Opportunities and Challenges of SWAT for Modelling Coastal Environmental Processes

D.D. Poudel[1] and R. Srinivasan[2]

[1]Environmental Science Program., School of Geosciences, University of Louisiana at Lafayette, Lafayette, Louisiana, USA
[2]Texas A&M University, Texas, USA

International Soil and Water Assessment Tool (SWAT) Conference and Workshop
September, 2024
Organized by the Pontificia Universidad Católica del Perú in collaboration with the USDA-ARS and Texas A&M AgriLife Research, USA

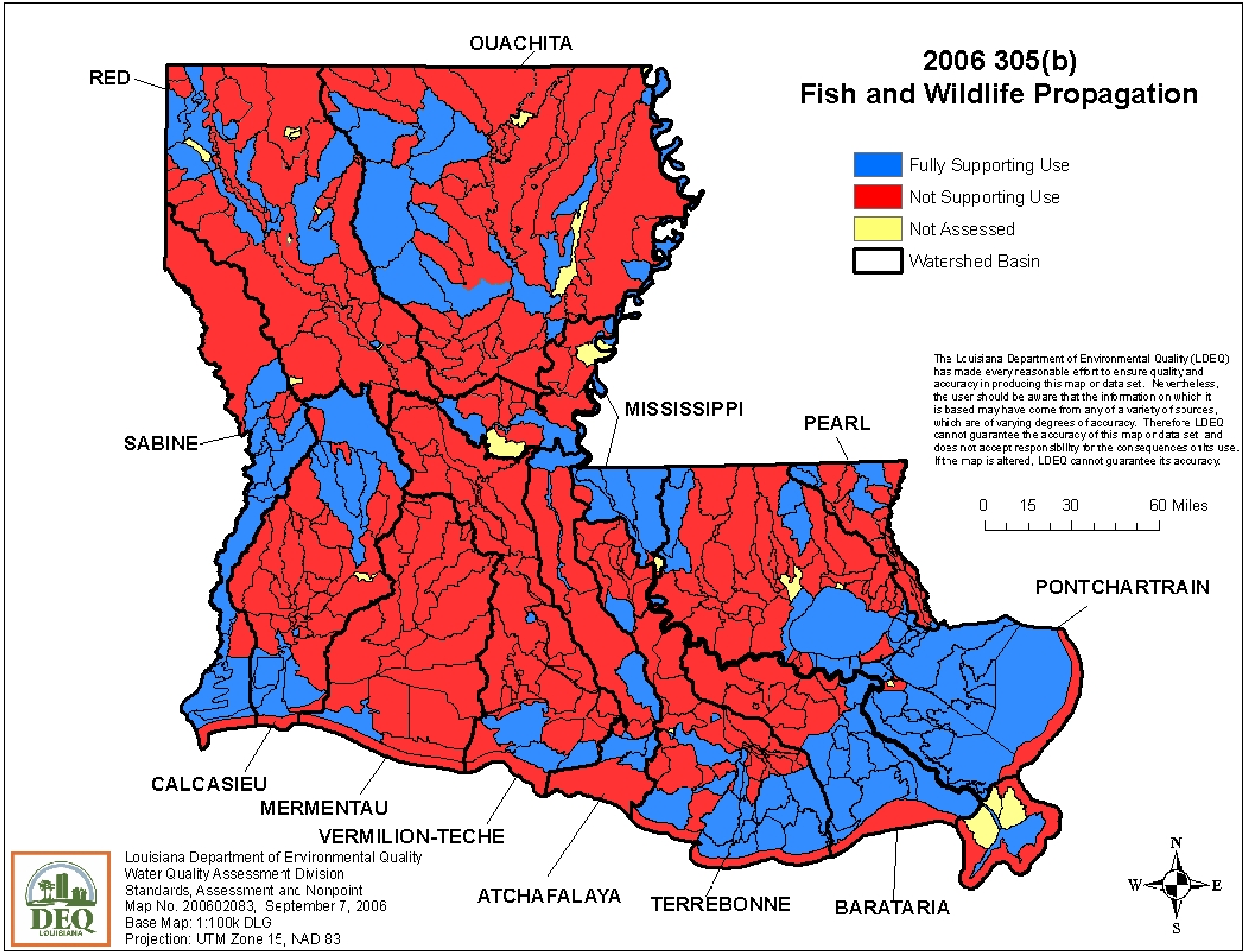
SWAT for Environmental Modeling

- Bayou Plaquenine Brule Watershed
- Coulee Baton Micro-watershed
- Bayou Chene Watershed
- On-going Graduate Research Projects
- Coastal Landscape
- SWAT+

Map of the United States

http://www.statemapsonline.com/images/usa/USA-State-Map-With-Rivers-And-Cities.jpg

Water Quality Assessment - Louisiana



Map courtesy: LDEQ GIS Unit, 2008

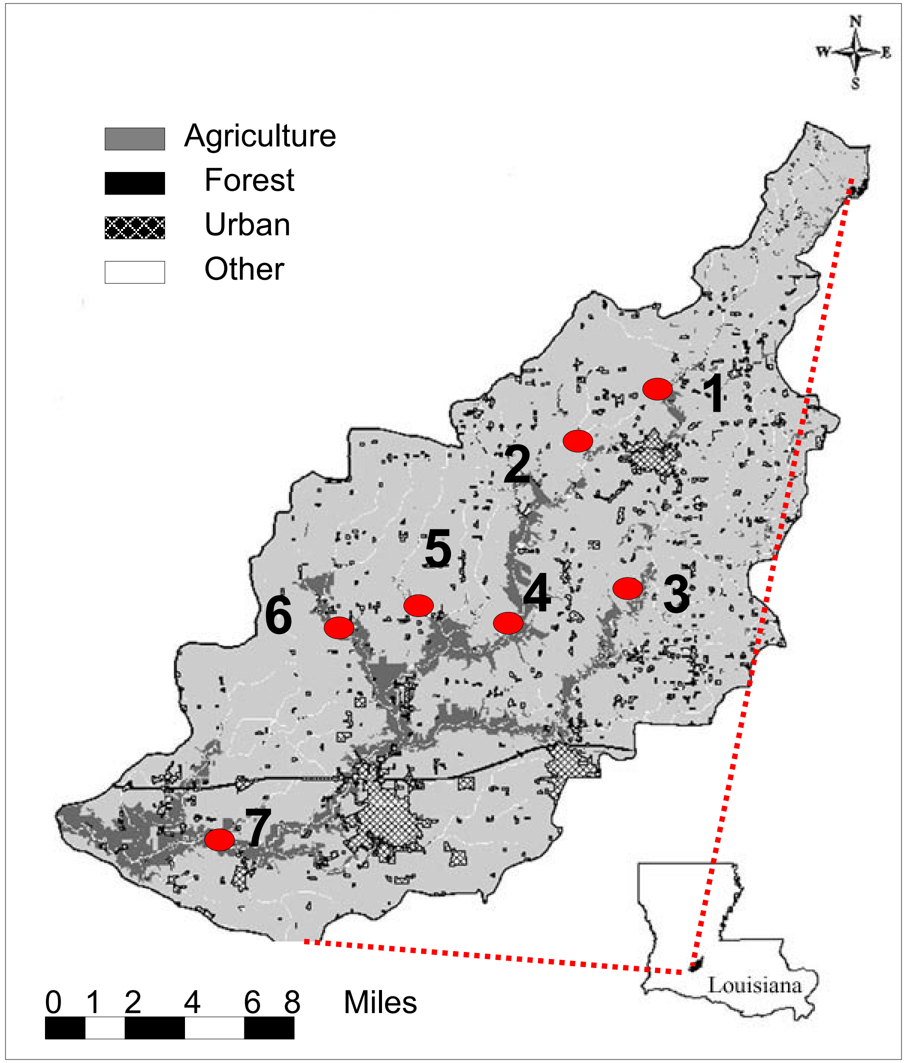
Bayou Plaquemine Brule Watershed

The Soil and Water Assessment Tool
(SWAT) Model

ArcSWAT Version 2.3.3, ArcGIS 9.3 SP1

A process-based model.

Watershed-scale Water Quality Monitoring and Modeling (April 2001- June 2009)



1998 303(d) list due to not meeting EPA standards for designated uses of contact recreational uses and wildlife propagation.

The suspected causes of impairment were organic enrichment/low dissolved oxygen, and nutrients. Priority rank 1.

