EVALUATING GEOMORPHIC EVOLUTION IN CONSTRUCTED TWO-STAGE DITCHES

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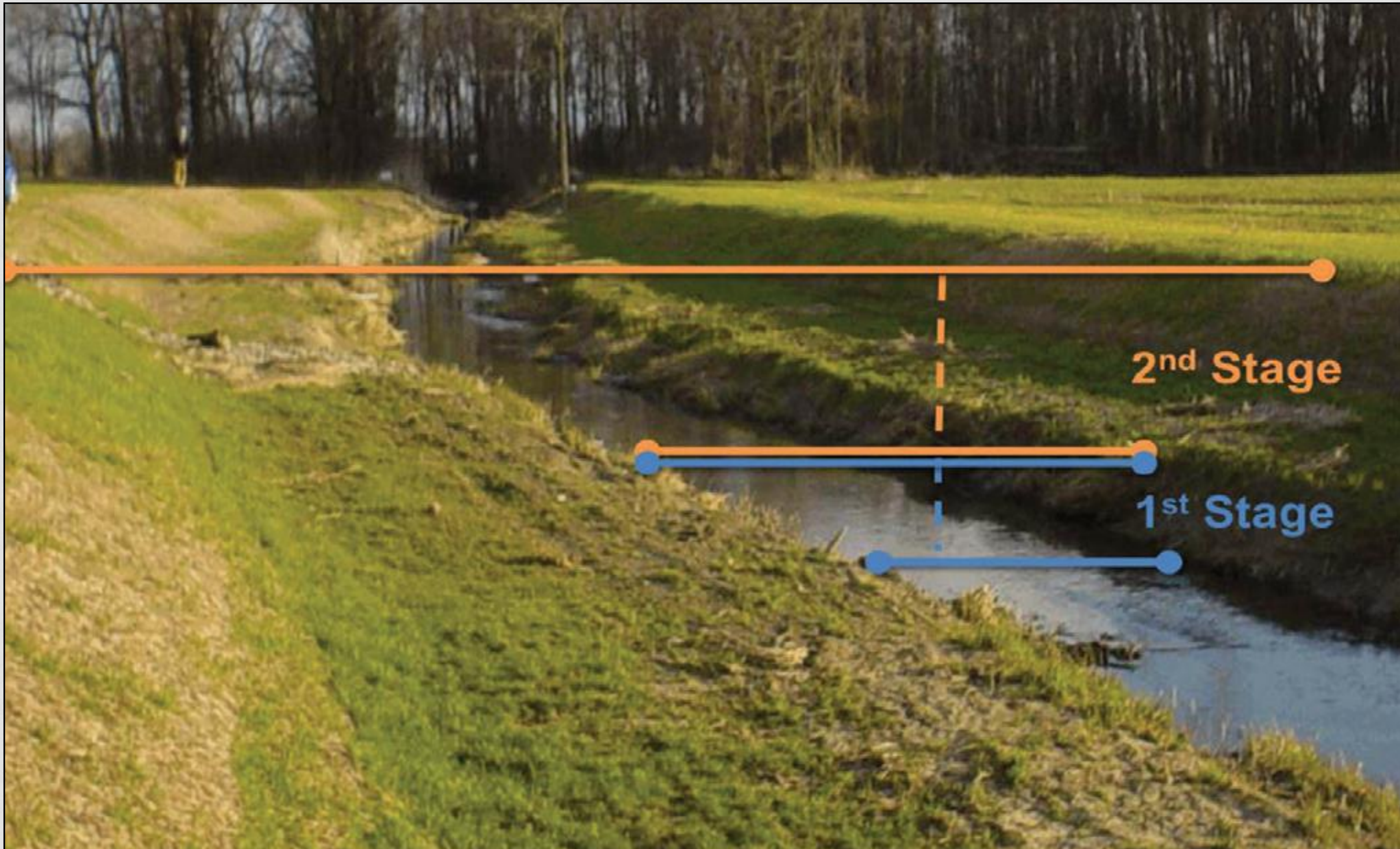
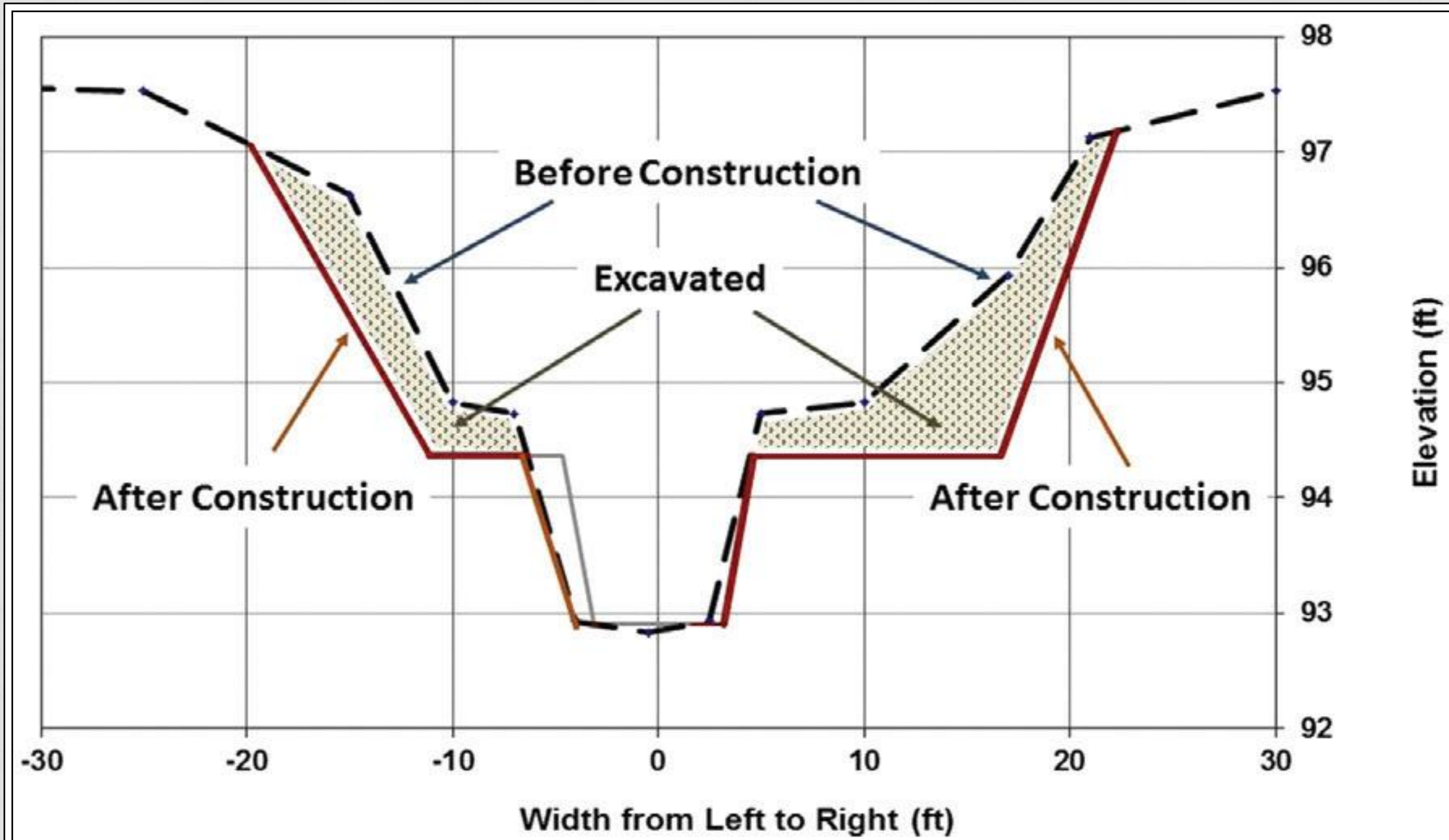
THE OHIO STATE UNIVERSITY EXTENSION

TWO-STAGE CHANNEL DESIGN

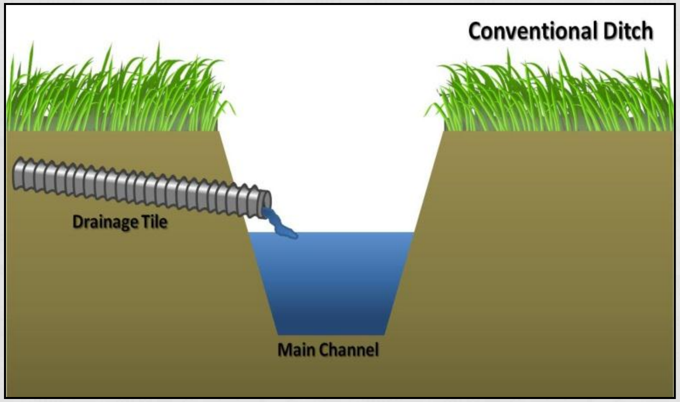


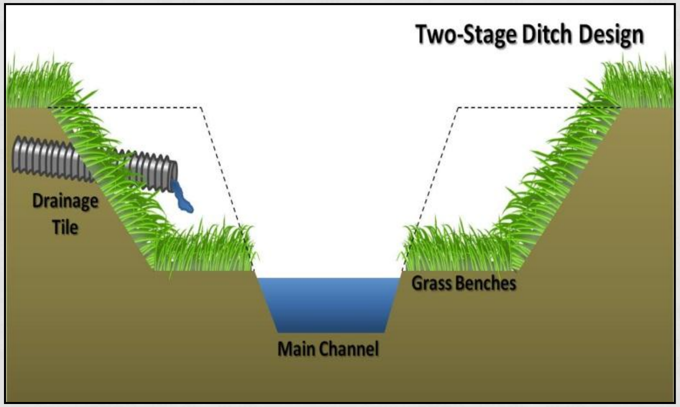
TWO-STAGE CHANNEL DESIGN



THEORY SAYS… *IN CONDITIONS WHERE THE TWO-STAGE DITCH PRACTICE APPLIES*

- ✓ Stabilizes ditch banks.
- ✓ Increases or maintains drainage capacity for subsurface tile flows.
- ✓ Lowers the water surface elevation/stage of peak flows.
- ✓ Creates a self-flushing system by maintaining an inset channel that effectively transports sediment.
- ✓ Provides detention by creating valley storage.
- ✓ Reduces need for maintenance or clean-out.
- ✓ Reestablishes some habitat and watershed functions including pollutant assimilation.





