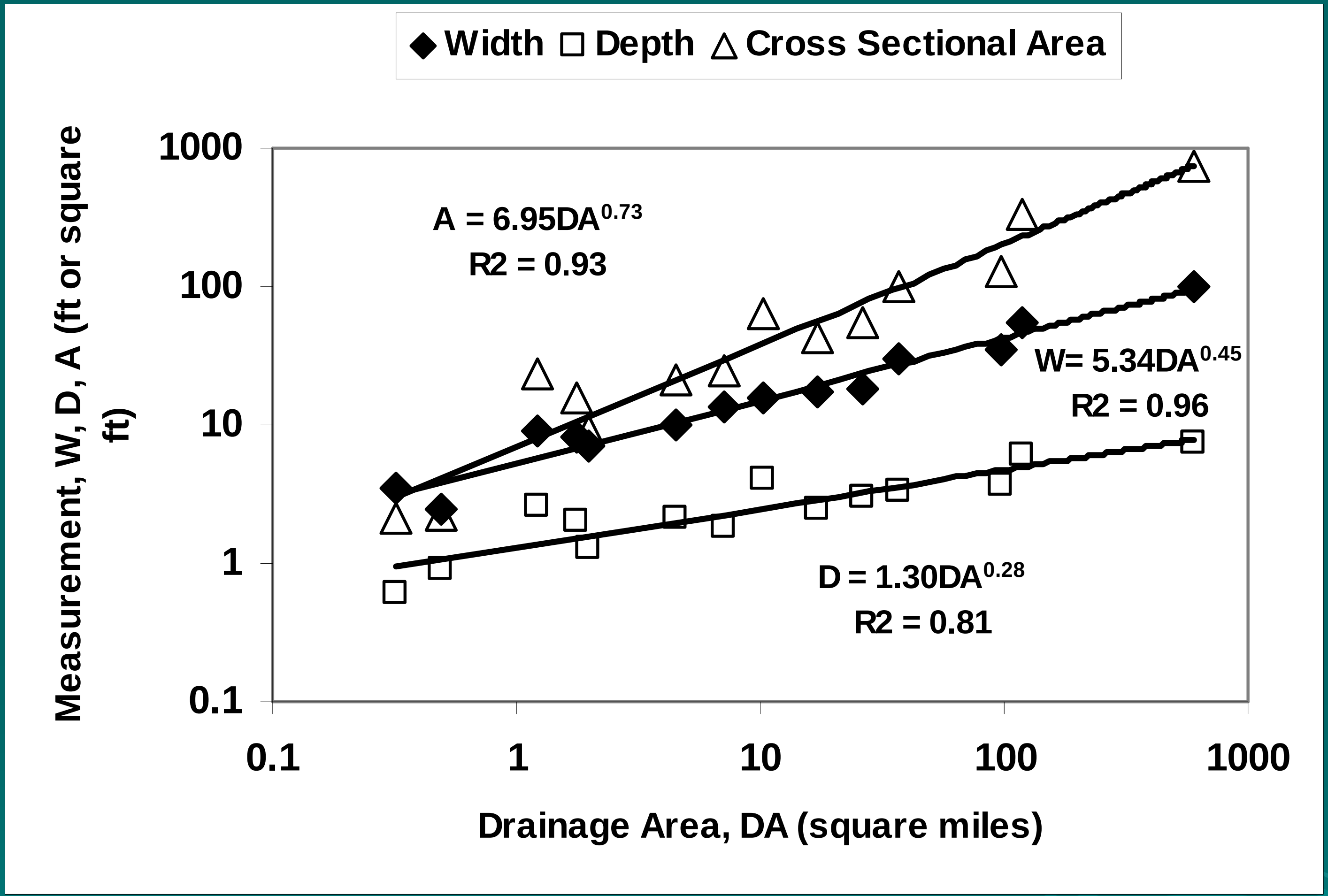
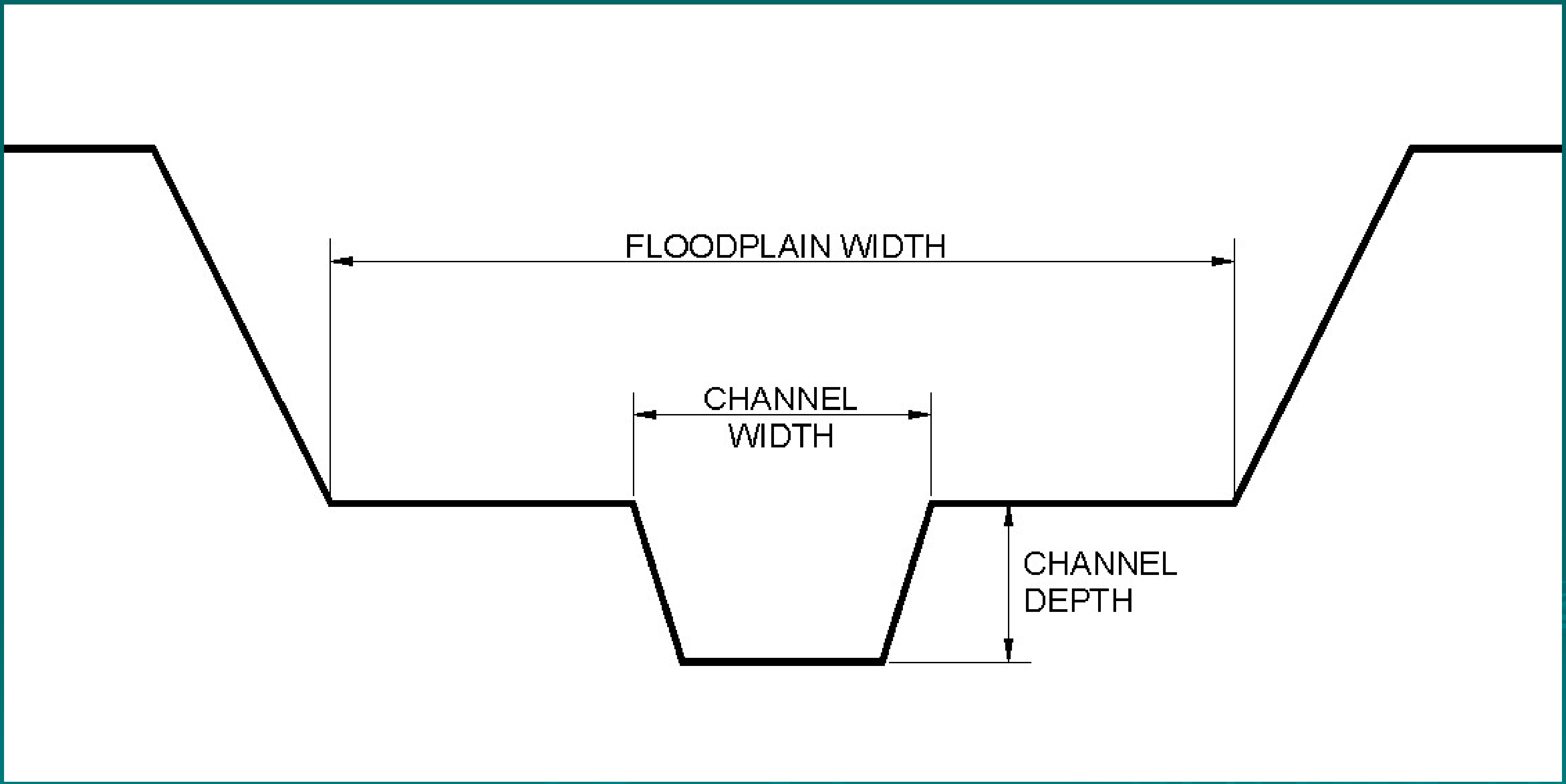


