Assessing and predicting in-stream processes in the Catalpa Creek watershed

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1. Summary

Hypothesizing in-stream processes are important mechanisms driving sediment supply into the streams and an important portion of the sediment budget for the Catalpa Creek Watershed, this research will focus on the identification, assessment, evaluation and prediction of in-stream processes within the study watershed. To address the research objectives three studies are undertaken using a combination of methods including field reconnaissance and detailed data collection, laboratory analysis, and channel modeling. Modeling results can help to determine critical areas to be potentially considered for future management and restoration activities, as well as to optimize a design for a desired outcome and to understand what results might be expected. The project has been subdivided in three studies oriented to respond specific objectives related to the spatial variation and change of sediment loads, the occurrence of in-stream processes and the capability of the models to predict streambank erosion and instabilities for the study area. The project involves important collaborative efforts with MSU faculty members from other departments and institutes and from state and federal research and education institutions. The training of students with different levels of involvement has been of fundamental support to the performance of the project. Project results will be transferred to a broad group of academic, technical and research stakeholders, supported in collaboration with private, federal and state agencies.

2. Accomplishments

Study 1. Analysis of spatial and temporal variation of suspended sediment transport rates and initial assessment of dominant mechanisms driving sediment supply and exportation for the Catalpa Creek.

- Weekly data collection was advanced along 40 stations in the main stream and three headwater tributaries, in order to quantify stream hydrologic and hydraulic characteristics (flow velocity and depth), water quality characteristics (pH, turbidity, temperature, total dissolved solids) and collect grab water samples for assessing total suspended concentrations.
- Automatic samples were collected at two stations along the main stream, in which an ISCO auto sampler and an area-velocity device were installed.
- Biological assessment of two tributaries to identify spatial and temporal distribution of macroinvertebrates along studied reaches was advanced during spring, summer and fall 2018.