NRCS RESOURCE CONCERNS

- **Soil Erosion**
- Soil Condition
- **Water Quality**
- Air Quality
- **Plant Condition**
- **Fish and Wildlife**
- Domestic Animals
- **Water Quantity**
- Energy

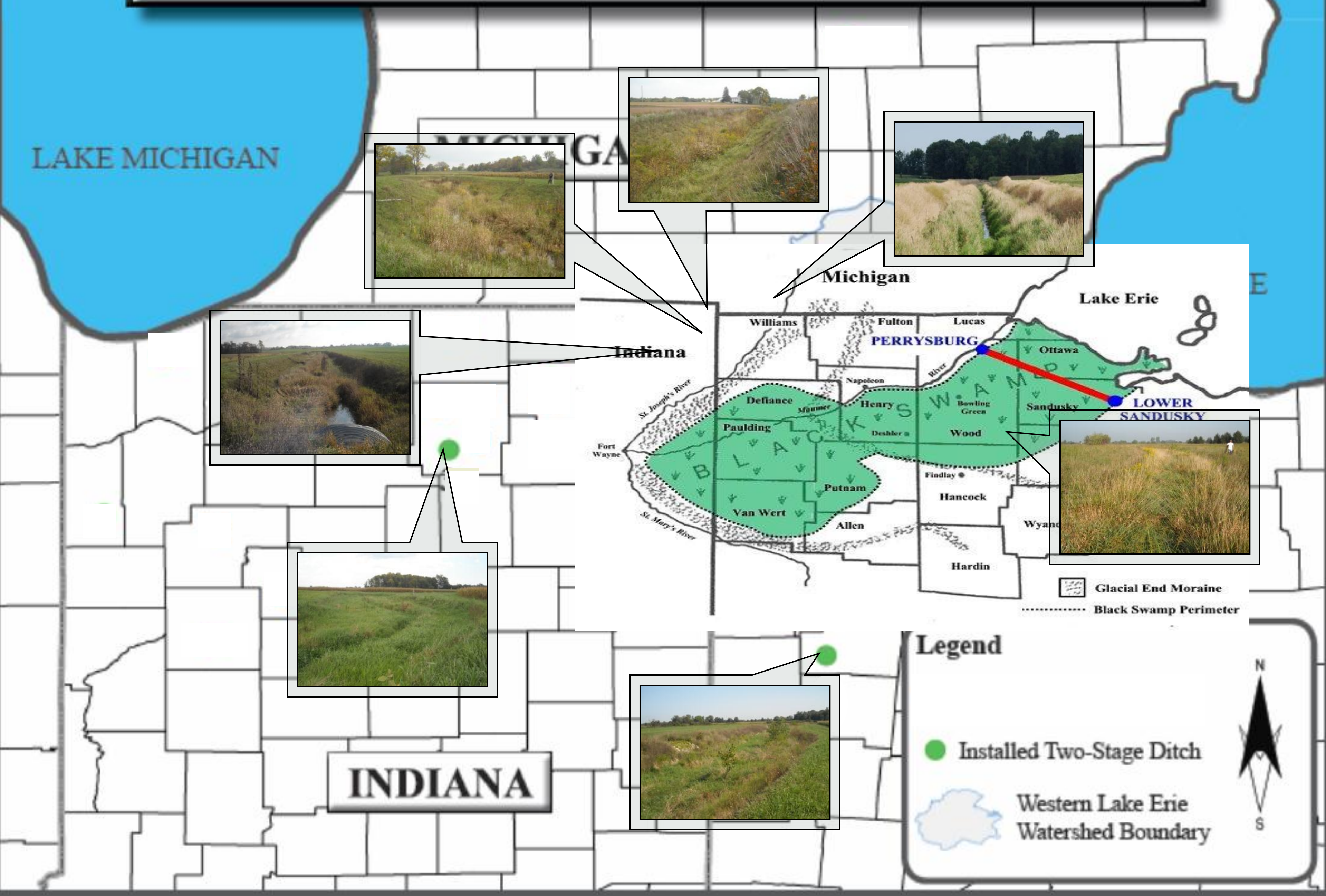
EVALUATION OF EVOLUTION AND WATER QUALITY BENEFITS OF TWO-STAGE DITCHES IN A TRI-STATE REGION OF THE USA

- **Determine the evolution and stability of two-stage channels in the tri-state region *(Research Objective)*.**
- Ascertain the enhanced nitrate removal benefits of two-stage channels in the tri-state region *(Research Objective)*.
- Demonstrate the water quality or drainage benefits of alternative land management and channel system practices to rural and urban stakeholders using a suite of modeling and management tools *(Education and Extension Objective)*.

RESEARCH QUESTIONS

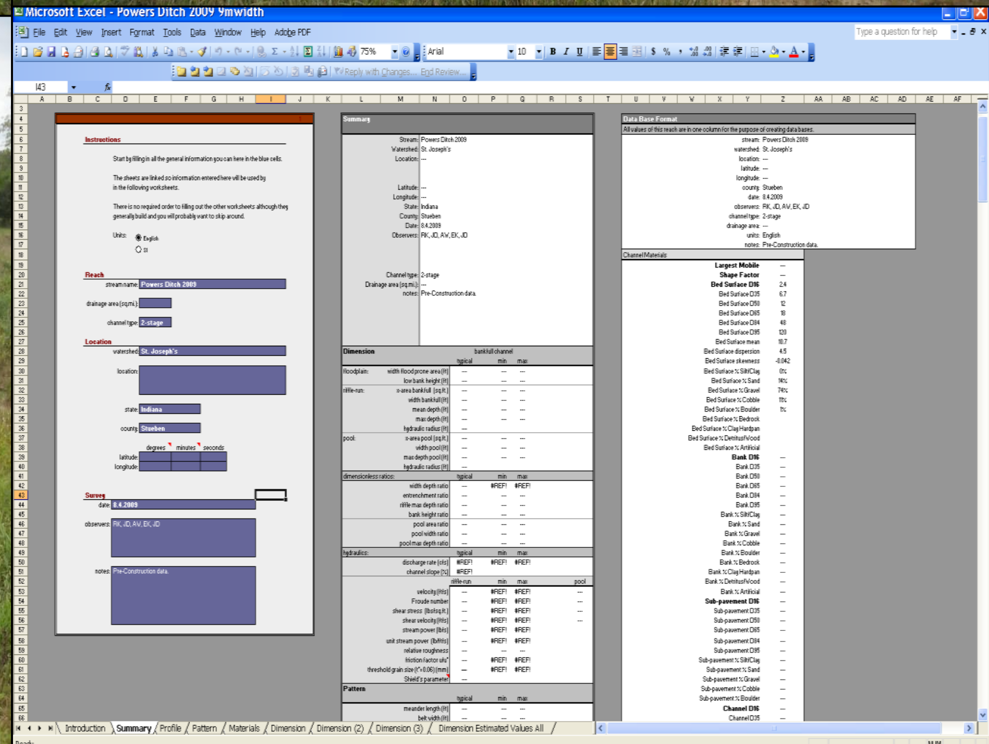
1. Where are significant geomorphic changes occurring within the ditch?
2. Do two-stage ditches maintain their drainage capacity over time?
3. Has the two-stage ditch maintained an inset channel and reached a quasi-equilibrium state?
4. Did the two-stage ditch meet the goals of the project for which it was designed?