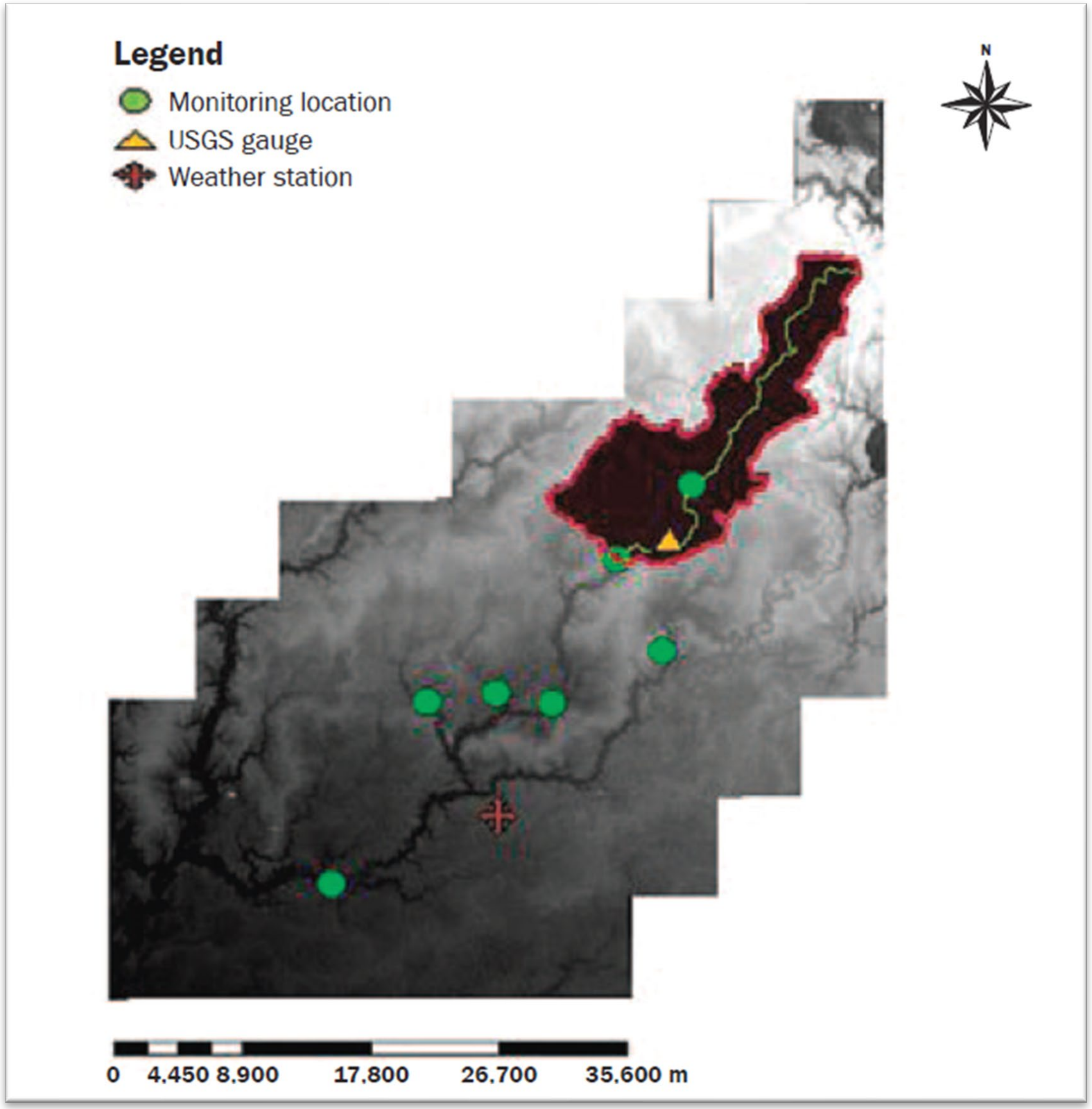
TMDLs for DO, fecal coliform, mercury, nutrients, TSS, and TDS were developed in in Dec. 1999 and approved by EPA in Feb. 2000.

ArcSWAT Project – Database Setup

- Digital Elevation Model (DEM), LiDAR Data –
- 5 m DEM (http://atlas.lsu.edu/LiDAR)
- Landuse map (LDEQ – Landsat TM, 1998)
- Soils data (STATSGO 1:250,000 scale)
- Weather data (Rice Research Station, Crowley, Louisiana, 1980 to 2008)
- Daily discharge data for flow calibration and validation (http://ida.water.USGS.gov/ida/available_records.cfm?sn=08010200), June 2002 to November 2005),

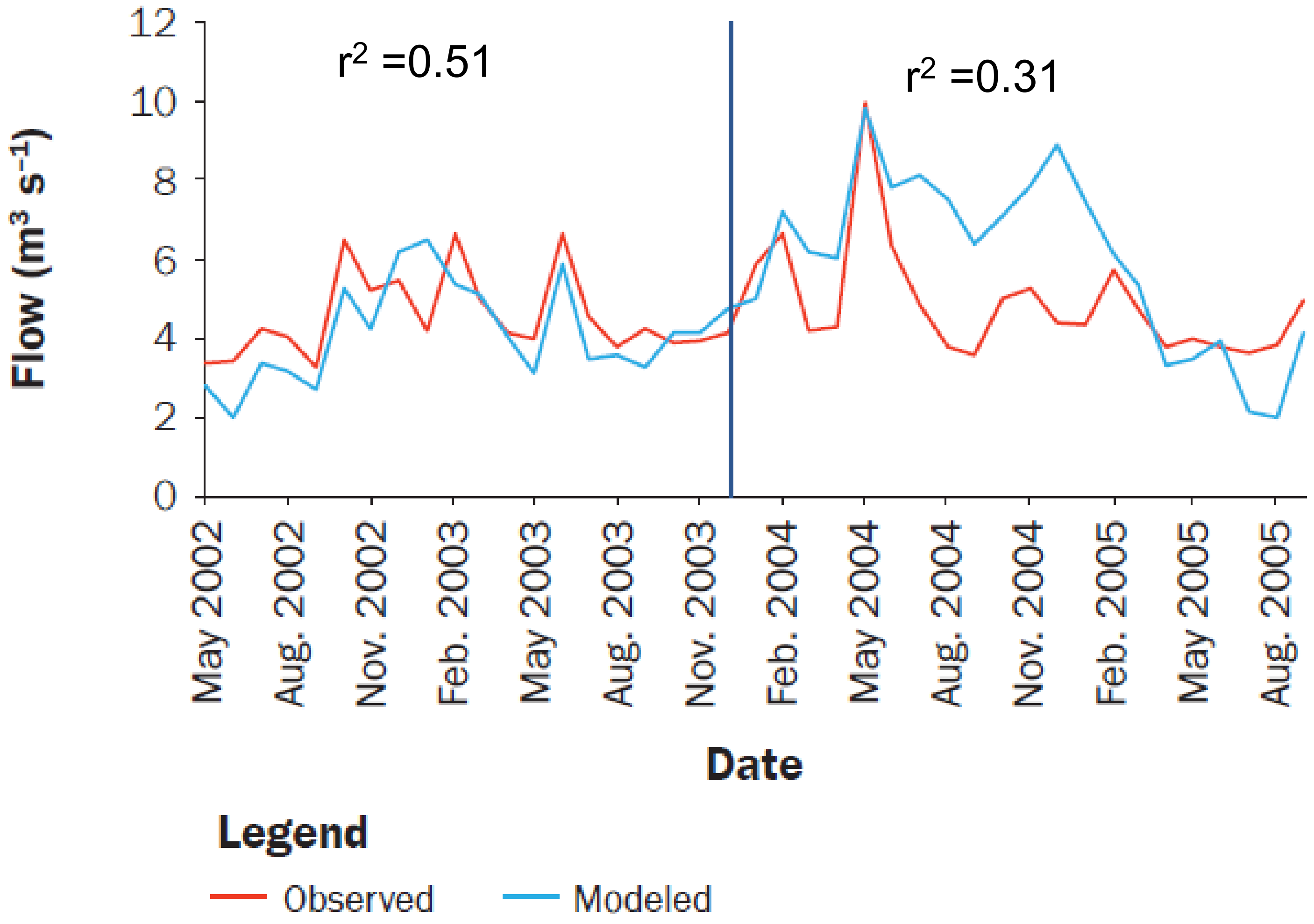
  USGS 08010200 BYU PLAQUEMINE BRULE at CHURCH POINT, LA

Pilot basin for flow calibration and validation



Poudel et al., 2013

Model calibration and validation



Poudel et al., 2013

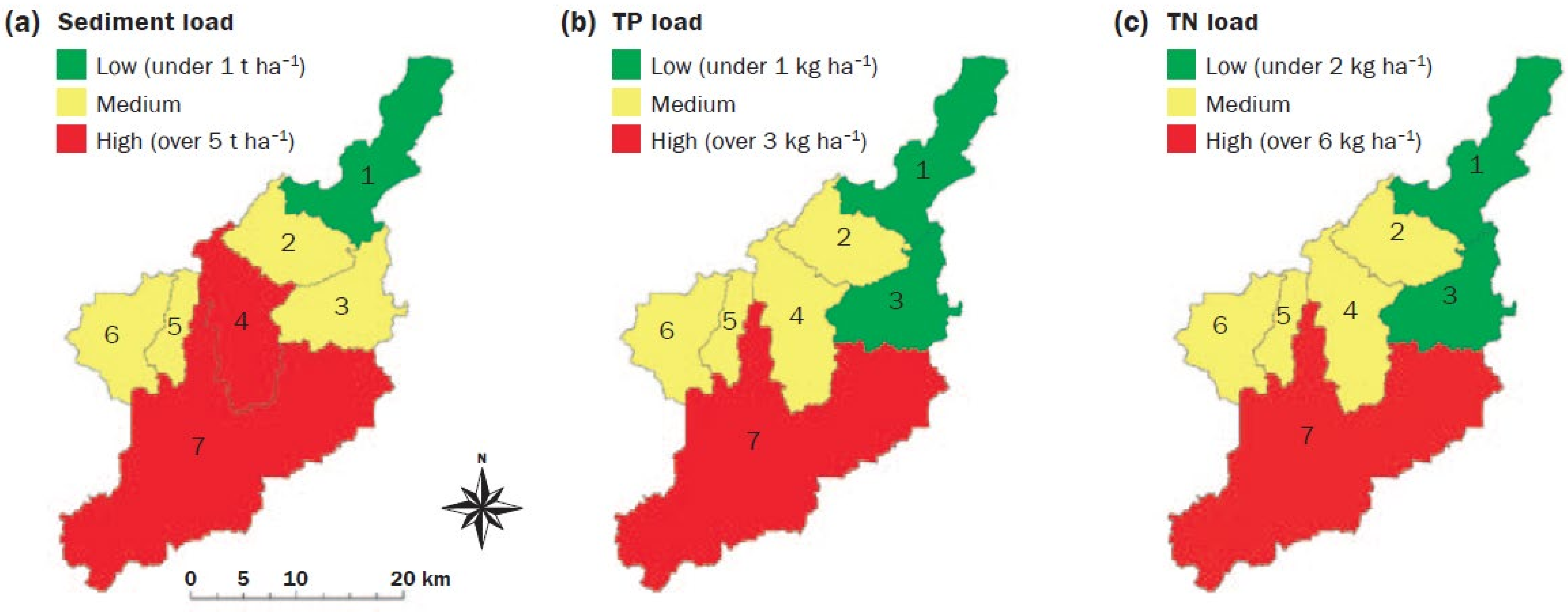
Total mass and average load observed and modeled

(May 1, 2002, to Sept. 30, 2005)	Sediment (t)		TN (kg)		TP (kg)	
	Observed	Modeled	Observed	Modeled	Observed	Modeled
Total mass	88.2	88.4	3,160.0	4,458.1	519.6	397.7
Average	1.1	1.1	45.8	64.6	7.5	5.8

Notes: TN = total nitrogen. TP = total phosphorous.

