Development & Application of SWAT Models to Support the Saginaw Bay Optimization Decision Model

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Funded by:
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LimnoTech
Water Environment | Scientists Engineers

Presentation Outline

- Saginaw Bay Project Overview
- Previous SWAT Modeling in Maumee River Basin
- SWAT Challenges

Saginaw Bay Optimization Decision Tool: Linking Management Actions to Multiple Ecological Benefits via Integrated Modeling

Project Funding: WATER CENTER UNIVERSITY OF MICHIGAN

Principle Investigators:

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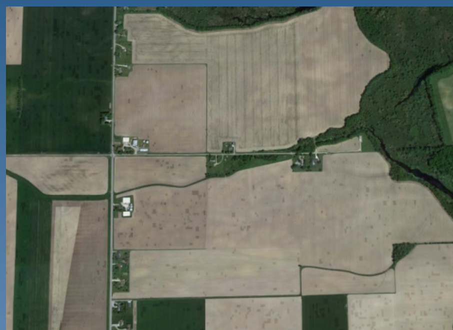
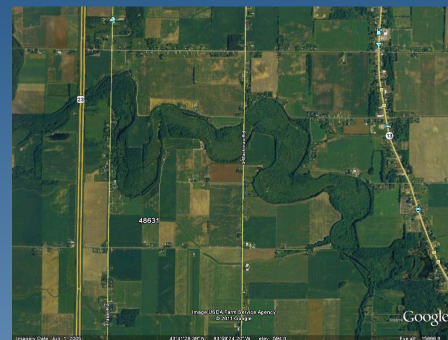
- Andrew Miller
- Rhett Mohler
- Jon Bartholic
- Vicki Anderson

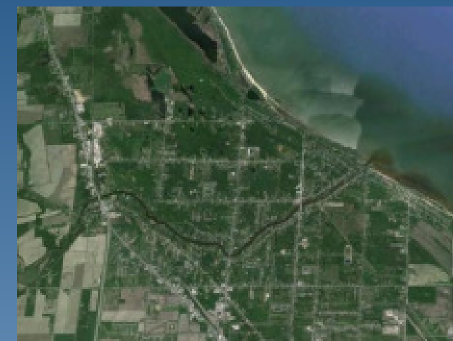
Project Background & Goals



Conservation actions & locations



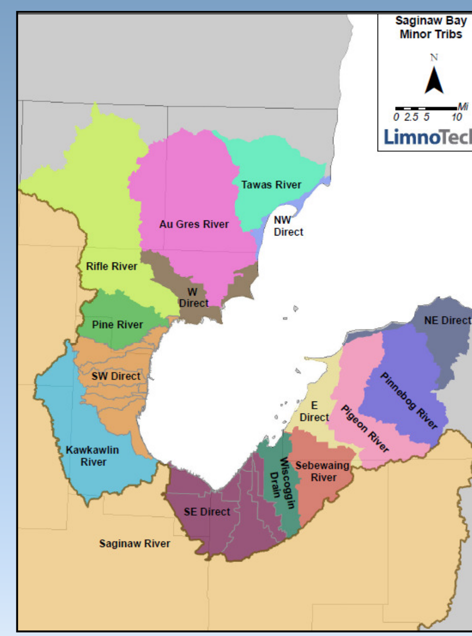
Riverine water and ecosystem habitat



Nearshore ecological outcomes

Goal: Develop a science-based, system wide integrated framework to guide conservation and restoration actions – an ***Optimization Decision Model Toolkit***

ODM Toolkit: A suite of data, models and decision tools that help set realistic goals and support strategic conservation decisions for farms, rivers and nearshore ecosystems



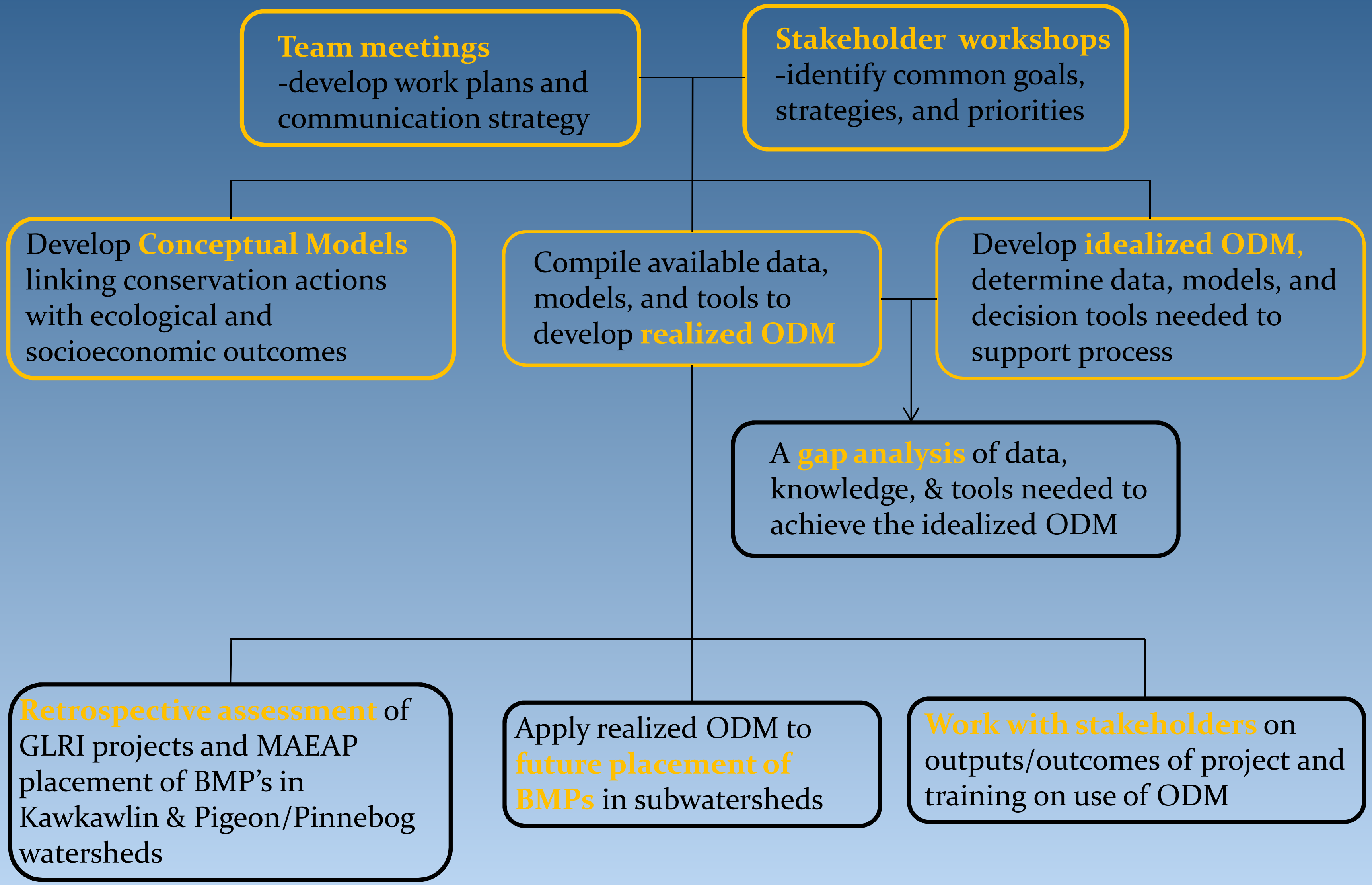
Project Scope:

- Ecosystems/habitats: Rivers and nearshore/littoral areas
- Biological groups: Phytoplankton (algae) and fish
- Socioeconomic/ecosystem indicators: crop yield, beach closures, sediment removal cost

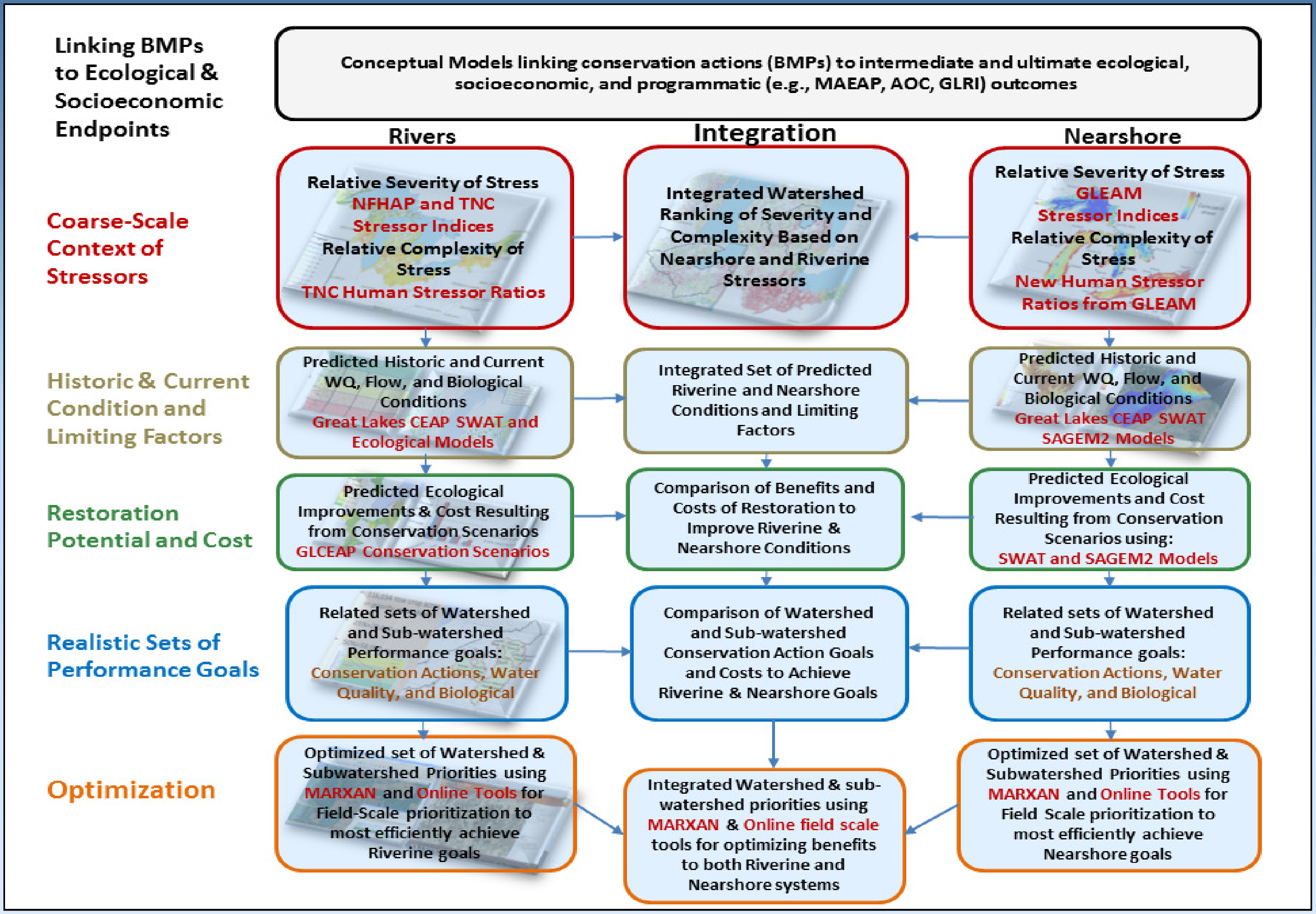
Geographic Focus:

- Kawkawlin and Pigeon/Pinnebog River watersheds and nearshore rivermouth waters in the bay

Project Approach



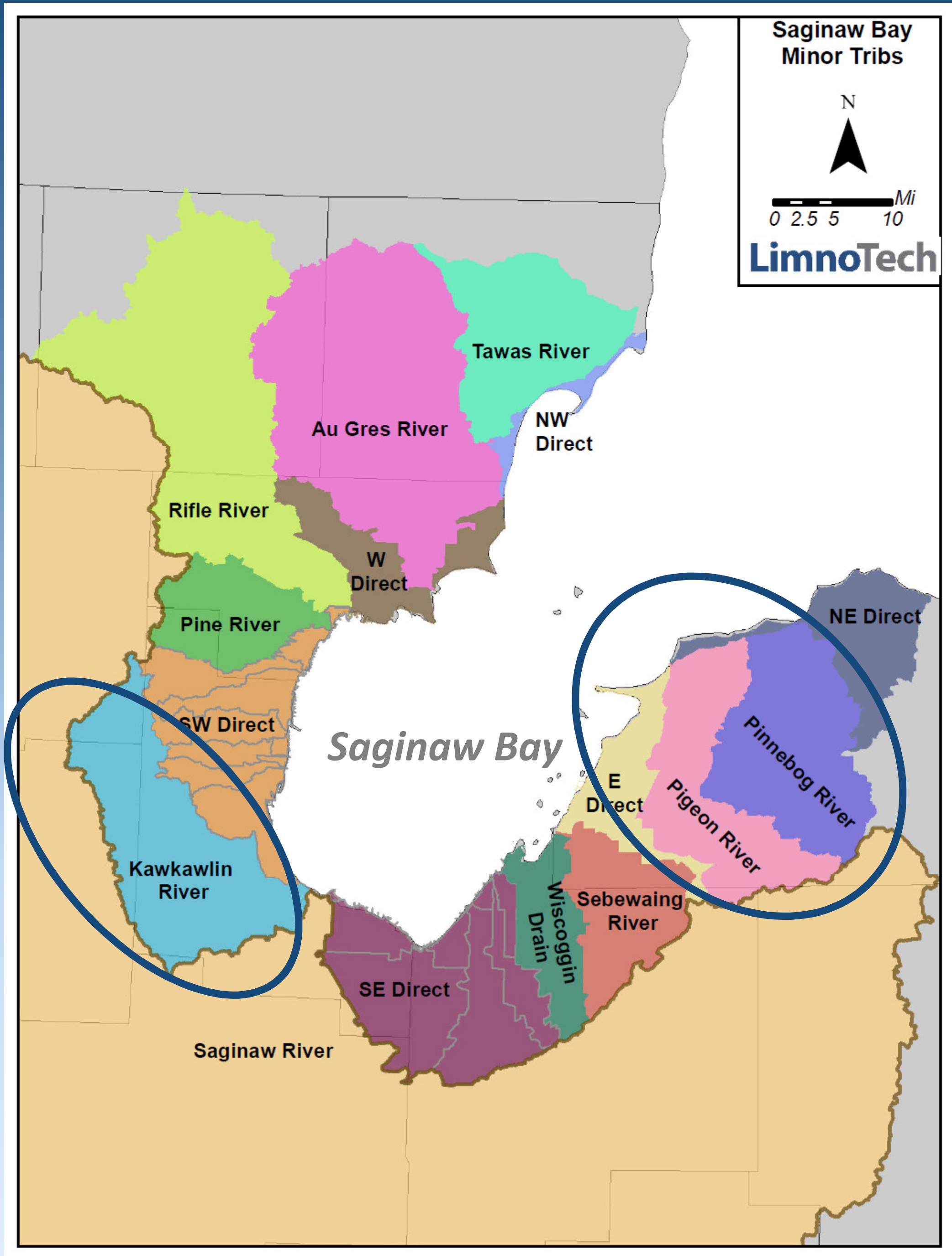
Linking BMPs to Outcomes



Saginaw Bay Watershed Map

Focus Watersheds:

- Kawkawlin
- Pigeon/Pinnebog



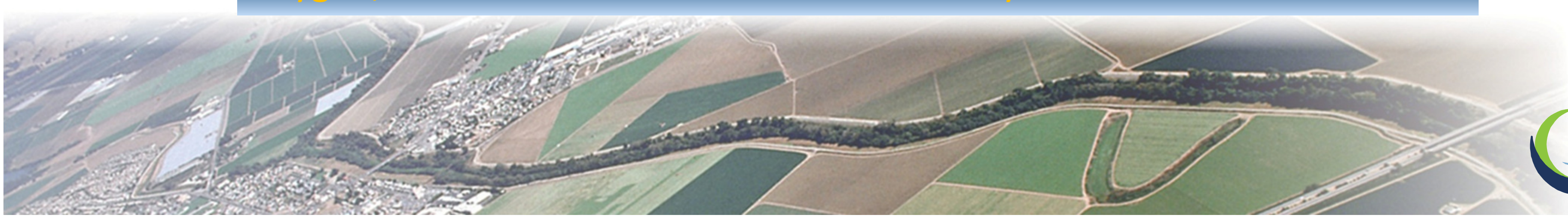
Kawkawlin Watershed Characteristics

- Kawkawlin
  - 225 mi^2 (144,000 acres)
  - Average slopes of <1-3%
  - Soils are moderately well to poorly drained (mostly HSG C and D)
  - ~43-73% agricultural, 2-12% urban, 7-40% forestland, and 1-7% wetland

Land use	North Branch Kawkawlin River	South Branch Kawkawlin River
Urban	2.6%	12.6%
Agriculture	43.1%	73.3%
Forested	40.2%	7.5%
Water	0.1%	0.3%
Non-formal	6.1%	4.7%
Wetland	7.9%	1.6%

From Kawkawlin Watershed Management Plan, Spicer Group (Chapter 2, p. 16)

Water quality & habitat impairments → *E. coli*, phosphorus, dissolved oxygen, sediment and lack of habitat diversity



Pigeon-Pinnebog Watershed Characteristics

- Pigeon
  - 145 mi^2 (92,799 acres)
  - Slopes range from <1-6%
  - Soils are moderately well to very poorly drained (mostly HSG B and D)
  - 82% agricultural, 5% urban, 10% forestland, and 3% wetland
- Pinnebog
  - 195 mi^2 (124,800 acres)
  - Average slopes are 0-2%
  - Soils are well to poorly drained (dominated by HSG C)
  - 82% agricultural, 2% urban, 10% forestland, 3 % wetlands, and 3% rangeland

Water quality & habitat impairments → bacteria, sediment, nutrients and loss of habitat

Model Framework

- Watershed-Bay → linked **SWAT**-watershed ecological model-SAGEM2
- Will develop fine-scale, SWAT models for Pigeon/Pinnebog & Kawkawlin subwatersheds
- SAGEM2 model developed as part of a NOAA Multi-stressor project.
- Framework will integrate all loads to the bay to develop simulations of the bay's multiple responses to multiple stressors.
- SWAT models will also drive TNC assessment of BMPs on stream network fish communities

SWAT Model Development Plan

- Software (latest versions)
  - ArcSWAT Version →2012.10.14 (updated March 5)
  - SWAT Version → SWAT 2012 (rev. 622, March 4, 2014)
- Model scale (NHDPlus or finer)
- Simulation time period (~2000-2013)
- Complete development: December 2014
- Complete application: June 2015

Summary of data needs for SWAT model development

Data	Type	Time Scale	Dataset	Data Sources	Primary Party Responsible for Data Acquisition
Topography/DEM	Spatial Input	NA	NHDPlus	EPA, USGS, Horizon Systems	LimnoTech
Stream Network	Spatial Input	NA	NHDPlus	EPA, USGS, Horizon Systems	LimnoTech
Climate	Time Series Input	Daily (2000-2013)	BASINS, Summary of the Day	EPA, NCDC	LimnoTech
Soils	Spatial Input	NA	SSURGO	NRCS	LimnoTech
LU/LC	Spatial Input	Annual (2006, 2008-2013)	NLCD 2006, CDL 2008-2013	USGS, NASA, USDA, SWCDs	LimnoTech
Tillage	Spatial Input, Site Surveys	Spring, Fall, Annual (2000-2013)	Site-Specific Transects	USDA, SWCDs	LimnoTech, SVSU
Reach Geometry	Spatial Input, Site Measurements	NA	NHDPlus, Reach Cross Sections	EPA, USGS, Horizon Systems, USACE	LimnoTech, SVSU
Point Sources	Time Series Input	Daily-Monthly (2000-2013)	PCS, ICIS, State Data	EPA, MDEQ	LimnoTech
Feedlots	Time Series	Monthly-Annual	PCS, ICIS, State Data	EPA, MDEQ, NRCS, SWCDs	LimnoTech, SVSU
Fertilizer/Manure Application	Input by Crop Rotation	Monthly-Annual	Reports, Estimates from Census Animal Counts	NRCS, SWCDs	LimnoTech, SVSU
Streamflow Data	Calibration	Grab-Daily	NWIS Surface Water Data for the Nation	USGS, SVSU, MSU	SVSU, LimnoTech
Water Quality Data (TSS, Phosphorus, Nitrogen)	Calibration, Confirmation, Evaluate BMPs	Grab, Daily, Monthly, Annual	NWIS Surface Water Data for the Nation, State Data,	USGS, MDEQ, SVSU, MSU	SVSU, LimnoTech

