Storm Event Analysis at Nested Watershed Scales: Turkey Creek, Santee Experimental Forest, South Carolina

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COLLEGE of CHARLESTON GRADUATE PROGRAM IN ENVIRONMENTAL STUDIES

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ABSTRACT

Coastal areas are expected to see the greatest impact on water resources due to population increase and land development affecting the regional water budget by reducing evapotranspiration, groundwater recharge/discharge, and increase runoff. This project inspected forested watersheds in coastal South Carolina to understand their stream response to storm events. The objectives of this study were to (1) characterize the watershed conditions based on their land use/land cover, soil drainage class, and topography, (2) compare streamflow patterns using seasonal event hydrographs, and (3) compare results of analytical method of storm event hydrograph separation with that of the chemical method using stable water isotopes. Turkey Creek, a third-order watershed (5,240 ha), includes two first-order sub-watersheds. Physical and chemical hydrograph separation techniques and statistical methods were used for storm event analysis. Average annual rainfall for the study period was 1449 mm. The largest mean ROC, DROC, direct runoff to streamflow ratio, and peak flow rate were observed for the smallest sub-watershed (Conifer) and the lowest for the largest watershed (WS78). The largest baseflow to streamflow ratio was observed in WS78. Stable water isotope results show surface water samples isotopically distinct compared to groundwater and rainfall samples. Isotope results indicated baseflow contribution was 58-65% of streamflow in contrast to 35-41% as estimated from the hydrograph separation method. Interpretations of the results suggest that storm response was dependent on the antecedent conditions and soil type in the watershed. Scientists and land managers can use this data to predict runoff changes in areas affected by land development.