Figure 9. A regional curve for the St. Joseph watershed developed by the project team.

4. Channel Sizing



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MAJOR PROGRAMS
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Agricultural Pollution Abatement Program
Conservation Reserve Enhancement Programs
Rainwater and Land Development Manual
Source Water Environmental Education Teams (SWEET)
Technician Development Program
Watershed Coordinator Program

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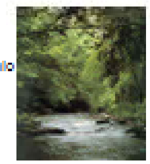
Phone
FAX: (614) 262-2064

Location Map

For general information about the Division of Soil & Water Conservation, e-mail your questions here.

Stream Morphology

STREAM Modules
Spreadsheet Tools for River Evaluation, Assessment and Monitoring



Stream physical condition is increasingly a priority for resource managers. Assessment, monitoring and restoration techniques continue to be developed and standardized. Toward these ends a suite of spreadsheet tools, the STREAM Modules, has been developed by the Ohio Department of Natural Resources and Ohio State University.

This ongoing project began in 1998 and currently freely provides the following modules:

1. Reference Reach Spreadsheet for reducing channel survey data and calculating basic bankfull hydraulic characteristics,
2. Regime Equations for determining the dimensions of typical channel form,
3. Meander Pattern that dimensions a simple arc and line best fit of the sine-generated curve,
4. Cross-section and Profile that can be used to illustrate the difference between existing and proposed channel form,
5. Sediment Equations which includes expanded and condensed forms of critical dimensionless shear, boundary roughness and common bed load equations, and finally
6. Contrasting Channels that computes hydraulic and bed load characteristics in a side-by-side comparison of two channels of different user defined forms.

Channel Form (in Microsoft Excel format)

- Meander Pattern 4-1.xls
- Reference Reach Survey 4-2 T.xls
- Reference Reach Survey 4-3 L.xls
- Regime Equations 4-0.xls
- Two-Stage X-Section Plots 4-0.xls

Channel Process (in Microsoft Excel format)

- Contrasting Channels 4-0.xls
- Dynamic Equilibrium Balance with Exercises.xls
- Dynamic Equilibrium Balance.xls
- Miscellaneous (english units only)
  - Effective Discharge from Suspended Sediment.xls
  - Floodplain Hydraulics and Watershed Development.xls
- Sediment Equations 4-0.xls