Model Application Plan

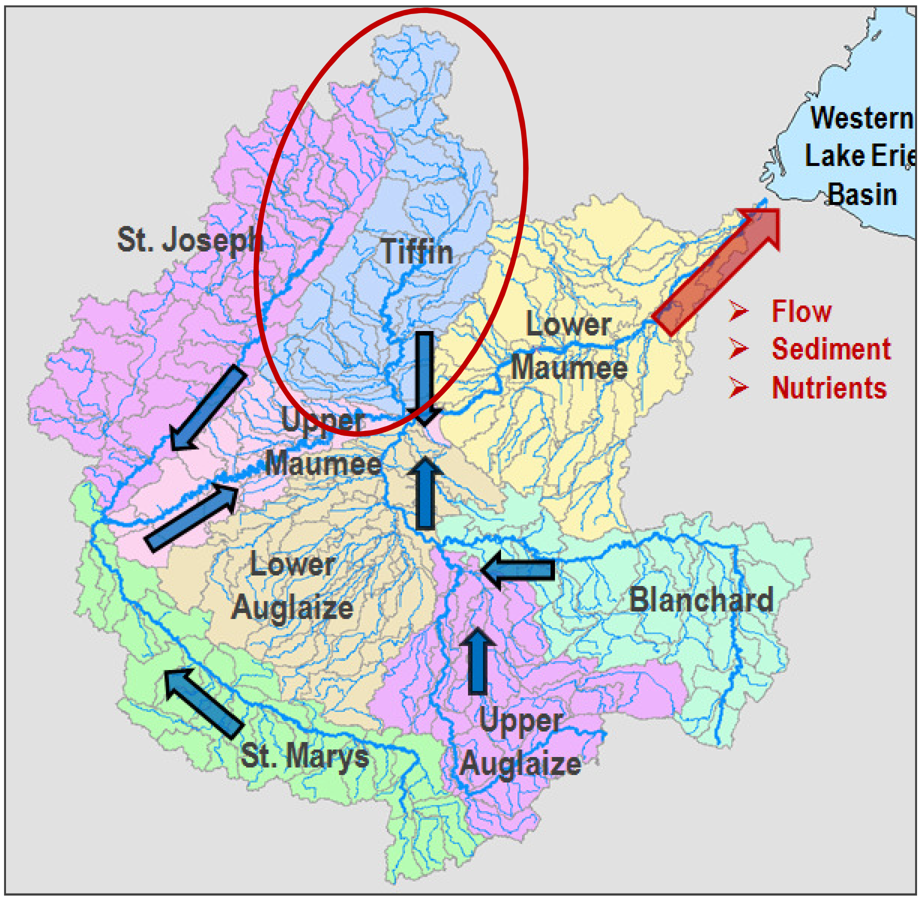
- The linked models will be used to…
  1) Evaluate existing programs that have been/are being implemented in Pigeon/Pinnebog and Kawkawlin watersheds; and
  2) Run agricultural land management scenarios to identify optimum location & type of BMPs to apply based on the ecological endpoints of nearshore bay algae & instream fish.

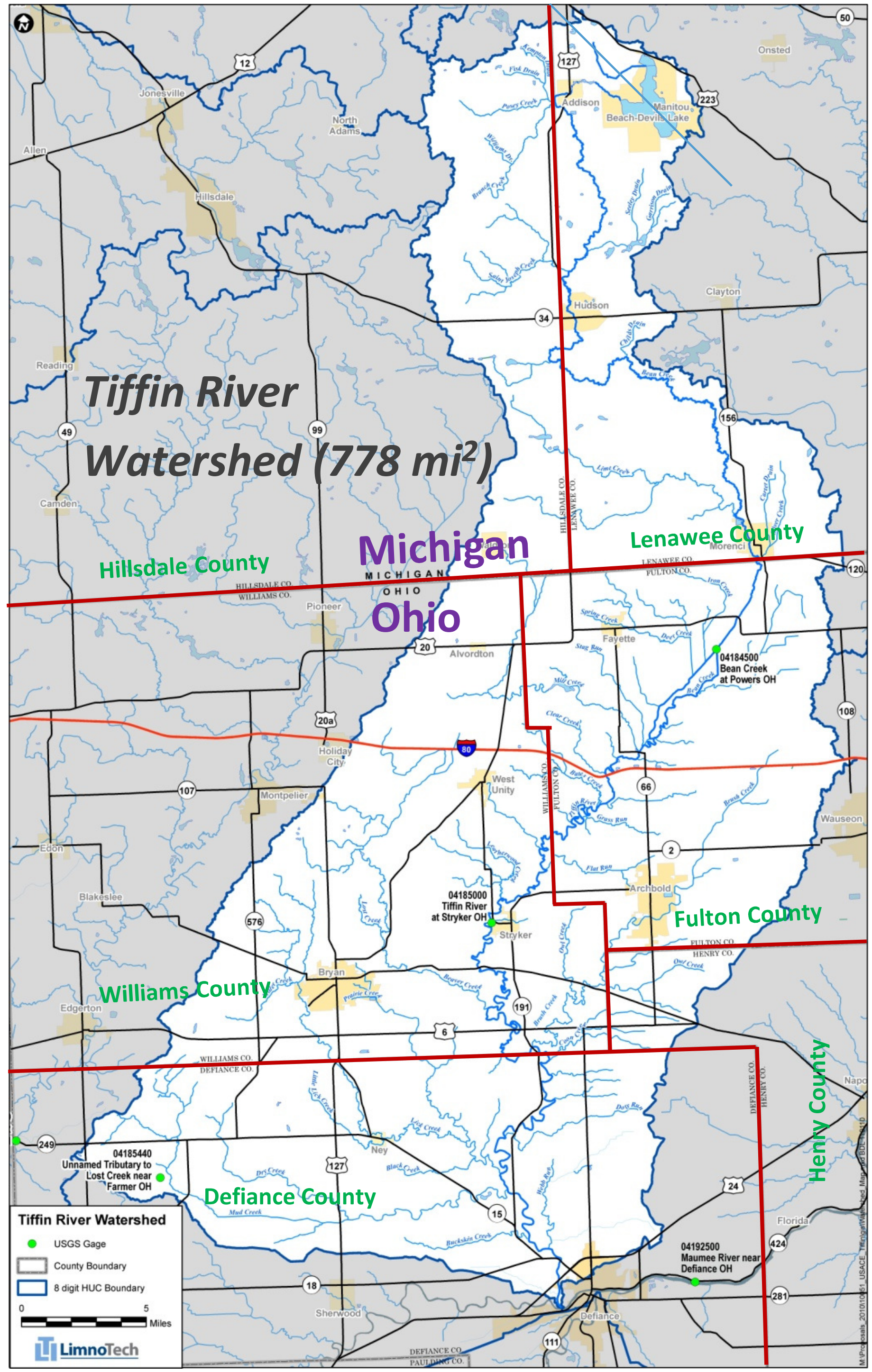
Previous SWAT Modeling Tiffin River Watershed

- Great Lakes Tributary Modeling Program
- Funded by the USACE-Buffalo District under 516(e)
- Primary objectives are to determine sediment and nutrient critical source areas, major transport pathways, and effect of BMPs on load reductions
- Developing, calibrating, and applying a watershed model to the Tiffin River watershed.
- Timeline: Summer 2011 - Fall 2013
- Based on SWAT2009

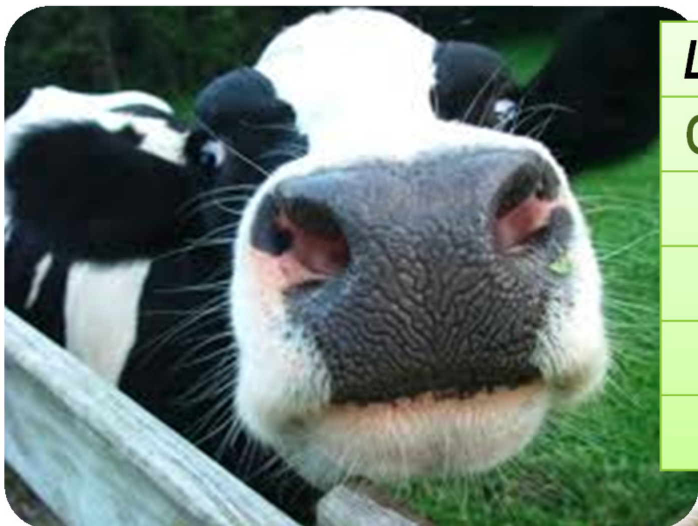
Where:
Tiffin River Watershed

Maumee River Basin (6,300 mi²)