Poudel et al., 2013

Critical areas for sediment and nutrient loads



Poudel et al., 2013

Table 4. List of parameter values after adjustment for model calibration including flow, sediment, and nutrients. It should be noticed that ground water delay in flow parameter was very high (400 days) and this seems to be because the ground water in this area has been used up for crawfish and rice production and has not been recharging channel.

Component	Parameter (file)	Description	Input Value
Flow	CN2 (.mgt)	SCS runoff curve number (adjustment range)	-5 to -20
	ESCO (.hru)	Soil evaporation factor	0.9
	GW_DELAY (.gw)	Groundwater delay time (days)	400
	GWQMN (.gw)	Groundwater storage required for return flow (mm)	1.00
	SOL_K (.sol)	Soil hydrologic conductivity (mm/hr)	10
Sediment	LAT_SED (.hru)	Sediment concentration in lateral and ground water flow (mg/L)	10
	SPCON (.bsn)	Linear parameter for calculating the maximum amount of sediment that can be re-entrained	0.0011
	SPEXP (.bsn)	Exponent parameter for calculating sediment re-entrained	1.2
	CH_COV (.rte)	Channel cover factor	0.5
	CH_EROD (.rte)	Channel erodibility factor	0.5
Nitrogen	N_PERCO (.bsn)	Nitrogen percolation coefficient	0.9
	BC1 (.swq)	Rate constant for biological oxidation of NH_4 to NO_2 (/day)	0.01
	BC3 (.swq)	Rate constant for hydrolysis of organic N to NH_4 (/day)	0.1
	RS3 (.swq)	Benthic source rate for NH_4-N	0.1
Phosphorous	PSP (.bsn)	Phosphorous availability index	0.1
	RS2 (.swq)	Benthic source rate for dissolved phosphorous	0.3
	BC4 (.swq)	Rate constant for mineralization of organic P to dissolved P	0.7

Poudel et al., 2013

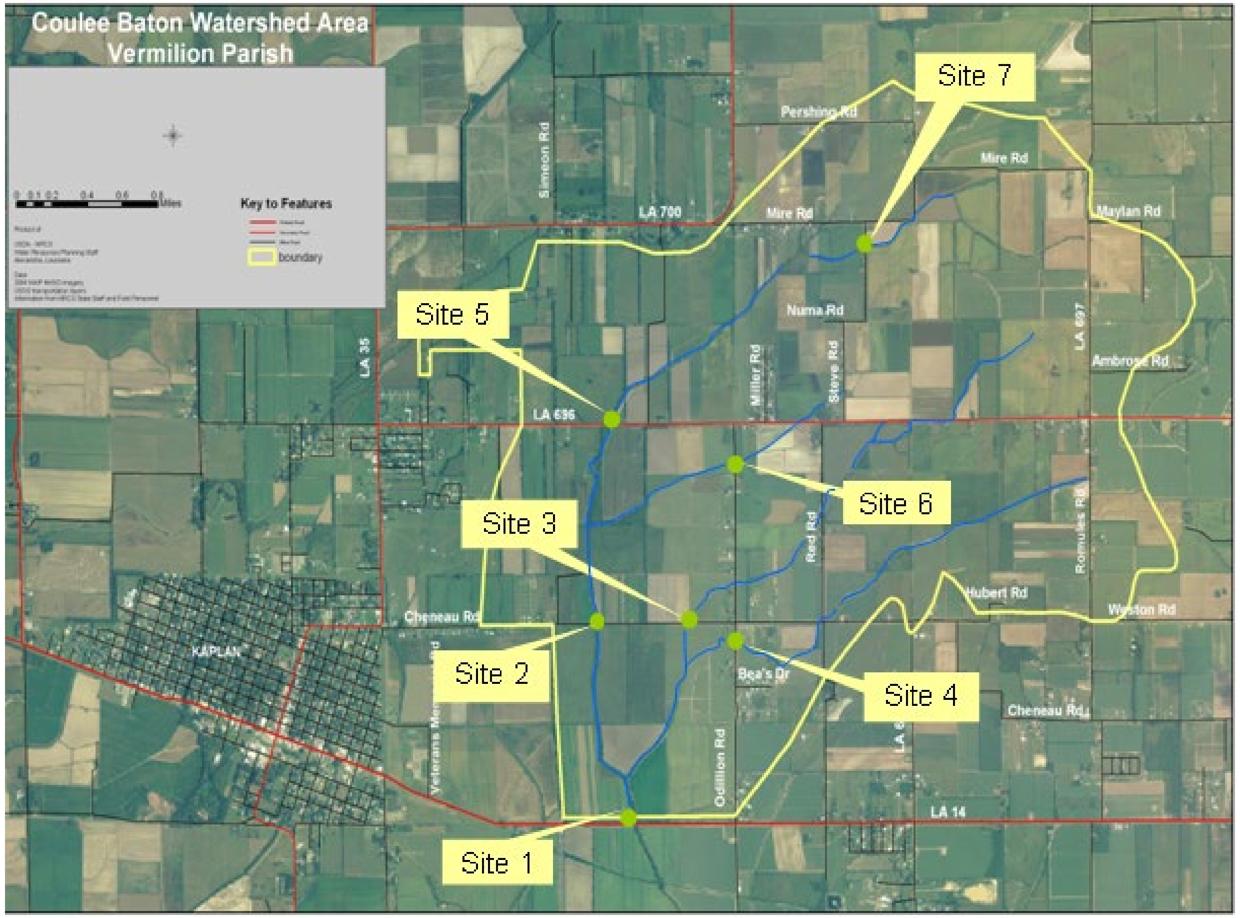
- Sediment, nutrients, temperature, dissolved solids, and acidity/alkalinity are the factors responsible for the variation in surface water quality across the watershed.

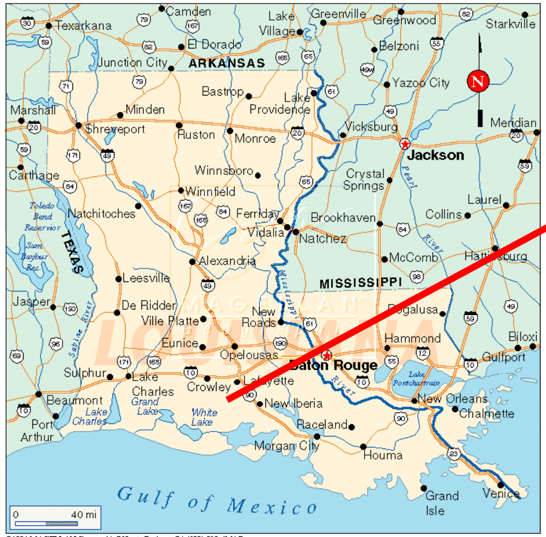
- Extreme rain events following long drought cause much harm than an extreme rain events after the onset of rainfalls.

- Drying upstreams of water bodies is a concern.

- SWAT model is very useful in identifying critical areas for nonpoint source pollution control in a watershed.

Coulee Baton Microwatershed





The Coulee Baton Microwatershed is in Mermentau River Basin and drains into the LA-050702 waterbody description of GIWW from the Mermentau River to the Leland Bowman Locks.