RESEARCH QUESTIONS AND SIGNIFICANCE

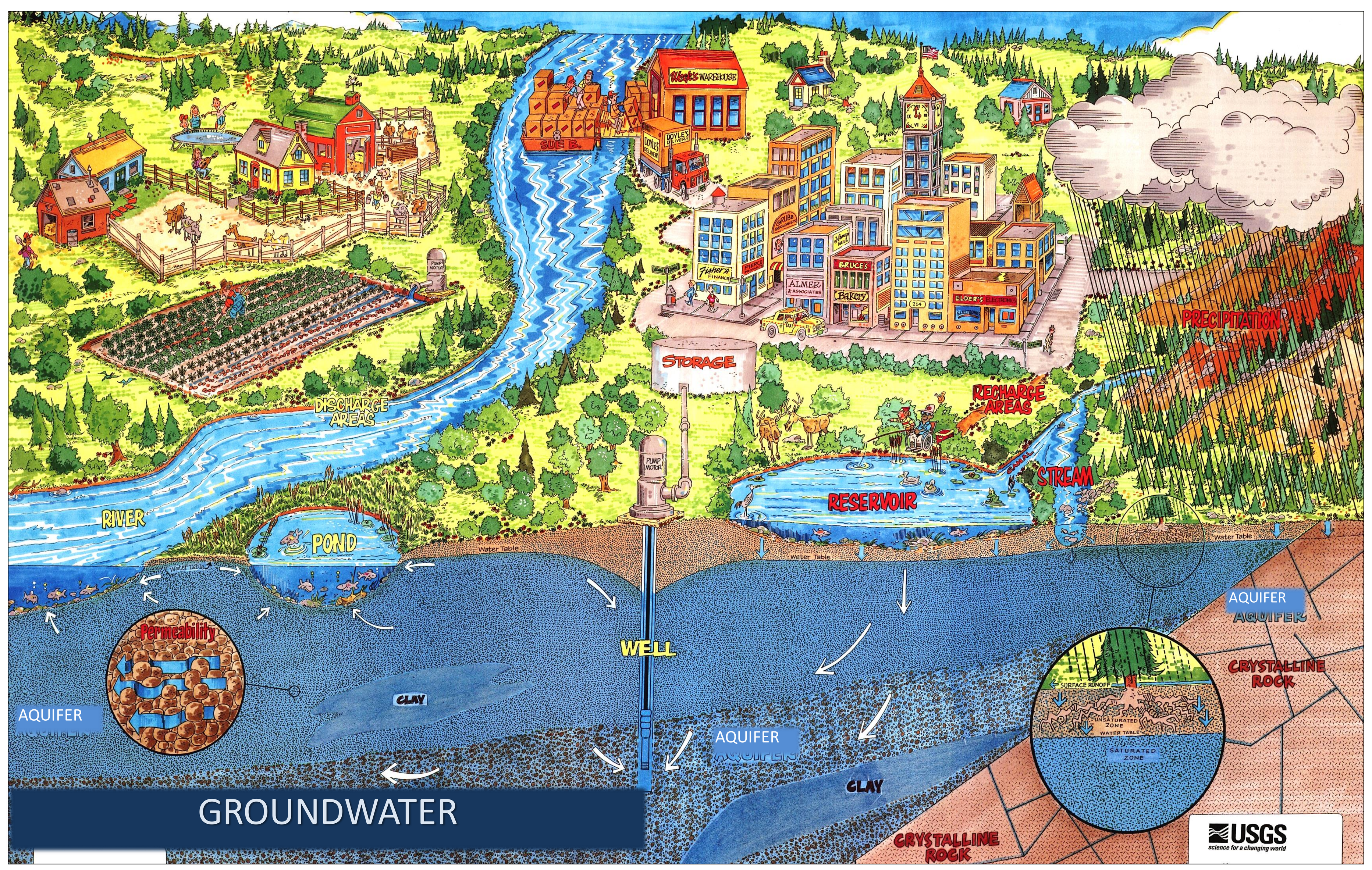


Figure 1. Conceptual diagram showing the movement of water (USGS).

Research Questions:

- What are the effects of spatial-scaling on runoff dynamics in a Lower Coastal Plain forested watershed; specifically how does the runoff response in terms of its magnitude, duration, and timing to storm events at small (<250 ha) first-order watersheds differ from a much larger (5,240 ha) third-order watershed that contains the smaller first order ones, and how do the rainfall-runoff relationships between each of the smaller watersheds and the larger watershed differ?
- What are the key factors influencing the runoff response metrics on the watersheds of varying scales?
- What are the changes in groundwater and surface runoff contribution to streamflow behavior and their timings due to the scaling effects?

Significance

- Population Growth
- Climate Change (Sea Level Rise, Strom Frequency and Severity)

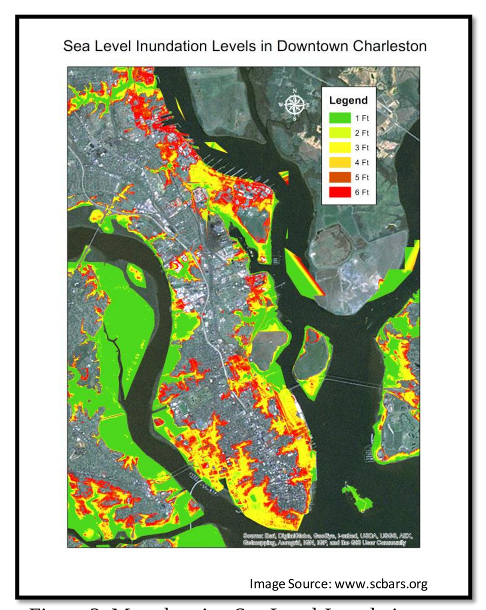
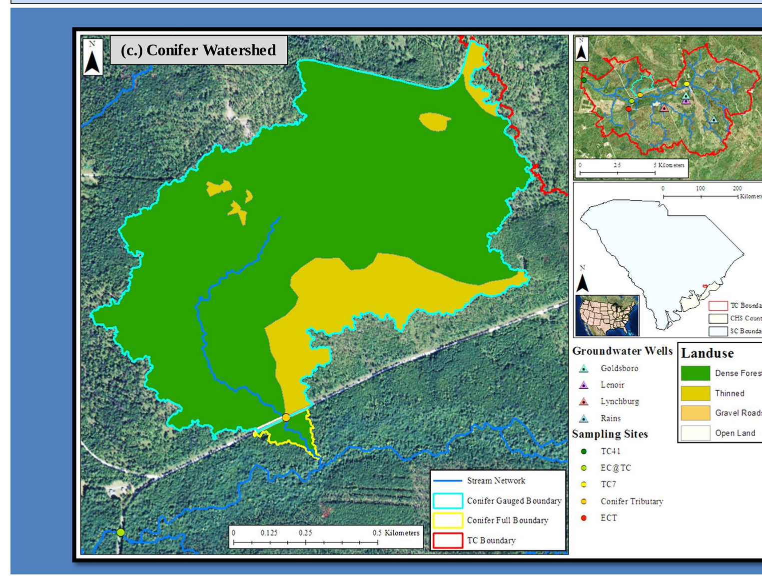