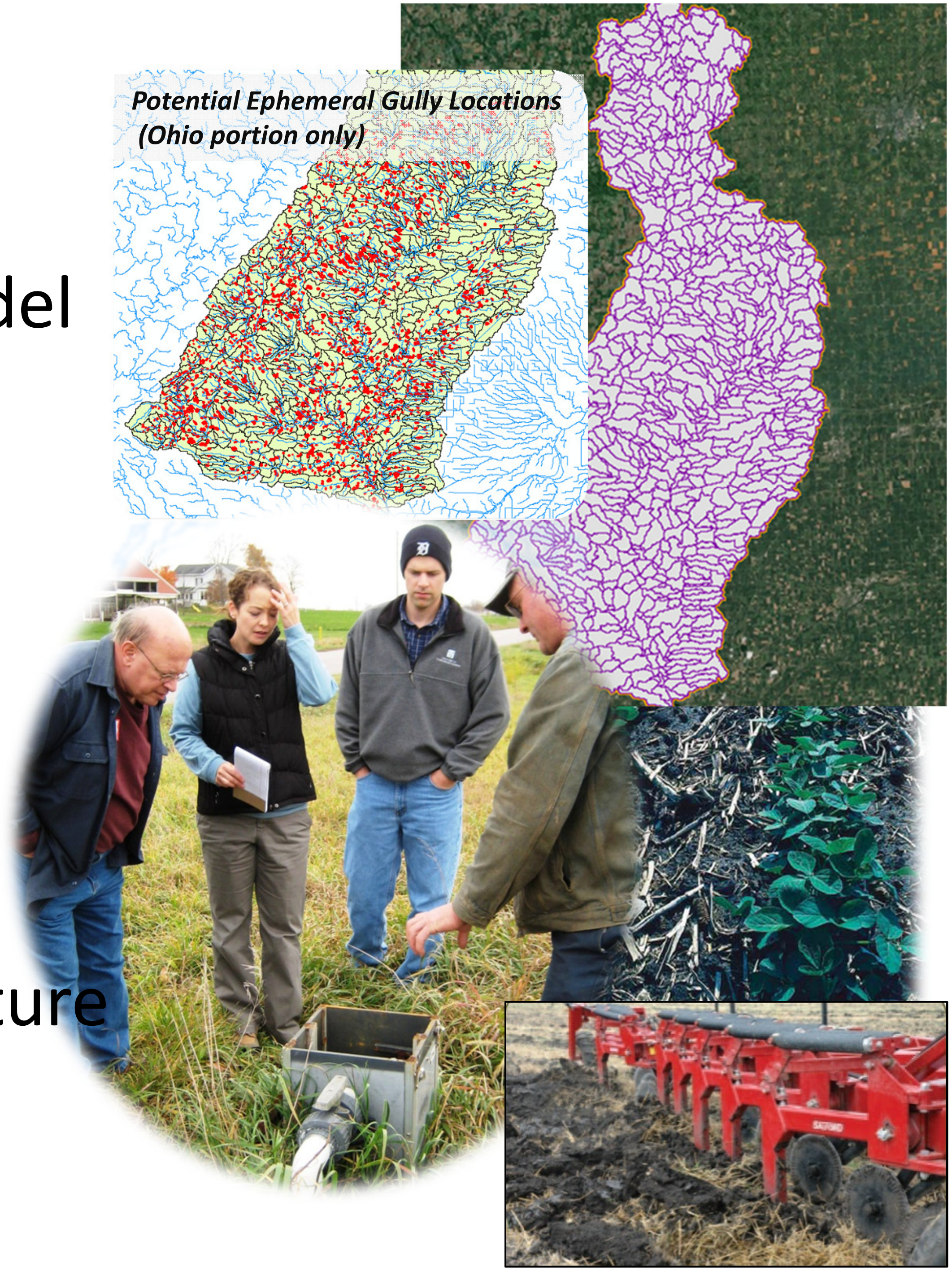
Why:
Sediment & Nutrients → Sedimentation & Algal Blooms



Land Use	*Percent of Area*
Cropland	**51.7%**
Forest	19.1%
Pasture	**10.3%**
Urban	16.7%
Wetland	2.1%

Key Elements:

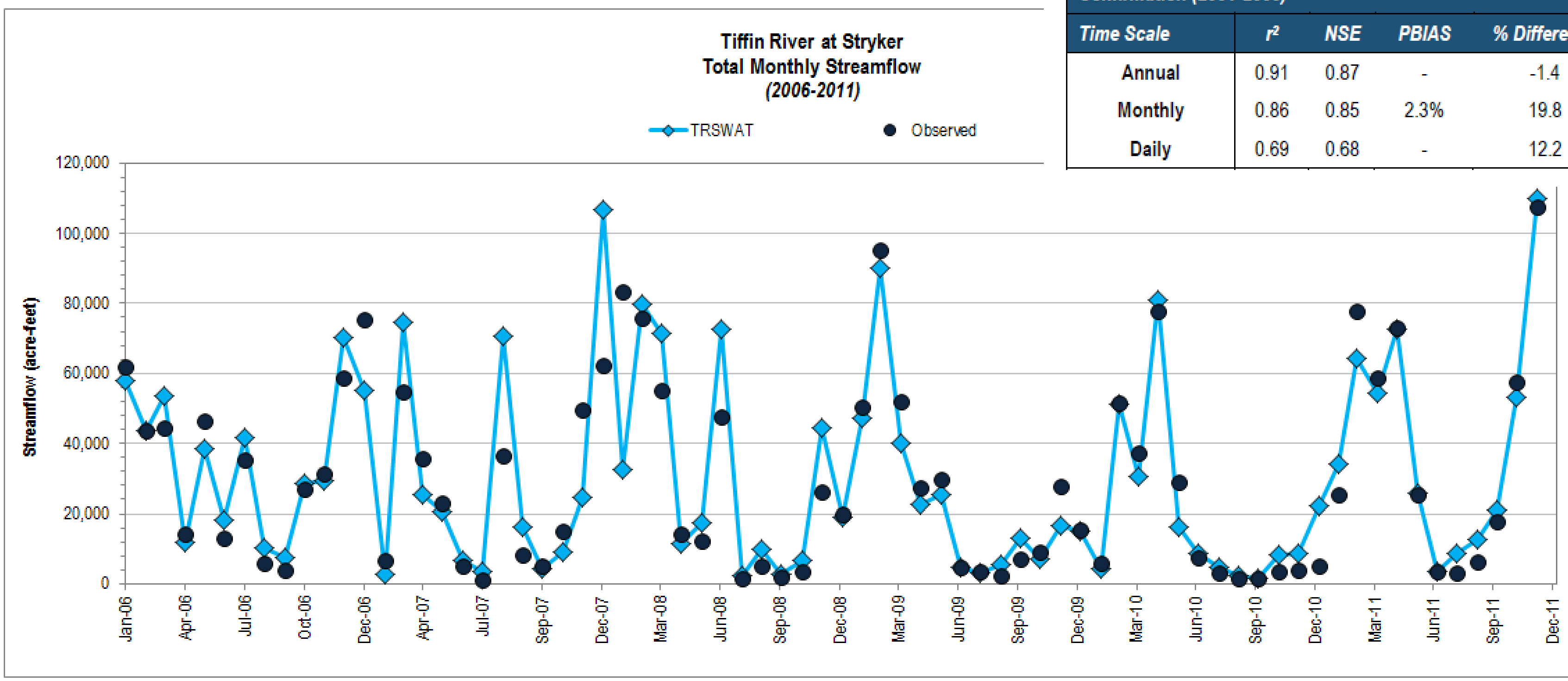
- Fine-scale, SWAT model
- Ephemeral Gully (EG) Erosion
- Understanding of agricultural practices (crop/tillage/ fertilizer/livestock)
- Working with agriculture focused stakeholders