SWAT Modeling

5 m LiDAR data for DEM
1:250,000 scale STATSGO data for soils
NLCD 2001 landcover dataset for landuse map
Management information
Precipitation and temperature data 1980 – 2010 Abbeville and Iberia station
Parameterization from Bayaou Plaquemine Brule SWAT project
Hotspots based on annual loads

MRLC Home
NCLD 2001
NCLD 1992
NCLD Change
NCLD 2006
Publications

NLCD Classification Schemes (Level II)

Class I and II Definitions

1992 Scheme	2001 Scheme
11 - Open water 12 - Perennial Ice/Snow	11 - Open water 12 - Perennial Ice/Snow
21 - Low Intensity Residential 22 - High Intensity Residential 23 - Commercial/Industrial/Transportation	21 - Developed, Open Space 22 - Developed, Low Intensity 23 - Developed, Medium Intensity 24 - Developed, High Intensity
31 - Bare Rock/Sand/Clay 32 - Quarries/Strip Mines/Gravel Pits 33 - Transitional	31 - Barren Land 32 - Unconsolidated Shore [1]
41 - Deciduous Forest 42 - Evergreen Forest 43 - Mixed Forest	41 - Deciduous Forest 42 - Evergreen Forest 43 - Mixed Forest
51 - Shrubland	51 - Dwarf Scrub [2] 52 - Scrub/Shrub
61 - Orchards/Vineyards/Other	
71 - Grassland/Herbaceous	71 - Grassland/Herbaceous 72 - Sedge Herbaceous [2] 73 - Lichens [2] 74 - Moss [2]
81 - Pasture/Hay 82 - Row Crops 83 - Small Grains 84 - Fallow 85 - Urban/Recreational Grasses	81 - Pasture/Hay 82 - Cultivated Crops
91 - Woody Wetlands 92 - Emergent Herbaceous Wetlands	90 - Woody Wetlands 91 - Palustrine Forested Wetland [1] 92 - Palustrine Scrub/Shrub [1] 93 - Estuarine Forested Wetlands [1] 94 - Estuarine Scrub/Shrub [1] 95 - Emergent Herbaceous Wetland 96 - Palustrine Emergent Wetland (Persistent) [1] 97 - Palustrine Emergent Wetland [1] 98 - Palustrine Aquatic Bed [1]


Ambrose Pasture
Pasture
Rice
CF/RE
Coulee Baton
LA 14

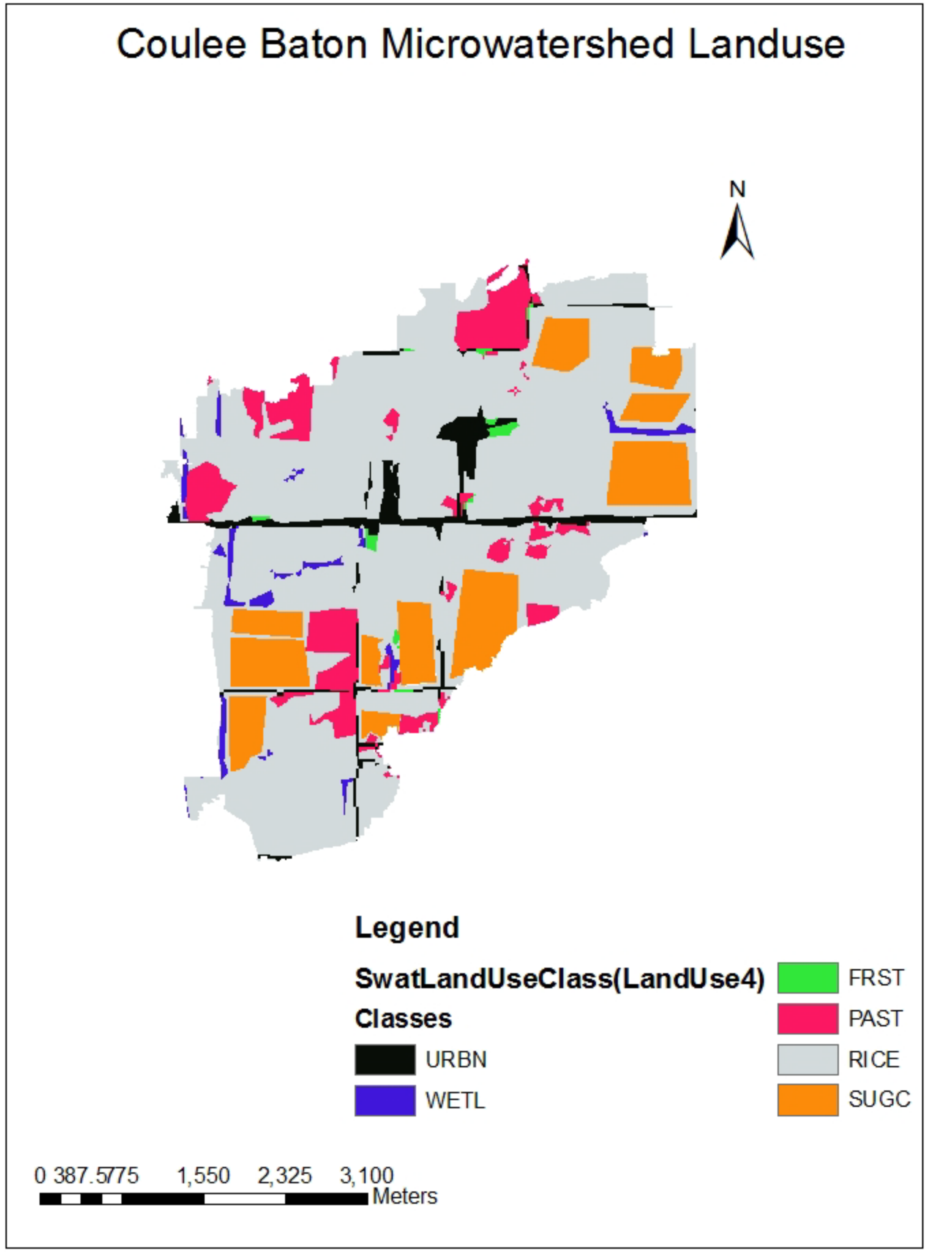
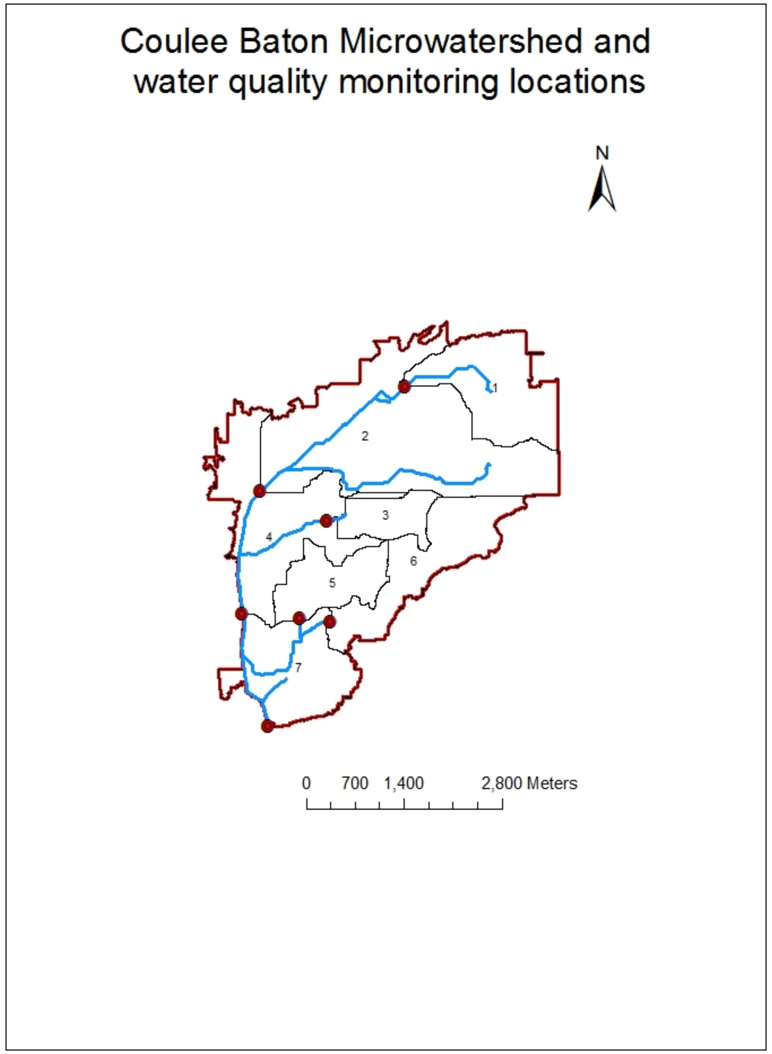
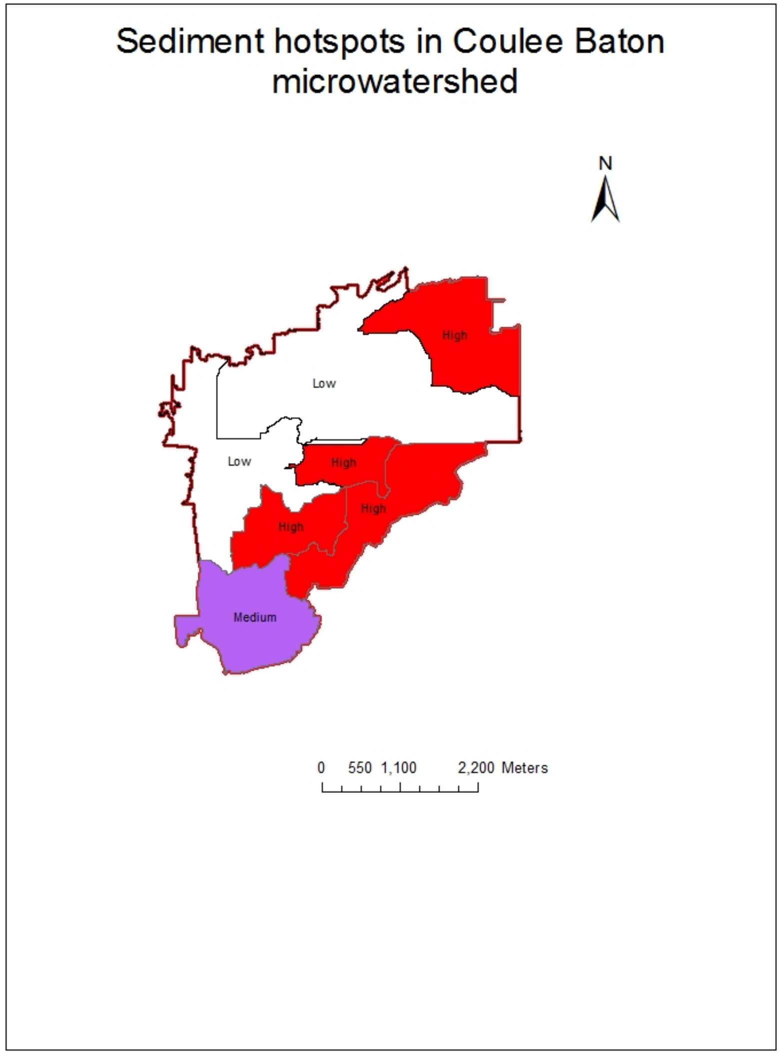

Coulee Baton Microwatershed Landuse
N
Legend
SwatLandUseClass(LandUse4)
Classes
URBN
WETL
FRST
PAST
RICE
SUGC
0 387.5775 1,550 2,325 3,100
Meters

Table 4. List of parameter values after adjustment for model calibration including flow, sediment, and nutrients. It should be noticed that ground water delay in flow parameter was very high (400 days) and this seems to be because the ground water in this area has been used up for crawfish and rice production and has not been recharging channel.