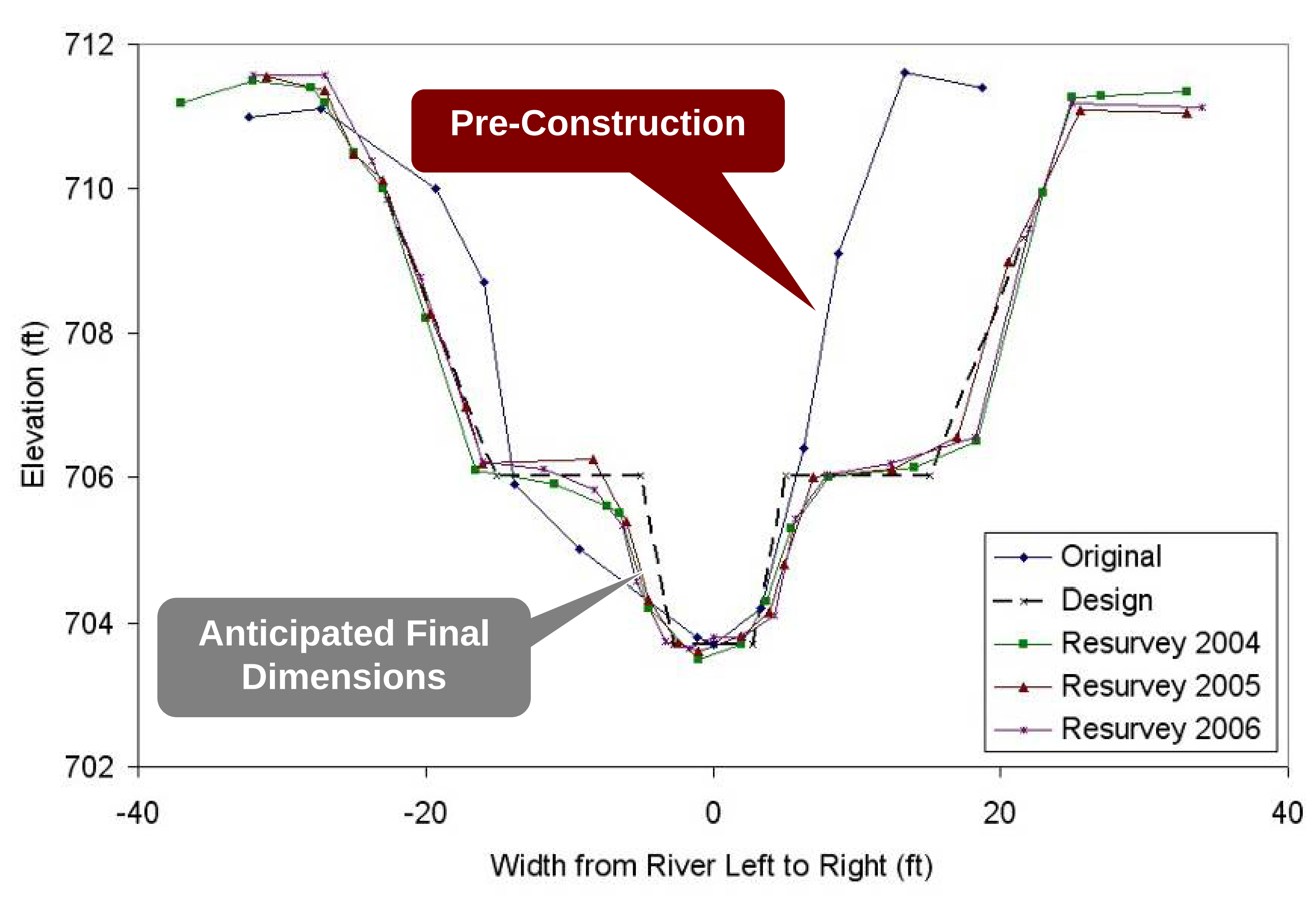
Information

6. Project Assessment

- A final project assessment and design presentation should occur with all stakeholders participating

8. Construction

9. Monitoring



Fast Road, Wood County

Klase Ditch, Ohio

Crommer Ditch, Michigan

- **TNC constructed two-stage ditch (2003)**
- **Drainage area of 4.5 mi^2**

Creel Ditch, Indiana

Two-Stage Ditch in Minnesota

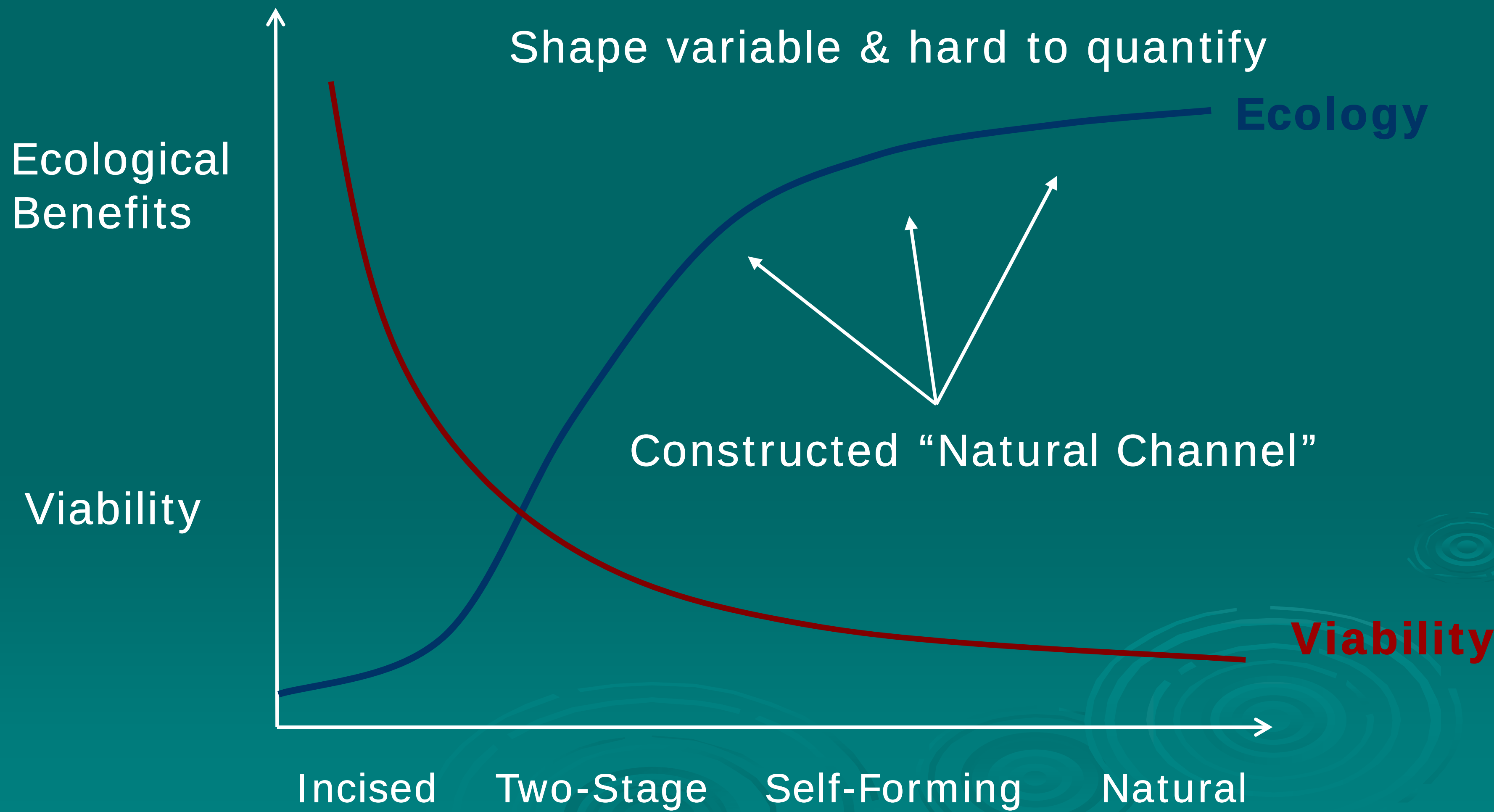
A. Prior to construction a sandy point bar at a bend.
B. During construction – a stabilizing blanket was placed on the benches and bank

