Appendices

2014 Pigeon Creek Watershed Management Plan

Appendix A

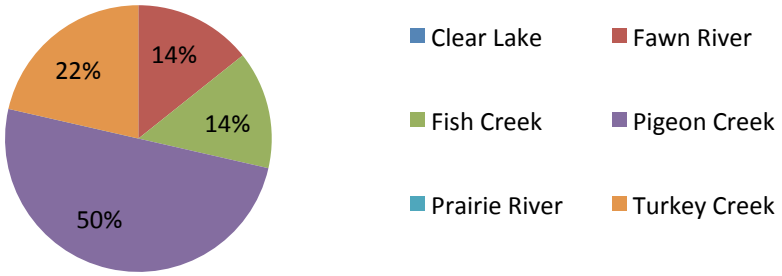
Public Participation

&

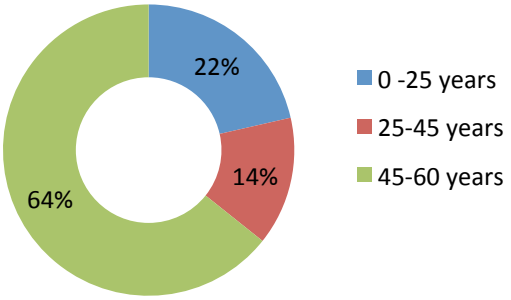
Supplemental Project Information

Annual Meeting 2013 Survey Results, Participants in survey: 14

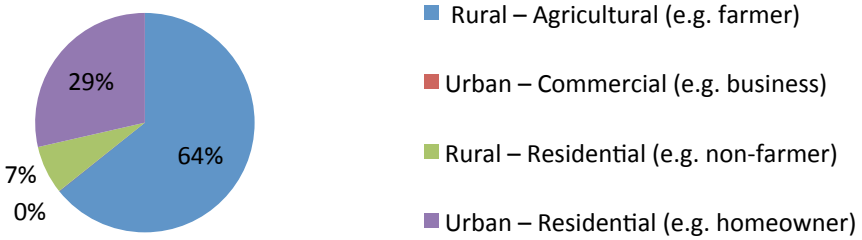
1) Which watershed that best represents where you live or work?



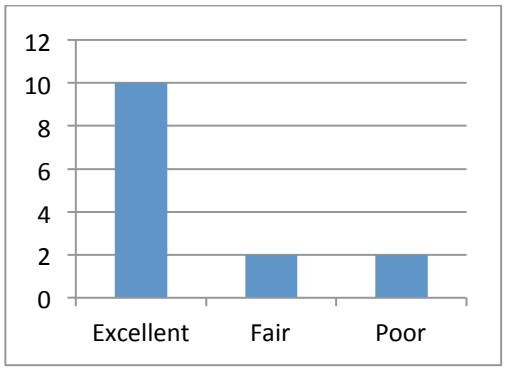
2) How long have you lived (or worked) in that watershed?



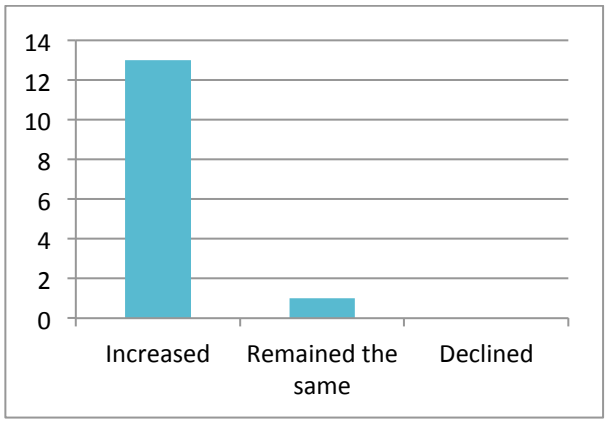
3) Which one of the following best represents your relationship to your watershed?



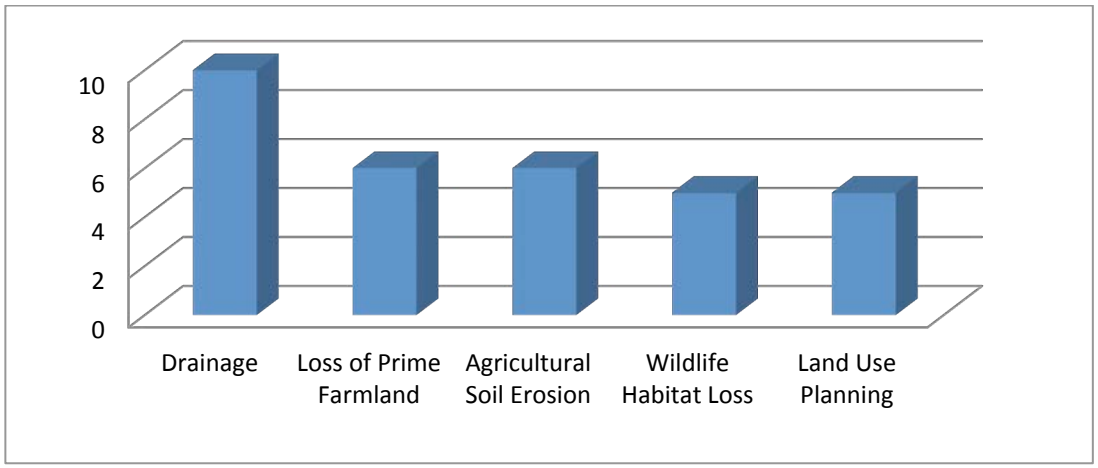
4) How would you rate the water quality of your watershed?



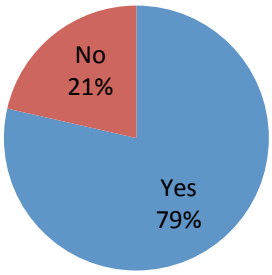
5) Do you believe conservation knowledge & practices within your watershed have:



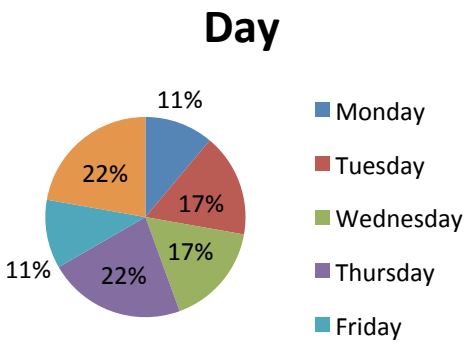
6) Mark your top 5 natural resource concerns for your watershed from the topics listed below

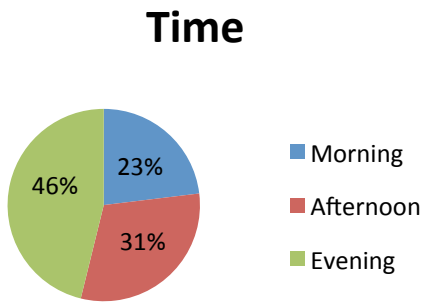


7) Have you ever attended SWCD informational meetings or field days?

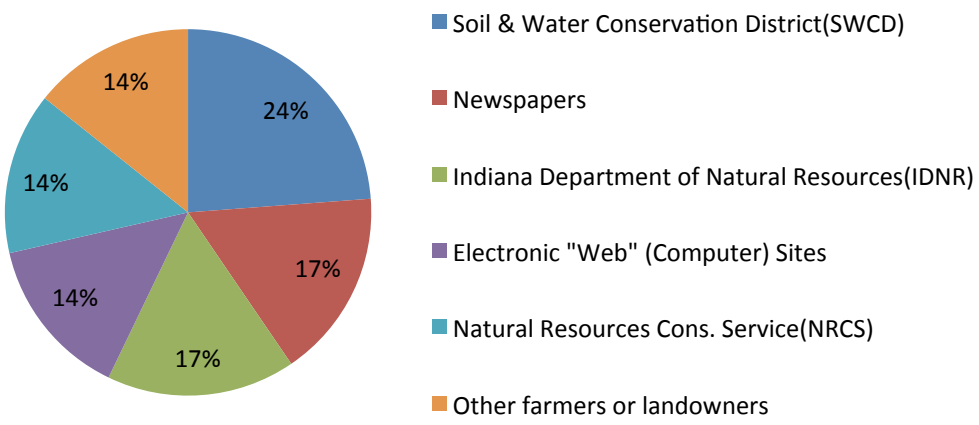


8) If you were interested in attending future SWCD informational meetings or field days, when would you most likely attend such an event?(Please choose one)



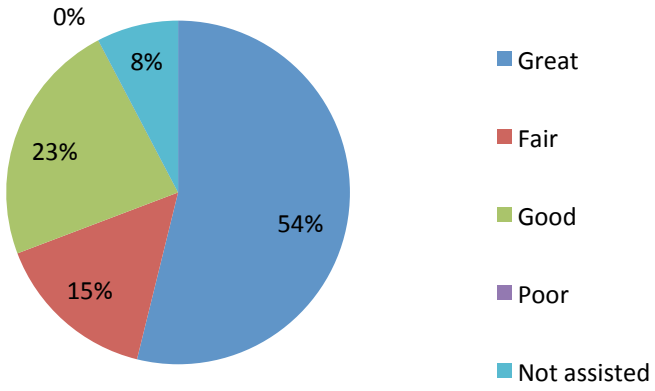


9) Where do you get information on natural resources topics? (Mark your top 5 sources)

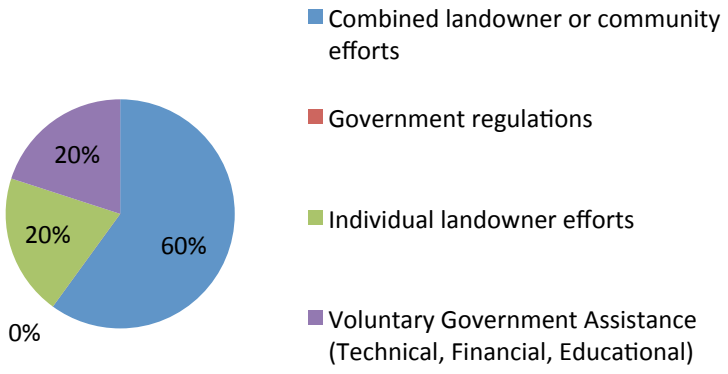


10) What topics should be included in such future events?
- Best use of land without doing CRP
- Soil analysis organic improvement: testing current soil

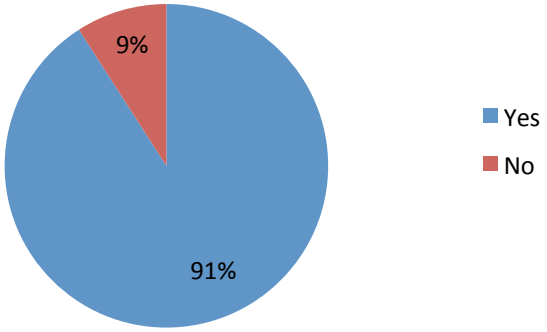
11) How would you rate the assistance provided to you by the SWCD in the past?