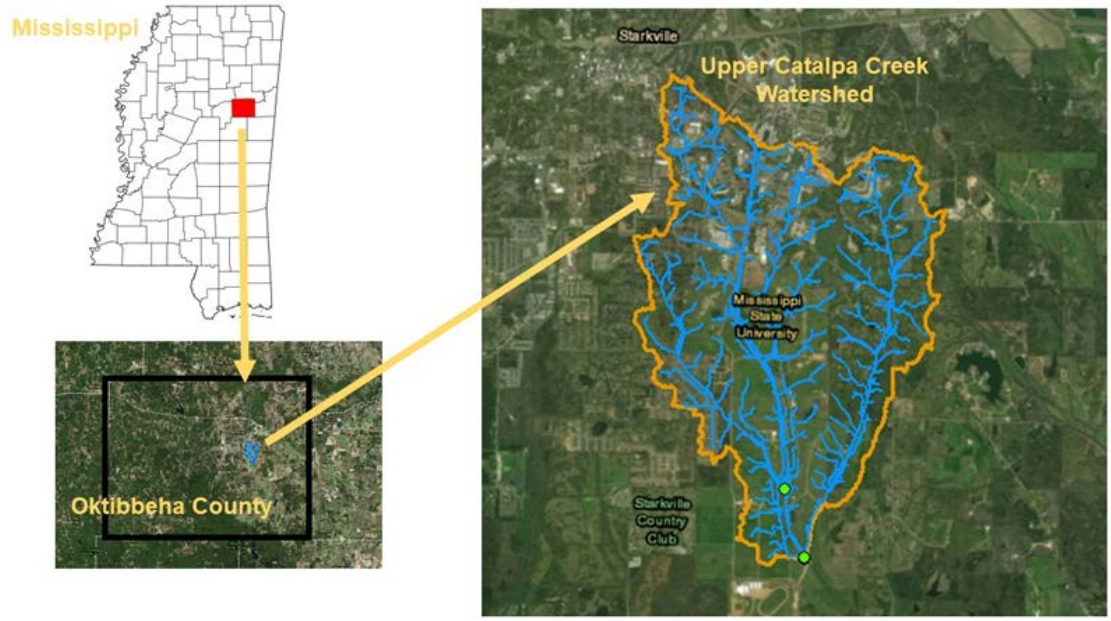

Figure 1. Catalpa Creek Watershed

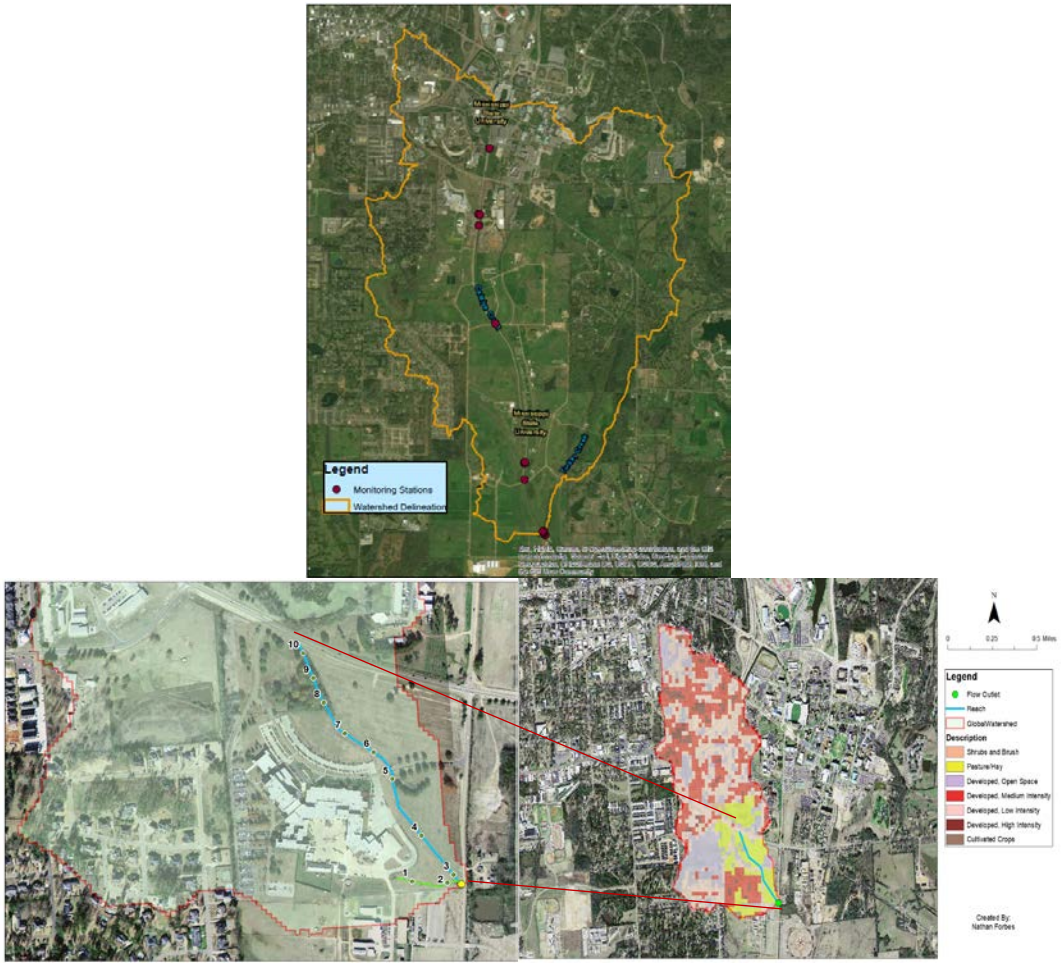

Figure 2. Location of monitoring stations along main stream (up) and a headwater tributary (down) of the Catalpa Creek

Figure 3. Stream monitoring and laboratory analysis

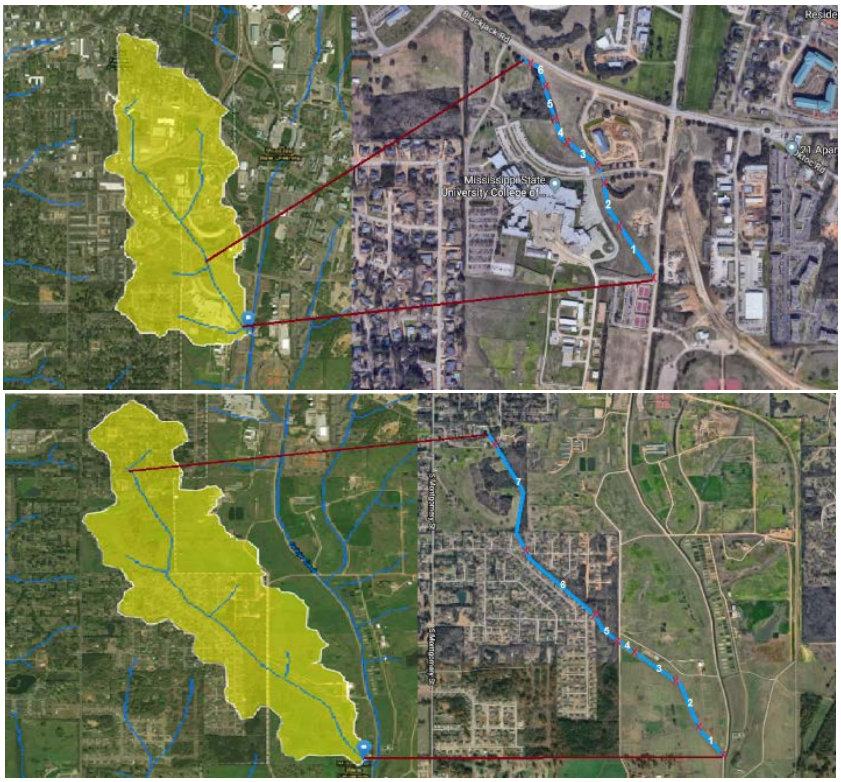

Figure 4. Location of biological monitoring segments along headwater tributaries of Catalpa Creek

Figure 5. Biological assessment along tributaries

Study 2. Assessment of in-stream erosion or deposition rates along the main channel reach and main tributaries.

- Cross sections along the upper four miles of the main stream and tributaries were periodically surveyed in collaboration with researchers from the Landscape Architecture, the Geosystem Research institute (GRI) and the Mississippi Agricultural and Forestry Experiment Station (MAFES). Corrections of the field procedures were taken in consideration to properly compare changes in monitored cross sections. Spatio-temporal changes in channel morphology are evaluated to quantify erosion and sediment deposition rates along streambanks and streambed.

Figure 6. Cross sections survey.