TRSWAT Calibration/Confirmation: *Hydrology*

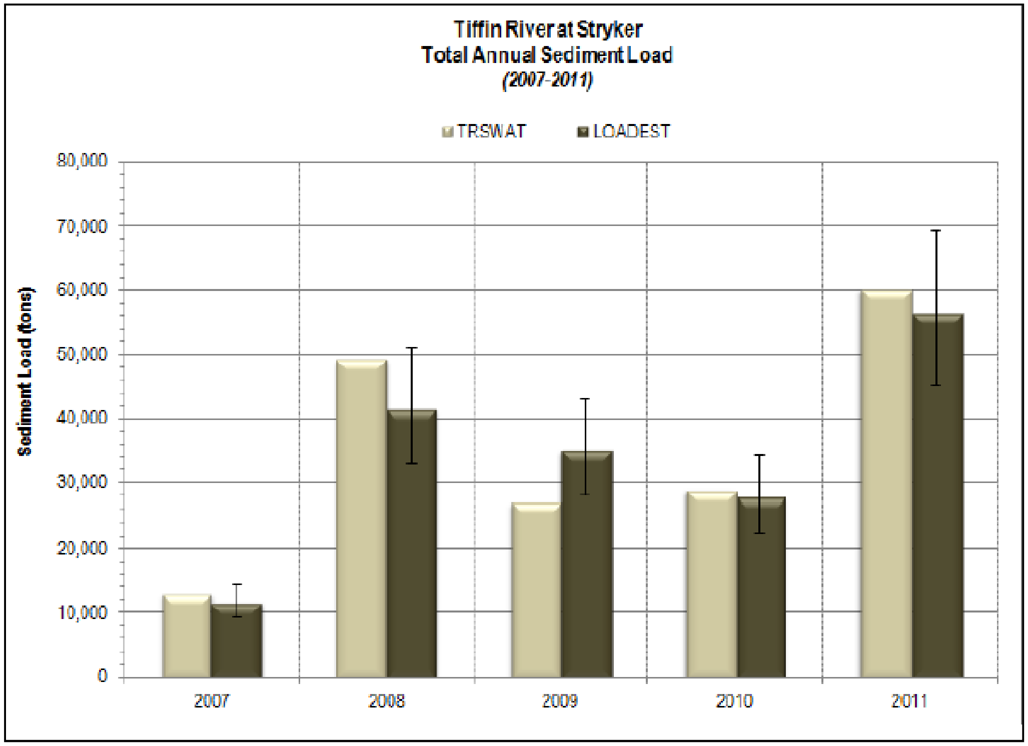
Tiffin River at Stryker: TRSWAT does "good to very good" job reproducing annual and monthly streamflow volumes as well as daily streamflow.

Calibration & Confirmation (2001-2011)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	0.91	0.87	-	0.56
Monthly	0.82	0.82	-1.3%	15.3
Daily	0.71	0.66	-	6.2
Calibration (2006-2011)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	0.93	0.76	-	2.2
Monthly	0.81	0.80	-3.4%	11.6
Daily	0.73	0.64	-	1.2
Confirmation (2001-2005)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	0.91	0.87	-	-1.4
Monthly	0.86	0.85	2.3%	19.8
Daily	0.69	0.68	-	12.2



TRSWAT Calibration/Confirmation: *Sediment*

Tiffin River at Stryker: TRSWAT does a "good" job reproducing annual and monthly sediment loads as well as baseflow and storm peak loads.

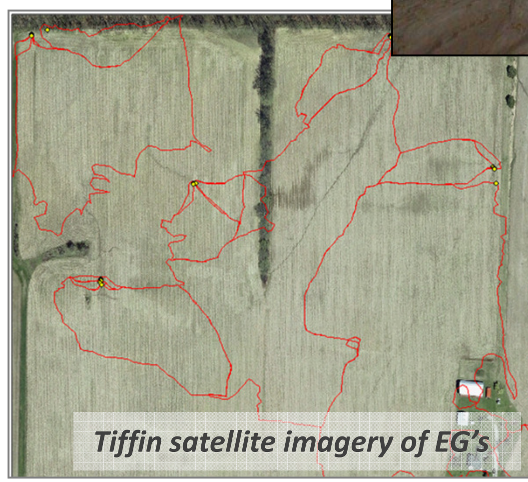


Calibration & Confirmation (2007-2011)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	0.91	0.87	-	2.5
Monthly	0.79	0.79	-3.5%	-5.7
Daily	0.59	0.57	-	59.9
Calibration (2009-2011)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	0.92	0.82	-	-5.1
Monthly	0.79	0.88	2.6%	-10.0
Daily	0.59	0.65	-	64.2
Confirmation (2007-2008)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	1.00	0.86	-	13.9
Monthly	0.97	0.48	-17.1%	3.0
Daily	0.53	0.23	-	51.2

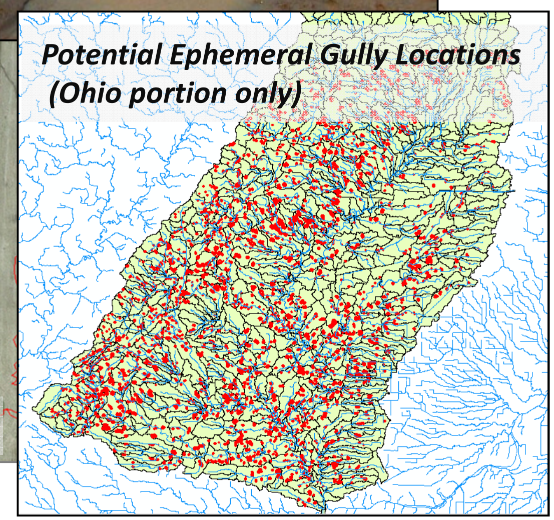
Ephemeral Gully Erosion

- Incorporate TI-EGEM algorithms from AnnAGNPS into SWAT code
- Testing, diagnostics, and confirmation
- Identify PEG's based on high-resolution DEM, satellite imagery, CTI
- Implementation in TRSWAT

Ephemeral gully in Upper Auglaize watershed (Bingner et al. 2005)



Tiffin satellite imagery of EG's



Potential Ephemeral Gully Locations (Ohio portion only)

Ephemeral Gully Contributions

- Relative proportions of erosion sources "watershed wide"