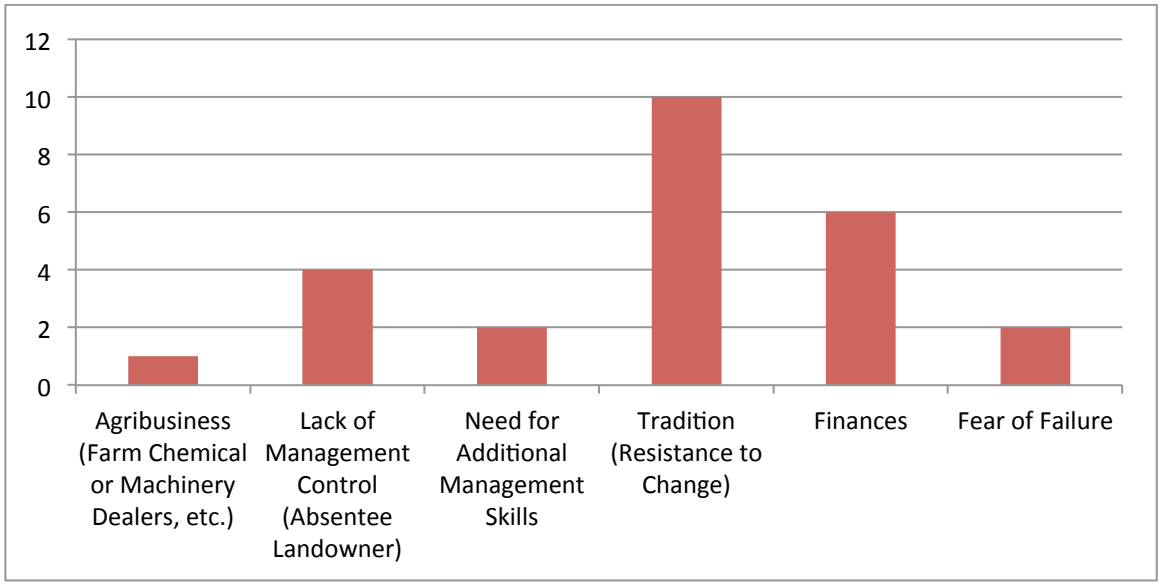
12) How should the water quality issues within your watershed be addressed?



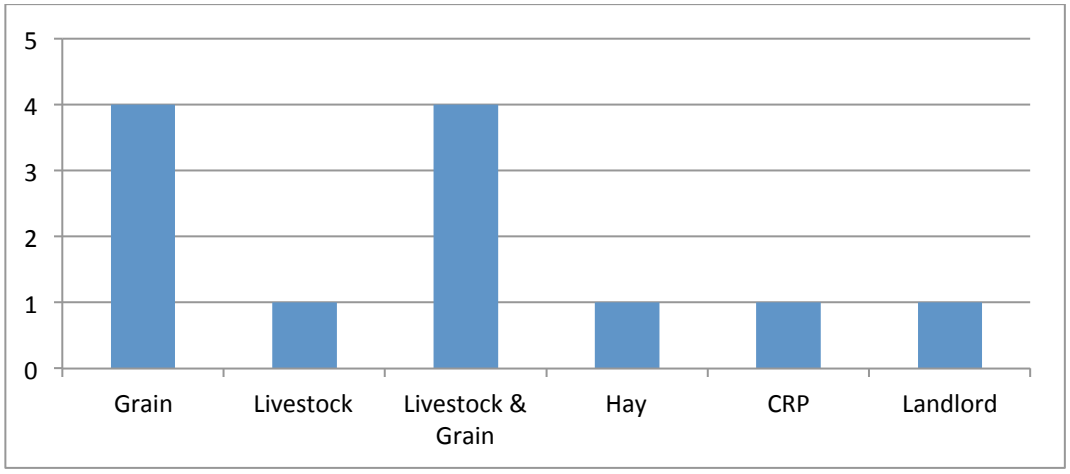
13) Would you recommend conservation practices to other farmers or landowners?



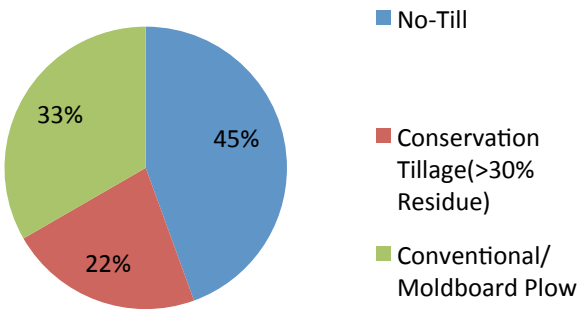
14) Which of the following factors do you feel limit the adoption of conservation practices in your watershed? (Mark all that apply)



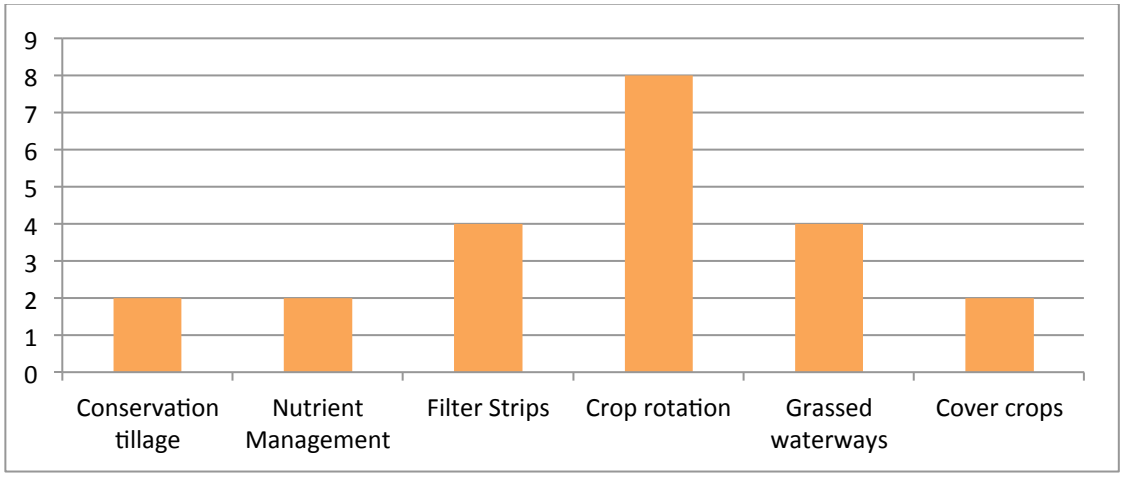
15) If you farm: What type of farming operation do you have?



What is your predominant tillage system?



What conservation practices do you use to control soil erosion?



16) Additional Comments: Our watershed in Steuben is a great asset to a huge area of this country. Keep up the progress towards excellent information sharing.

List of Attendees at April 9, 2013 Steering Committee Meeting

Attendee	Affiliation
Kayleen Hart	Administrative Coordinator SWCD
Mandy Courtright	Resource Conservationist SWCD
Lee Courtright	Landowner in Pigeon
John Williamson	West Otter Lake
Eric Henion	MS4
Brian Musser	NRCS
Tharon Shultz	Pigeon Creek Watershed (Hudson)/Trine University
Rachel Wisman	Trine University
Bob Glick	Long Lake
Beth Warner	The Nature Conservancy
Tom Green	SWCD Chairman of the Board
Larry Gilbert	Surveyor
Bill Schmidt	Steuben County Lakes Council
Joe Schmees	IDEM Project Manager

Detailed Past Project Summary Table (Agricultural)

Project Table - Agricultural

	HUAs (#)	Filter Strips (acres)	Grassed Waterways (feet)	Water and Sediment Control Basin/ Drop Inlet Structure	Hay/ Pasture (acres)	Fence - Exclusion and Rotational Grazing (feet)	Livestock Watering Facility (number)	Trees (acres)	Cover Crops (acres)	Critical Area Seeding (acres)	Wetlands (acres)	Two-Stage Ditch (acres)	Compre-hensive Nutrient Manage-ment Plan (acres)
Phase 1 (319)		0.65	3,550	20									
Phase 2 (319)					15	4295		30					
LARE (2007-2012)		20.6	3,200		683	36,832	4	86	878	8.35			
CWI (2012)	2								355				
LARE Pigeon (2013)					92.5			2	124	4			83
LARE Turkey (2013)					34			10	14		6		
NRCS (2006-2013)								15	2,963		406	1.3	
TOTAL	2	21.25	6,750	20	824.5	41,127	4	143	4,334	12.35	412	1.3	83

Detailed Past Project Summary Table (Urban)

Project Table - Urban						
	Wetlands (acres)	Streambank Stabilization	Rain Garden (number)	Rain Barrels (number)	Pervious Concrete (Square Feet)	Bio-Swale (Square-feet)
Phase 2 (319)	2.66	307	3	43	324	4,100
National Cons. Found. Award (NCF)				51 (Pigeon/Turkey)		

Appendix B

Monitoring Score Cards

Goal #1 Milestone Scorecard: Reduce Bacteria Loading

Milestones; S = 1-5 yrs / M = 6-10 yrs / L = 10+ yrs

Objective	***Indicator***		***Milestone***	***Grade***
Implement a basin-wide septic inspection and tracking program; inspect 1,000 septic systems	*Number of water quality samples exceeding 235 CFU/100 mL*	*S*	250 systems	
		M	500 systems (cumulative)	
		L	1,000 systems (cumulative)	
Install diversions and waste lagoons on 25 small animal feed operations	*Number of water quality samples exceeding 235 CFU/100 mL*	*S*	5 operations	
		M	10 operations (cumulative)	
		L	25 operations (cumulative)	
Implement pasture management practices on 30 pasture operations	*Number of water quality samples exceeding 235 CFU/100 mL*	*S*	10 operations	
		M	20 operations (cumulative)	
		L	30 operations (cumulative)	
Install 5 detention basins	*Number of water quality samples exceeding 235 CFU/100 mL*	*S*	2 basins	
		M	2 basins (additional)	
		L	1 basin (additional)	
Continue local education and water quality monitoring programs.	*Number of water quality samples exceeding 235 CFU/100 mL*	*S*	2 education/outreach programs and continue monitoring	
		M	2 education/outreach programs and continue monitoring	
		L	2 education/outreach programs and continue monitoring	

Milestone Grading System

A=Met or exceeded milestone
B=Milestone 75% achieved
C=Milestone 50% achieved
D=Milestone 25% achieved
F=Milestone not achieved

Goal #2 Milestone Scorecard: Reduce Phosphorus & Nitrogen Loading

Milestones; S = 1-5 yrs / M = 6-10 yrs / L = 10+ yrs

Objective	***Indicator***		***Milestone***	***Grade***
Install cover crops on 5,000 acres	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	2,000 acres	
		M	3,000 acres (cumulative)	
		L	5,000 acres (cumulative)	
Install 100 acres of filter strips	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	50 acres	
		M	75 acres (cumulative)	
		L	100 acres (cumulative)	
Install 5 detention basins	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	2 basins	
		M	2 basins (additional)	
		L	1 basin (additional)	
Create 2 wetlands in urban areas and 3 wetlands on agricultural ground	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	2 wetlands	
		M	2 wetlands (additional)	
		L	1 wetland (additional)	
Restore 100 acres of existing wetlands	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	25 acres	
		M	50 acres (additional)	
		L	25 acres (additional)	
Treat 5,000 acres with denitrifying bioreactors	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L*	*S*	2,000 acres	
		M	3,000 acres (cumulative)	
		L	5,000 acres (cumulative)	
Treat 500 acres of urban and residential areas with rain barrels, rain gardens, and porous pavement	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	100 acres	
		M	200 acres (cumulative)	
		L	500 acres (cumulative)	
Continue local education and water quality monitoring programs to evaluate reductions in phosphorus and nitrogen	*a) Nitrogen: Number of water quality samples exceeding 10 Mg/L* *b) Phosphorus: Number of water quality samples exceeding 0.3 mg/L*	*S*	2 education/outreach programs and continue monitoring	
		M	2 education/outreach programs and continue monitoring	
		L	2 education/outreach programs and continue monitoring	