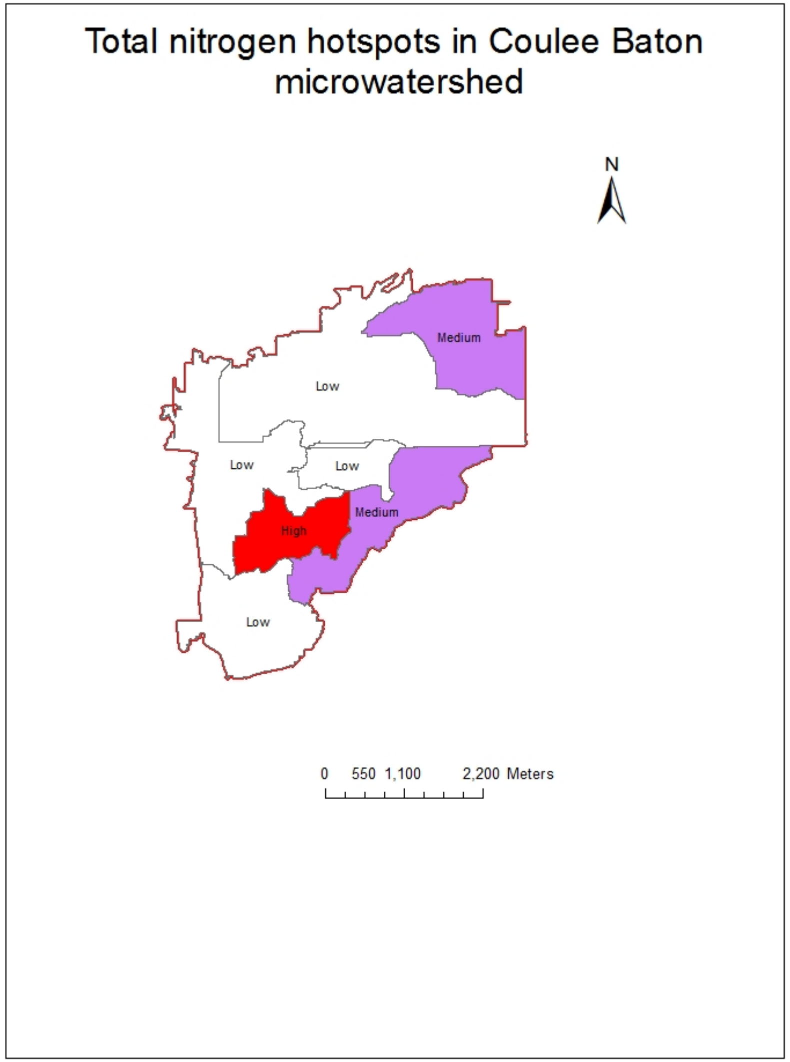
Component	Parameter (file)	Description	Input Value
Flow	CN2 (.mgt)	SCS runoff curve number (adjustment range)	-5 to -20
	ESCO (.hru)	Soil evaporation factor	0.9
	GW_DELAY (.gw)	Groundwater delay time (days)	400
	GWQMN (.gw)	Groundwater storage required for return flow (mm)	1.00
	SOL_K (.sol)	Soil hydrologic conductivity (mm/hr)	10
Sediment	LAT_SED (.hru)	Sediment concentration in lateral and ground water flow (mg/L)	10
	SPCON (.bsn)	Linear parameter for calculating the maximum amount of sediment that can be re-entrained	0.0011
	SPEXP (.bsn)	Exponent parameter for calculating sediment re-entrained	1.2
	CH_COV (.rte)	Channel cover factor	0.5
	CH_EROD (.rte)	Channel erodibility factor	0.5
Nitrogen	N_PERCO (.bsn)	Nitrogen percolation coefficient	0.9
	BC1 (.swq)	Rate constant for biological oxidation of NH_4 to NO_2 (/day)	0.01
	BC3 (.swq)	Rate constant for hydrolysis of organic N to NH_4 (/day)	0.1
	RS3 (.swq)	Benthic source rate for NH_4-N	0.1
Phosphorous	PSP (.bsn)	Phosphorous availability index	0.1
	RS2 (.swq)	Benthic source rate for dissolved phosphorous	0.3
	BC4 (.swq)	Rate constant for mineralization of organic P to dissolved P	0.7