Study 3. Assessing the application of the computational model BSTEM and HEC-RAS, to predict in-stream processes within the Catalpa Creek watershed, and evaluate stream restoration design scenarios.

- In order to setup the HEC-RAS and BSTEM models to evaluate streambank erosion and instability, some streambank material characteristics related to water movement (grain size distribution, bulk and particle density, porosity, permeability), resistance to erosion (critical shear stress and erodibility) and resistance to failure (cohesion, friction angle, suction angle) were estimated and determined.
- A one dimensional hydraulic and sediment transport model was setup in HEC-RAS. This USA Corp of Engineers tool was recently enhanced with routines from the models BSTEM and CONCEPTS models to build its capability to predict streambank erosion analysis. This capability is tested in this project to advance the study performance.

Student Training.

- Student involvement played a significant role in the performance of this project and related collaborative efforts. Two graduate students and 14 undergraduate students from three different departments were involved in the different activates of the project working as graduate research assistants, undergraduate researchers sponsored by the Bagley College of Engineering, MAFES, MWRRI, and as undergraduate researchers advancing Directed Individual Study or volunteering their work. All listed students became members of the Watersheds and Water Quality Research Lab (http://www.cee.msstate.edu/wwqrl/).

  1. James Grafe (Fall 2017 to Fall 2018) - MS Student, Civil and Environmental Eng.
  2. Bradley Richardson (Fall 2017 to Fall 2018) - PhD Student, Wildlife, Fisheries & Aq.
  3. Taylor Noble (Fall 2017 to Fall 2018) - Senior Civil and Environmental Eng.
  4. Shanika Musser (Spring 2018 to Fall 2018) - Junior Civil and Environmental Eng.
  5. Ryan Horton (Fall 2018) - Junior Civil and Environmental Eng.
  6. Andre Remedios (Fall 2018) - Senior Civil and Environmental Eng.
  7. Geneva Cattle (Spring 2018) - Senior, Agricultural and Biological Eng.
  8. Jennifer Deignan (Spring 2018) - Senior, Civil and Environmental Eng.
  9. Claire Ray (Spring 2018) - Senior, Civil and Environmental Eng.
  10. Germaine Cole (Spring 2018) - Senior Chemical Eng.
  11. Diana Linder (Fall 2017 to Spring 2018) - Senior Civil and Environmental Eng.
  12. Jim Steele (Fall 2017) - Senior, Civil and Environmental Eng.
  13. Harley Wilkinson (Fall 2017) - Senior, Civil and Environmental Eng.
  14. Taylor Buie (Fall 2017) - Senior, Civil and Environmental Eng.
  15. Ben Spiller (Fall 2017) - Senior, Civil and Environmental Eng.
  16. Nathan Forbes (Fall 2017) - Senior, Civil and Environmental Eng.

- Catalpa Creek watershed is an experimental laboratory used by different instructors in their academic exercise. Under that premise, more than 50 students enrolled in the courses Open Channel Hydraulics and Stream Reconnaissance in fall 2017, and Engineering Hydrology in spring 2018 advanced some studies (listed below) that guided or supported the development and evaluation of the models prepared in the execution of this project.

  - Hydrologic characterization of different reaches and the main stream within the Catalpa Creek watershed involving the use of the hydrologic model HEC-HMS.

  - Analysis of stream functionality and preliminary stream restoration design for headwater tributaries of the Catalpa Creek, involving the use of the models HEC-HMS and HEC-RAS.

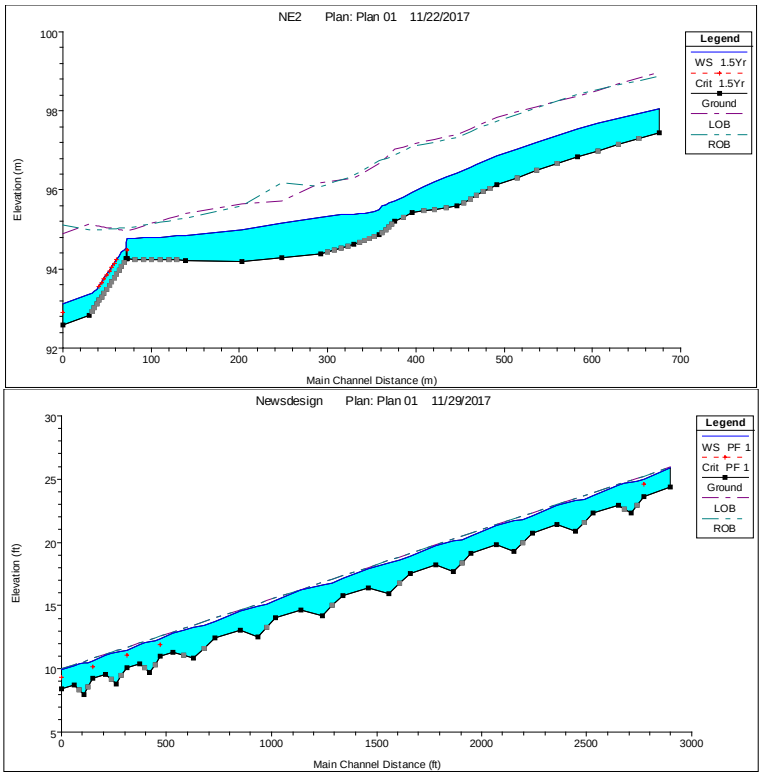

Figure 7. Example of hydraulic analysis of stream restoration designs in HEC-RAS proposed by students in the Stream Reconnaissance course (fall 2017).