Milestone Grading System

A=Met or exceeded milestone
B=Milestone 75% achieved
C=Milestone 50% achieved
D=Milestone 25% achieved
F=Milestone not achieved

Goal #3 Milestone Scorecard: Reduce Sediment Loading

Milestones; S = 1-5 yrs / M = 6-10 yrs / L = 10+ yrs

Objective	***Indicator***		***Milestone***	***Grade***
Install blind inlets on 100 fields	*Number of water quality samples exceeding 30 Mg/L*	*S*	25 fields	
		M	50 fields (additional)	
		L	25 fields (additional)	
Install 5 detention basins	*Number of water quality samples exceeding 30 Mg/L*	*S*	2 basins	
		M	2 basins (additional)	
		L	1 basin (additional)	
Install 1 rock riffle	*Number of water quality samples exceeding 30 Mg/L*	*S*	1 riffle	
		M	No action	
		L	No action	
Install terraces or WASCB systems on 100 fields	*Number of water quality samples exceeding 30 Mg/L*	*S*	25 fields	
		M	50 fields (additional)	
		L	25 fields (additional)	
Install 9 grass waterways	*Number of water quality samples exceeding 30 Mg/L*	*S*	5 waterways	
		M	3 waterways (additional)	
		L	1 waterway (additional)	
Continue local education and water quality monitoring programs	*Number of water quality samples exceeding 30 Mg/L*	*S*	2 education/outreach programs and continue monitoring	
		M	2 education/outreach programs and continue monitoring	
		L	2 education/outreach programs and continue monitoring	

Milestone Grading System

A=Met or exceeded milestone
B=Milestone 75% achieved
C=Milestone 50% achieved
D=Milestone 25% achieved
F=Milestone not achieved

Goal #4 Milestone Scorecard: Reduce Flooding by Increasing Storage

Milestones; S = 1-5 yrs / M = 6-10 yrs / L = 10+ yrs

Objective	***Indicator***		***Milestone***	***Grade***
Install 25,000 feet of two-stage drainage ditch	*1) Acres of restored wetland in headwaters* *2) Feet of two-stage drainage ditches*	*S*	10,000 feet	
		M	10,000 feet (additional)	
		L	5,000 feet (additional)	
Implement 1 regional detention area; Bill Deller Rd	*1) Acres of restored wetland in headwaters* *2) Feet of two-stage drainage ditches L*	*S*	No action	
		M	1 detention area	
		L	No action	
Restore 100 acres of existing wetlands	*1) Acres of restored wetland in headwaters* *2) Feet of two-stage drainage ditches*	*S*	25 acres	
		M	50 acres (additional)	
		L	25 acres (additional)	
Treat 500 acres of urban and residential areas with rain barrels, rain gardens, and porous pavement	*1) Acres of restored wetland in headwaters* *2) Feet of two-stage drainage ditches*	*S*	100 acres	
		M	200 acres (cumulative)	
		L	500 acres (cumulative)	
Continue local education programs	*1) Acres of restored wetland in headwaters* *2) Feet of two-stage drainage ditches*	*S*	2 education/outreach programs and continue monitoring	
		M	2 education/outreach programs and continue monitoring	
		L	2 education/outreach programs and continue monitoring	

Milestone Grading System

A=Met or exceeded milestone
B=Milestone 75% achieved
C=Milestone 50% achieved
D=Milestone 25% achieved
F=Milestone not achieved

Appendix C

Biological Data

T&E Species List

Scientific Name	Common Name	Type	Frequency Occurrence
Accipiter striatus	Sharp-shinned Hawk	Bird	1
Actaea rubra	Red Baneberry	Vascular Plant	2
Aeshna mutata	Spatterdock Darner	Insect Odonata	3
Aeshna tuberculifera	Black-tipped Darner	Insect Odonata	3
Ambystoma laterale	Blue-spotted Salamander	Amphibian	1
Amelanchier humilis	Running Serviceberry	Vascular Plant	1
Anepia capsularis	The Starry Campion Capsule Moth	Insect Lepidoptera	1
Apamea verbascoides	The Boreal Apamea	Insect Lepidoptera	1
Arabis missouriensis var. deamii	Missouri Rockcress	Vascular Plant	1
Ardea herodias	Great Blue Heron	Bird	2
Armoracia aquatica	Lake Cress	Vascular Plant	1
Aster borealis	Rushlike Aster	Vascular Plant	2
Bidens beckii	Beck Water-marigold	Vascular Plant	1
Boloria selene myrina	Silver-bordered Fritillary	Insect Lepidoptera	2
Botaurus lentiginosus	American Bittern	Bird	1
Botrychium matricariifolium	Chamomile Grape-fern	Vascular Plant	2
Calephelis muticum	Swamp Metalmark	Insect Lepidoptera	1
Calla palustris	Wild Calla	Vascular Plant	1
Capis curvata	A Noctuid Moth	Insect Lepidoptera	1
Carex alopecoidea	Foxtail Sedge	Vascular Plant	1
Carex debilis var. rudgei	White-edge Sedge	Vascular Plant	3
Carex flava	Yellow Sedge	Vascular Plant	1
Carex limosa	Mud Sedge	Vascular Plant	1
Carex retrorsa	Retrorse Sedge	Vascular Plant	1
Catocala praeclara	Praeclara Underwing	Insect Lepidoptera	1
Certhia americana	Brown Creeper	Bird	2
Chimaphila umbellata ssp. cisatlantica	Pipsissewa	Vascular Plant	2
Chlidonias niger	Black Tern	Bird	1
Chortodes inquinata	Tufted Sedge Moth	Insect Lepidoptera	1
Circaea alpina	Small Enchanter's Nightshade	Vascular Plant	2
Cistothorus palustris	Marsh Wren	Bird	1
Cistothorus platensis	Sedge Wren	Bird	2
Clemmys guttata	Spotted Turtle	Reptile	5
Condylura cristata	Star-nosed Mole	Mammal	4
Cordulegaster bilineata	Brown Spiketail	Insect Odonata	1
Coregonus artedi	Cisco	Fish	5
Crambus girardellus	Orange-striped Sedge Moth	Insect Lepidoptera	1
Cryptocala acadiensis	Catocaline Dart	Insect Lepidoptera	1
Cypripedium calceolus var. parviflorum	Small Yellow Lady's-slipper	Vascular Plant	3
Cypripedium candidum	Small White Lady's-slipper	Vascular Plant	2
Dasychira cinnamomea	A Moth	Insect Lepidoptera	1
Dendroica cerulea	Cerulean Warbler	Bird	1
Dendroica virens	Black-throated Green Warbler	Bird	1
Deschampsia cespitosa	Tufted Hairgrass	Vascular Plant	1

Dorocordulia libera	Racket-tailed Emerald	Insect Odonata	1
Drosera intermedia	Spoon-leaved Sundew	Vascular Plant	
Eleocharis robbinsii	Robbins Spikerush	Vascular Plant	1
Empidonax alnorum	Alder Flycatcher	Bird	2
Emydoidea blandingii	Blanding's Turtle	Reptile	7
Epioblasma triquetra	Snuffbox	Mollusk	1
Equisetum variegatum	Variegated Horsetail	Vascular Plant	1
Eriocaulon aquaticum	Pipewort	Vascular Plant	1
Eriophorum viridicarinatum	Green-keeled Cotton-grass	Vascular Plant	2
Euphydryas phaeton	Baltimore	Insect Lepidoptera	5
Exyra rolandiana	Pitcher Window Moth	Insect Lepidoptera	1
Forest - flatwoods sand	Sand Flatwoods	High Quality Natural Community	1
	Wet Floodplain Forest	High Quality Natural Community	2
Forest - upland dry	Dry Upland Forest	High Quality Natural Community	2
Forest - upland dry-mesic	Dry-mesic Upland Forest	High Quality Natural Community	1
Forest - upland mesic	Mesic Upland Forest	High Quality Natural Community	1
Fuirena pumila	Dwarf Umbrella-sedge	Vascular Plant	1
Gallinula chloropus	Common Moorhen	Bird	1
Geum rivale	Purple Avens	Vascular Plant	1
Glaucopsyche lygdamus couperi	Silvery Blue	Insect Lepidoptera	1
Glyceria borealis	Small Floating Manna-grass	Vascular Plant	2
Glyceria grandis	American Manna-grass	Vascular Plant	1
Gnaphalium macounii	Winged Cudweed	Vascular Plant	1
Grammia phyllira	The Sand Barrens Grammia	Insect Lepidoptera	1
Grus canadensis	Sandhill Crane	Bird	1
Hemidactylium scutatum	Four-toed Salamander	Amphibian	2
Iodopepla u-album	A Noctuid Moth	Insect Lepidoptera	1
Ixobrychus exilis	Least Bittern	Bird	3
Juncus balticus var. littoralis	Baltic Rush	Vascular Plant	1
Juniperus communis	Ground Juniper	Vascular Plant	1
Lake - lake	Lake	High Quality Natural Community	2
Lemna valdiviana	Pale Duckweed	Vascular Plant	1
Leucania inermis	A Moth	Insect Lepidoptera	1
Leucania multilinea		Insect Lepidoptera	1
Loxagrotis grotei	Grote's Black-tipped Quaker	Insect Lepidoptera	1
Lutra canadensis	Northern River Otter	Mammal	1
Lycaeides melissa samuelis	Karner Blue	Insect Lepidoptera	1
Lycaena dorcas dorcas	Dorcas Copper	Insect Lepidoptera	2
Lycopodiella inundata	Northern Bog Clubmoss	Vascular Plant	2
Lycopodium hickeyi	Hickey's Clubmoss	Vascular Plant	1
Lycopodium obscurum	Tree Clubmoss	Vascular Plant	1
Lynx rufus	Bobcat	Mammal	5
Macrochilo absorptalis	A Moth	Insect Lepidoptera	1
Macrochilo bivittata	Two-striped Cord Grass Moth	Insect Lepidoptera	1