TWO-STAGE DITCHES IN TRI-STATE REGION



EXPERIMENTAL DESIGN

- Before After Control Impact (BACI).
- 1 year of pre-construction data collection.
- 2+ years of post-construction data collection.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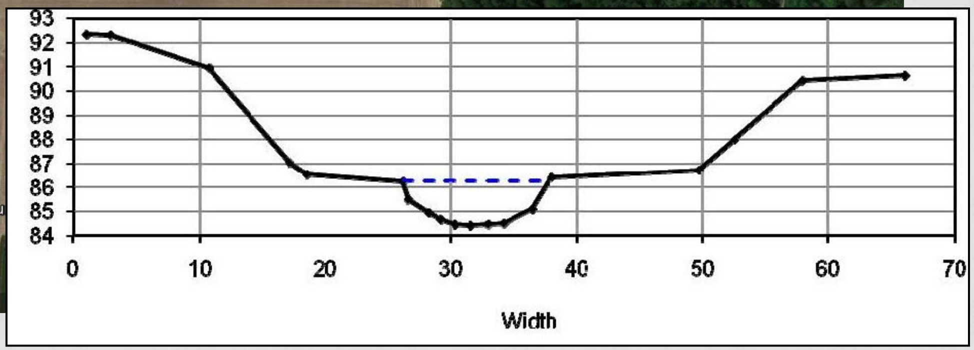
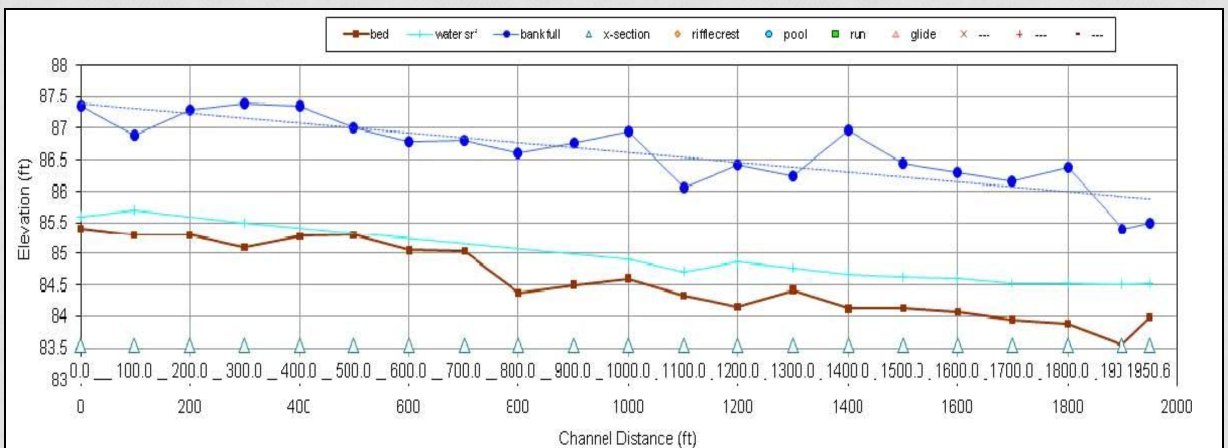
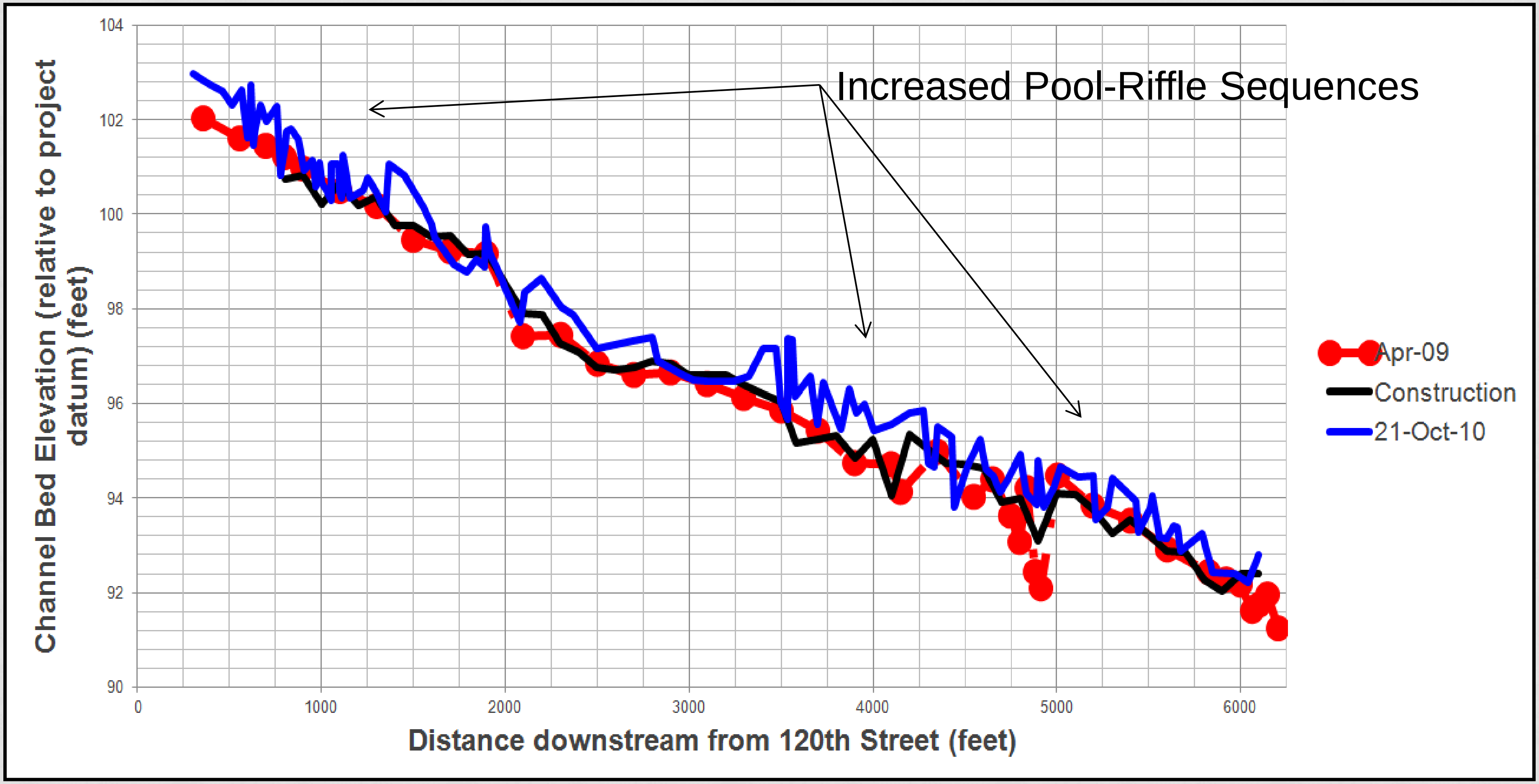
Instructions
Summary
Data Base Format
Introduction Summary Profile Pattern Materials Dimension Dimension (2) Dimension (3) Dimension Estimated Values All