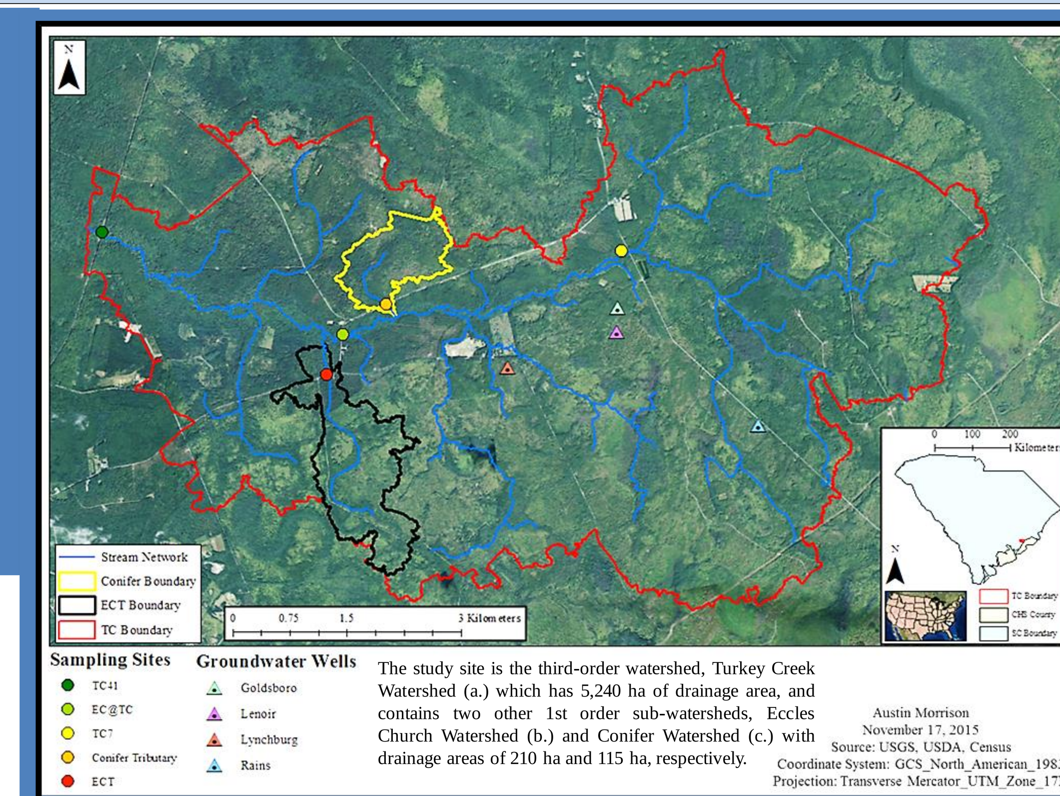
Figure 2. Map showing Sea Level Inundation levels in downtown Charleston, SC


Figure 3. Photo of normal vegetation conditions in Francis Marion National Forest.