Things do not always work as

Benefits of Two-Stage Systems

- Ecological Benefits?
- Lower Shear Stresses on Bed and Bank
- Peak Flow Reduction
- Nitrate-Nitrogen Reduction
- Other Water Quality Benefits?

Ecological Benefits of Alternatives



Benefits of Benches

Peak Flow Reduction

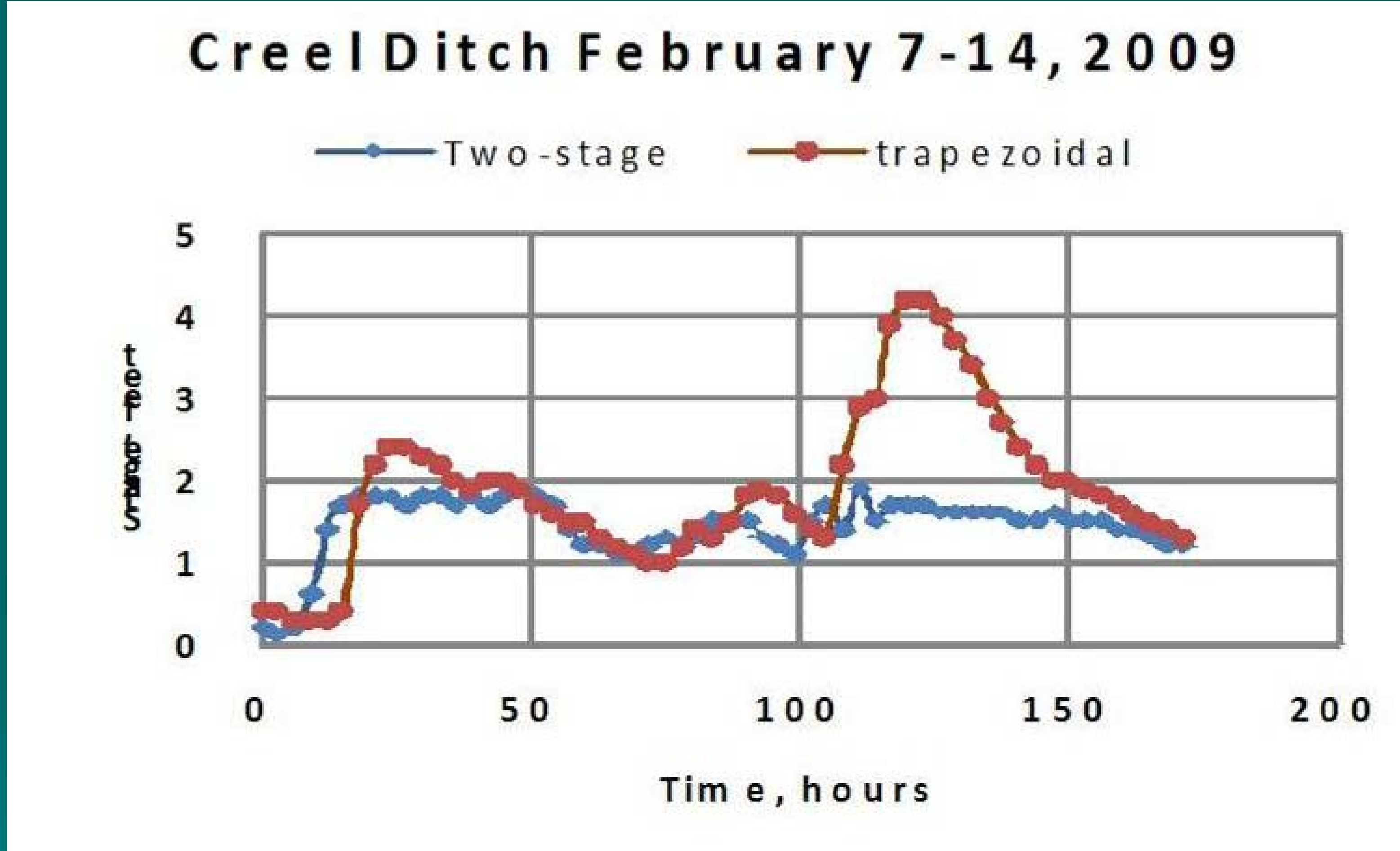
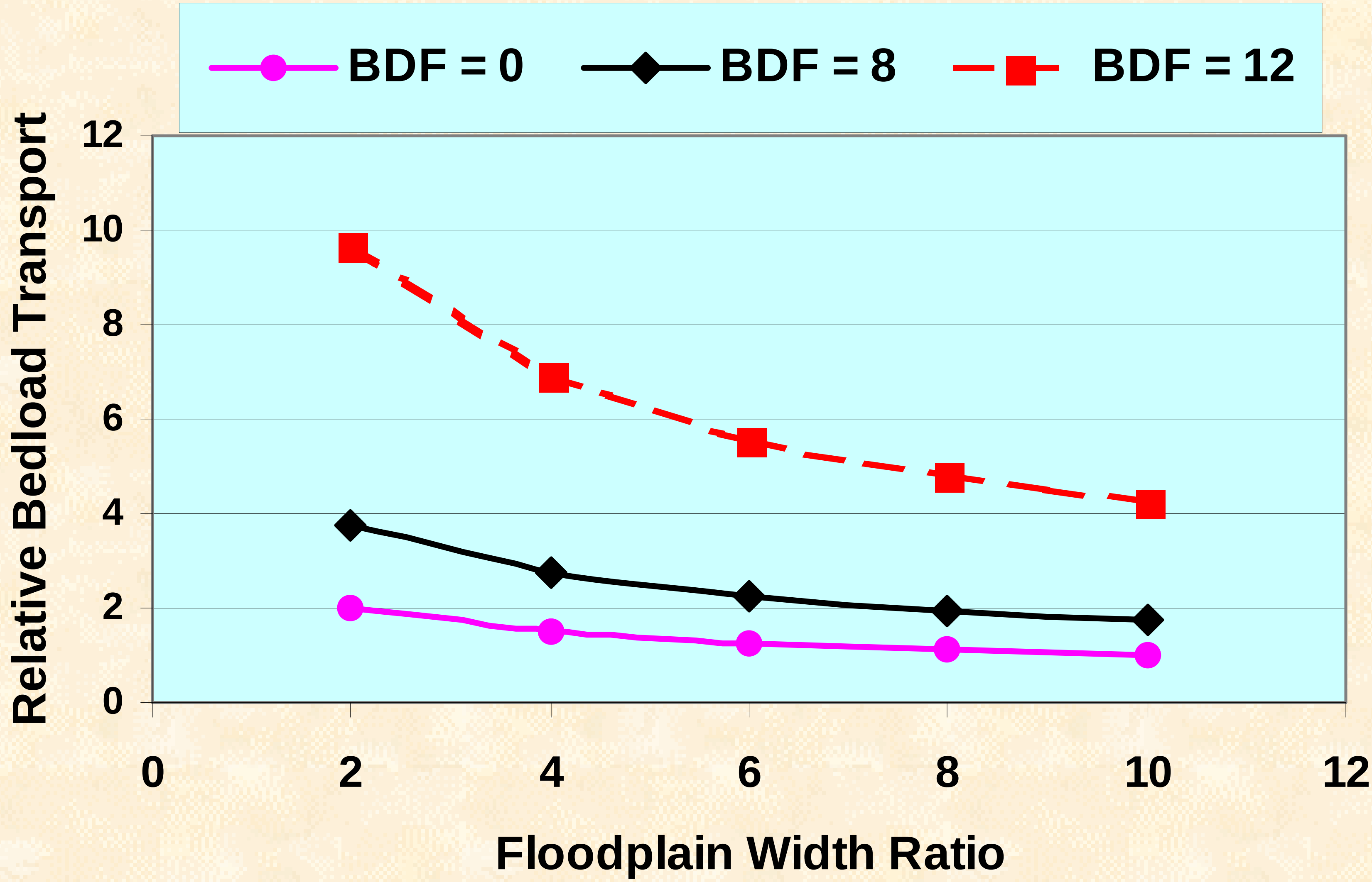
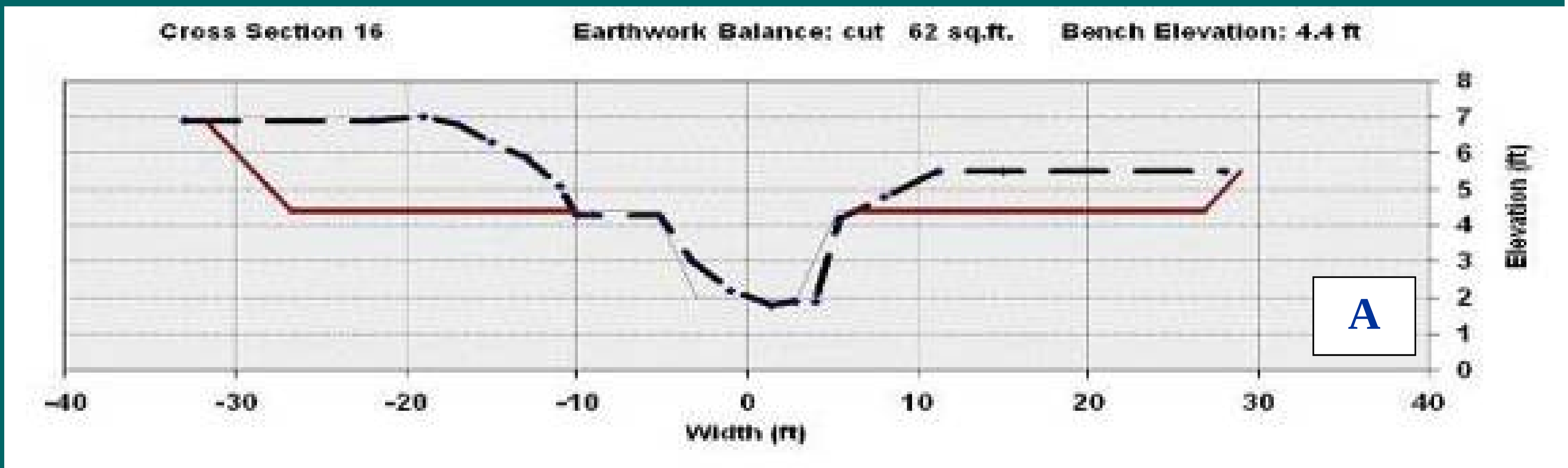
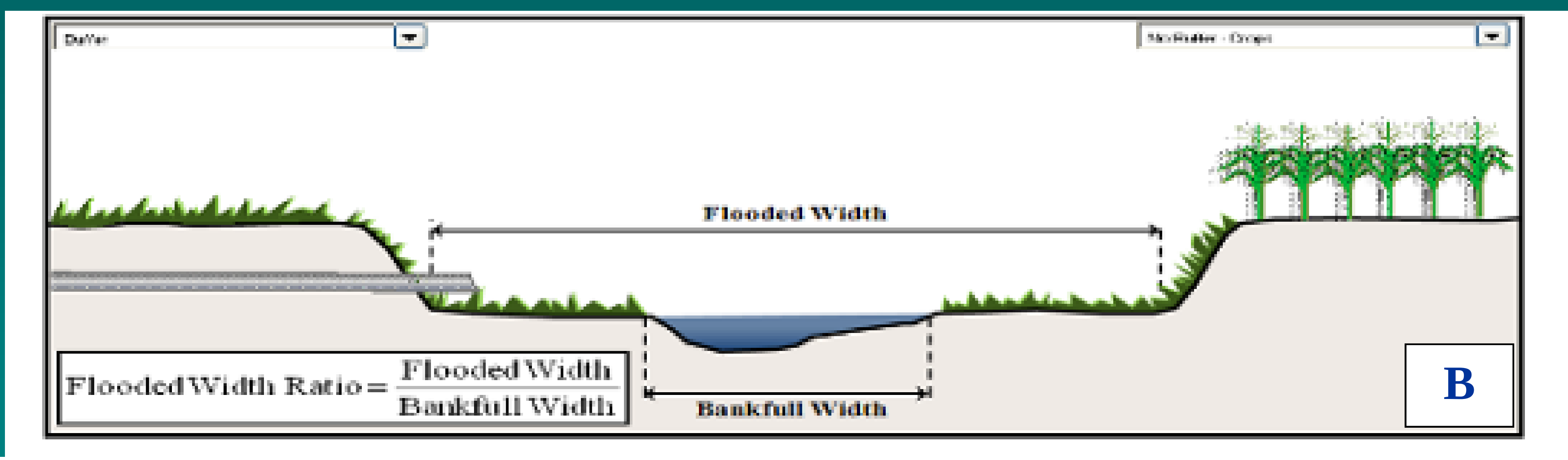