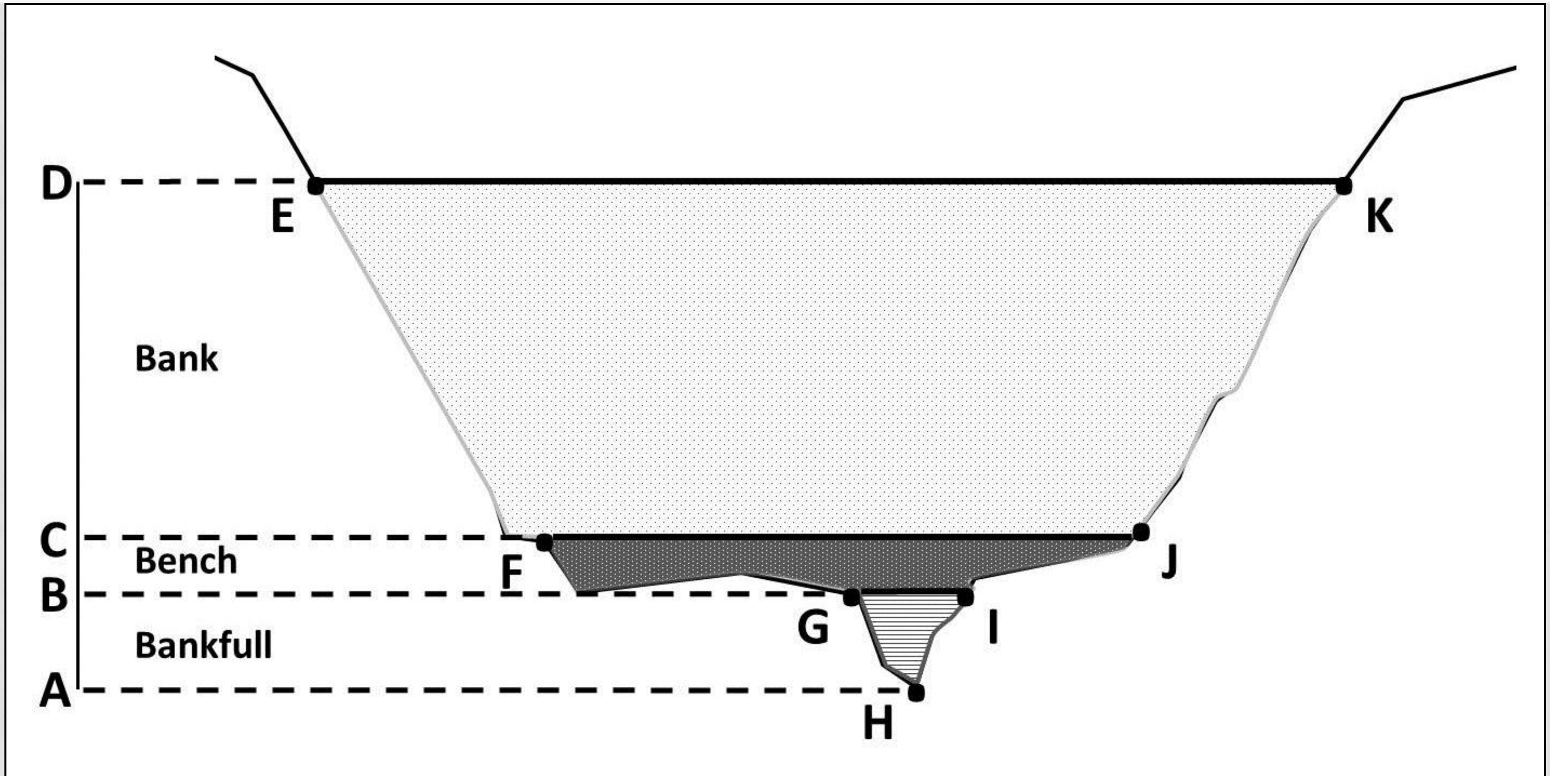


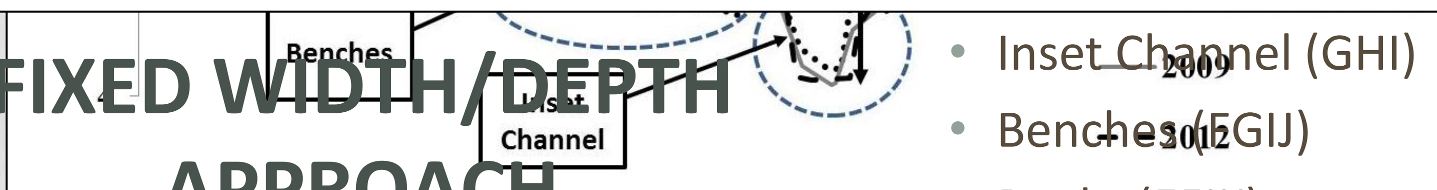
Width				
Station	2001	2004	2009	2012
0	20.1		53.0	35.0
100			37.3	35.8
200	25.8		30.2	27.7
300	25.5		46.5	36.0
400			55.1	35.4
500	33.6		34.1	30.1
600	50.8		31.7	35.1
700	29.1		32.3	34.6
800	21.3		34.9	34.1
900		35.2	51.0	29.3
1000	63.2	43.6	43.6	54.5
1100		43.3	35.1	44.6
1200		58.9	44.0	44.1
1300		32.9	53.0	37.1
1400		55.7	33.5	37.2
1500		34.2	31.1	32.7
1600		32.1	32.2	33.0
1700		39.9	30.3	42.1
1800		51.0	33.8	30.9
1900		30.5	47.2	44.7
2000				48.0
2100				38.7

EVALUATING GEOMORPHIC CHANGE: INSTABILITY OR NATURAL ADJUSTMENTS?



Evaluating Geomorphic Change





FIXED WIDTH/DEPTH APPROACH

- Inset Channel (GHI)
- Benches (FGIJ)
- Banks (EFJK)
- Top of Ditch (EK)

BULL CREEK TRIBUTARY, WOOD COUNTY, OH (BUILT 2002)

Results: No significant changes to inset channel dimensions; scour on benches.

PRE- CONSTRUCTION

DURING CONSTRUCTION

FLOOD EVENT 2 YEARS POST-CONSTRUCTION

8 YEARS POST-CONSTRUCTION

CROMMER DITCH, HILLSDALE COUNTY, MI (BUILT 2003)

Results: No significant changes to dimensions.

PRE- CONSTRUCTION

FLOOD EVENT DURING CONSTRUCTION

1 MONTH AFTER CONSTRUCTION

5 YEARS POST- CONSTRUCTION

KLASE DITCH, SHELBY COUNTY, OH (BUILT 2005)

Results: No significant changes to dimensions.

PRE-CONSTRUCTION (2004)

2 YEARS POST-CONSTRUCTION

4 YEARS POST-CONSTRUCTION

7 YEARS POST-CONSTRUCTION

SHATTO DITCH, KOSCKIUSKO COUNTY, IN (BUILT 2007)

Results: Inset channel significantly smaller after construction.

PRE-CONSTRUCTION (2007)

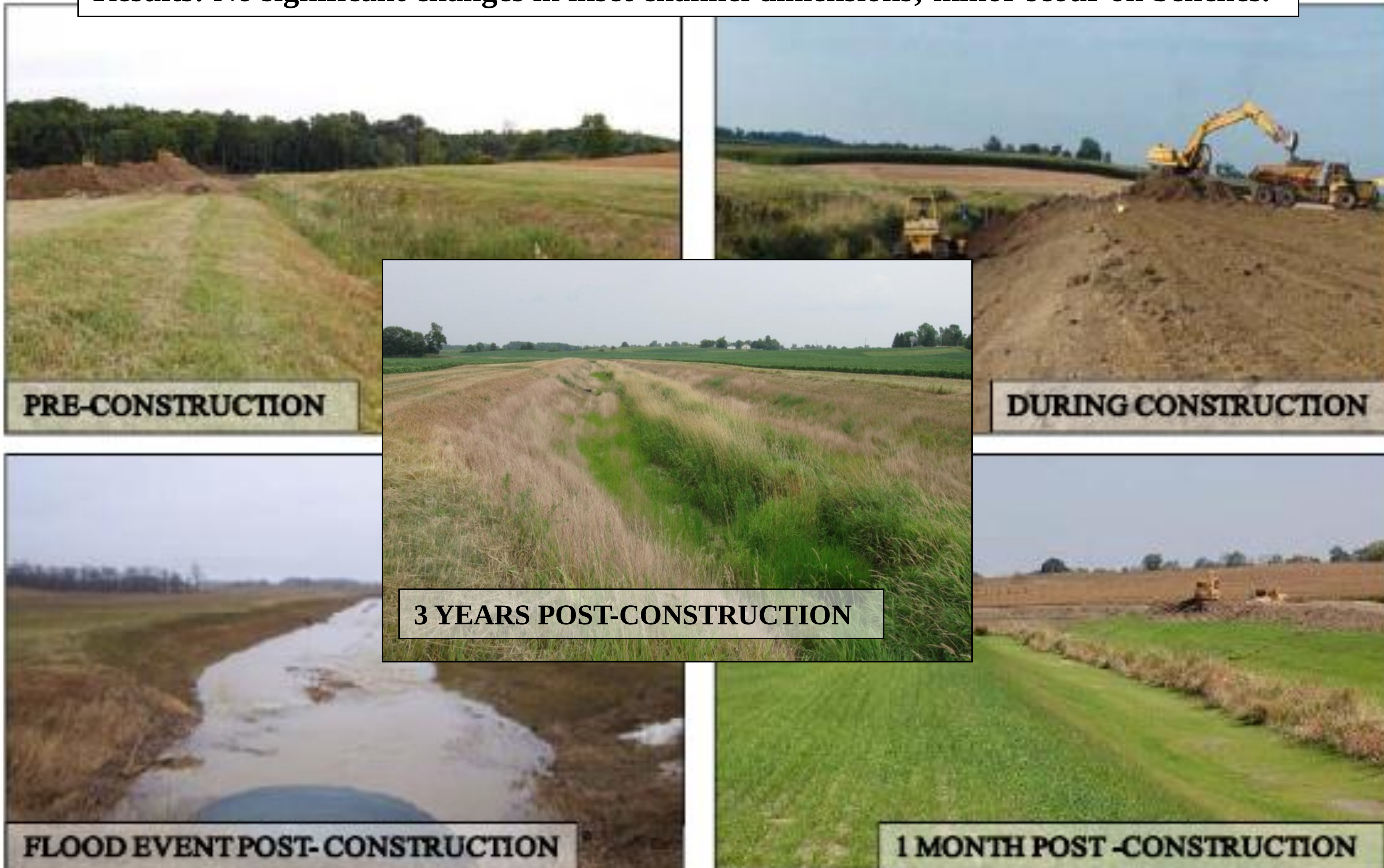
FLOOD EVENT DURING CONSTRUCTION

1 YEAR POST-CONSTRUCTION

5 YEARS POST-CONSTRUCTION

CREEL DITCH, STEUBEN COUNTY, IN (BUILT 2008)

Results: No significant changes in inset channel dimensions; minor scour on benches.



POWERS DITCH, STEUBEN COUNTY, IN (BUILT 2009)

Results: No significant changes in dimensions; issues with 1-sided construction.

RIDENOUR DITCH, STEUBEN COUNTY, IN (BUILT 2009)

Results: Inset channel wider and deeper post-construction.