Figure 4. Photo of vegetation conditions in Francis Marion National Forest after Hurricane Hugo, 1989.

FIELD SITES





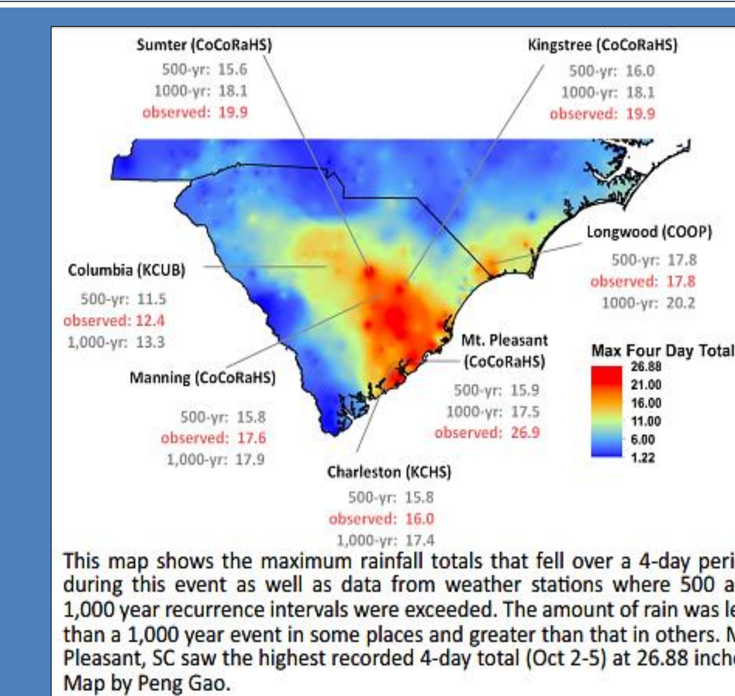
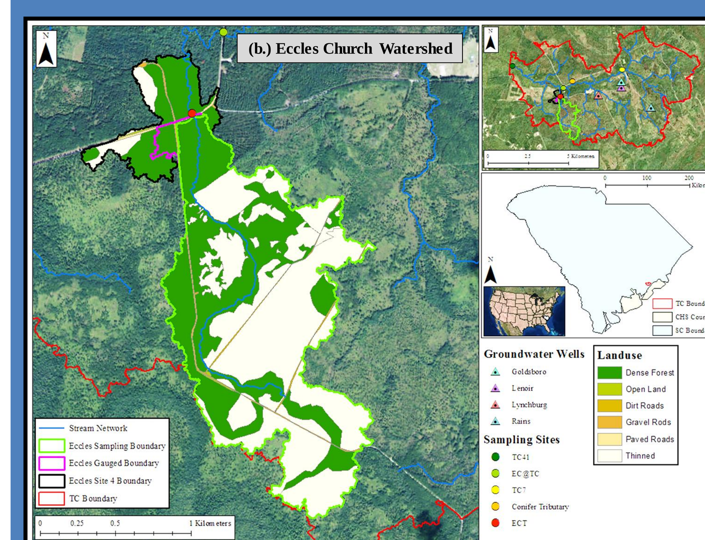


Figure 10. Excerpt from CISA report of the South Carolina Floods of October 2015. (http://www.cisa.sc.edu).



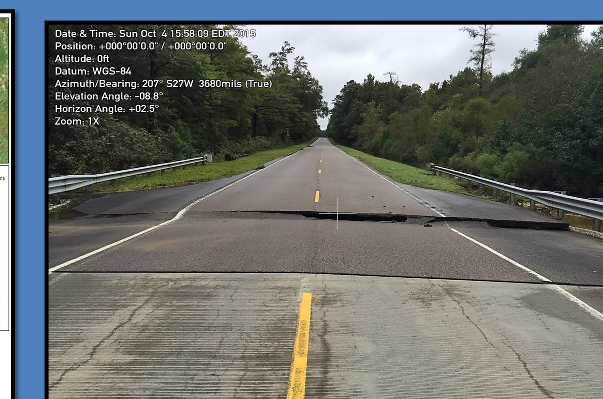


Figure 9. Hwy 41 going over site TC41 (outlet of Turkey Creek watershed) during the October 2015 floods. (Source: Ricky Wrenn, Francis Marion Ranger District, USFS).