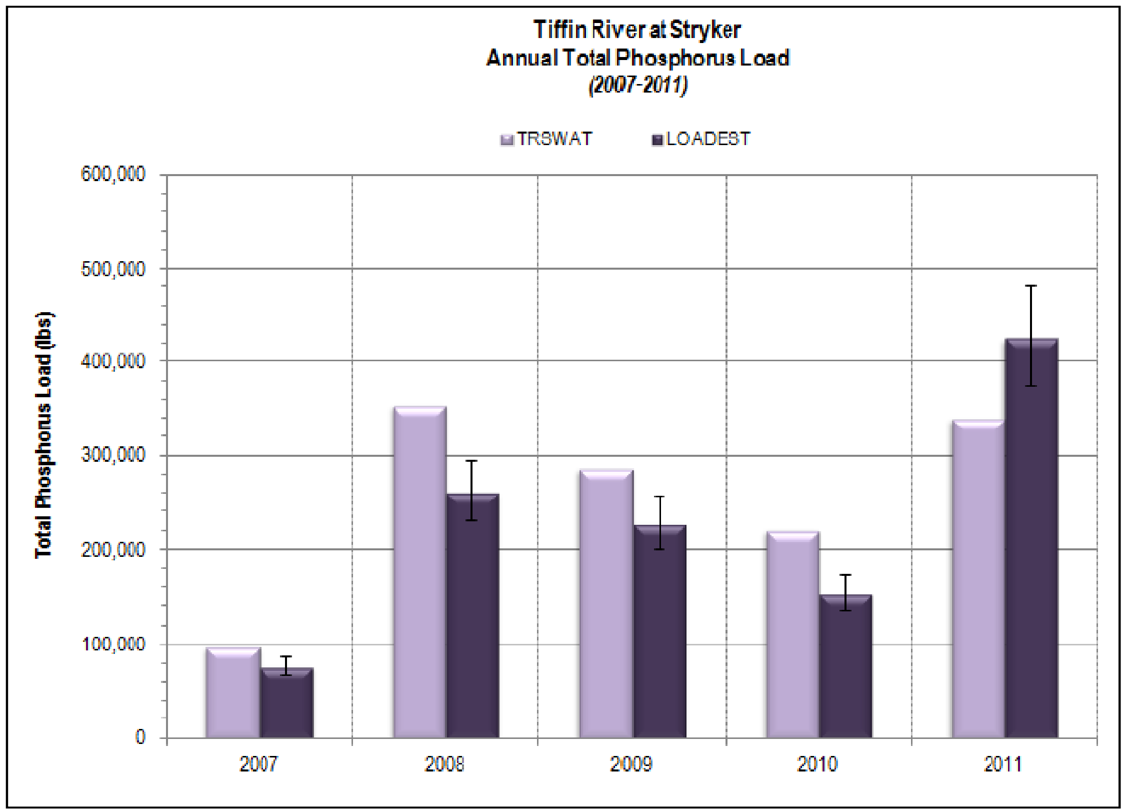
Sediment Source	% Source Contribution to Total Sediment Yield
Sheet and Rill	85%
Ephemeral Gully	15%

- Ephemeral gully erosion contribution varies significantly by HRU, contributing ~0 to 90% of the total sediment load

TRSWAT Calibration/Confirmation: *Total Phosphorus*

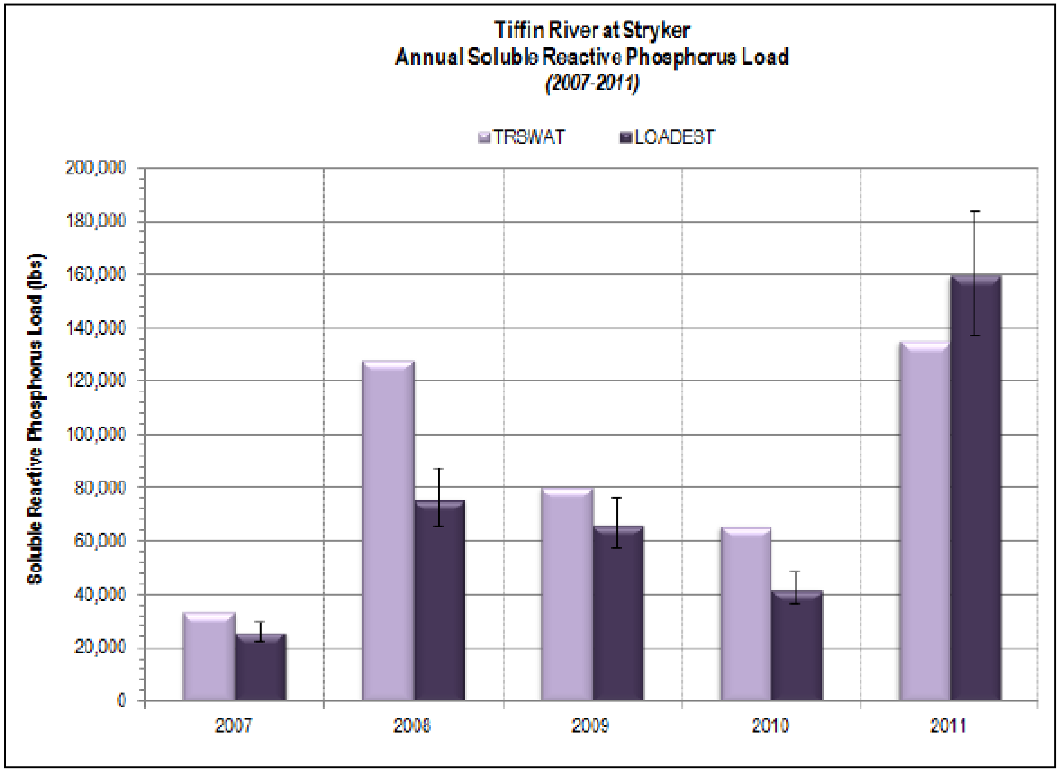
Tiffin River at Stryker: TRSWAT does a "fair to good" job reproducing annual and monthly TP loads as well as baseflow and storm peak loads.

Time Scale	r^2	NSE	PBIAS	% Difference
Calibration & Confirmation (2007-2011)				
Annual	0.71	0.64	-	18.4
Monthly	0.49	0.47	-13.7%	49.2
Daily	0.39	0.39	-	55.8
Calibration (2009-2011)				
Annual	0.90	0.61	-	12.4
Monthly	0.54	0.53	-5.2%	45.8
Daily	0.37	0.36	-	49.8
Confirmation (2007-2008)				
Annual	1.00	0.46	-	27.3
Monthly	0.51	0.20	-33.9%	56.0
Daily	0.59	0.54	-	67.7



TRSWAT Calibration/Confirmation: *Soluble Reactive Phosphorus*

Tiffin River at Stryker: TRSWAT does a "fair to good" job reproducing annual and monthly SRP loads as well as baseflow and storm peak loads.

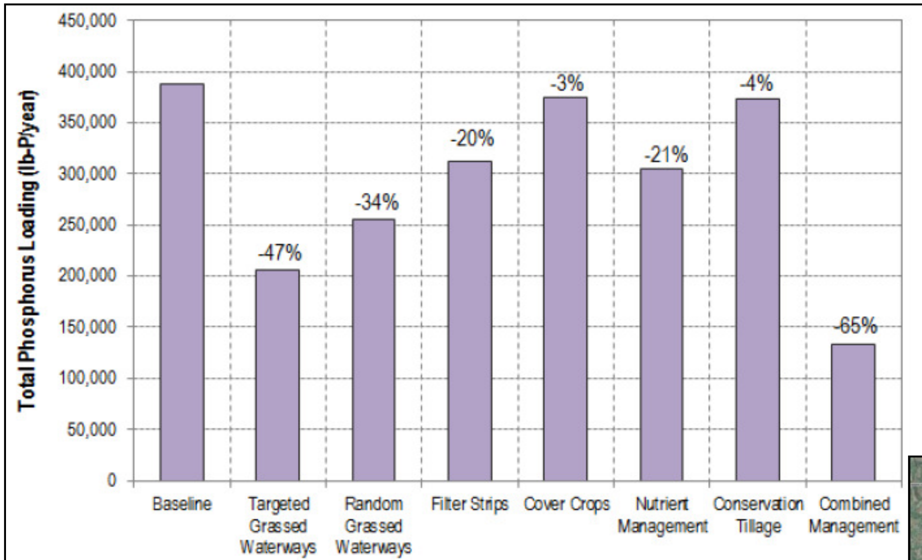


Time Scale	r^2	NSE	PBIAS	% Difference
Calibration & Confirmation (2007-2011)				
Annual	0.71	0.61	-	24.7
Monthly	0.63	0.62	-19.7%	54.4
Daily	0.48	0.48	-	59.3
Calibration (2009-2011)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	1.00	0.82	-	15.5
Monthly	0.76	0.71	-4.9%	48.7
Daily	0.57	0.52	-	52.9
Confirmation (2007-2008)				
Time Scale	*r^2*	*NSE*	*PBIAS*	*% Difference*
Annual	1.00	-1.20	-	38.7
Monthly	0.65	-0.17	-59.0%	65.8
Daily	0.66	0.10	-	71.9