1 YEAR POST-CONSTRUCTION (2010)

3 YEARS POST-CONSTRUCTION

3 YEARS POST-CONSTRUCTION

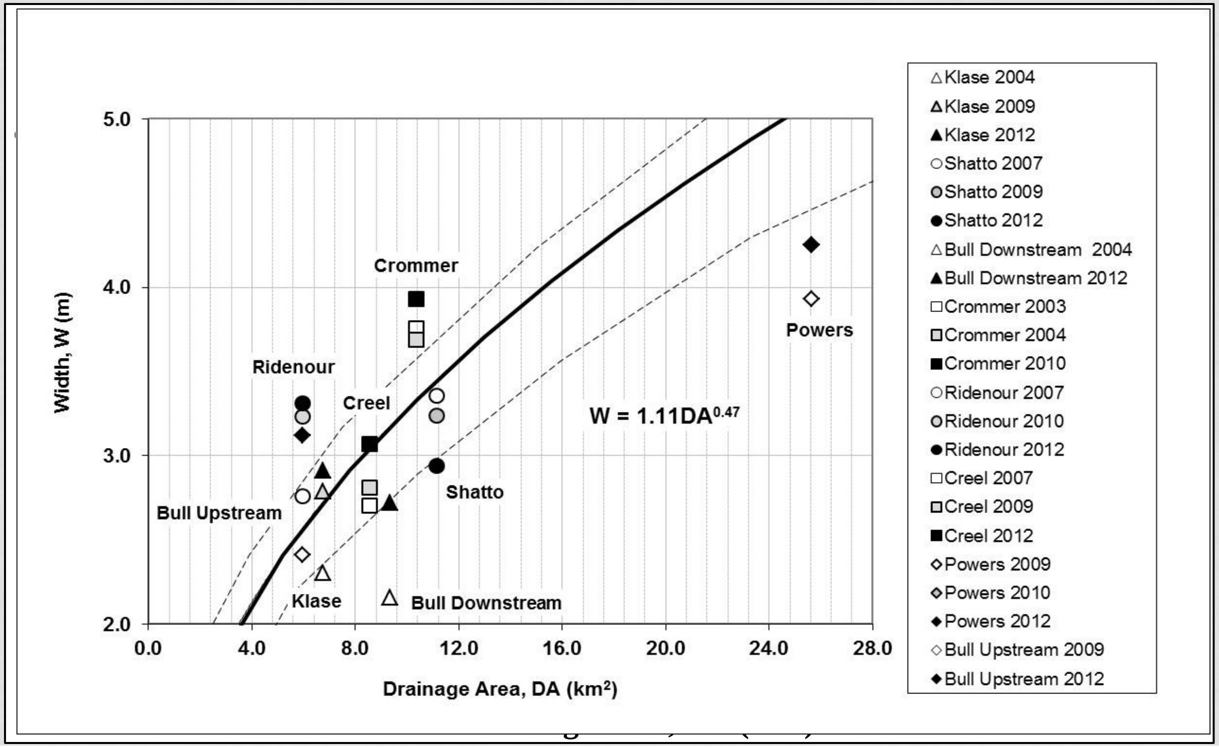
3 YEARS POST-CONSTRUCTION, 1-SIDED

RESEARCH QUESTIONS

HAS THE TWO-STAGE DITCH MAINTAINED AN INSET CHANNEL AND REACHED A QUASI-EQUILIBRIUM STATE?

Findings:

- Inset channel maintained based on regional curve predicted design
  - Inset channel changes reflected natural adjustments, but not all ditches had reached their quasi-equilibrium state.
  - Nearly all of the sites fell within the expected range for the inset channel width.



RESEARCH QUESTIONS

HAS THE TWO-STAGE DITCH MAINTAINED AN INSET CHANNEL AND REACHED A QUASI-EQUILIBRIUM STATE?

Findings:

- Minor changes detected in the inset channel and on the benches. Few exhibited scour on the side slopes.
  - Benches inundated 75-175 times/yr (wet year); 5-125 times/yr (dry year)*
  - Ditches had experienced both degradation and aggradation on the benches at a rate of 0.5-13 mm/yr (Ave. rates of change along 400 m to 1200 m reaches).

*Data from Notre Dame (Tank et al.)

RESEARCH QUESTIONS

DO TWO-STAGE DITCHES MAINTAIN THEIR DRAINAGE CAPACITY OVER TIME?

WHERE ARE SIGNIFICANT GEOMORPHIC CHANGES OCCURRING WITHIN THE DITCH?

Findings:

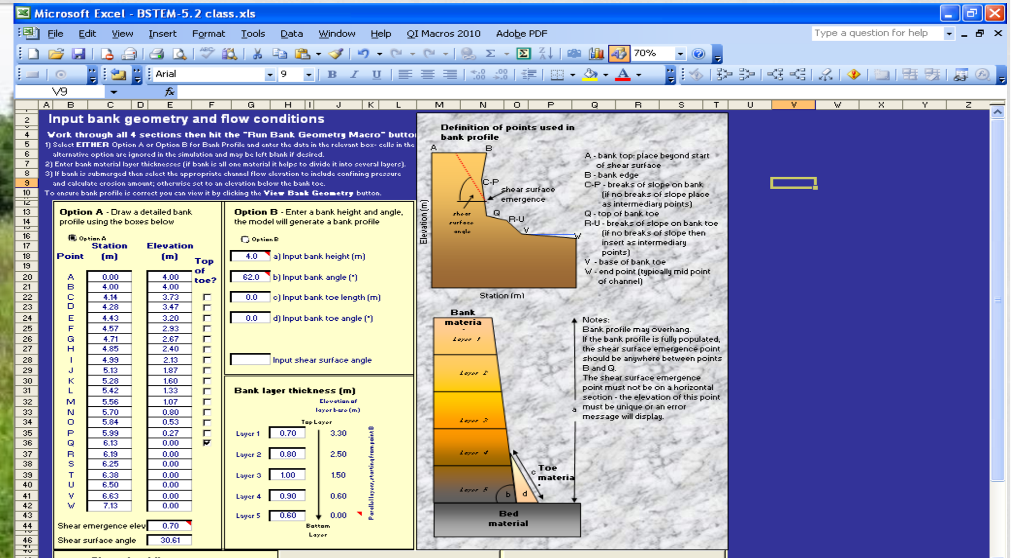
- Two-stage ditches did not lose drainage capacity (i.e., fill in) 3-10 years after construction.
  - Aggradation on the benches was not likely to threaten tile drain outlets.
  - Localized scour was observed on the banks at some sites, but at all but one site changes were not statistically significant.

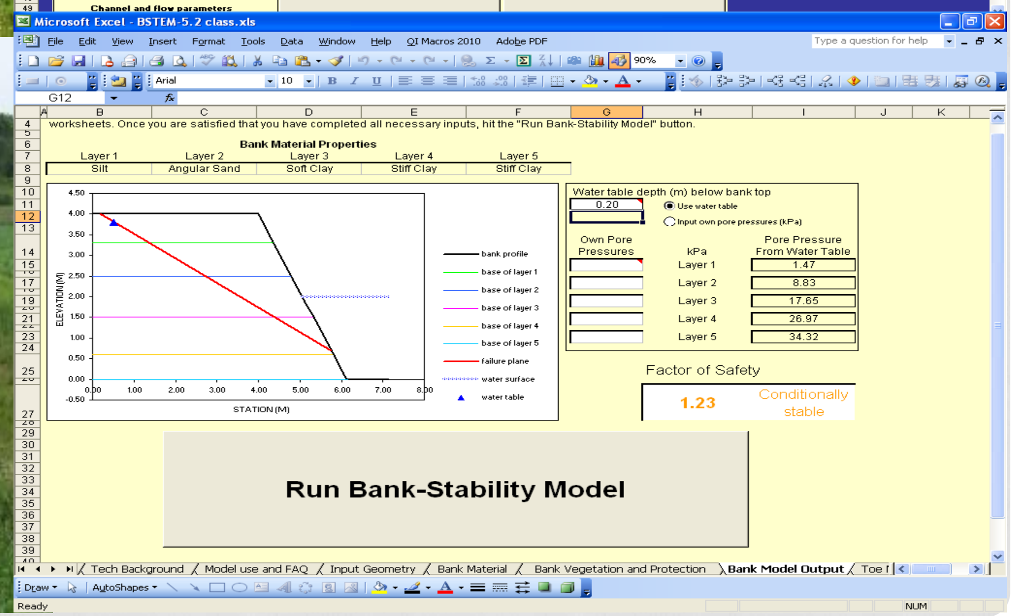
Findings:

- All ditches designed to reduce ditch bank instability, excessive aggradation, and flooding have achieved their goals.
- None have needed traditional maintenance since construction.