Figure 5. Comparison of stage depths for trapezoidal and two-stage ditch cross-sections at Creel Ditch, IN.

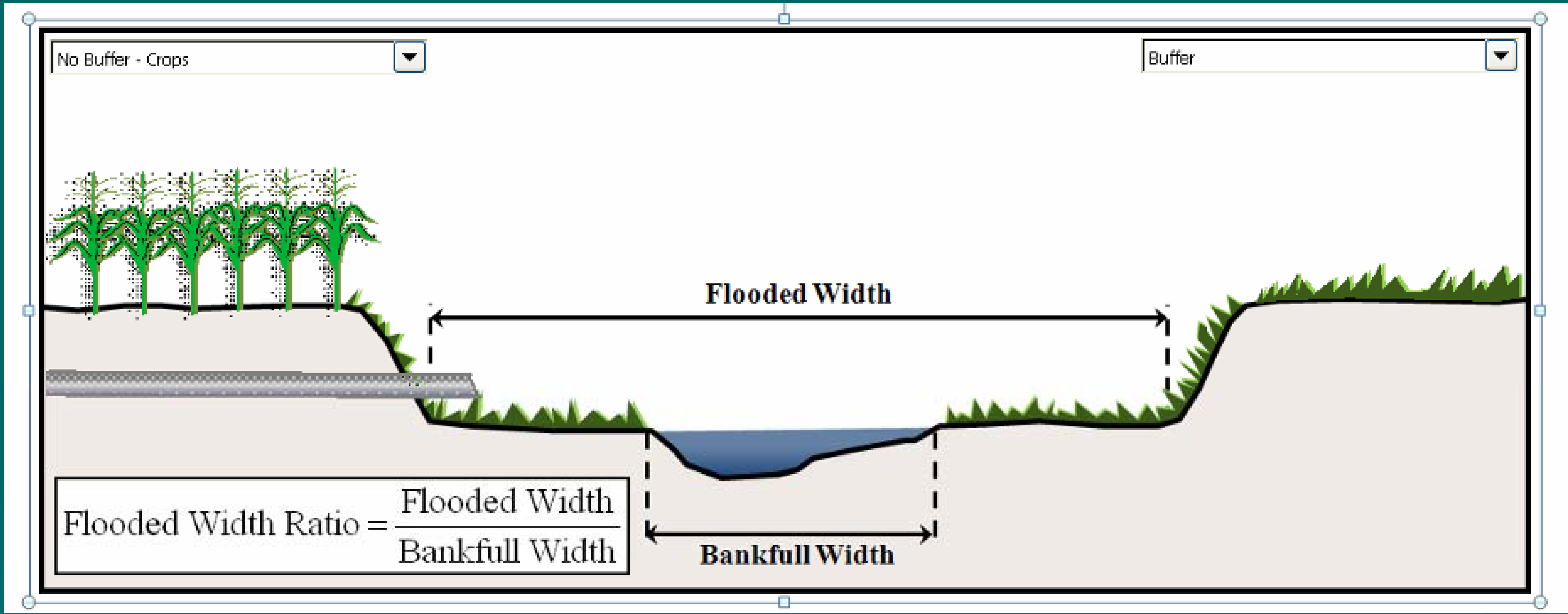
Little Schenk: Relative Bedload Transport vs Floodplain Width Ratio




Cross Section 16
Earthwork Balance: cut 62 sq.ft.
Bench Elevation: 4.4 ft
8
7
6
5
4
3
2
1
0
Elevation (ft)
-40
-30
-20
-10
0
10
20
30
40
Width (ft)
A


Flooded Width
Bankfull Width
Flooded Width Ratio = Flooded Width / Bankfull Width
B

Nitrate-Nitrogen Reduction



USGS GAGE SELECTION

Select a USGS Gage: Claridon

Percentage of 2-year Discharge: 35%

	Lower Range		Upper Range	Units	Comments
Number of Days with No Flow	30		60	days	

	Lower Range	Average	Upper Range	Units	Comments
Days with Flow in Main Channel with Denitrification	228.9	240.1	251.4	days	
Days with Saturated Benches with Denitrification	12.6	16.8	21.0	days	
Days with Unsaturated Benches with Dentrification	9.3	12.1	14.9	days	