Poudel et al., 2013

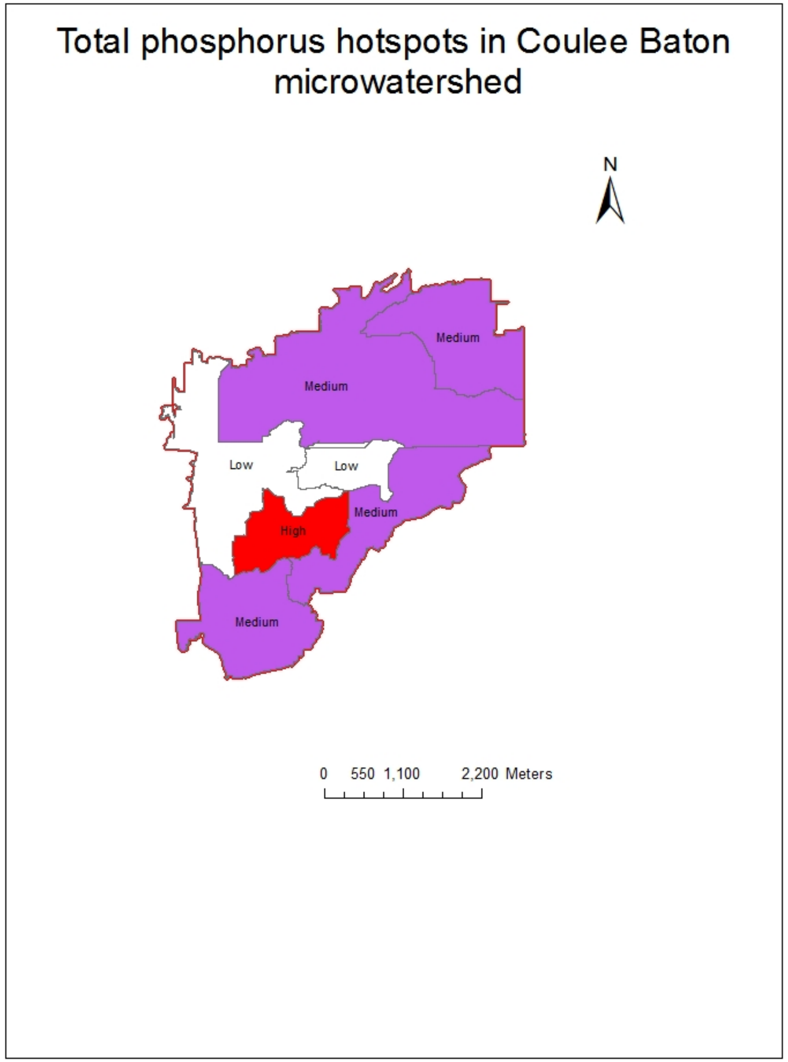




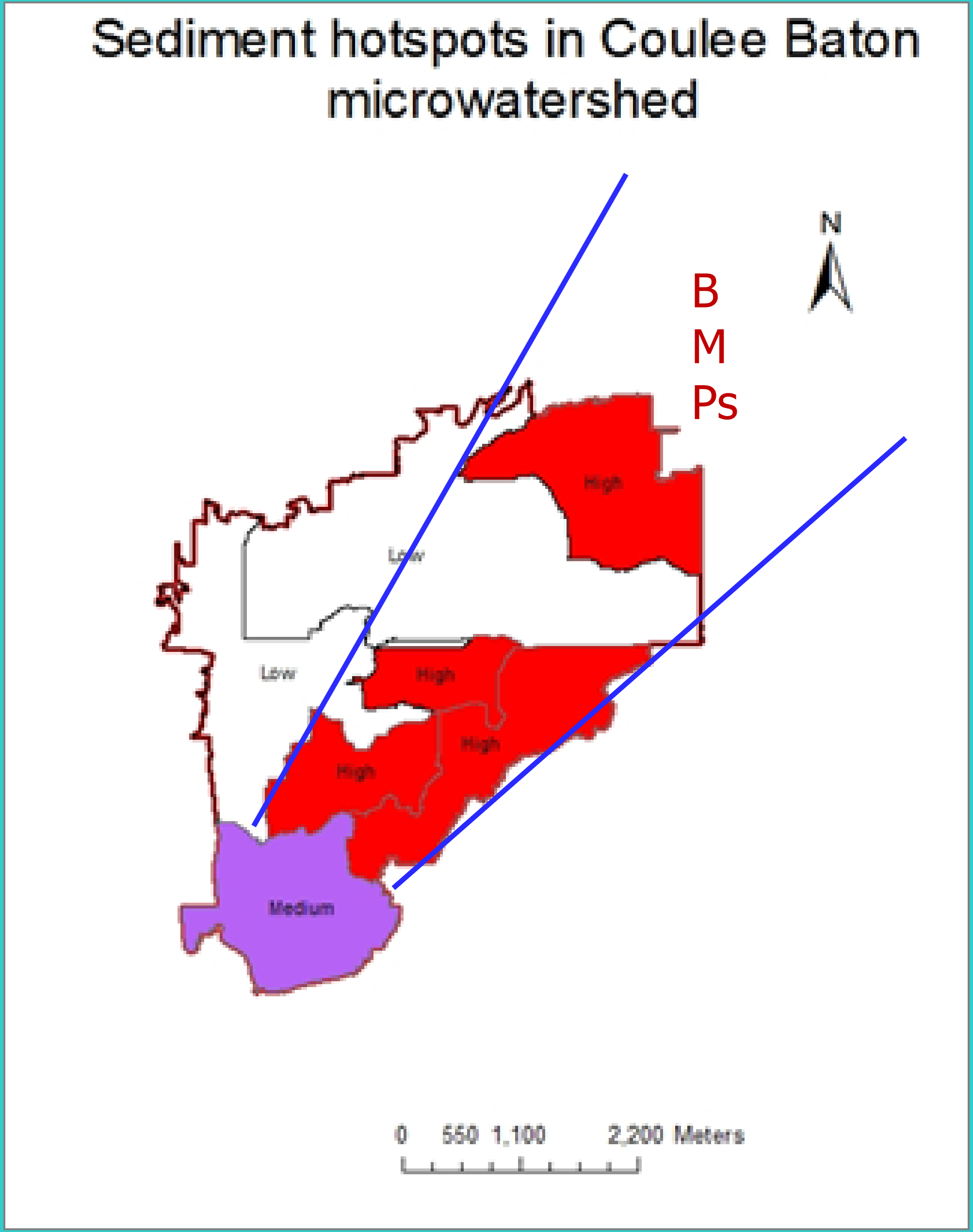
Low < 1 mt/ha, medium 1- 5 mt/ha and high > 5 mt/ha.



Low < 50 kg/ha, medium 50-70 kg/ha, and high >70 kg/ha



Low < 8 kg/ha, medium 8-10 kg/ha, and high > 10 kg/ha

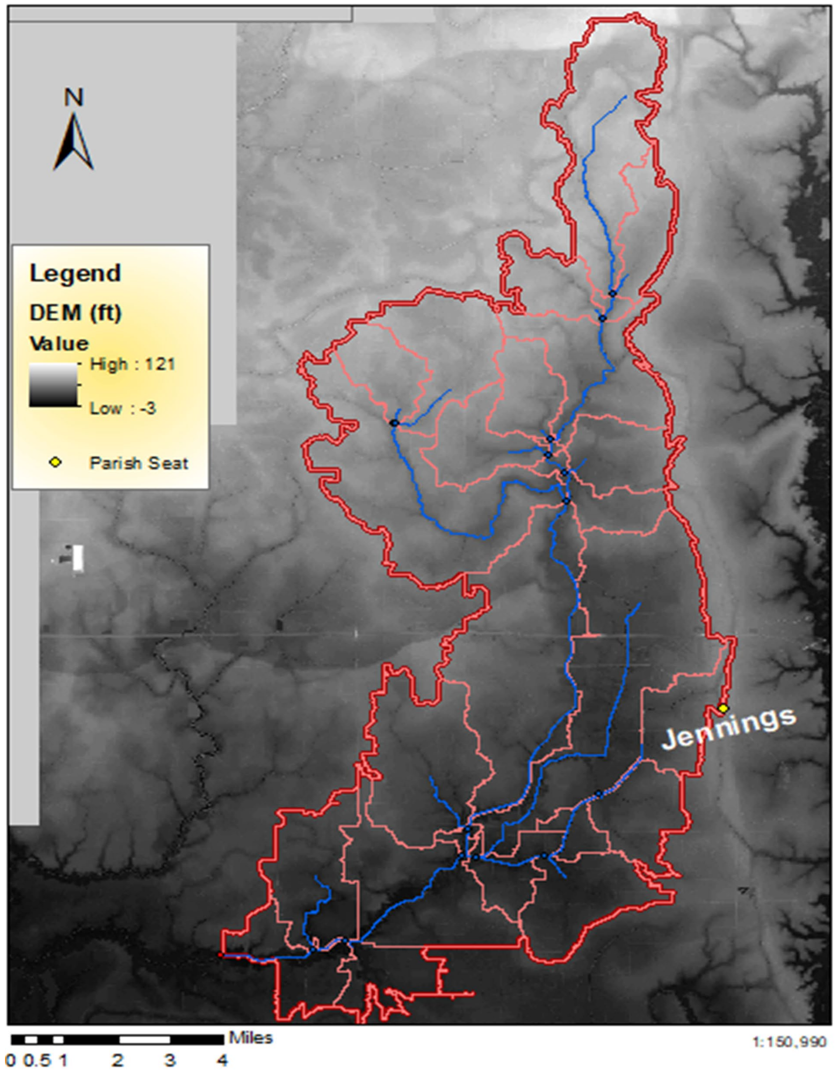

Sediment hotspots in Coulee Baton microwatershed
B
M
Ps
N
High
Low
Low
High
High
High
Medium
0 550 1,100 2,200 Meters

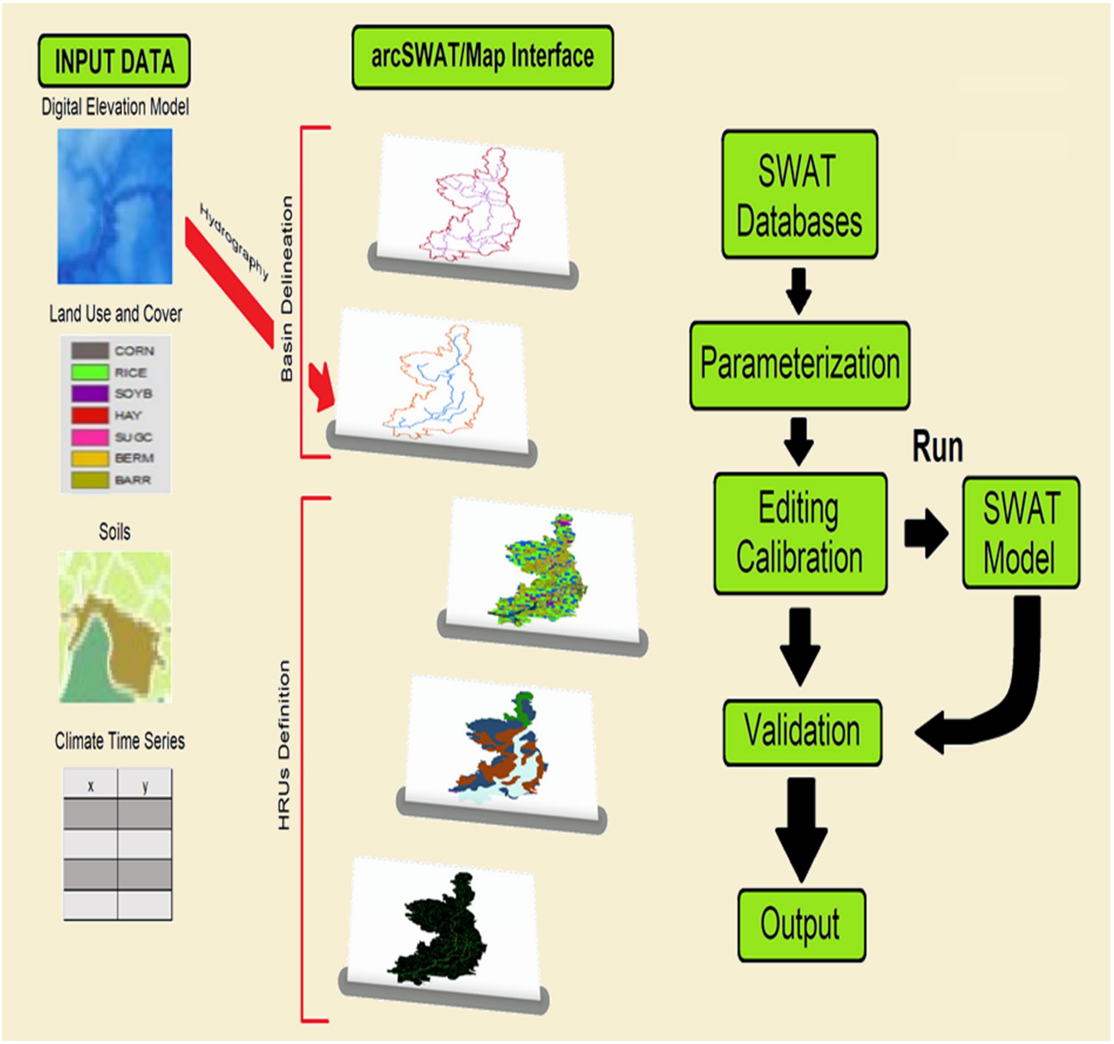
- Drainage networks especially drainage pipes, ditches, and rice fields, were difficult to model.