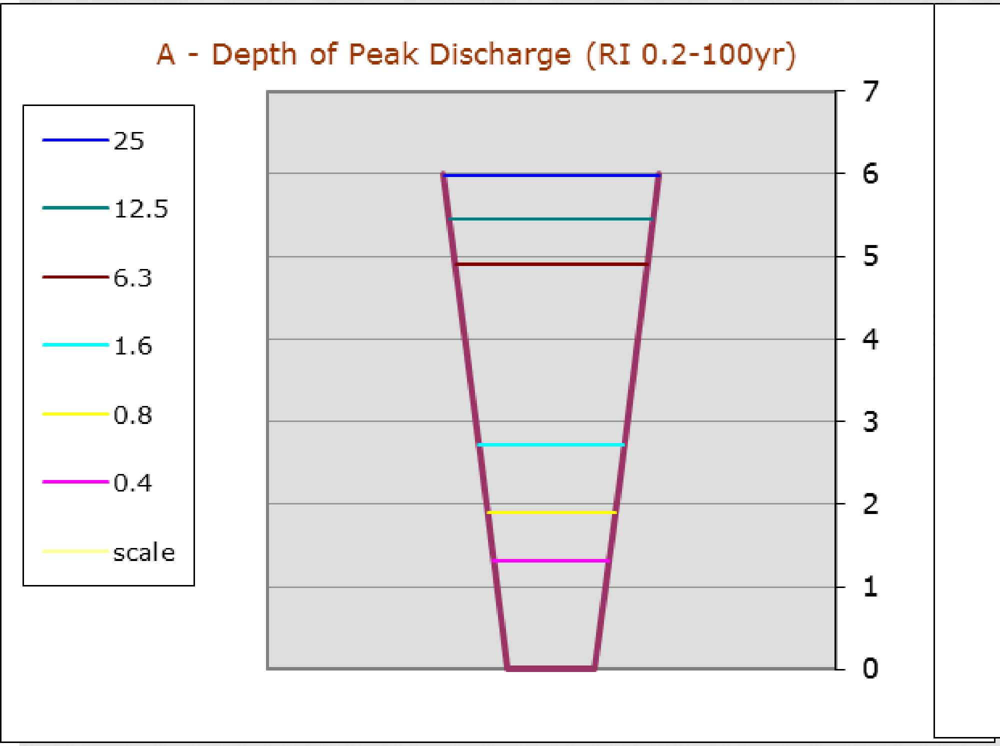
BANK STABILITY: LOWERING SHEAR STRESSES ON THE BENCHES?

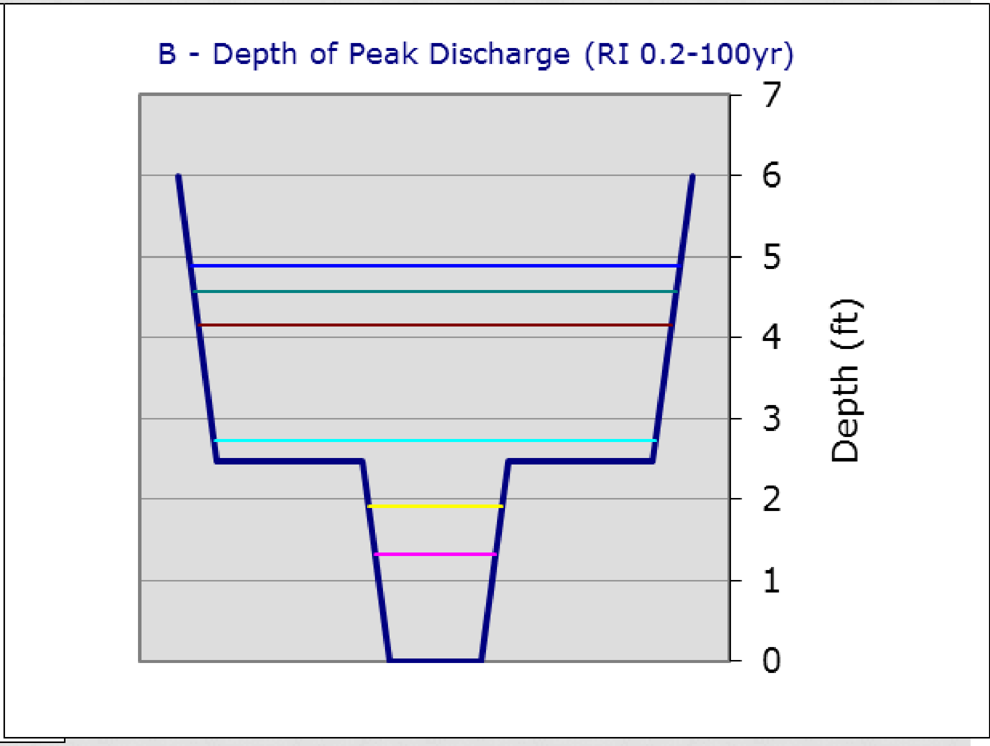
BANK STABILITY: BSTEM MODEL





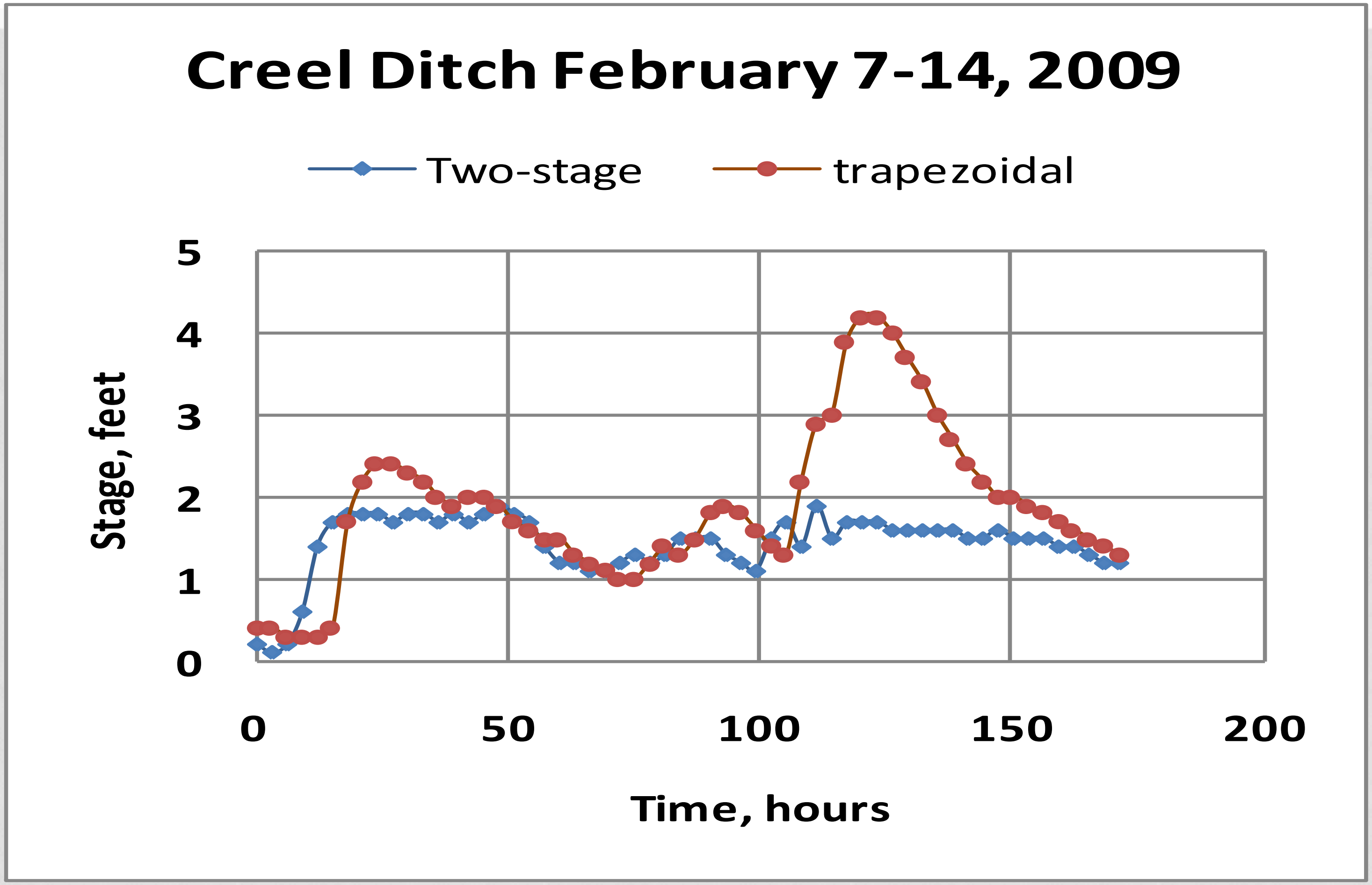
FLOOD STAGE REDUCTION: CONTRASTING CHANNELS TOOL