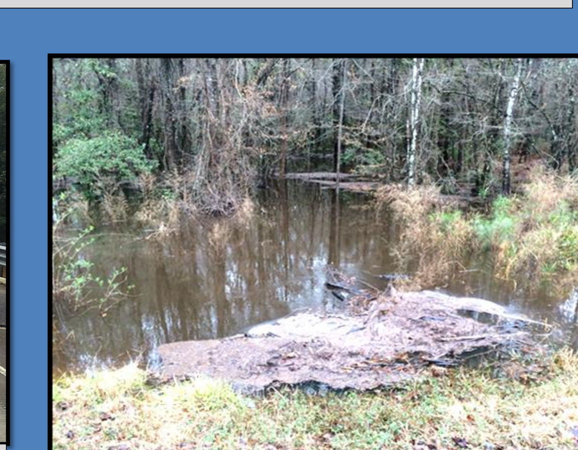


Figure 6. Site ECT in Eccles Church Watershed.

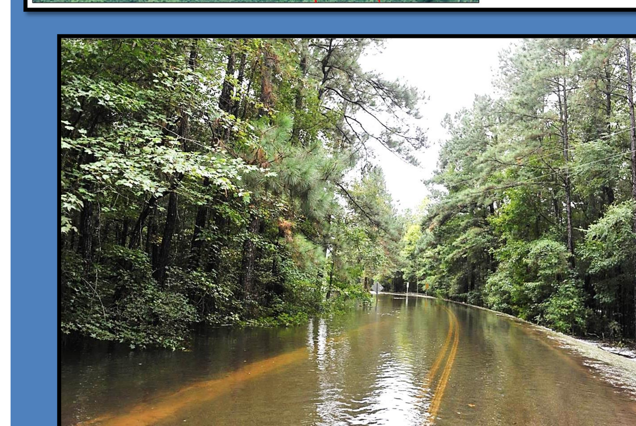



Figure 7 (left). Site EC@TC in Turkey Creek watershed during the October 2015 floods.
Figure 8. (right). Lotti Bridge in FMNF during October 2015 floods.
(Source: Ricky Wrenn, Francis Marion Ranger District, USFS).

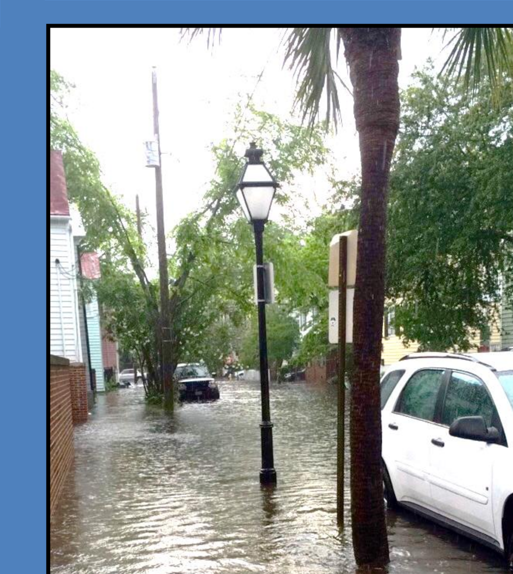


Figure 11. Photo of flooding on Duncan Street in downtown Charleston, SC

LABORATORY AND DATA ANALYSIS

Table 1. Summary of baseflow contribution and hydrograph stage for February 27, 2015 event.