OUTPUT

TOTAL NITROGEN LOAD TO DITCH

	Lower Range	Average	Upper Range	Units	Comments
Total Nitrogen Load Exported to Ditch	9022	12799	17079		

TRAPEZOIDAL DITCH SYSTEM

	Lower Range	Average	Upper Range	Units	Comments
Trapezoidal Ditch Bed N Removal	405	954	1552	lbs-N	
Trapezoidal Ditch Side Slopes N Removal	8	19	31	lbs-N	
N Removal in Left Buffer	0	0	0	lbs-N	
N Removal in Right Buffer	0	0	0	lbs-N	
Combined N Removal in Buffers	0	0	0	lbs-N	
Total N Removal (Trapezoidal Ditch + Buffer)	413	973	1583	lbs-N	
Total N Removal (Trapezoidal Ditch + Buffer System)	2.6%	7.7%	15.8%	% of total load	
% Watershed in Trapezoidal Ditch + Buffer		0.3%		% of area	
Benefit Ratio (% Removal ÷ % Watershed Area)		24:1		dimensionless	

Confidence Intervals on Trapezoidal Ditch N Removal	Lower Range		Upper Range	Units	Comments
95% of the Time	3.4%		13.3%	lbs-N	
90% of the Time	3.7%		12.5%	lbs-N	
75% of the Time	4.4%		11.1%	lbs-N	
68% of the Time	4.7%		10.7%	lbs-N	
50% of the Time	5.5%		9.7%	lbs-N	

TWO-STAGE DITCH SYSTEM	Lower Range	Average	Upper Range	Units
Two-Stage Ditch Bed N Removal	403	957	1552	lbs-N
Bench N Removal - Saturated Conditions	66	200	391	lbs-N
Bench N Removal - Unsaturated Conditions	7	27	65	lbs-N
Two-Stage Ditch Side Slopes N Removal	1	4	8	lbs-N
N Removal in Left Buffer	0	0	0	lbs-N
N Removal in Right Buffer	0	0	0	lbs-N
Combined N Removal in Buffers	0	0	0	lbs-N
N Reduction from Land Conversion	32	45	60	lbs-N
Total N Removal (Two-Stage Ditch + Buffer)	558	1233	1945	lbs-N
Total N Removal (Two-Stage Ditch + Buffer)	3.7%	9.8%	18.4%	% of total load
% Watershed in Two-Stage + Buffer		0.5%		% of area
Benefit Ratio (% Removal ÷ % Watershed Area)		20:1		dimensionless

Confidence Intervals on Two-Stage Ditch N Removal	Lower Range		Upper Range	Units
95% of the Time	5.0%		15.9%	lbs-N
90% of the Time	5.5%		14.9%	lbs-N
75% of the Time	6.4%		13.3%	lbs-N
68% of the Time	6.7%		12.9%	lbs-N
50% of the Time	7.5%		11.9%	lbs-N

Potential Processing of Nitrogen in Benches vs. Grass Buffer Strips

Benches – high potential

- **Benches receive NO_3^- via tile drains and stream flooding**
- **Fr st**
- **Close to the water table (more saturation = increased anoxia)**