BANKFULL DISCHARGES MAINTAINED, PEAK DISCHARGE STAGES LOWERED

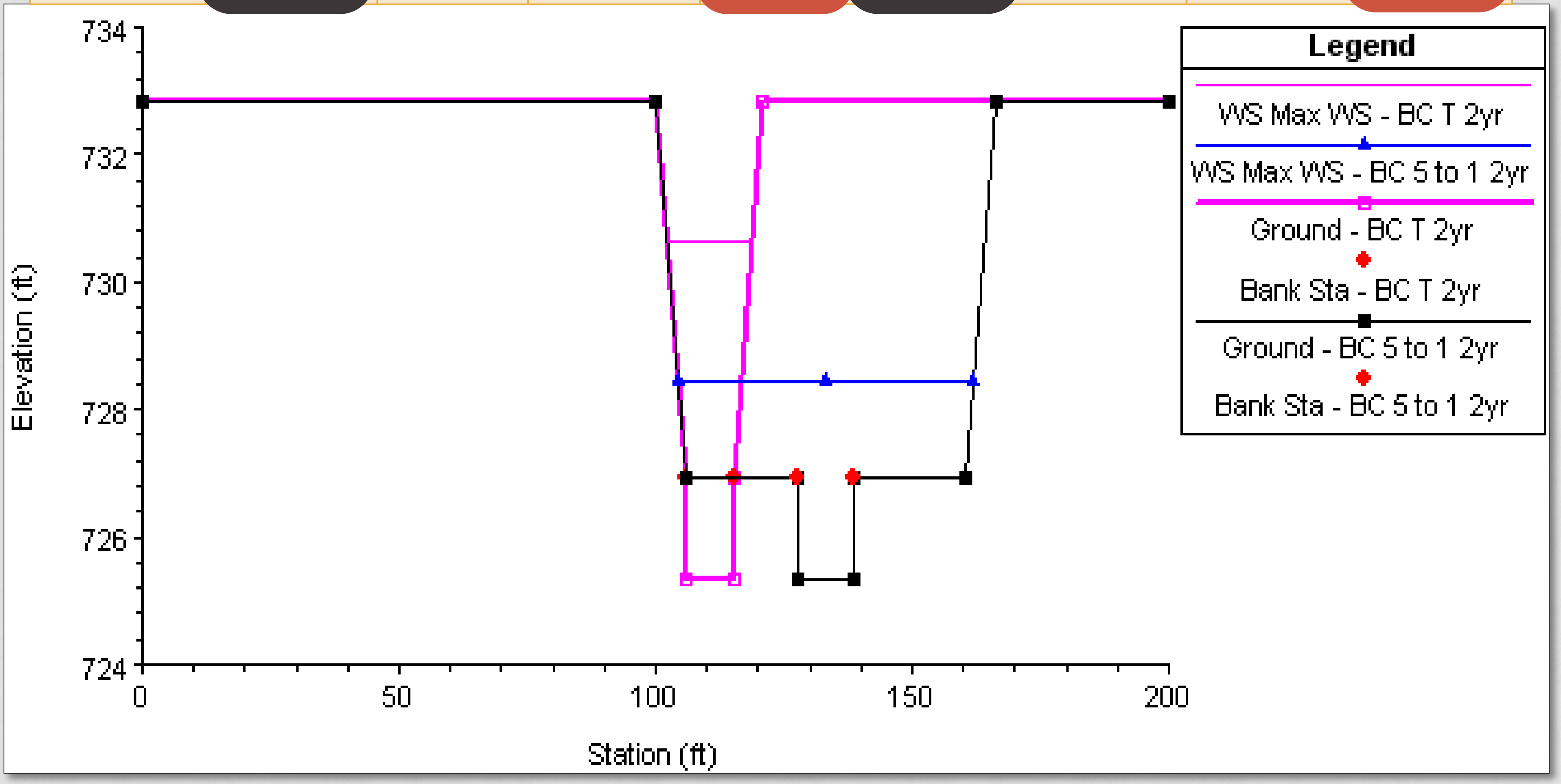
PEAK FLOW STAGE REDUCTION: MEASURED DATA



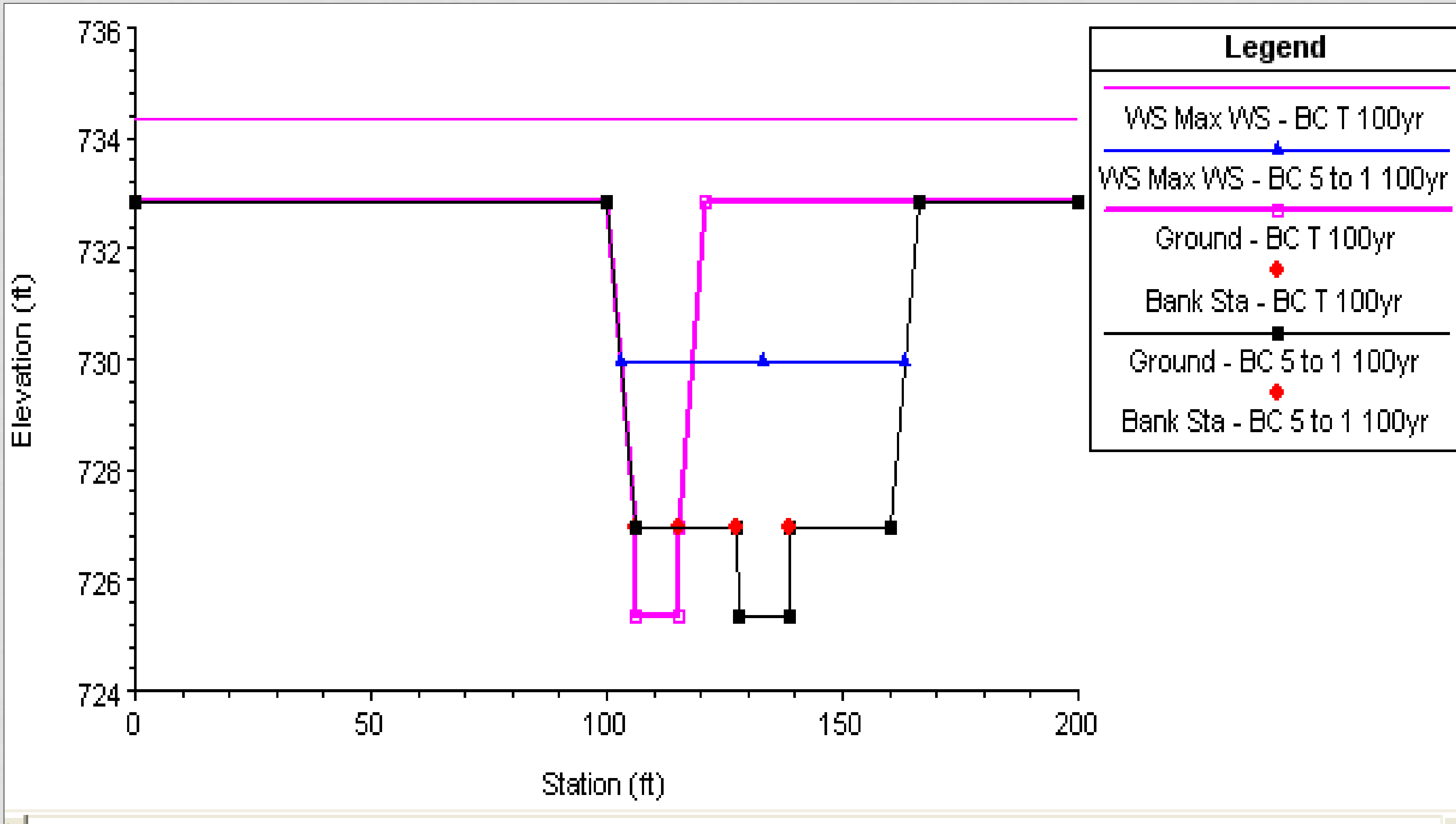
Comparison of stage depths for trapezoidal and two-stage ditch cross-sections at Creel Ditch, IN.

FLOOD STAGE REDUCTION: HEC-RAS

	Trapezoidal				5 to 1 Two-Stage			
RI	Velocity (m/s)	Area (sq. m)	Discharge (cms)	Stage (m)	Velocity (m/s)	Area (sq. m)	Discharge (cms)	Stage (m)
2	0.7	5.8	4.1	1.6	0.5	9.3	4.2	0.9



RI	Trapezoidal Velocity (m/s)	Trapezoidal Area (sq. m)	Trapezoidal Discharge (cms)	Trapezoidal Stage (m)	5 to 1 Two-Stage Velocity (m/s)	5 to 1 Two-Stage Area (sq. m)	5 to 1 Two-Stage Discharge (cms)	5 to 1 Two-Stage Stage (m)
100	0.3	37.2	11.3	2.7	0.6	17.5	11.4	1.4



PREDICTING STABILITY AND FLOODING

Result-Ditch_HerbE_C1_D0.4_FP3_S0.1_M0.03.xls [Compatibility Mode] - Microsoft Excel

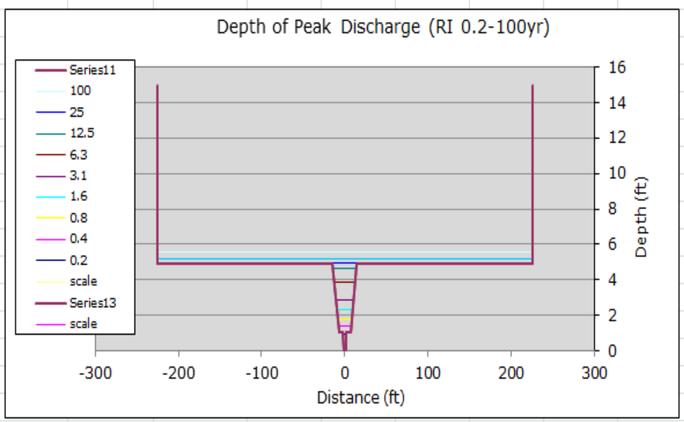
Discharge	(cfs)										
1st Stage	2nd Stage	0.4	0.8	1.6	3.1	6.3	12.5	25	50	100	
4.26	268.95	10.40	22.10	42.32	73.03	153.70	234.37	266.52	379.54	540.49	