February 27, 2015	Rising Limb 02/23/2015 Baseflow	Rising Limb 02/23/2015 Precipitation	Peak 02/26/2015 Baseflow	Peak 02/26/2015 Precipitation	Falling Limb (1) 02/27/2015 Baseflow	Falling Limb (1) 02/27/2015 Precipitation	Falling Limb (2) 02/28/2015 Baseflow	Falling Limb (2) 02/28/2015 Precipitation	Tail 03/20/2015 Baseflow	Tail 03/20/2015 Precipitation
Physical Hydrograph Separation	NA	NA	NA	NA	41%	59%	53%	47%	NA	NA
Chemical Isotope Separation	80% (SE:0.04)	20%	56% (SE: 0.03)	44%	60% (SE:0.05)	40%	60% (SE:0.12)	40%	85% (SE:0.12)	15%

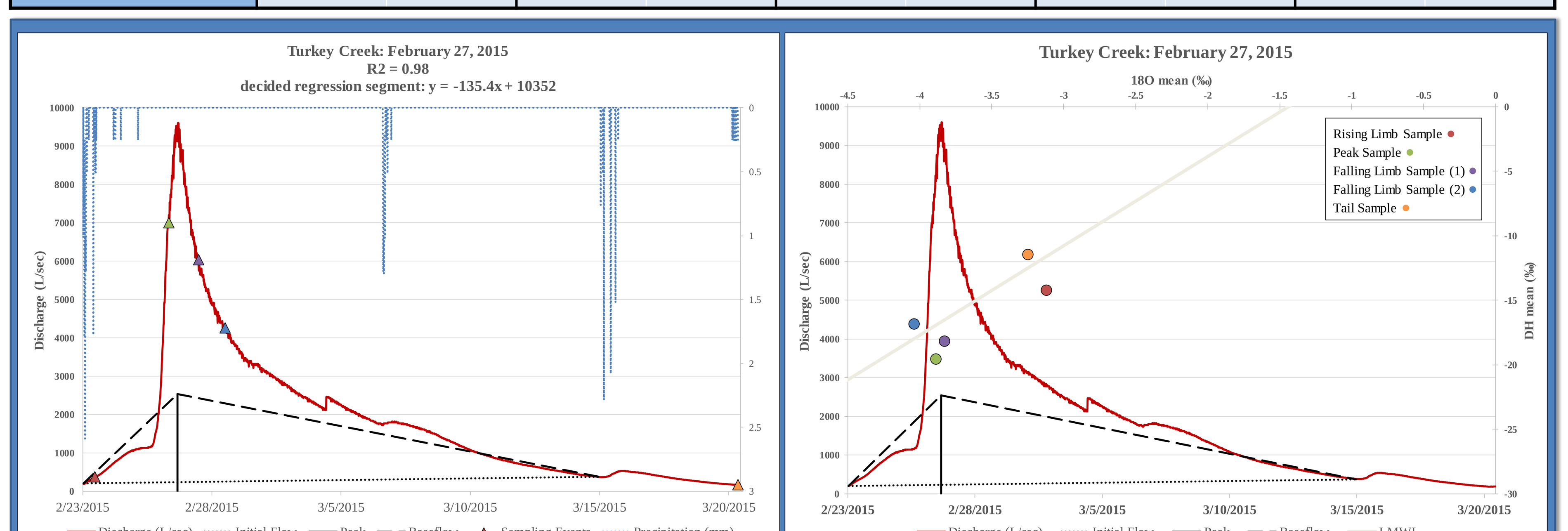


Figure 12. Hydrograph Separation, Sampling Event, and precipitation (left) and hydrograph and stable water isotopes (right) comparison for February 27, 2015 storm event.

Figure 13. The analysis of stable water isotopes will be conducted through the use of a cavity ring-down spectroscopy liquid and vapor isotopic measurement analyzer (Picarro L2120-I, pictured).