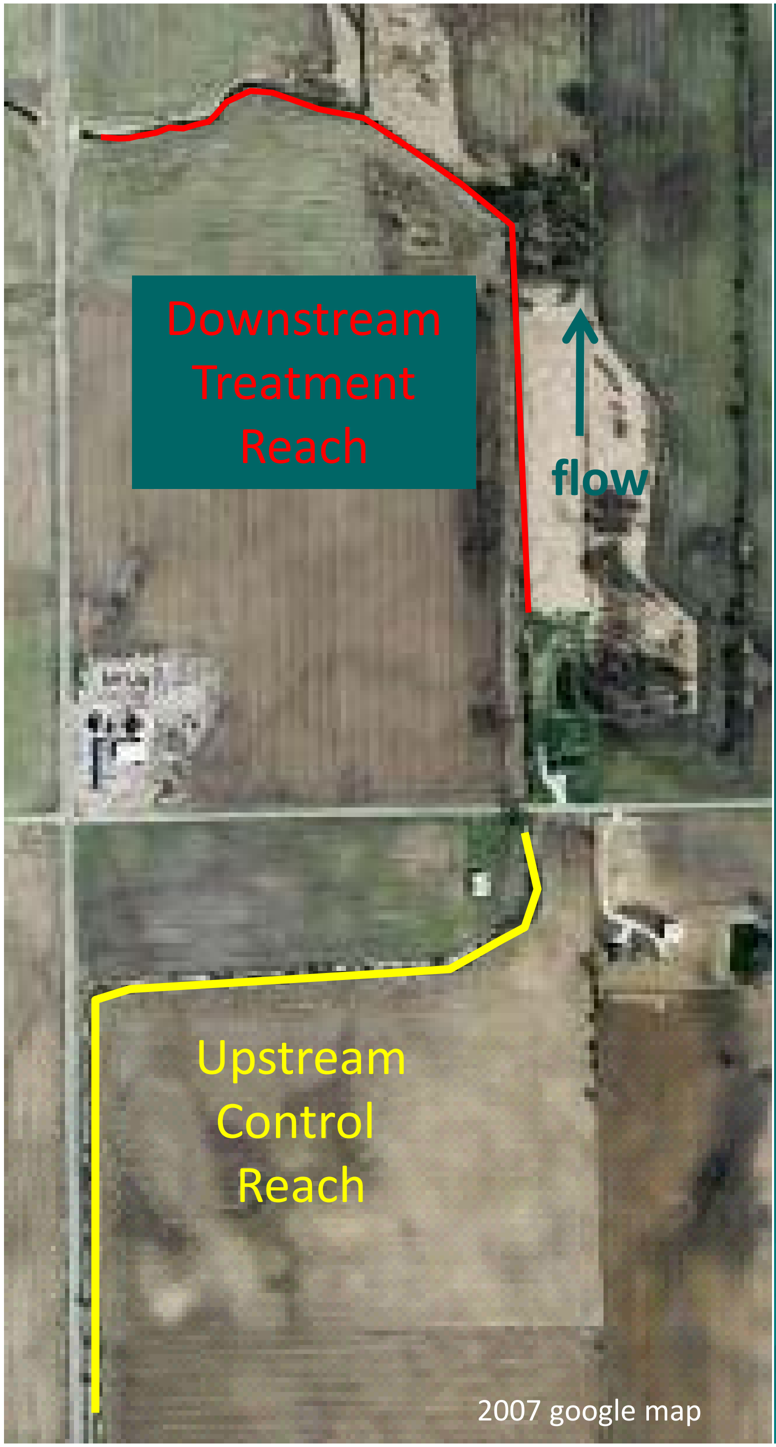
Grass Buffer Strips – low poter

- **NO_3^- bypasses buffer via tile drains and deep ground water flood)**
- **Well-drained, further from the water table**

More bench surface area = more N removal

Two-Stage at Shatto Ditch

- Etna Green, IN (Kosciusko County)
- Tile drain inputs
- Watershed > 80% row crop agriculture
- Historically, conventional ditch maintenance

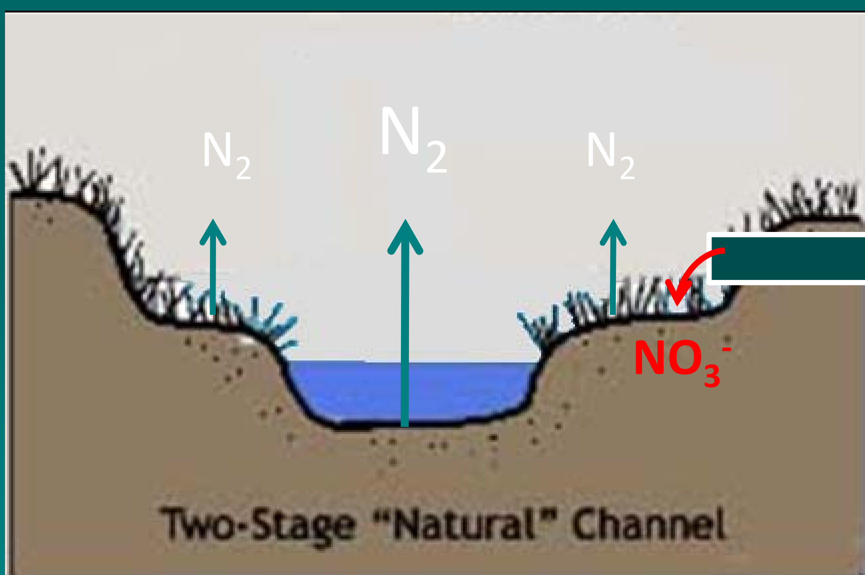


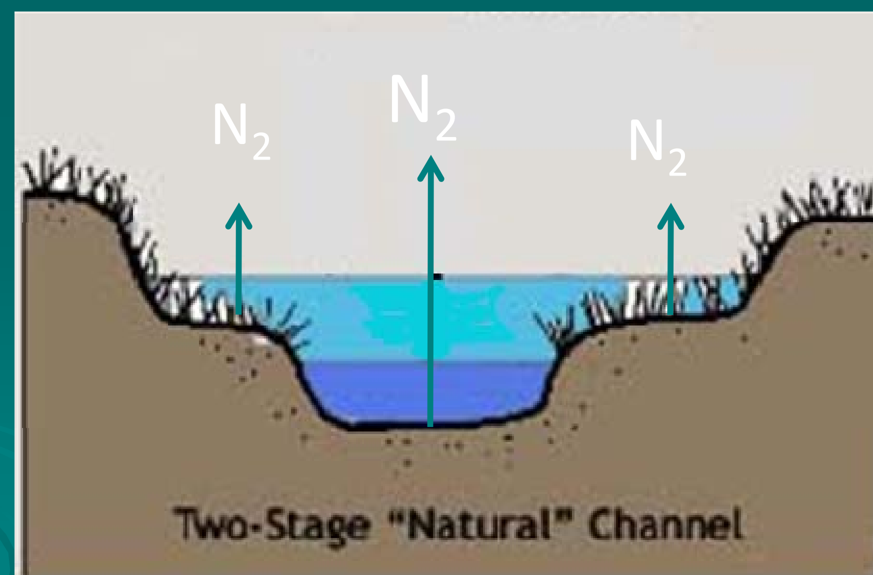
Experimental Design

- Before After Control Impact (BACI)
- 1 year of pre-construction data collection (Sept 2006 – Nov 2007)
- ~2 years of planned post-construction data collection (Nov 2007 – Nov 2009)

What Do We Expect on the Benches?

- Denitrification occurs at depth in benches due to increased nitrate penetration
- Inundation stimulates bench denitrification by creating anoxic conditions in bench





Flood Response

December 2007

You can see the edge of the bench by the grass tussocks in the water

Scaling Bench Denitrification to the Reach

- Conservative estimate based on average December denitrification in dry, new bench

Area (m^2)	Before	After
bench	756	3780
stream	1502	1502
Ratio of bench area to stream	**50%**	**252%**

Scaling denitrification rate to reach

- Take-home message: Adding bench surface area with two-stage construction increased N-removal by **500%**

Summary

- Two-stage channels, based on geomorphic principles, are an alternative to traditional trapezoidal channels

- Inset channels are more "self-flushing", and have coarser bed materials

Floodplain Recommendations (low gradient channel systems)

- Minimum Rules for Floodplains
  - 2 – 5 bankfull widths (rural)
  - 5 – 10 bankfull widths (urban)
- Target Condition
  - 10+ bankfull widths


Thank You
Questions?