- Water flows everywhere after a big rain event in flatlands like Coulee Baton area.

- It seems that microwatersheds especially in flatlands like those in Louisiana are difficult to model with the earlier version of SWAT.

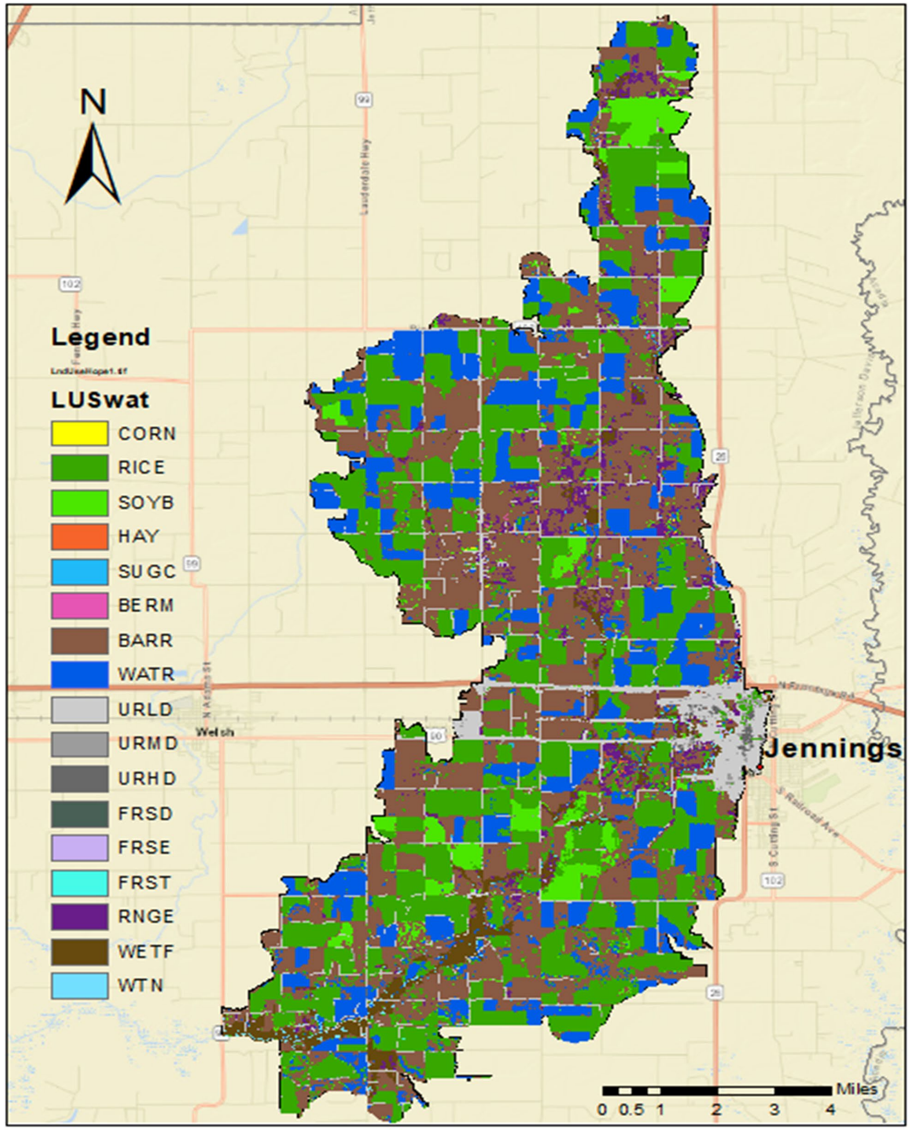
Bayou Chene Watershed, Louisiana





Muir et al., 2017

2016 Landuse in Bayou Chene



Methods and Model Process

•Previous data collection took place at 10 sample sites on weekly intervals; discharge measured using Son Tek RiverCAT from a stationary boat

•Weekly data sampled from 2012-2017 will be used to calibrate and validate the arcSWAT model

•Discharge data is sparse and will need to be extrapolated via regression analysis

OBJECTIVES:

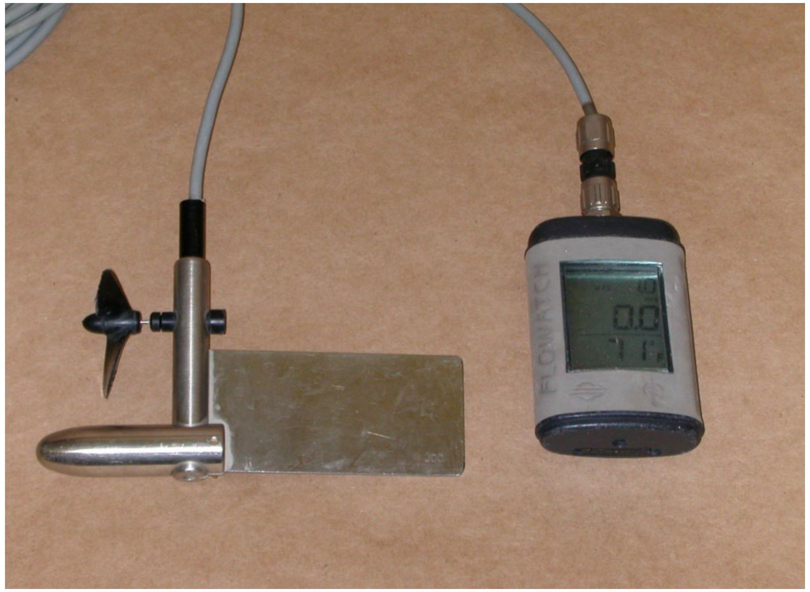
- Establish linkages from land use and water quality
- Find critical areas of agricultural NPS pollution within the watershed
- Rank priority management areas (PMAs) for potential improved resource allocation or cost-utility ratio

CHALLENGE:

- Discharge is the key input variable for the SWAT model. The obvious error within this model stems from extrapolating or making artificial predictions in which the model will run on the extrapolation technique, not the data.

Muir et al., 2017

Discharge measurement



Coastal Basins of Louisiana

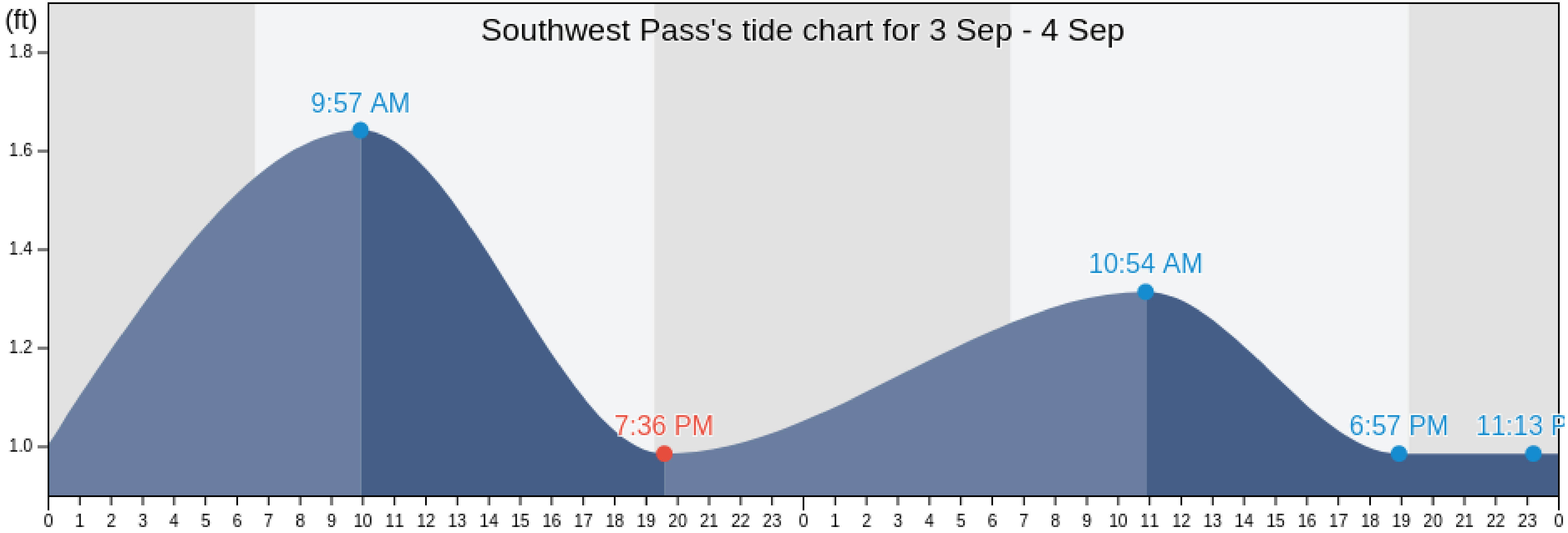
COASTAL PROTECTION AND RESTORATION AUTHORITY
CPRA
www.coastal.la.gov

On-going Graduate Student's Projects:

1) Climate change effects on water resources in the Gulf Coast
2) Climate change and anthropogenic impact on coastal hydrology
3) Effects of Climate Change on Soils especially on nitrogen, phosphorus and salinity levels across Louisiana Coastal Basins
4) Dissolved Oxygen profiles in oyster reefs in Louisiana Coast

Extreme rain events and flooding

Tidal Influences



Source: https://www.tideschart.com/United-States/Louisiana/Plaquemines-Parish/Southwest-Pass/#google_vignette