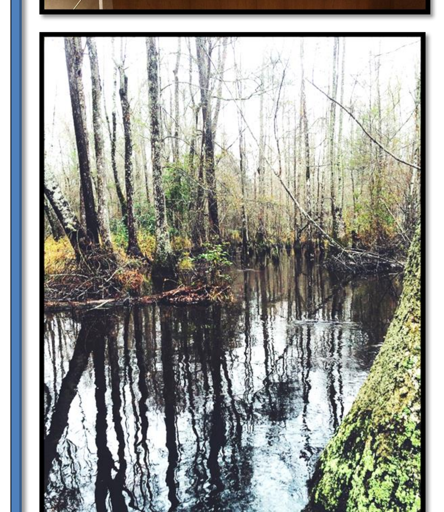


Figure 14. Photo of Turkey Creek during the wet season.

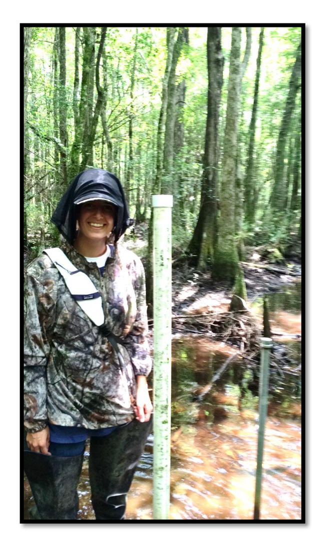


Figure 5. Photo of Austin Morrison at site TC7.

RESULTS

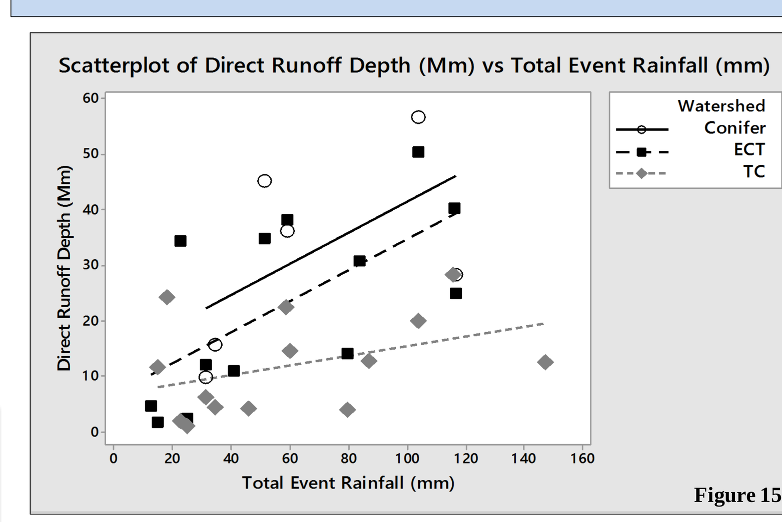


Figure 15.

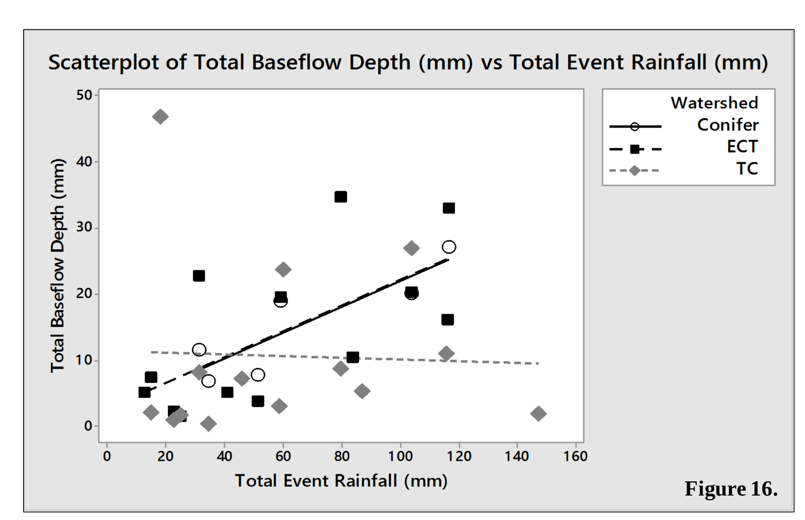


Figure 16.