Macrochilo hypocritalis	A Noctuid Moth	Insect Lepidoptera	1
Matteuccia struthiopteris	Ostrich Fern	Vascular Plant	1
Melampyrum lineare	American Cow-wheat	Vascular Plant	1
Melanchra assimilis	The Shadowy Arches	Insect Lepidoptera	1
Milium effusum	Tall Millet-grass	Vascular Plant	1
Moxostoma valenciennesi	Greater Redhorse	Fish	1
Mustela nivalis	Least Weasel	Mammal	3
Nannothemis bella	Elfin Skimmer	Insect Odonata	2
Nehalennia gracilis	Sphagnum Sprite	Insect Odonata	3
Neonympha mitchellii mitchellii	Mitchell's Satyr	Insect Lepidoptera	1
Nerodia erythrogaster neglecta	Copperbelly Water Snake	Reptile	1
Oligia bridghami	A Noctuid Moth	Insect Lepidoptera	1
Oryzopsis racemosa	Black-fruit Mountain-ricegrass	Vascular Plant	1
Pandion haliaetus	Osprey	Bird	1
Panicum boreale	Northern Witchgrass	Vascular Plant	4
Panicum leibergii	Leiberg's Witchgrass	Vascular Plant	1
Panicum subvillosum	A Panic-grass	Vascular Plant	2
Papaipema silphii	Silphium Borer Moth	Insect Lepidoptera	1
Pieris oleracea	Eastern Veined White	Insect Lepidoptera	3
Platanthera ciliaris	Yellow-fringe Orchis	Vascular Plant	2
Platanthera hyperborea	Leafy Northern Green Orchis	Vascular Plant	3
Platanthera leucophaea	Prairie White-fringed Orchid	Vascular Plant	1
Platanthera psycodes	Small Purple-fringe Orchis	Vascular Plant	3
Poa alsodes	Grove Meadow Grass	Vascular Plant	1
Poa paludigena	Bog Bluegrass	Vascular Plant	1
Poanes viator viator	Big Broad-winged Skipper	Insect Lepidoptera	1
Potamogeton friesii	Fries' Pondweed	Vascular Plant	1
Potamogeton pusillus	Slender Pondweed	Vascular Plant	1
Potamogeton richardsonii	Redheadgrass	Vascular Plant	1
Potamogeton robbinsii	Flatleaf Pondweed	Vascular Plant	3
Psilocarya scirpoides	Long-beaked Baldrush	Vascular Plant	2
Pyrola rotundifolia var. americana	American Wintergreen	Vascular Plant	3
Rallus limicola	Virginia Rail	Bird	1
Rana pipiens	Northern Leopard Frog	Amphibian	2
Rhynchospora macrostachya	Tall Beaked-rush	Vascular Plant	3
Salix serissima	Autumn Willow	Vascular Plant	2
Scirpus purshianus	Weakstalk Bulrush	Vascular Plant	1
Scirpus subterminalis	Water Bulrush	Vascular Plant	2
Sistrurus catenatus catenatus	Eastern Massasauga	Reptile	7
Spartiniphaga includens	The Included Cordgrass Borer	Insect Lepidoptera	1
Speyeria idalia	Regal Fritillary	Insect Lepidoptera	1
Spiranthes lucida	Shining Ladies'-tresses	Vascular Plant	1
Spiranthes romanzoffiana	Hooded Ladies'-tresses	Vascular Plant	3
Stipa avenacea	Blackseed Needlegrass	Vascular Plant	
Stylurus amnicola	Riverine Clubtail	Insect Odonata	1
Sympetrum semicinctum	Band-winged Meadowhawk	Insect Odonata	1
Taxidea taxus	American Badger	Mammal	12

Tofieldia glutinosa	False Asphodel	Vascular Plant	4
Triglochin palustris	Marsh Arrow-grass	Vascular Plant	5
Utricularia cornuta	Horned Bladderwort	Vascular Plant	2
Utricularia minor	Lesser Bladderwort	Vascular Plant	2
Utricularia purpurea	Purple Bladderwort	Vascular Plant	2
Utricularia resupinata	Northeastern Bladderwort	Vascular Plant	1
Vaccinium oxycoccos	Small Cranberry	Vascular Plant	1
Valeriana uliginosa	Marsh Valerian	Vascular Plant	2
Venustaconcha ellipsiformis	Ellipse	Mollusk	3
Vermivora chrysoptera	Golden-winged Warbler	Bird	1
Viburnum cassinoides	Northern Wild-raisin	Vascular Plant	4
Viburnum opulus var. americanum	Highbush-cranberry	Vascular Plant	1
Wetland - fen	Fen	High Quality Natural Community	8
Wetland - flat muck	Muck Flat	High Quality Natural Community	3
Wetland - marsh	Marsh	High Quality Natural Community	3
Wetland - meadow sedge	Sedge Meadow	High Quality Natural Community	1
Wetland - swamp forest	Forested Swamp	High Quality Natural Community	
Wetland - swamp shrub	Shrub Swamp	High Quality Natural Community	1
Wilsonia canadensis	Canada Warbler	Bird	1
Wilsonia citrina	Hooded Warbler	Bird	2
Zigadenus elegans var. glaucus	White Camas	Vascular Plant	5

Appendix D

Water Quality Monitoring

Quality Assurance Report
&
Quality Assurance Project Plan (QAPP)

Quality Assurance Report

for

2012 Pigeon Creek Water Quality Sampling

Steuben County, Indiana

ARN # 9-275

Prepared by:

Scott Banfield

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for

Steuben County Soil and Water Conservation District, Steuben County Lakes Council

Indiana Department of Environmental Management

Office of Water Management

NPS/TMDL Section

Introduction

To serve the goal and objectives listed in section 8.1 of the ARN 9-275 monitoring QAPP (Aquatic Enhancement & Survey, Inc. 2010) water samples were collected from sixteen Pigeon Creek sites. Samples for total phosphorus, total suspended solids, and E coli were collected three times in 2012 (sites 1-16, page 8). Measurements for pH, temperature, D.O., specific conductance, and discharge were made at each of these sites where conditions permitted. Samples were delivered to Sherry Laboratories in Fort Wayne, Indiana for professional analysis. Data was used to provide simple estimations for each respective parameter to provide general insight into water quality in the Pigeon Creek watershed. Monitoring was not designed to trigger specific project decisions, actions, or quantify load reductions resulting from specific project BMP installations. Collections occurred in May, July, and August of 2012. Five sites were located at or near the exit points of each 12 digit HUC within ARN#9-275 to generally guage the water quality influence of each respective unit. Sites were also selected to include the confluence point and exit point of Pigeon Creek with each lake in the Pigeon Creek Chain, sites with a prior history of notable poor water quality, and sites immediately downstream of the confluence of major tributaries to the Pigeon. Fourteen of the sites were funded with the Phase 2 319 grant for ARN#9-275. Two additional sites have been funded by the City of Angola/Trine University MS4 Program. Although sampling occured at sites one through nine following a rain event in July, droughty conditions generally persisted throughout the 2012 sampling season and all sampling represents relatively "low flow" conditions. Sampling, blank, and duplicate analysis results are presented in the accompanying AIMS data upload results spreadsheet. This Report is presented to provide a short summary of 2012 season findings with regard to water quality target goals established in the QAPP and present a summary of Q.C. data and year 2012 deviations from quality goals.

Summary of Water Quality Target Results

Table 1 contains water quality targets from the Pigeon Creek Management Plan (PCMP V3, 2006) as well as revised targets from the current QAPP and results from 2010, 2011, and 2012 sampling.

E-coli: Pigeon Creek and tributary baseline flow data from the 2006 PCMP indicated variable concentrations of 250-4500 Colonies per 100 ml. This was refined by utilizing more recent data collected from Pigeon Creek by the Steuben County Lakes Council (SCLC) in 2008 and 2009. This data was used to produce a characterization for Pigeon Creek of variable concentrations of 3-1240 with an average concentration of 240. These figures are based on sites 2,3; 6-9; and 11-16. To maintain comparability in this analysis with the 2008 and 2009 data, the reported data/ranges are limited to baseline flow from the same sites. The target goals from both the PCMP (goal for 2010) and QAPP (goal for 2013) are based on the IDEM maximum of 235. Concentrations in baseline flow (no rain events) in 2012 sampling were variable, with results occurring between 1 and 1990. E-coli measurements were generally considerably lower in 2012 than in previous seasons. Of 48 samplings only five exceeded the target maximum of 235. The average concentration was 184, in compliance with the target goal of maximum 235. Droughty conditions may have contributed to reduced E-coli measurements as runoff produced during the sampling period was quite limited.

Total Phosphorus Concentration: Pigeon Creek and tributary baseline flow data from the 2006 PCMP indicated total phosphorus concentrations between .2 and 3 mg/l. This figure was refined by utilizing more recent baseline flow data collected from Pigeon Creek proper by the SCLC in 2008 and 2009 to produce and average of .03 mg/l. The target goals from both the PCMP (goal for 2011) and QAPP (goal for 2013) are based on the IDEM state standard maximum of .025 mg/l. While additional sampling sites were added after 2009, sampling sites included in average calculations for this report were limited to those sampled during 2008-2009 to facilitate direct comparison. Concentrations in baseline flow 2012 sampling were variable, with results occurring between .02 and .12 mg/l. The average concentration was .05 mg/l, slightly above the 2011 season average of .04 mg/l and equal to the .05 mg/l average of 2010. This exceeds the 2010 PCMP and 2013 QAAP target goal of max. .025 mg/l and exceeds the 2008/2009 SCLC average of .03 mg/l.

Total Phosphorus Target Load Reduction: In the QAPP an annual phosphorus load reduction goal was established. An estimate was calculated using the projected 2010 stream flow from the 2006 PCMP (100 CFS) and the average total phosphorus concentration from Pigeon Creek 2008 and 2009 baseline sampling (.03 mg/l). This established an annual total phosphorus loading figure of 2679.30 kg/year. Based on the target baseline flow goal of .025 mg/l. average total phosphorus concentration, the estimated flow rate (104 CFS based on PCMP) would produce a load of 2232.75 kg/year. This was used to establish a target load reduction of 446.55 kg/year for 2013. The average concentration in 2012 baseline samples (collected from the same sampling sites as in 2008-2009) was .05 mg/l. This was used to produce an estimated annual loading figure of 4465.50 kg/year for 2012 using the estimated flow rate from the PCMP. No loading reduction was apparent. The estimated loading figure for 2012 increased by 1786.20 kg/year. Using flow data collected in 2012 near the former USGS monitoring site used to produce the PCMP flow estimate produced an average baseline flow rate for 2012 of 1585.11 CFM (26.42 CFS). In the drought conditions of 2012 the flow rate was only 25% of that estimated in the PCMP. It should be noted that this yields an annual loading figure of only 1179.78 kg/year, well below the 2232.75 kg/year target.

Total Suspended Solids: Pigeon Creek baseline flow sampling data from the 2008-2009 SCLC dataset indicated total suspended solids (TSS) concentrations between <1 and 104 mg/l. with an average of 13 mg/l Results in 2012 ranged between <2 and 87 mg/l with an average of 11 mg/l. All but a single sample were below the 30 mg/l QAPP target goal for 2013.

Dissolved Oxygen: Pigeon Creek baseline flow sampling data from the 2008-2009 SCLC dataset indicated (D.O.) concentrations between 6.56 and 15.04 with an average of 9 mg/l. Baseline flow data from the same sites in 2012 ranged between 4.50 and 14.19 mg/l. with an average of 8.50 mg/l. Three sites exceeded the upper limit of the QAPP 2013 target goal range of 4-12 mg/l. Photosynthetic activity in the lake basins may have produced unusually high dissolved oxygen levels. All readings above 12 mg/l were recorded at lake outlets.

pH: Pigeon Creek and tributary baseline flow data from the 2008/2009 SCLC data set indicated variable pH's between 7.37 and 8.61 with an average of 8. The 2012 season baseline flow data collected from the same sites was similar, with pH's ranging between 7.31 and 8.35 with an average of 7.94. All fell within the 2013 QAPP target goal of 6 to 9.