- From the group of students involved in research (listed above), four poster/oral presentations were performed at the MSU Undergraduate Research Symposium, two at the 2018 Environmental and Water Resources Conference (ASCE-EWRI) including their corresponding proceedings, and one at the Mississippi Water Resources Conference (MWRC). James Grafe awarded a second place for his oral presentation at the MWRC. Similarly, James Steele awarded second place for his manuscript submitted to the ASCE-EWRI conference.
- Graduate Research Assistant James Grafe was supported by the project from January to August 2018. He continues to be supported by the Civil and Environmental Engineering Department through the fall semester 2018 and spring semester 2019. The corresponding thesis research “Assessment of in-stream processes in the Catalpa Creek headwaters” is in progress and expected to be submitted in February 2019 as a fulfillment requirement for graduation in May 2019.
- In collaboration with the Mississippi Wildlife Federation and the MSU Chapter of the Soil and Water Conservation Society (SWCS), two hands-on trainings oriented to teach participants about fundamental concepts of hydrology, water quality and stream health were performed during the fall semester in 2017 and 2018. Approximately 30 MSU students from different departments, and four students and one faculty from the Columbus High School participated in the training sessions lead by Mrs. Debra Veeder and John Ramirez-Avila.

Figure 8. Hands on training performed in collaboration with MWF and SCWS in October 2017

Figure 9. Hands on training performed in collaboration with MWF and SCWS in November 2018

3. Results

- Spatial variation of sediment concentrations and some water quality parameters (i.e. pH, DO, TDS and temperature) were identified due to differences in vegetation present along riparian corridors.
- Increase in sediment concentrations were notorious in stations adjacent to building constructions in progress.
- Not much seasonal difference in sediment concentrations under baseflow conditions due to the flashy behavior of the streams. Variability of sediment concentration and loads in tributaries and main stream driven by stormflow events, especially observed in winter and spring.
- Landscape management (i.e. mowing and landscape maintenance) could be a factor driving the differences in sediment concentrations and loads along streams. Additional correlation analysis should be completed.
- Very weak relationship between sediment concentrations and loads with stream water turbidity were observed at upstream stations on the main channel, which directly receive runoff flow from campus. Relationship improves for downstream stations with a dominant land use of pastures.

Figure 10. Changes in flow and sediment transport along a headwater tributary (up) and the main stream (down) of Catalpa Creek before, before, during and after a stormflow event.

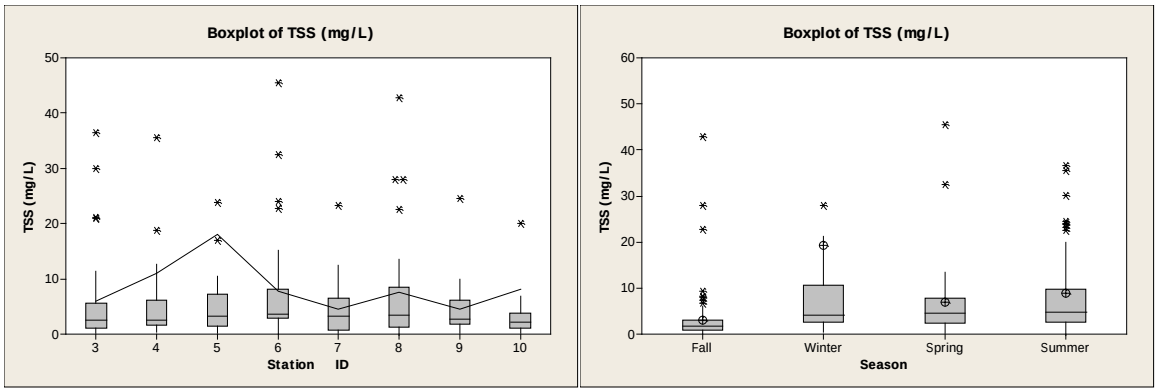

Figure 11. Spatial and temporal variation of sediment concentrations along a headwater tributary of Catalpa Creek

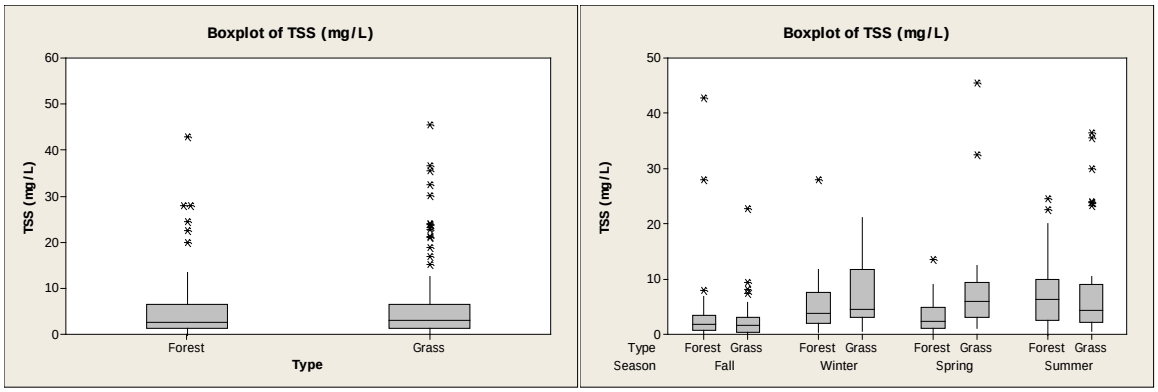

Figure 12. Concentrations of suspended sediments in forested and grassed riparian zones along a headwater tributary of Catalpa Creek