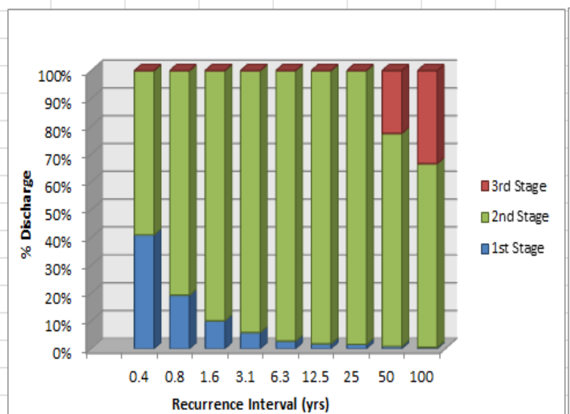
Stage	(ft)										Flow
Second S	Third Stage	0.4	0.8	1.6	3.1	6.3	12.5	25	50	100	1st Stag
1.02	4.95	1.40	1.81	2.29	2.84	3.88	4.66	4.93	5.20	5.55	3.5

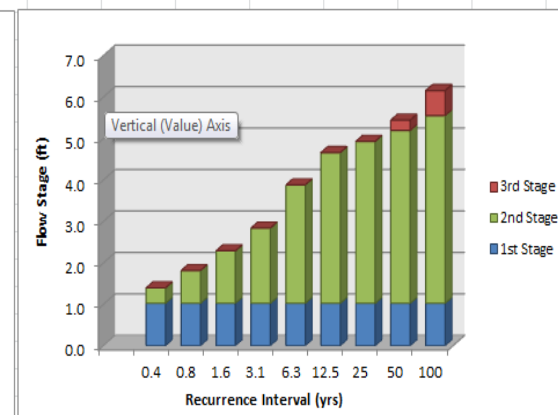
n	RI	0.4	0.8	1.6	3.1	6.3	12.5	25	50	100
0.03	1st Stage	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
0.03	2nd Stage	6.1	17.8	38.1	68.8	149.4	230.1	262.3	375.3	536.2
0.06	3rd Stage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.6	271.5

	0.4	0.8	1.6	3.1	6.3	12.5	25	50	100
1st Stage	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2nd Stage	0.4	0.8	1.3	1.8	2.9	3.6	3.9	4.2	4.5
3rd Stage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6

The bankfull discharge corresponds to less than a 0.4 year recurrence interval event. All flows up to and including the 25 year event are contained in the 1st and 2nd stages. The 50 and 100 year events are in the 3rd Stage. Depth of flow for the 100 year discharge is 0.6 ft. The inset channel (1st stage) has a discharge velocity of 1.2 f/s (4.3 cfs/3.6 ft^2). Having benches 3 times the bankfull channel width, the 2nd stage ty of 1.5 f/s (536 cfs/355 ft^2). Velocity of the 100 year discharge is 1.0 f/s (272 cfs/271 ft^2).

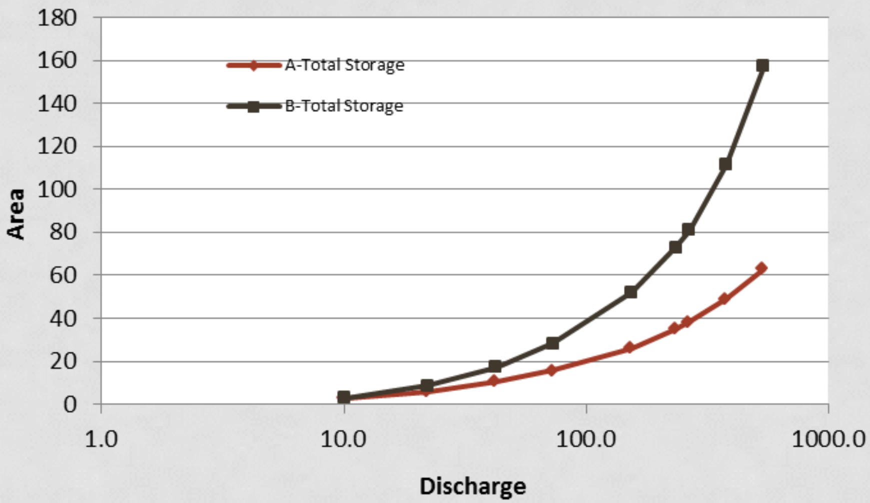


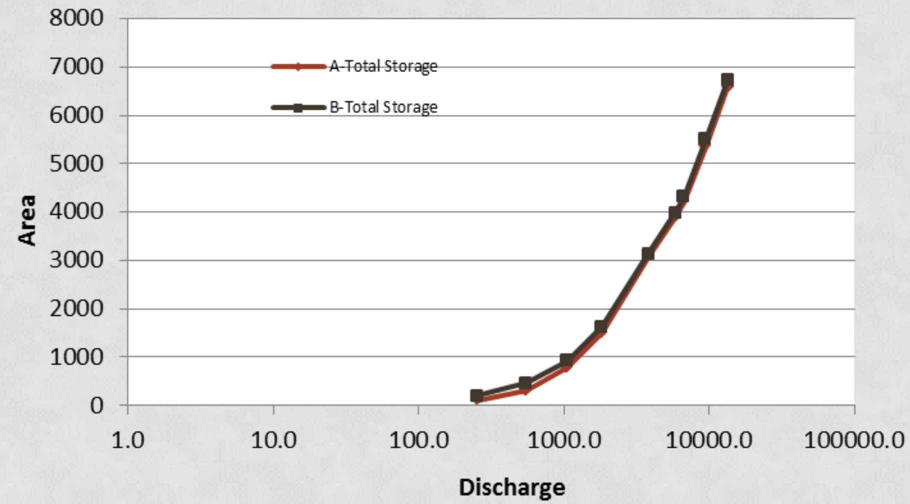


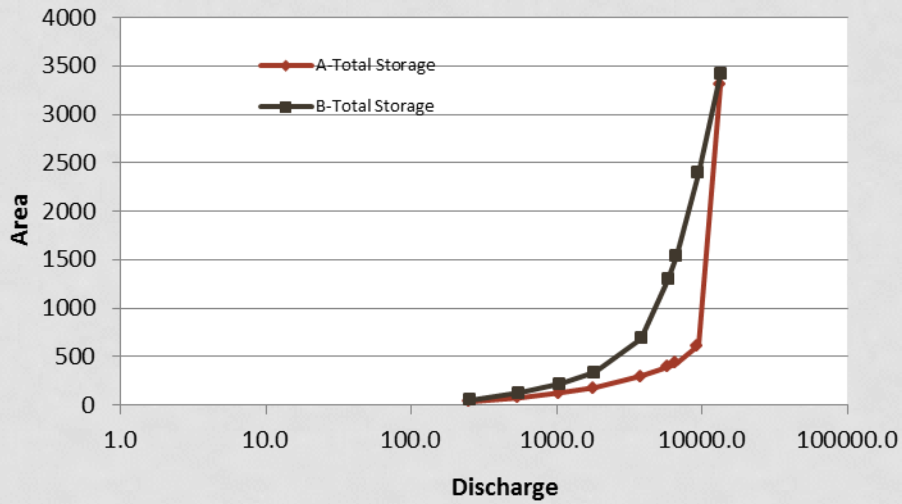


Velocity	0.4	0.8	1.6	3.1	6.3	12.5	25	50	100
1st stage	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
2nd stage	1.2	1.5	1.9	2.2	2.7	3.0	3.1	1.9	1.5
3rd stage								1.0	1.0

PREDICTING CHANNEL AND WATERSHED CONDITIONS THAT MAXIMIZE FLOODPLAIN STORAGE







CONCLUSIONS (TO DATE)

- ✓ Constructed two-stage ditches ages 3-10yrs are stable and are progressing towards quasi-equilibrium.
- ✓ Two-stage channels with at least 3:1 bench width to bankfull width ratio reduce flood stage and provide storage benefits.
- ✓ Banks are stable under a variety of modeled conditions. Watch out for overbank runoff, design/construction errors, poorly established vegetation, and 1-sided construction.
- ✓ Stable constructed Two-stage Channels have potential ecological benefits that may improve over time.

ACKNOWLEDGEMENTS

- Landowners
- USDA-NIFA
- USDA-NRCS
- The Nature Conservancy
- North Central Region Water Network
- The Joyce Foundation
- Ohio Water Development Authority
- Great Lakes Protection Fund
- Indiana DEM
- Ohio DNR
- Ohio EPA
- County Ditch Managers

THE OHIO STATE UNIVERSITY EXTENSION

TO BUILD A BETTER DITCH…

(http://vimeo.com/7901535)

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THE OHIO STATE UNIVERSITY EXTENSION

http://agditches.osu.edu