PCMP Goal	Parameter	Current Status (2006 PCMP)	Current Status (2008, 2009 SCLC data)	Target Goal (2006 PCMP, target date 2010)	2010 Results	2011 Results	2012 Results	Target Goal (Phase 2, target date 2013)
Improved Water Quality	E. coli	Variable Concentrations 250-4500 Colonies/100 ml	Variable Concentrations <3-1240 Colonies or CFU per 100/ml average 240	235 Colonies/100 ml (Dry weather-excludes 48-72 hours after rain)	Variable Concentrations 10-880 Colonies or CFU per 100/ml average 231	Variable Concentrations 10-13,680 Colonies or CFU per 100/ml average 720	Variable Concentrations 1-1990 Colonies or CFU per 100/ml average 184	235 Colonies/100 ml (Dry weather-excludes 48-72 hours after rain, IAC
	Phosphates	Avg. 0.2-3 mg/l	<.01-.09 average .03	0.025 mg/l	.02-.11 average .05	.01-.12 average .04	.02-.12 average .05	0.025 mg/l (source PCMP, "state standard" cited)
	Nitrates	0-39 mg/l	-	10 mg/l	-			-
	Total Suspended Solids	-	<1-104 mg/l average13	-	1-26 mg/l average 11	7-34 mg/l average 15	<2-87 mg/l average 11	Max 30 mg/L, IDEM draft TMDL
	Dissolved Oxygen	-	6.56-15.04 mg/l average 9	-	5.44-10.16 mg/l average 7.35	4.94-10.22 mg/l average 7.29	4.50-14.19 mg/l average 8.50	Min 4 mg/L, Max 12 mg/L, IDEM cited IAC
	pH	-	7.37-8.61 average 8	-	7.63-8.28 average 7.96	7.37-8.61 average 8	7.31-8.35 average 7.94	6-9 may exceed 9 daily if coincides with photosynthetic activity, IAC
		-	**Annual Load**	**Target Load Reduction 2006 PCMP**	**Load Reduction 2010**	**Load Reduction 2011**	**Load Reduction 2012**	**Target Load Reduction Phase 2**
	Phosphates	-	2679.30 kg/yr	1.28 tons/yr	-1786.20 kg/yr (load 4465.50)	-1035.99 kg/yr (load 3715.29)	-1786.20 kg/yr (load 4465.50)	446.55 kg (.49 tons/yr)
	Nitrates	-	-	19.3 tons/yr	-	-	-	-

Table 1 Summary of revised water quality target goals, target load reductions, and 2010-2012 monitoring results. Current status data is average baseline flow measurements from May-August Baseline 2012 SCLC data, sites 2, 3, 6-9, 11-16. Sites 1, 4, 5, and 9 were omitted from the current analysis as they were not included in the 2008 and 2009 reference data. Data from PCMP 2006 is average baseline flow measurements from Hoosier Riverwatch volunteer data.

Site	At or near HUC 12 Outlet	Lat	Lon	Location Description	Mean baseline flow total phosphorus. (mg/l)			Mean baseline flow total suspended solids. (mg/l)			Mean baseline flow E-coli. (Colonies/100 ml)		
					2010	2011	2012	2010	2011	2012	2010	2011	2012
4.	040500011001	N41° 37' 54.927"	W84° 56' 15.939"	Pigeon, U.S. 20 Bridge, Below juncture with Berlien Ditch	.06	.04	.05	8	18	11	112	149	100
6.	040500011002	N41° 35' 46.813"	W84° 58' 31.815"	Pigeon Creek, Bill Deller Road	.08	.05	.06	15	16	13	513	580	780
10.	040500011003	N41° 35' 28.993"	W85° 02' 35.501"	Pigeon Creek, Mud Lake Outlet just west of Long Lake, Johnson Ditch from Ashley	.05	.04	.05	10	8	11	168	48	30
15.	040500011006	N41° 37' 25.724"	W85° 05' 43.654"	Pigeon Creek, Hogback Lake Outlet	.04	.04	.03	9	12	5	32	70	38
16.	040500011007	N41° 39' 4.780"	W85° 10' 27.312"	Pigeon Creek at 327	.04	.03	.03	6	10	4	220	258	102

Table 2 Baseline flow results for T.P., T.S.S. and E-coli from sampling points near HUC 12 Outlets.

12 Digit Hydrologic Units: Table 2 summarizes 2010 through 2012 data collected from the 5 sampling sites located within ARN 9-275 which are at or near the outlet of HUC 12 units. In baseline flow 2012 sampling all of these sites averaged above the .025 mg/l target concentration for total phosphorus. Phosphorus measurements were highest at the outlet of HUC 040500011002 (Bill Deller Road) averaging .06 mg/l. The highest total suspended solids average (13 mg/l) also occurred at Bill Deller Rd. This T.S.S. figure was still well below the QAPP 2013 target goal of a maximum of 30 mg/l. The E-coli average was also highest at Bill Deller Road (780 col/100 ml). Bill Deller was the only HUC outlet site average to exceed the 235 col/100 ml target goal listed in the PCMP and QAPP. As it did in 2010, the data suggests that the Bill Deller unit (HUC 040500011002) may be reasonably prioritized as a candidate area for management practice improvement. It should however be noted that comparisons with sites 4,10 and 15 should be made cautiously as these sites are influenced by the filtering effects of

large water bodies just upstream of the collection sites. The Bill Deller site passes drainage waters from a relatively large watershed area without those waters being subjected to attenuation by any large upstream water bodies.

Sampling Site	Parameter or Measurement	Proposed Annual Samples	Samples Needed to Accomplish Project Objectives	Possible Constraints	Completeness Goal (% of proposed samples)	2012 Completeness (% of proposed samples)	2012 Constraint
All	Total Phosphorus	3	3	Container loss or damage, unusual flow conditions	100	100	n/a
All	Total suspended solids	3	3	Container loss or damage, unusual flow conditions	100	100	n/a
All	E-coli	3	3	Container loss or damage, expiration, unusual flow conditions	100	100	n/a
All	Dissolved oxygen	3	2	equipment/probe failure, data record loss in field, exclusion for accuracy/ bias	67	100	n/a
All	Specific conductance	3	2	equipment/probe failure, data record loss in field, exclusion for accuracy/ bias	67	100	n/a
All	Temperature	3	2	equipment/probe failure, data record loss in field, exclusion for accuracy/ bias	67	100	n/a
All	pH	3	2	equipment/probe failure, data record loss in field, exclusion for accuracy/ bias	67	100	n/a
All	Discharge	3	2	Deep/flooded conditions, equipment/probe failure	67	88	Deep conditions & timber in stream

Table 3. Sampling site goals and performance for completeness.

Quality Results

Completeness: Completeness information is listed in table 3. All samples planned in the QAAP were collected and analyzed in 2012. Discharge was not measured at sites 11 and 13 due to the depth of water, fallen timber, and soft bottom conditions in those areas. The completeness in 2012 met all QAPP goals.

Precision and Accuracy: Precision and accuracy information is listed in table 4. All precision figures for data collected met QAPP control goals with the exception of E-coli. An average relative percent difference of 44% for duplicate E-coli samples exceeded the QAPP goal of 25% RPD. It's expected that this resulted from the E-coli counts in the duplicate sampling being relatively low (7.3 to 52 Col.) rather than from an inherent imprecision in the sampling or analysis. Per the QAPP, because the average RPD was between the control limit and two times the control limit, the data is estimated. The two samples exceeding the QAPP RPD goal will be flagged "D" and will be included as useful project data. Accuracy goals were met for nearly all parameters. A single pH measurement of a blank returned an 89% recovery, slightly below the 90% recovery goal. It's not expected that this deviation will affect project goals or warrant data rejection.

Parameter	duplicates (5% goal)	Field Precision Goal	Precision 2012 Result (mean)	Accuracy Goal	Accuracy 2012 Result (field blanks)	Data Qualifiers and Flags
Total Phosphorus	8%	25% RPD	11% RPD	90% – 110% recovery	100% no bias noted	
Total suspended solids	8%	25% RPD	11% RPD	90% – 110% recovery	100% no bias noted	
E-coli	8%	25% RPD	44% RPD	90% – 110% recovery	100% No bias noted	D
Dissolved oxygen	8%	10% RPD	1% RPD	±.39 mg/L	n/a	
Specific conductance	8%	10% RPD	0% RPD	90% – 110% recovery	102% recovery	
Temperature	8%	10% RPD	1% RPD	±.2 º C	n/a	
pH	8%	10% RPD	1% RPD	90% – 110% recovery	89% - 108% recovery	
Velocity (flow speed)	8%	20%	9% RPD	n/a	n/a	

Table 4. Quality goals and performance for accuracy and precision.

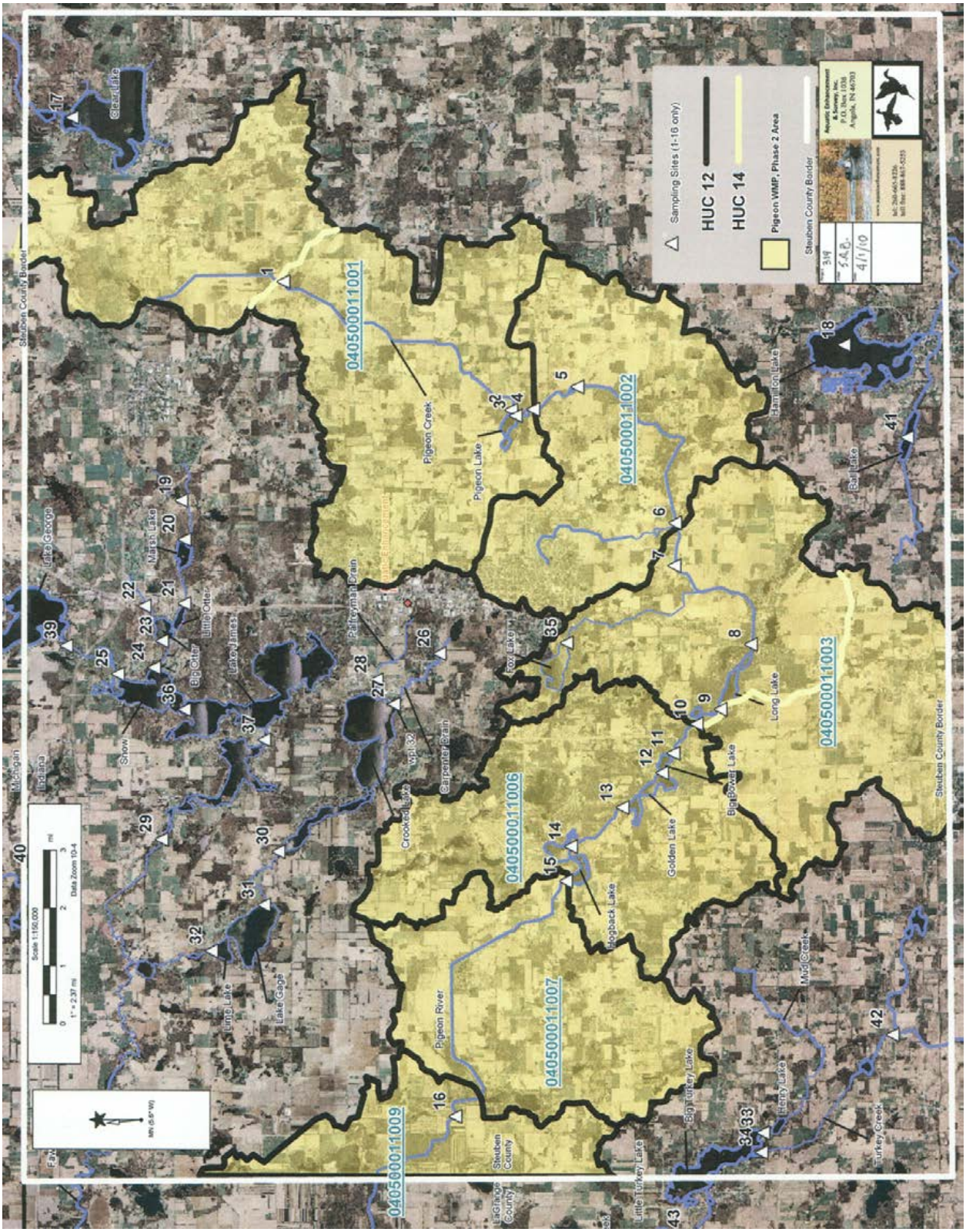

Figure 1. Pigeon Creek Sampling Map

Literature Cited

QAAP. Quality Assurance Project Plan for 2010 Pigeon Creek Water Quality Sampling. Steuben County, Indiana ARN # 9-275. Aquatic Enhancement & Survey, Inc., P.O. Box 1036, Angola, IN 46703