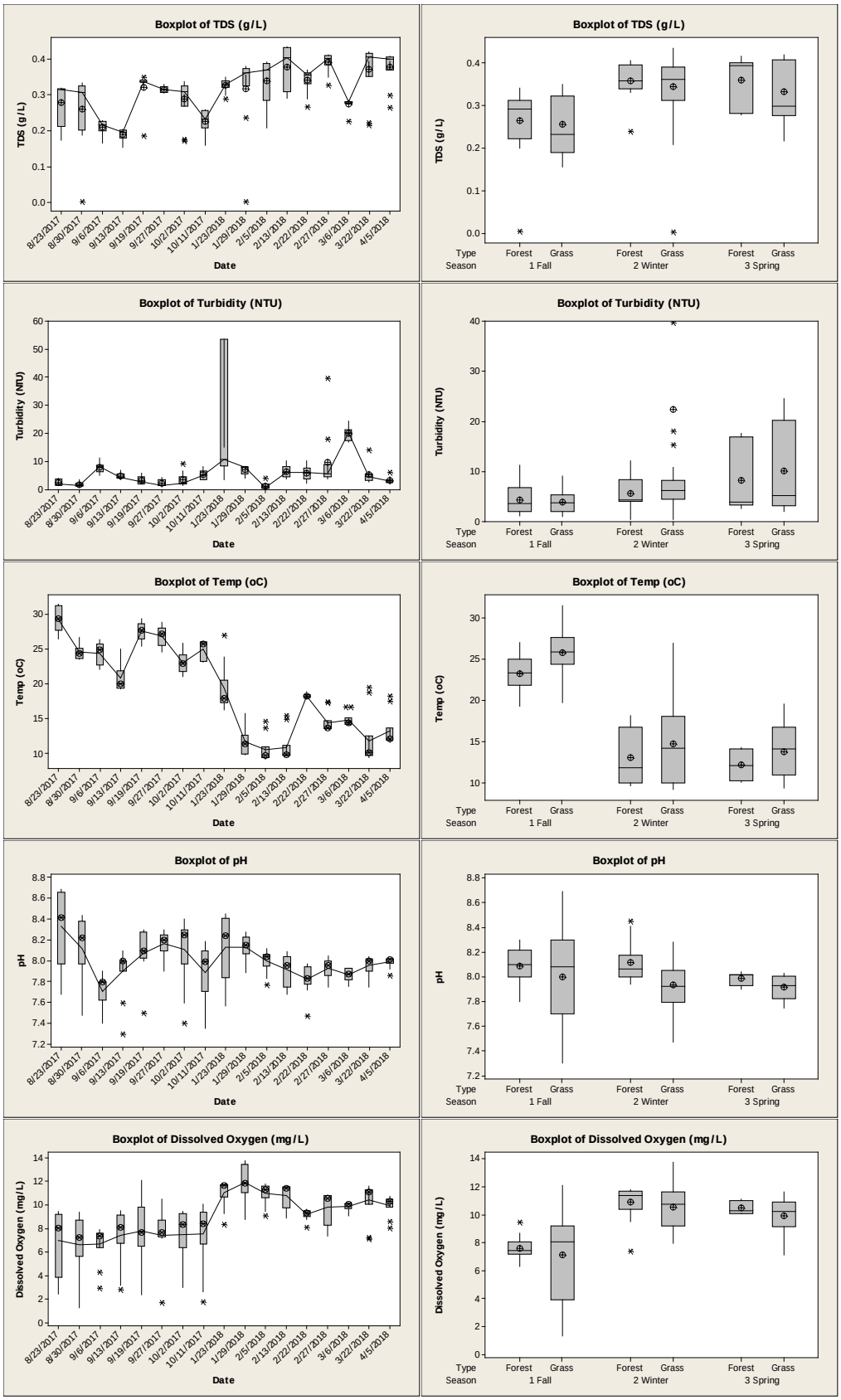

Figure 13. Temporal variation and changes on water quality parameters due to riparian vegetation along a headwater tributary of the Catalpa Creek