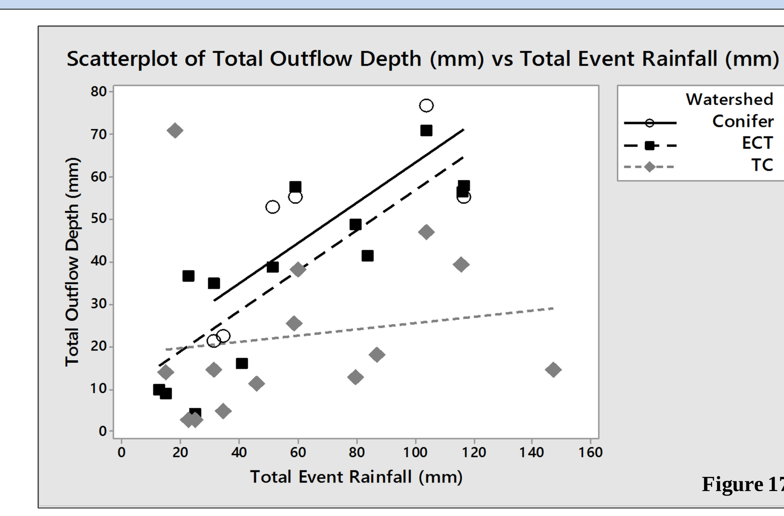


Figure 17.

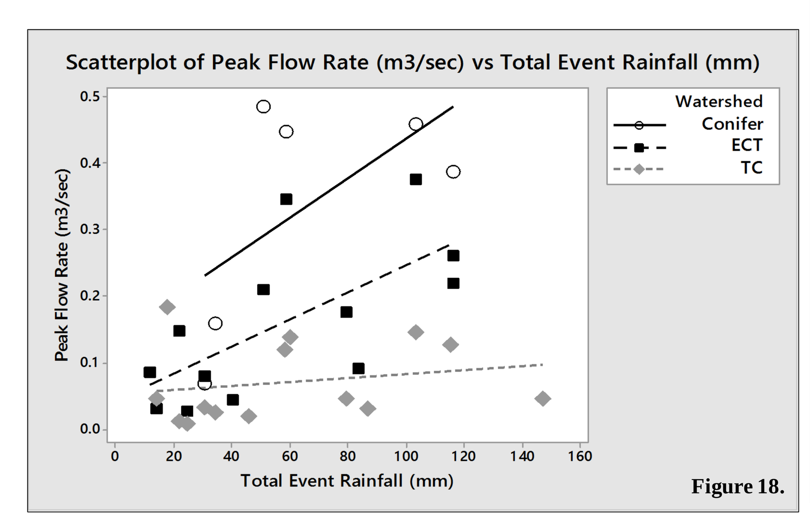


Figure 18.

Figure 15. Direct Runoff Depth (mm) vs Total Rainfall (mm)
R^2 (Conifer) = 32%; R^2 (ECT) = 43%; R^2 (WS78) = 16%
Figure 16. Total Baseflow Depth (mm) vs Total Rainfall (mm)
R^2 (Conifer) = 78%; R^2 (ECT) = 43%; R^2 (WS78) = 0.13%
Figure 17. Total Outflow Depth (mm) vs Total Rainfall (mm)
R^2 (Conifer) = 63%; R^2 (ECT) = 70%; R^2 (WS78) = 2%
Figure 18. Peak Flow Rate ($m^3/sec/km^2$) vs Total Rainfall (mm)
R^2 (Conifer) = 37%; R^2 (ECT) = 45%; R^2 (WS78) = 4%

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