PCMP, V3, 2006. Pigeon Creek Watershed Management Plan. V3 Companies, Ltd. 9601 N. Industrial Drive, Suite A, St. John, Indiana 46373

Quality Assurance Report

for

2010 Pigeon Creek Water Quality Sampling

Steuben County, Indiana

ARN # 9-275

Prepared by:
Scott Banfield

Aquatic Biologist, Aquatic Enhancement & Survey, Inc.

for

Steuben County Soil and Water Conservation District, Steuben County Lakes Council

Indiana Department of Environmental Management

Office of Water Management

NPS/TMDL Section

Due to the size of this document, it can be accessed at the following link:

http://www.aquaticenhancement.com/AES%20documents/ARN%209-275%20phase%202%20QAPP%20draft.pdf

Appendix E

Two-Stage Ditch

Supplemental Information

Tri-State Hydraulic Geometry Relationships for Sizing Two-Stage Agricultural Ditches

Applying knowledge to improve water quality
Great Lakes Regional Water Program
A Partnership of USDA NIFA & Land Grant Colleges and Universities

GREAT LAKES REGION

2013

The objective of this fact sheet is to provide guidelines for the tri-state region (Indiana, Michigan, Ohio) on determining the geometry of a two-stage ditch system based on the size of the upstream drainage area. In the region, agricultural drainage ditches serve as outlets for subsurface drainage systems. They traditionally are designed with a trapezoidal cross-section to move water downstream efficiently. In comparison to streams that have connected and active floodplains, trapezoidal ditches lack floodplains and as a result often experience bank erosion or excessive accumulation of sediments (Figure 1A). An improvement on the traditional trapezoidal ditch design is a two-stage channel system that is designed to take advantage of the benefits of active floodplains[1]. These systems are more self-sustaining as they work in harmony with fluvial processes so that sediment transport is in balance (Figure 1B).

Figure 1. A: A trapezoidal ditch in Indiana with bank erosion and mass bank failures.

Figure 1. B: A two-stage ditch in Michigan.

The main objectives in modifying a ditch to a two-stage geometry are to provide a connected active floodplain, to reduce maintenance, reduce bank erosion, reduce the frequency of flooding into adjacent fields, improve water quality, and enhance the ecological function of the system[1,2]. Two-stage channel systems consist of an inset channel (1st Stage) to convey the bankfull discharge and attached benches or shelves (2nd Stage) that serves as a floodplain to aid in sustaining dynamic equilibrium in the system (Figure 1B). Agricultural fields, woods, pastures, roads, and areas associated with human activities adjacent to the ditch for the top of the two-stage system and are important because: (1) runoff from these areas might cause erosion problems; (2) they are the upper boundary of the system that influence bank stability; (3) excavated material is often placed in these areas; and (4) in agricultural settings, this is where Best Management Practices (BMP) are located.

The two-stage system is best suited for drainage areas smaller than 10 square miles where natural drainage patterns have been altered, in ditches with bed slopes that are less than 0.5%, and in settings where existing land use must be preserved. To a large extent, the approach is a floodplain enhancement practice that does not modify an existing inset channel or the ditch channel below the benches (see Figure 3B). Sizing a two-stage channel involves A) determining the inset channel geometry, which defines the bench height, B) sizing the flooded width at the bankfull elevation of the inset channel, and C) determining the channel side slope for the second stage. The floodplain width includes the two constructed benches and the channel width (Figure 2). The elevation and size of the benches should be based on data collection and analyses associated with a weight-of-evidence approach[3,4,5]. Ideally, the analysis should use published regional hydraulic geometry relationships for agricultural ditches, or the development and use of these relationships, to provide estimates of the expected inset channel geometry[3,5,6]. These relationships relate drainage area to the dimensions of the fluvial channel, the inset channel, that might naturally occur in a particular setting.

Estimates from the regional relationships should be compared with actual measured fluvial features at the project site, the reference reach, hydrologic estimates, shear stress depth, and estimated bankfull/effective discharge depth. If there is good agreement between all of these factors then the likelihood of success is high and the project should proceed.

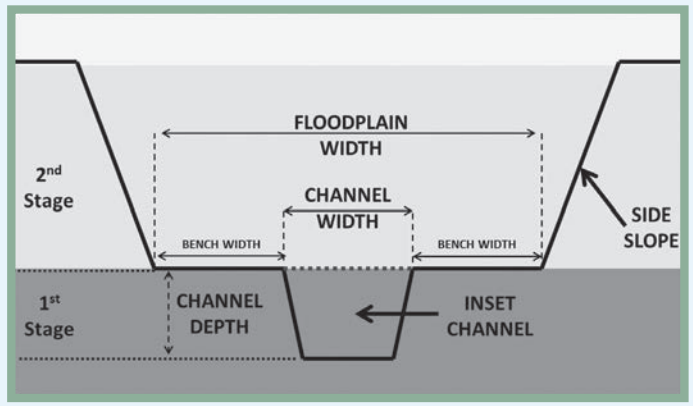

Figure 2: Dimensions of a two-stage ditch that need to be sized.

The design of the new floodplain width in the ditch is a function of the top width of the inset channel. In systems with cohesive bank materials that can readily be vegetated with grasses, the ratio of the flooded width to the inset channel width should be 3 to 5. The bench elevation corresponds to the height above the channel bed as estimated by the inset channel depth; the existing bank will be excavated at the bench elevation (Figure 2). In cohesive soils, the inset channel side slopes typically form at slopes steeper than 1.5 to 1. In the 2nd Stage of the channel, side slopes should be constructed at two-to-one or flatter slopes. The side slopes need to be stable so slump failures do not occur during high flow events. By constructing benches, and perhaps flatter slopes, the conveyance capacity of the modified ditch will be greater than the existing trapezoidal channel. If there is a need to further increase conveyance to satisfy an extreme discharge design requirement, or to provide flood storage, this can be accomplished by increasing the bench widths or further flattening the side slopes of the 2nd stage. Wider benches should provide more fluvial and ecosystem benefits but also increase the potential for the inset channel to meander and encroach on the banks of the 2nd Stage.

Table 1: Approximate hydraulic geometry relationships for two-stage agricultural ditches in Indiana, Michigan and Ohio

Drainage Area	Inset Channel Width	Max. Inset Channel Depth	3:1 Ratio		5:1 Ratio	
			Each Bench	Flooded Width	Each Bench	Flooded Width
mi^2	ft	ft	ft	ft	ft	ft
1	7	1.2	7	21	14	35
2	9	1.4	9	27	18	45
3	11	1.6	11	33	22	55
4	13	1.8	13	39	26	65
5	14	1.9	14	42	28	70
6	15	2.0	15	45	30	75
8	17	2.2	17	51	34	85
10	19	2.4	19	57	38	95

A. Channel widths and depths are the tabulated inset channel dimensions.
B. Floodplain widths are the tabulated flooded widths.

In many cases, published regional hydraulic geometry relationships for agricultural ditches are not available, developing relationships for sizing purposes is beyond the expertise of the project team, or there is a need to develop a preliminary design for feasibility purposes. The relationships presented in Table 1 should provide reasonable hydraulic geometry estimates for low gradient agricultural ditches in the tri-state region.

The benches do not need to be the same size but we recommend caution in using a one-sided construction as we have seen some failures with that approach – either because the one-sided bench was too small or the hydraulics of the system resulted in scour of the bench. The existing inset channel size likely will be different from the predicted inset channel size. The flooded width and depth sizes in Table 1 are guidelines primarily for use in evaluating the cost and feasibility of a proposed project. It is recommended that final designs be based on measured data at the ditch and for the region that are specific to agricultural ditches. In most cases, final dimensions based on measured data will probably not deviate by more than 25% from the values in Table 1. Making the depths a few tenths of a foot shallower will promote flooding on to the benches and should provide more water quality and ecological benefits. In the absence of measured data the flooded width should not be made less than that for a 3:1 ratio in Table 1.

Example: A ditch with a 3.5 mi^2 drainage area has a measured inset channel width of 12 ft and existing 3-4 ft wide benches about 1.7 ft above the bottom of the ditch. If a two-stage ditch will solve an existing problem then we would recommend widening the existing benches to give a total flooded width of 36 ft (from Table 1) about 1.7 ft above the bottom of the ditch. Figure 3.A shows the original geometry (dashed line), the excavated material (shaded areas), the design geometry (solid line), a 8 ft bench to the left of the inset channel, and a 16 ft bench to the right of the inset channel 9 (corresponds to 24 ft of benches in Table 1 for a 3:1 ratio). Figure 3.B show the two-stage construction concept that does not modify the inset channel, leaves the grass fringe along the inset channel, and pulls back the banks to establish benches.

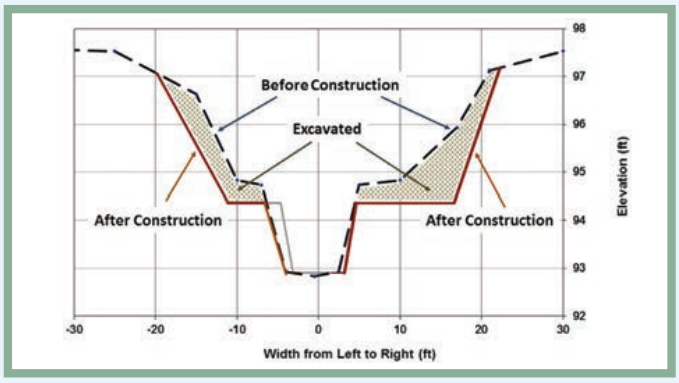

Figure 3. A: Pre and post-construction geometry for the example.

Figure 3. B: Modification of a ditch to a two-stage geometry by pulling the banks back to form benches.