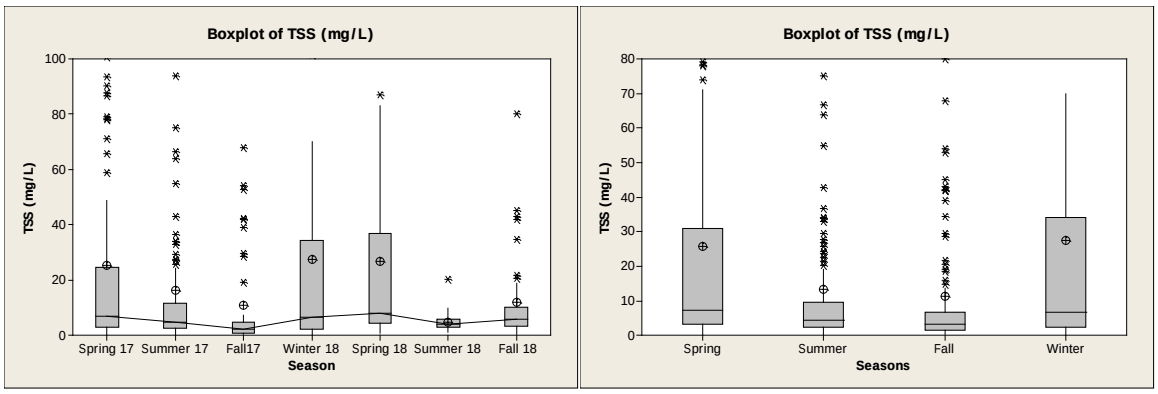

Figure 14. Seasonal variation in suspended sediment concentrations along the main channel of Catalpa Creek

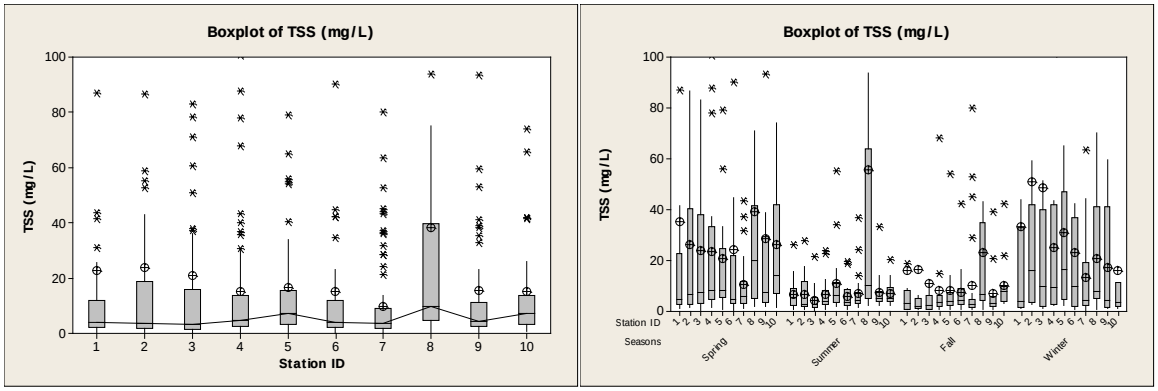

Figure 15. Spatial and seasonal variation in suspended sediment concentrations along the main channel of Catalpa Creek (Station 10 is waterhed outlet)

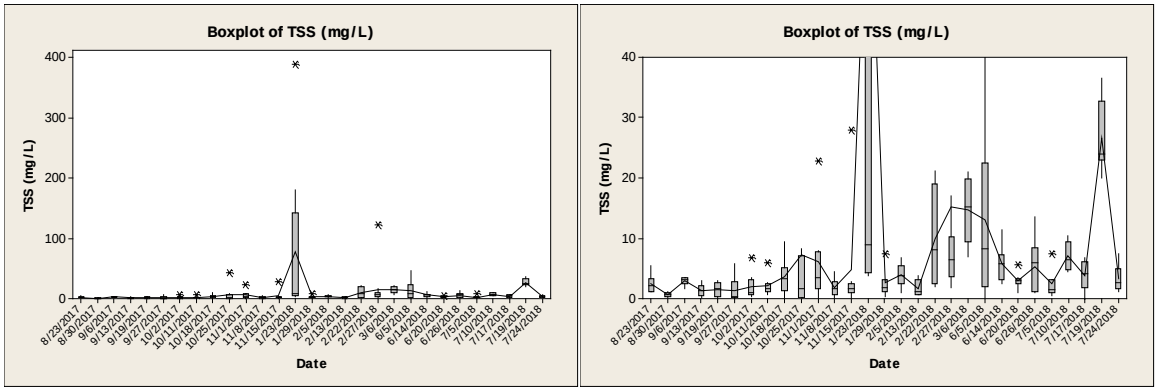

Figure 16. Temporal variation in suspended sediment concentrations the main channel of Catalpa Creek

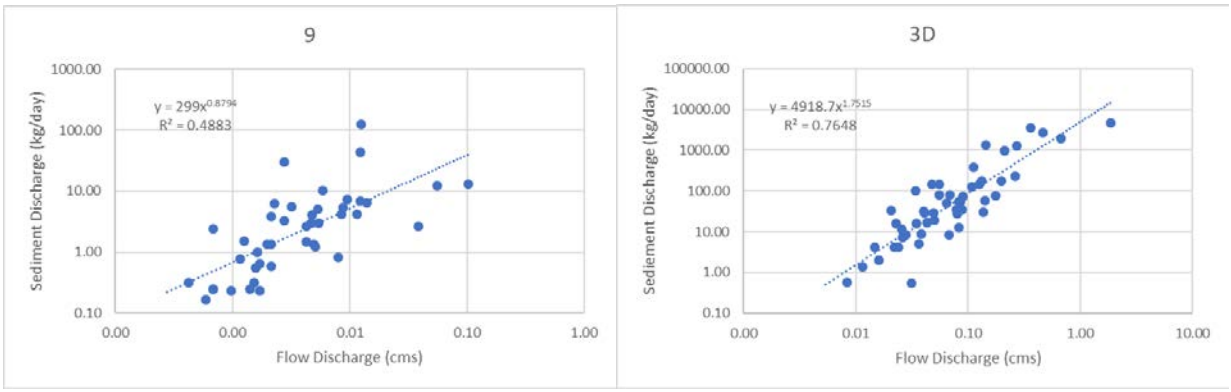

Figure 17. Relationships between sediment concentrations and turbidity for an upstream and a downstream station along the main channel of Catalpa Creek