TRSWAT Management Application

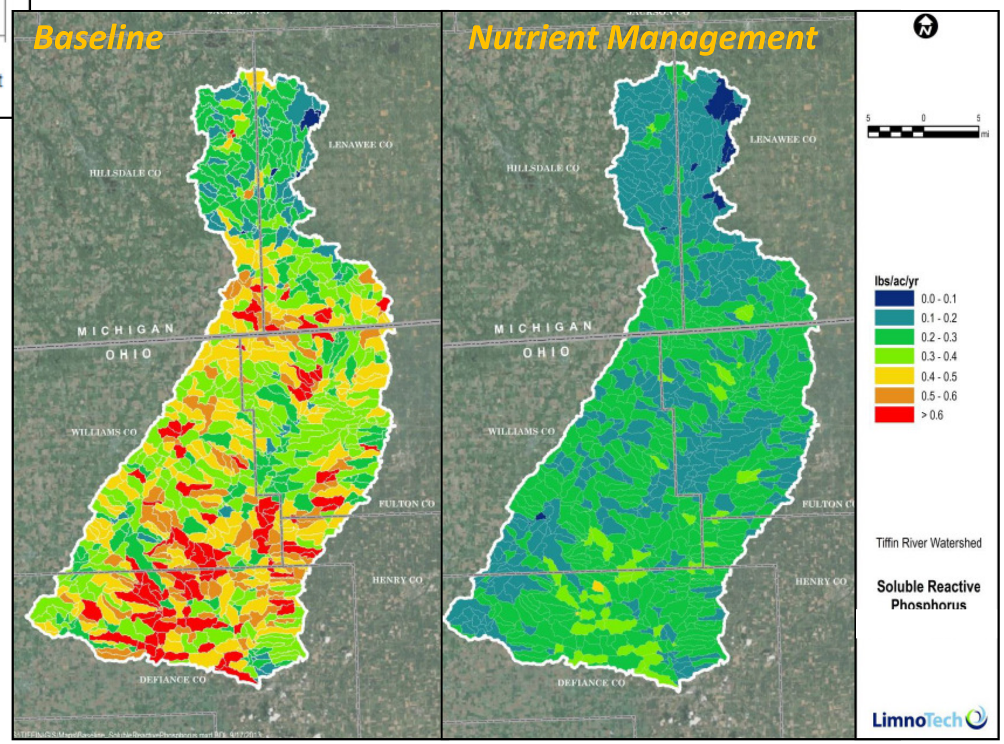
- A. Grassed waterways (random), 20% of cropland acres
- B. Grassed waterways (targeted), 20% of cropland acres
- C. Filter strips, 20% of cropland acres
- D. Cover crops, 30% of cropland acres
- E. Conservation tillage, 100% of cropland acres
- F. Nutrient management, 100% of cropland acres
- G. A combination of all practices (B-F), set at the implementation levels specified for B-F (where B=20% + C=20% + D=30% + E=100% + F=100%).

TRSWAT Management Results



← TP: G. combined management (-65%), B. targeted grassed waterways (-47%), A. random grassed waterways (-34%) and F. nutrient management (-21%).

SRP →: G. combined management (-41%) and F. nutrient management (-40%).

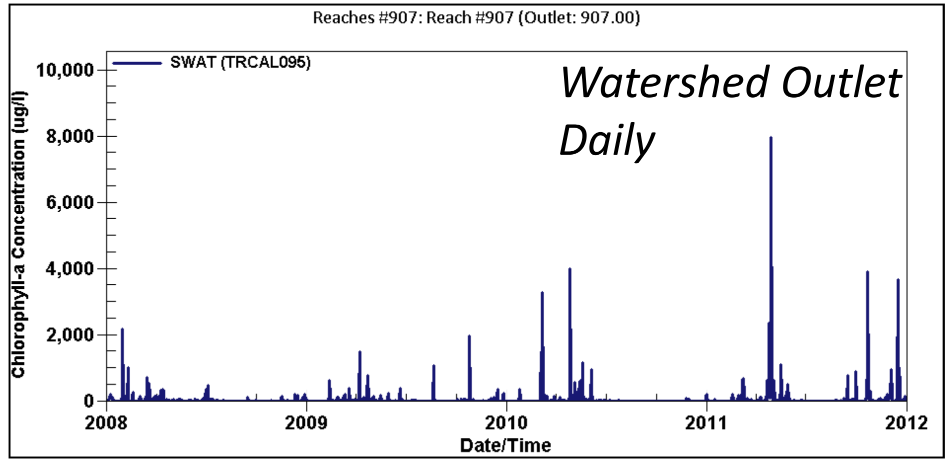


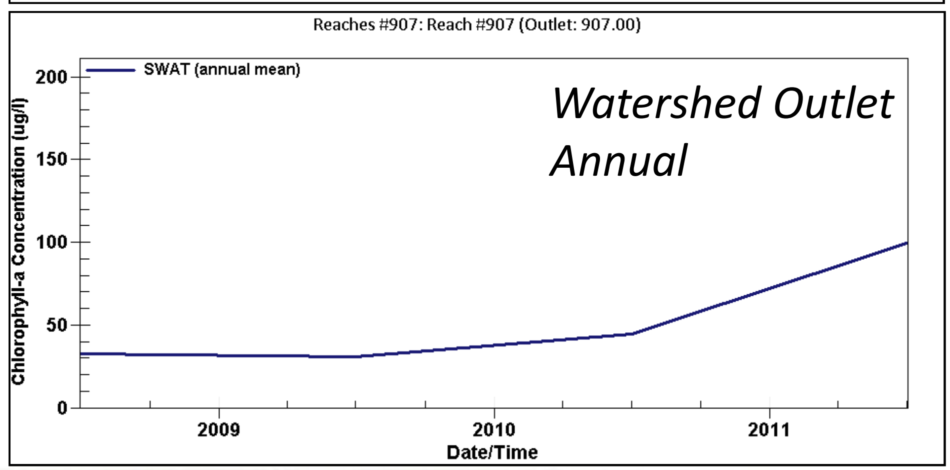
SWAT Challenges Identified: *SRP Transport*

- Lack of SRP transport in tile drains (most SRP in surface runoff) likely underestimates transport pathway.
- Small flow contribution from tile drain pathway and constant concentration assigned to lateral flows.
- Limitation likely impacts the results of the estimated load reduction benefits for TP & SRP (i.e., practices that address surface transport pathway likely overestimates load reduction estimates)

SWAT Challenges Identified: *Instream Cycling*

- Unrealistic simulation of phytoplankton limited the representation of instream nutrient cycling & impact on nutrient transport & fate.
- Found similar phytoplankton results in other SWAT models
- “Turned” off phytoplankton and adjusted nutrient parameters to compensate





Solutions

- Are these issues completely addressed in the SWAT2012?
- If not, what can we do to address them?

Questions?

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