[1] D'Ambrosio, J.D. Witter, and A.D. Ward. 2011 Building Better Ditches. Madison: Great Lakes Regional Water Program.

[2] Witter, J.D., J.L. D'Ambrosio, A.D. Ward, J. Magner, and B. Wilson. 2011 Considerations for Implementing Two-Stage Channels. Madison: Great Lakes Regional Water Program.

[3] Powell, G.E., A.D. Ward, D.E. Mecklenburg, and A.D. Jayakaran. 2007a. Two-stage channel systems: Part 1, a practical approach for sizing agricultural ditches. JSWC, 62(4):277-286.

[4] Powell, G.E., A.D. Ward, D. E. Mecklenburg, J. Draper, and W. Word. 2007b. 1Two-stage channel systems: Part 2: Case studies. JSWC, 62(4):286-296.

[5] USDA-NRCS. 2007. National Engineering Handbook Part 654 Stream Restoration Design. Chapter 10 Two-Stage Channel Design. (available of the internet so conduct a search)

[6] Ward, A.D., Witter, J.D., J.L. D'Ambrosio, J. Magner. 2013. Developing regional hydraulic geometry relationships for streams and ditches. Madison: Great Lakes Regional Water Program.

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Applying knowledge to improve water quality
Great Lakes Regional Water Program
A Partnership of USDA NIFA & Land Grant Colleges and Universities

http://greatlakeswater.uwex.edu/

This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, National Integrated Water Quality Program, under Agreement No. 2008-51130-04751. *Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer, and prohibits discrimination in all its programs and activities on the basis of race, color, national origin, sex, religion, age, disability, political beliefs, sexual orientation, and marital or family status.*

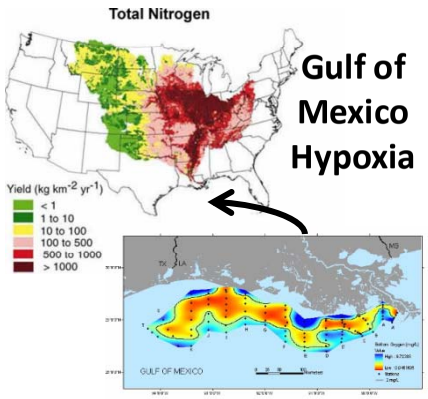
Two-Stage Management: Nitrogen & Sediment Dynamics in Agricultural Streams

Laboratory of Dr. Jennifer Tank, Department of Biological Sciences

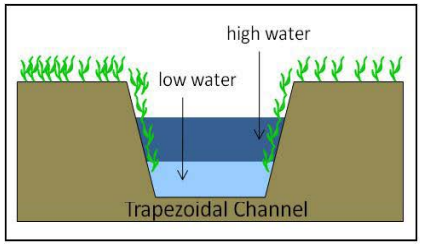
Problem of Excess

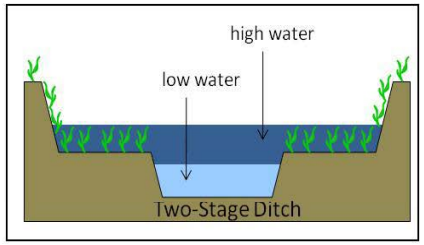
Streams in the agricultural Midwest can be a source of excess nutrients and sediments that pollute downstream ecosystems. Example: fertilizer runoff is responsible for the periodic "dead zone" in the Gulf of Mexico. Our goal is to maximize in-stream N and sediment removal before downstream export.

Can 2-stage ditch management reduce nitrogen and sediment export?



Two-Stage Restoration Strategy





During high flows, water spreads onto the floodplains, increasing the area over which N removal can occur.

N Removal via Denitrification

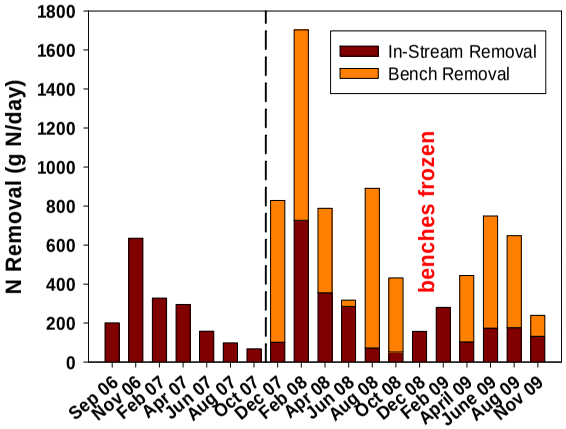
- Denitrification is the microbial conversion of nitrate (NO_3^-) to dinitrogen gas (N_2), and is a **permanent removal of nitrogen**
- Denitrification occurs naturally in stream sediments
- The two-stage ditch increases stream surface area, resulting in increased permanent N removal

Shatto Ditch Demonstration Project

← Turbidity probe

Bench Flooding

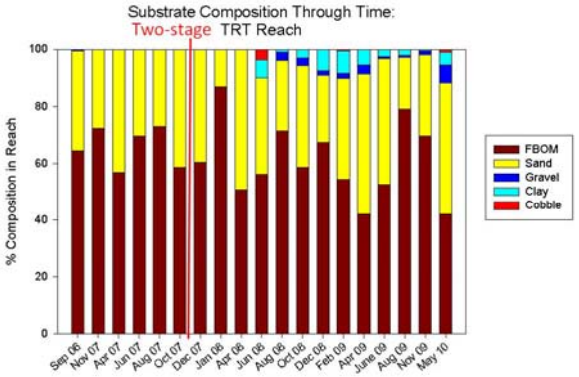
- Most N & sediment export occurs during high flows
- Flooded benches increase water residence time, which results in increased N processing and sediment removal
- Conditions are ideal for denitrification in flooded benches (high NO_3^- and C, anoxia)



Data from Roley et al. in press, 29 July 2011

Sediment Effects

- Water column turbidity decreased by 43%
- New streambed substrates are exposed



Implications for Downstream Water Quality

- Because of very high N loads, the increase in N removal translates only to 2-16% of the NO_3^- load
- In-stream management practices are most effective if coupled with watershed and landscape-level management programs
- **Both enhancing in-stream removal and reducing inputs are necessary to reduce downstream export**

Future Directions

- Study the effect of the two-stage across a range of streams and determine the change in two-stage function over time and with varying nitrate loads.
- Develop a management tool to evaluate the influence of the two-stage in different conservation scenarios.

Two-Stage Ditches

Much of the landscape in the Wabash River basin, a large-river watershed that drains to the Gulf of Mexico, has been converted to agricultural use. With this massive landscape conversion has come altered hydrologic function and significant changes in the flow of nutrients and sediments out of these agricultural watersheds. Infrastructure of old simply can't handle the needs and demands that they are receiving today. One tool in the toolbox to combat this is the Two-Stage Ditch. Utilizing current infrastructure of drainage ditches, the Two-Stage Ditch enhances these systems to provide additional function of sediment removal, nutrient uptake, and still allows for sufficient water flows and drainage.

Issues: impaired water quality, stream bank erosion, sedimentation, turbidity, flooding

Function: "mini floodplains" or "benches" that slows down the water velocity and allows for sediment sorting and nutrient uptake to occur, reconnecting agricultural streams to floodplains.

Two-Stage Ditch performance:

1. Yearly in a ½ mile segment the sediment inputs reduce by 53 tons versus a conventional ditch
2. As benches age the nutrient uptake and removal increases (a gift that keeps on giving)
3. Benches filter tile water, provide bank stability, and decreases water velocities by 50%
4. Performs the best in elevated water flows resulting in lower peak discharges in storm events
5. Reduces regular ditch maintenance frequency as a result of self cleaning/stability
6. Shows increased nutrient uptake and removal immediately after construction

Details: Flooding is the key to naturally mitigating the impacts of high flows. Properly designed Two-Stage Ditches accommodate large flows and should rarely, if ever, flood surrounding land except for extreme conditions. Two-Stage Ditches do form naturally, but generally this is when the perception is to dip them out, not always is there a drainage impact. Two-Stage Ditches do require more room than conventional ditches and they do cost more to construct. Typical bottom cleanout of conventional ditches as the result of sediment build up will cost between $1 and $1.50 per linear foot. The average Two-Stage Ditch will cost around $10-$12/linear foot. One option is immediate the other is permanent.

Challenges and Future Direction: Farmers (usually the same ones already with land in some program) are being asked to take land out of production to create them. A Two-Stage Ditch will take some ground out of production (.5 to 1.5 acres per ½ mile). The practice does reduce ponding in fields and limits soil loss from bank failure/erosion. It is essential to maintain highly productive agriculture land and at the same time improve water quality. Two-Stage Ditches are detailed in the NRCS Technical Manual, but not yet recognized by the Farm Service Agency (FSA) as a contracting practice. It is cost-sharable through the EQIP program (75% cost share), but will not rank out as high as other practices and therefore is not being adopted as readily. Conservation begins at the farm scale and ramps up to larger watershed areas to make improvements locally that will have impacts that reach far downstream to places like the Mississippi River and ultimately the Gulf of Mexico. When managed for water quality, ditches have the potential to make positive impacts toward improving water quality. The Nature Conservancy believes that the Two-Stage Ditch is a viable and practical conservation tool.

Appendix F

SWAMM Methodology

SWAMM Pollutant Load Model Methodology

NORTHWATER
CONSULTING

1/31/2014

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Pollutant Loading Model Methodology

1.0 Introduction

A GIS spatially based pollution load model or SWAMM (Spatial Watershed Assessment and Management Model) was developed to estimate field level pollutant loading from, phosphorus, nitrogen, sediment and bacteria (Fecal Coliform). Constructed using soils, landuse and precipitation data the model provides both annual and storm event loading for individual land parcels within the Pigeon Creek Watershed. Results are organized through a unique combination of parcel ownership, landuse and soils, delineated into individual units of pollution loading. Accepted equations for calculating runoff and soil erosion are integrated into the model to provide realistic estimations of the quantity and distribution of pollution loading throughout the study area. The model was directly calibrated to local water quality data. A time period of 12/31/1982 to 12/31/2012 was used for generating rainfall values.

The GIS data set is organized in such a way that results can easily be queried by subwatersheds, by parcel boundaries and by landuse. Results can also be analyzed based on user defined boundaries and presented in map format, easily overlaid on existing base maps. The model includes 100,651 unique records from which to assess pollution loading. The following methodology document provides key model equations and values, references and summary statistics.

2.0 Methodology

The custom SWAMM model consists of two primary components:

- Universal Soil Loss Equation (USLE) Component
- Event Mean Concentration (EMC) Component

2.1 USLE Component

The overall analysis methodology modified by Northwater from*:*

Mitasova and Lubos Mitas: Modeling soil detachment with RUSLE3d using GIS, 1999; University of Illinois. http:/skagit.meas.ncsu.edu/~helena/gmslab/erosion/usle.html

The Universal Soil Loss Equation (USLE) component of the model is applied to agricultural land uses within the watershed (Row Crops). The USLE methodology incorporated into the model is summarized below:

- 1:24,000 NRCS Soil Survey Geographic Database (SSURGO) Digital Soils.
- Selected appropriate soil types and relevant USLE factors identified and calculated from SSURGO soils dataset and information from local Soil and Water Conservation District staff and staff from the Natural Resource Conservation Service.
- USLE erosion calculated with the following equation: LS * K * C * R. The P-factor was not incorporated as it is set to 1 for all soil units.