- Biological monitoring indicated variability of the number of macroinvertebrates that are very tolerant to pollution is seasonally affected trending to increase with warmer stream water temperatures.
- Pollution Tolerance Index (PTI) indicates that more than 90% of the assessed reach segments were rated as Excellent, which indicates that most of the time and along most of the segments on the surveyed streams, did not predominate organic pollution.
- Further analyses are be advanced to determine proper relationships between PTI ratings and monitored water quality parameters.

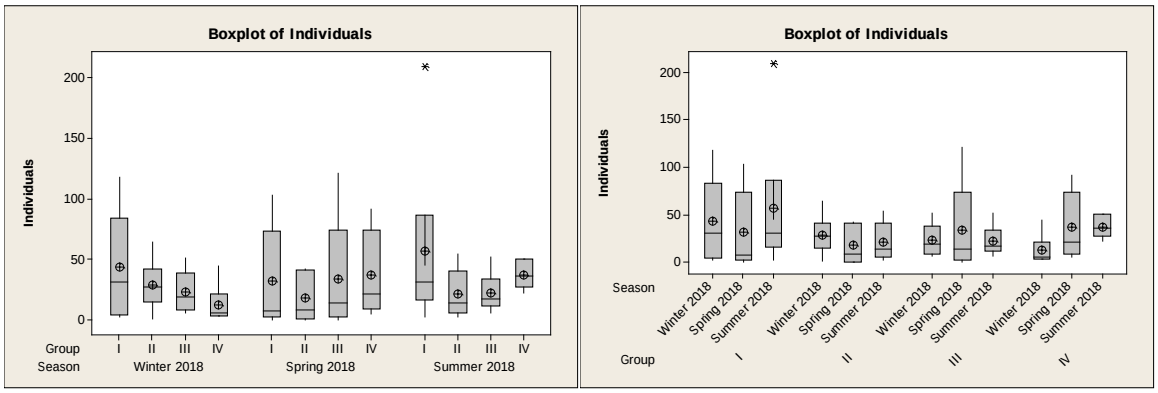

Figure 18. Seasonal variability of the number of macroinvertebrates from different pollution tolerance groups along a headwater tributary of Catalpa Creek

- Stream reconnaissance evidenced active streambank and streambed degradation along upstream stations and tributaries. Deposition of gravel from adjacent road is observed along the lower 1-mile (approximately) of the main stream segment studied for this project.
- Gravitational failures were identified as the dominant process contributing sediments to Catalpa Creek during stormflow events.
- Results and field observations evidenced high contributions of streambank material (up to 10 Mg per m streambank per year) and important morphological changes in streambed and streambanks (up to 2-m of retreat) in different locations along the main stream and tributaries of Catalpa Creek.

Figure 19. Upper picture evidences initial coarse material aggradation and posterior streambank toe and streambed degradation (erosion). As a reference, the rock in the middle part of the image was fully covered by sediment at the beginning of the study. Lower picture evidences streambank instabilities along the main stream of Catalpa Creek.

Figure 20. Progressive streambank instabilities and erosion after removal of culvert at the joint of a headwater tributary with main stream of Catalpa Creek.

Figure 21. Planar failure along headwater tributary

- As a component of the collaborative work advanced with Dr. Tim Schauwecker and Dr. Joby Czarnecki, the HEC-RAS model has been setup to evaluate hydrologic and hydraulic responses from different return period rainfall events within the entire watershed area. The tool is used to develop a sediment transport model along the main stream. In addition, the latest version of HEC-RAS (V. 5.0.2) includes routines to evaluate streambank instability and toe erosion from the models BSTEM and CONCEPTS. We are still working with Dr. Eddy J. Langendoen, developer of CONCEPTS, to complete the streambank erosion modeling task of the project.