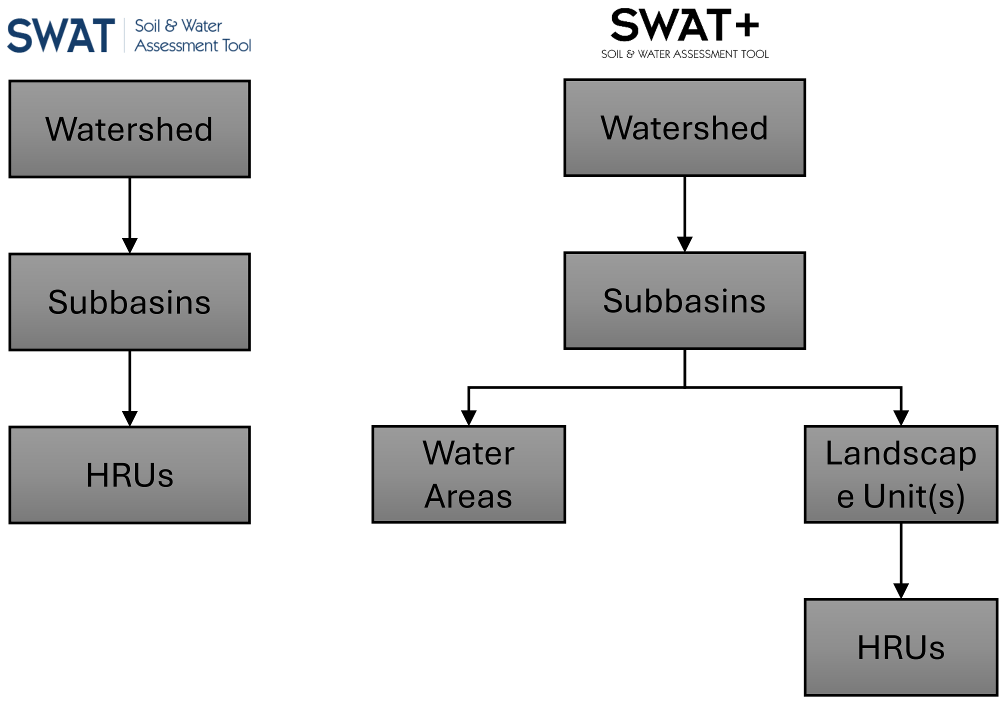
Literatures on the application of SWAT model in understanding coastal environmental processes:

1) There exist a lot of publications on SWAT application in coastal environment.

1) Upadhyay, P., A. Linhoss, C. Kelble, S. Ashby, N. Murphy, and P.B. Parajuli. 2022. Application of the SWAT model for coastal watersheds: Review and Recommendations, Journal of the ASABE. 65(2): 453-469. (doi: 10.13031/ja.14848) (**Recommendation-coupling SWAT with a hydrodynamic model to simulate tidal influences**).

SWAT+ for modelling coastal process

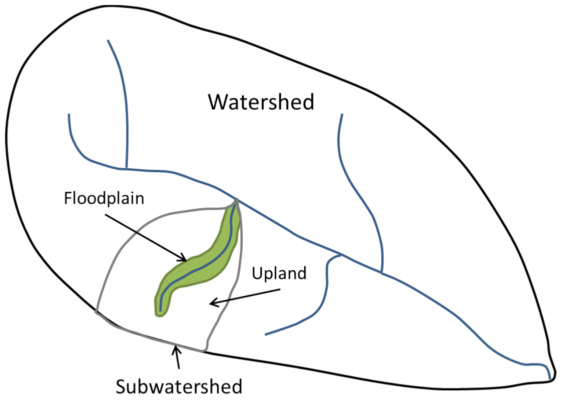
Watershed Configuration in SWAT+



- Improved simulation of landscape position, overland routing, and floodplain processes
- More realistic simulation of water areas

Landscape Units

- Hydrologic landscape units are elements of a (sub)watershed that are defined to account for landscape position

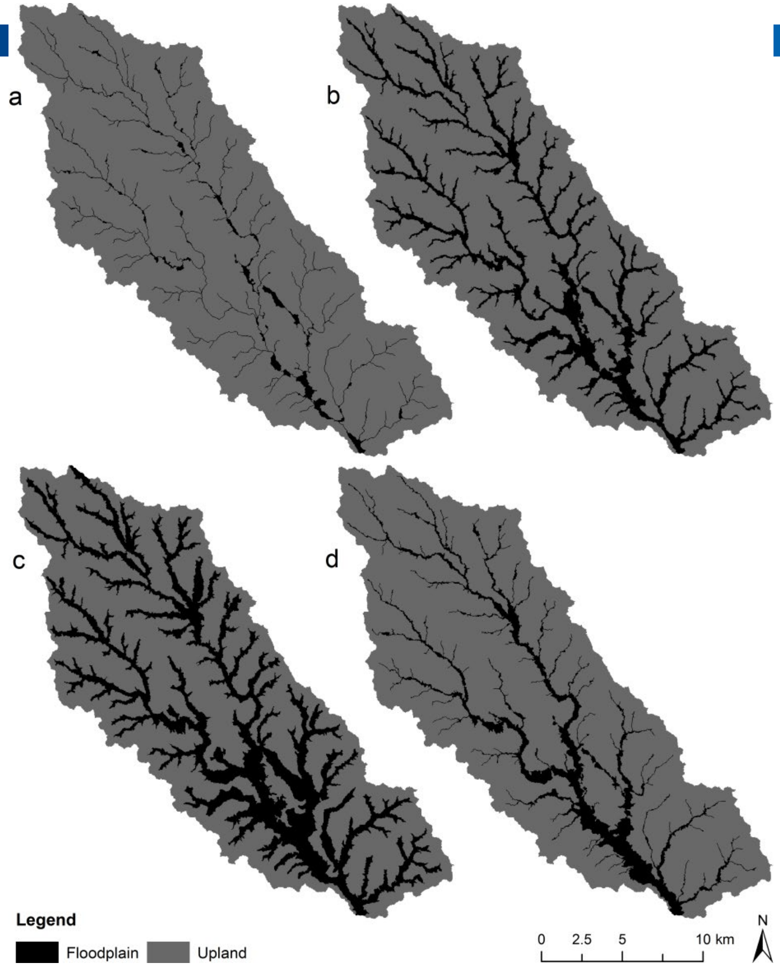


- Two landscape units in SWAT+:
  - Uplands and floodplains
  - Different hydrologic properties and processes (slope, storage, sediment processes)

Landscape Unit Delineation

SWAT+
SOIL & WATER ASSESSMENT TOOL

- Delineation methods:
  a) Topographic Wetness Index
  (Beven and Kirkby, 1979)
  b) Slope Position
  (USDA Forest Service, 1999)
  c) Uniform Flood Stage
  (Williams et al., 2000)
  d) Variable Flood Stage
  (Nardi et al., 2006)

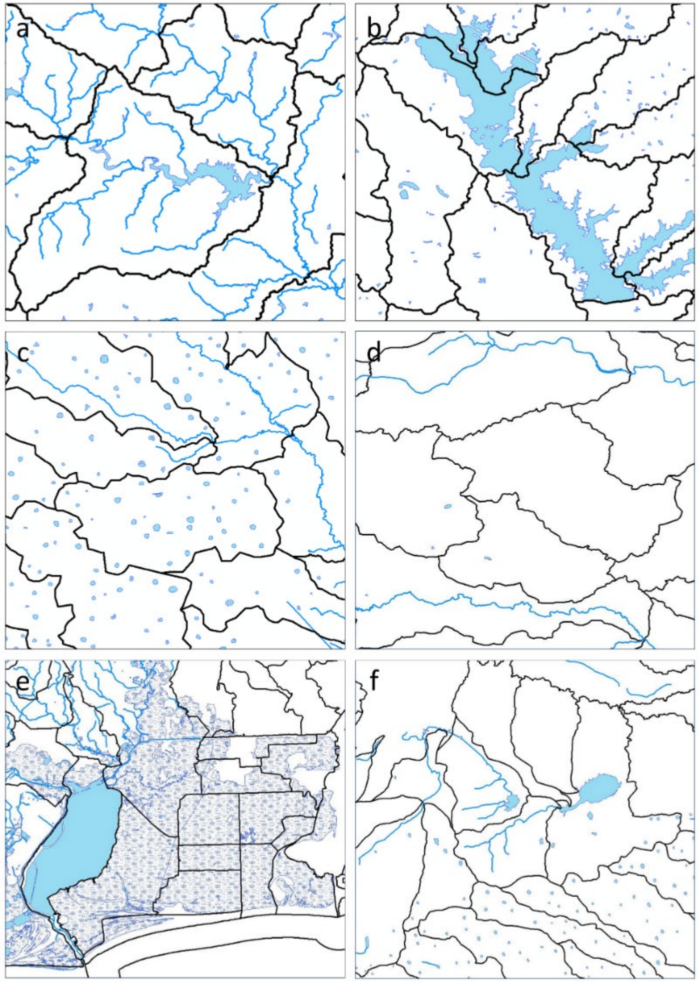


Rathjens et al., 2016. Delineating floodplain and upland areas for hydrologic models - A comparison of methods. Hydrological Processes 30(23):4367-4383.

Watershed Hydrography

Representation of various types of watershed hydrography facilitated by SWAT+ connect files:

a. Subbasin with reservoir at outlet
b. Reservoirs spanning multiple subbasins
c. Playa lakes and potholes
d. No water features in subbasin
e. Swamp/marsh covering entire subbasins
f. Unconnected drainage



Thank you for your attention.

Any questions?