Table 1 - USLE factors

Landcover	C factor	K factor	LS factor	R factor	P factor
Agriculture Crops (Row Crops)	Initial Values Provided by County NRCS Final Calibrated Values: 0.18, 0.09, and 0.001	Values included in SSURGO tabular data	Values included in SSURGO tabular data; calculated from slope and slope length values or from local NRCS Staff	140	1 used for all soil polygons

2.2 EMC Component

A) All formulas and selected variables are derived from: *STEPL (Spreadsheet Tool for Estimation of Pollutant Load) Version 3, Tetra Tech, 2004.* For Bacteria, Schueler's Simple Method (1987) is modified for calculating bacterial loads.

B) A storm runoff module was created to estimate runoff and pollutant loading from a 1.5 inch "first-flush" storm, 10 year (3.73 inches) and 25 year (4.46 inches) rainfall event. Runoff was computed as described in the table below. P or rainfall/precipitation values were provided by the Steuben County NRCS.

C) Event Mean Concentration Values and Curve Numbers were derived from the following sources:

1. *Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) Technical Guide, Version 1.0 Release 1, November 2004.*
2. *Lower DuPage River Watershed Plan Pollution Load Model Methodology, 2010.*
3. *V3 Companies, 2008. Elkhart River Watershed Management Plan, Appendix J; Pollutant Load Model Documentation for Critical Areas.*
4. *Price, Thomas H., 1993. Unit Area Pollutant Load Estimates for Lake County Illinois Lake Michigan Watersheds.*
5. *Todd D. Stuntebeck, Matthew J. Komiskey, Marie C. Peppler, David W. Owens, and Dennis R. Frame 2011. Precipitation-Runoff Relations and Water-Quality Characteristics at Edge-of-Field. Stations, Discovery Farms and Pioneer Farm, Wisconsin, 2003–08.*
6. *Northwater Consulting. 2013. Spatial Watershed Assessment and Management Model. Prepared for Chicago Metropolitan Agency for Planning, Chicago, IL.*

D) Precipitation: annual precipitation, number of rain days and correction factors using the following weather station: Angola, IN COOP Station ID 120200. A period of 30 years was used (1982-2012).

Table 2 – Rainfall Factors

Average Number of Rain Days	Rain Days Correction Factor	P Value (inches)
124.4	**0.446**	**0.6**

E) Delivery Ratio; distance based delivery ratio: *Minnesota Board of Water & Soil Resources, "Pollution Reduction Estimator Water Erosion - Microsoft Excel® Version September 2010."*

Polygon distance from major stream (ft) ^-0.2069

Table 3 - Pollutant Load Model Values

Model	Rain days	Correction Factor (precipitation and rain days)	Curve Number (by soil hydrologic group)	Runoff (by soil hydrologic group in inches)	EMC for N, P, TSS, Bacteria
All landuse	see table above	see table above	See below	Calculated using the following equation: $Q = \frac{((P - (IaXS))^{\wedge 2}}{P + 0.8 X S}$ $S = \frac{1000}{CN} - 10$ Q = Runoff (inches) P = Precipitation (inches) S = Potential max retention (inches) CN = Curve Number Ia = Initial abstraction factor; set to 0 for annual runoff and 0.2 for first flush, 10 and 25yr events	See Table Below

Table 4 - Event Mean Concentrations and Curve Numbers

Landuse Category	EMC P (mg/l)	EMC N (mg/l)	EMC TSS (mg/l)	Bacteria (counts/100ml)	Curve # A Group	Curve # B Group	Curve # C Group	Curve # D Group
2 - Golf Course	0.7	3.6	84	7,200	39	61	74	80
3 - Vacant (Undeveloped)	0.13	1.4	30	2,600	39	61	74	80
4 - Row Crops	1.1	7.1	N/A*	7,200	74	83	88	90
4 - Row Crops (Irrigated)	1.1	7.1	N/A*	7,200	76	85	90	92
5 - Open Space (Non-Tillable)	0.3	0.7	15	9,000	30	58	71	78
6 - Woodland	0.2	1.4	45	7,800	39	61	74	80
7 - Pasture (Low)	0.8	3.46	50	10,500	30	58	71	78
7 - Pasture (Medium)	1	6.75	100	13,000	67	78	85	89
7 - Pasture (High)	0.8	10.1	200	22,000	75	84	89	91
8 - Residential	0.4	3.2	150	9,000	76	85	90	92
9 - Residential Farm	0.6	3.3	175	10,500	74	83	88	90
10 - Quarry	0.31	1.79	93.9	2,500	81	88	91	93
11 - Primary Commercial/Industrial/Institutional	0.3	2.4	72	2,500	81	88	91	93
12 - Secondary Commercial/Industrial/Institutional	0.31	2.4	190	2,500	89	92	94	95
13 - Undeveloped Usable Commercial and Industrial	0.2	1.4	60	2,600	39	61	74	80
14 - Undeveloped Unusable Commercial and Industrial	0.2	1.4	60	2,600	39	61	74	80
15 - Nursery	0.6	3.6	240	5,200	32	58	72	79
16 - Open Water Lake/Pond	0.1	0.375	1.5	7,200	98	98	98	98
17 - Open Water Stream	0.3	1.25	3.1	5,200	98	98	98	98
21 - Classified Forest Land	0.2	1.4	45	7,200	39	61	74	80
22 - Classified Wildlife Habitat	0.2	1.4	20	7,200	30	58	71	78
26 - Cemeteries	0.46	3.1	80	5,200	49	69	79	84
70 - Feed Area (Low)	1	6.75	120	13,000	67	78	85	89

Landuse Category	EMC P (mg/l)	EMC N (mg/l)	EMC TSS (mg/l)	Bacteria (counts/100ml)	Curve # A Group	Curve # B Group	Curve # C Group	Curve # D Group
70 - Feed Area (Medium)	1.3	10.1	240	18,000	77	85	90	92
70 - Feed Area (High)	2.2	13.5	390	36,000	89	92	94	95
71 - Other Farmland/Farm Buildings and Barn Lots	0.6	7.1	195	9,500	89	92	94	95
73 - Wetlands	0.3	0.7	1	8,000	85	85	85	85
81 - Legal Ditch	0.9	7.1	3.1	5,200	98	98	98	98
82 - Road	0.34	2.3	240	1,700	98	98	98	98
83 - Public Utility Transmission Towers	0.34	2.1	153	1,400	81	88	91	93
85 - Railroad Right-of-Way	0.3	2	65	5,200	49	69	79	84
86 - Cellular Towers	0.3	2.1	65	2,600	49	69	79	84
91 - Public Open Space	0.3	1.4	30	7,200	49	69	79	84
92 - Agricultural Excess Area	0.2	1.4	30	5,200	30	58	71	78
98 - Confinement (Low)	0.6	6.75	60	10,500	89	92	94	95
98 - Confinement (Medium)	1.3	7.1	120	21,000	89	92	94	95
98 - Confinement (High)	2.6	13.5	240	57000	89	92	94	95
99 - Feed Area Hogs	2.6	13.5	350	57,000	89	92	94	95

USLE equation used

3.0 Model Calibration

Model calibration was performed to verify the model results against local water quality data and average per acre loading results for the Midwest. The calibration and verification served three purposes:

1. Quality Assurance / Quality Control – to find and correct user errors in the model scripts and algorithms.
2. To evaluate whether stream-flow (runoff) and pollutant loading were in the correct ranges based on existing data and literature.
3. To calibrate model by adjusting parameters so that cumulative model results represent regional averages.

The model is estimating accumulated/delivered pollutant loading, represented mostly in the literature. Important notes on the model include:

- The model does not directly account for point source pollution.
- The model estimates annual pollutant mobilization from individual parcels of land and does not take into account storage, fate and transport watershed processes.
- The model accounts for precipitation runoff; but not base flow, point source discharges or drainage-tile contributions.

Model calibration was performed by deriving streamflow statistics and analyzing readily available water quality data for each of the ten HUC 12 subwatersheds. Bacteria statistics were derived from the 2012 TMDL Report for the Pigeon River; this included samples from fifty stations during a sampling period in 2010. Total suspended sediment (TSS) and total phosphorus statistics were derived from water quality data provided by Steuben County, representing a period between 2007 and 2013 from thirty different stations.

Subwatershed average annual flow estimates were derived from the USGS Station 04099510, Pigeon Creek near Angola, Indiana. The period of 1990 – 2013 was used to determine average annual flow from the basin. An

estimate of average annual flow for each subwatershed was calculated by downscaling from the USGS station based on drainage area.

Analysis of water quality data commonly results in underestimating nonpoint source pollutant loading. This is primarily due to the lack of data during storm events when nonpoint source loading is typically highest. Further, many collection events do not measure stream-flow discharges which makes it difficult to estimate loading. The water quality data was used only as a validation tool to calibrate the model so that the results were not lower, or significantly higher than the values estimated with streamflow and water quality data.

To calibrate the Pigeon Creek SWAMM to existing water quality data, the following was performed:

- Water quality data was analyzed by subwatershed and annual in-stream loading was calculated.
- Adjustments were made to SWAMM to get modeled results within acceptable ranges for phosphorus, bacteria and sediment (TSS) including:
    - Crop C factors were reduced to account for differences in TSS.
    - Upward adjustments were made to EMCs for phosphorus and bacteria by individual landuse category.
    - EMCs for TSS were reduced for individual landuse categories
- No adjustments were made to nitrogen.
- Model calibration was performed over three iterations.

The model was also calibrated based using the delivery ratio; to account for differences between the delivery of sediment versus the delivery of dissolved pollutants. Since the delivery ratio is based on studies of sediment transport and not dissolved pollutants, an adjustment or multiplier of **1.25** was applied to the delivery ratio for nitrogen, phosphorous and bacteria to get the results within acceptable regional ranges. The assumption was made that dissolved pollutants are delivered at a slightly higher rate than that of sediment.

4.0 Model Notes

1. A 2012 local landuse layer was used and provided by the Steuben County Assessors office. The Landuse layer was modified to represent a hybrid landuse/landcover layer by interpreting recent aerial imagery and digitizing/labeling polygons. For example, the agriculture landuse category was further dissected into row crops and grazing. Residential areas were modified and classified into high, medium and low density and major road boundaries were digitized out of the base landuse layer.
2. Data on the location of irrigated fields was incorporated and associated curve numbers were adjusted upwards.
3. High, medium and low areas were determined based on a visual interpretation of density. High areas generally represented greater than 50% impervious, medium 25-50% impervious and low, less than 25%.
4. In general, residential farm areas also include some type of livestock or animal feeding area/barn and therefore received higher EMC values for nutrients, sediment and bacteria.
5. Pasture was classified into high, medium and low based on pasture quality and the observed impact to water quality during the 2012 windshield survey.
6. The stream/waterbody file used to run proximity calculations for the purposes of determining a delivery ratio was modified using NHD data and a Hydrology layer provided by the Steuben County Assessor's office. Duplicate lines were deleted to create a "clean" line file representing all streams and open water outlines.
7. An EMC of 750 mg/l for TSS was used for calculating row crop sediment loading from storm events, replacing the USLE.