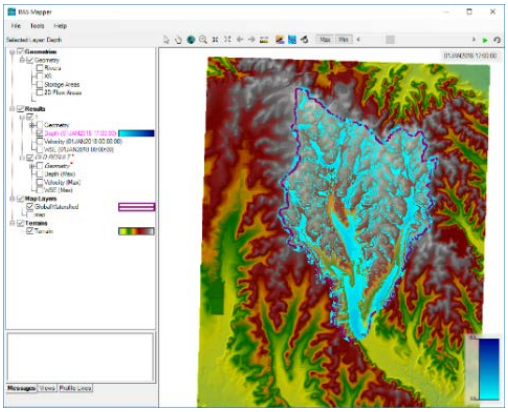

Figure 22. HEC-RAS model for headwaters areas of Catalpa Creek

4. Future Plans

- The Master thesis titled “Assessment of In-Stream Processes in Catalpa Creek Headwaters” is still in progress and expected to be published in May 2019.
- One peer reviewed journal paper is expected to be published from this effort as a product to fulfill graduation requirements.
    - In-stream processes within the Catalpa Creek. James Grafe, John J. Ramirez Avila, Tim Schuwecker, Joby Czarnecki, Sandra L. Ortega Achury, James L. Martin, Eddy J. Langendoen.
- Six presentations involving the different studies associated to this project were submitted to different regional (i.e. 2019 MWRRI) and national (i.e. EWRI 2019) conferences in 2019.
- Two student papers summarizing different components of our project results will be submitted in January 2019 to the ASCE-EWRI Undergraduate Student Paper contest.
    - Benthic macroinvertebrate diversity and water quality of Catalpa Creek in Mississippi. Taylor Noble, Bradley Richardson, Shanika Musser, Sandra L. Ortega Achury, John J. Ramirez-Avila
    - Influence of riparian vegetation on stream health and water quality. Shanika Musser, James Grafe, Sandra L. Ortega Achury, John J. Ramirez Avila
- At least two peer reviewed journal papers are in preparation.
    - Spatio-temporal variability of sediment concentrations and loads along the Catalpa Creek. John J. Ramirez-Avila, Sandra L. Ortega-Achury, Tim Schauwecker, Joby Czarnecki.
    - Understanding the Riparian Buffers in Mississippian Streams: Effects on nutrient loads. Sandra L. Ortega-Achury, John J. Ramirez-Avila, James L. Martin.

5. Publications

Conference Presentations and Posters (7)

1. Ramirez-Avila, J; T. Schauwecker; J. Czarnecki; S.L. Ortega-Achury; E.J. Langendoen and J.L. Martin. 2018. Identification and assessment of stream processes within the Catalpa Creek in Mississippi. Ecostream Conference. Asheville, NC. Poster Presentation.
2. Schauwecker, T.; J.J. Ramirez-Avila; J. Czarnecki, J; B. Baker. 2018. Hydraulic and vegetative modeling for the restoration design of the upper reach of Catalpa Creek, an impaired stream in northeast Mississippi. 2018 National Conference on Ecosystem Restoration. New Orleans, LA. Poster Presentation.
3. Ramirez-Avila, J.J., T. Schauwecker, J. Czarnecki, E. Langendoen, S. Ortega-Achury & J. Martin, 2018. Quantifying and Modeling in-Stream Processes: A first step to restore the Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation.
4. Ramirez-Avila, J. J.; T. Schauwecker; J.L. Martin; S.L. Ortega-Achury & J.M. Prince Czarnecki. 2018. A Project Based Learning Study Oriented to Develop a Natural Stream Restoration Design. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.
5. Ramirez-Avila, J. J.; J. Grafe; T. Schauwecker; J.M. Prince Czarnecki. S.L. Ortega-Achury; J.L. Martin & T. Noble. 2018. Impacts of Riparian Buffer Zones on Stream Water Quality: A Quantitative Assessment in the Catalpa Creek Watershed. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.
6. Ramirez-Avila, J.J., E. Langendoen, T. Schauwecker, S. Ortega-Achury, J. Czarnecki, W. McAnally and J. Martin. 2017. Estimación y predicción de descargas de sedimentos y tasas erosión de bancos fluviales. Invited Speaker. 1st International Congress of Rivers and Wetlands. Neiva, Colombia. (Invited Speaker). Oral Presentation.
7. Ramirez-Avila, J. J. 2017. Sediment Budget: From Hillslope to in-Stream Processes. 2017 ASA, CSSA, and SSSA Annual Meeting. Symposium -Managing Water Resources for a Secure Future. Tampa, FL. (Invited Speaker). Oral Presentation.

Students Papers and Presentations (7)

1. Musser, S; J. Grafe; S.L. Ortega-Achury; J.J. Ramirez-Avila. 2018. How Do Grassed Riparian Zones Affect Stream Temperature? MSU Undergraduate Research Symposium. Summer 2018. Poster Presentation.
2. Noble-Cagle, T.; J. Graffe; S.L. Ortega-Achury; J.J. Ramirez-Avila. 2018. Enhancing Water Resources in Mississippi: Effects of riparian zones on stream health and water quality. MSU Undergraduate Research Symposium. Spring 2018. Poster Presentation.
3. Catlett, G.E.; J. Grafe; S.L. Ortega-Achury; J.J. Ramirez-Avila. 2018. Temporal and Spatial Analysis of Water Quality for Catalpa Creek Watershed. MSU Undergraduate Research Symposium. Spring 2018. Poster Presentation.

4. Cooley, G.; J. Grafe; S.L. Ortega-Achury; J.J. Ramirez-Avila. 2018. Impacts of Land Use and Vegetation Corridors in Stream Water Quality. MSU Undergraduate Research Symposium. Spring 2018. Poster Presentation.
5. Steele, J., J. Grafe and J. J. Ramirez-Avila. 2018. Analyzing Suspended Sediment Transport in Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation and Undergraduate Research Paper.
6. Wilkinson, H., B. Spiller, N. Forbes, J. Ramirez-Avila. 2018. A comparison of water quality conditions of stream segments under forested and herbaceous riparian zones. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation and Undergraduate Research Paper.
7. Grafe, J., Ramirez-Avila, J. J., Schauwecker, T., Ortega-Achury, S. L., Prince Czarnecki, J. M., & Langendoen, E. 2018. Understanding Relations between Streamflow, Turbidity, and Suspended-Sediment Concentration in an Impaired Mississippian Stream. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.