Ecohydrology of Forested Wetlands on the Texas Gulf Coast

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Abstract

Wetlands provide critical ecological services, including flood control, water quality improvement, wildlife habitat, and enhancement of biodiversity. In the Texas Gulf Coast region, as in many areas of the country, industrialization and developmental pressures have led to a dramatic decline in wetland area over the past fifty years. Ironically, because many are considered to be isolated and not hydrologically connected to adjacent streams, they are not regulated. However, very little work has been done to examine the connectivity of these wetlands to nearby streams. As a means of investigating this issue, the intent of this study was to develop a better baseline understanding of hydrological processes of forested wetlands on the Texas Gulf Coast. An important first step in understanding hydrological processes on these wetlands is to develop quantified water budgets including rainfall, surface flow, soil water, and transpiration. We anticipate that this research will play an important role in determining the regulatory status of these wetland landscapes in the future by providing information to support policy decisions.

Problem and Research Objectives
Two of the most important water issues facing Houston and the Greater Houston area are flooding and water quality. High annual rainfall, widespread urban development, an extensive network of streams and floodplains, tidal surges, and generally flat terrain combine to make flooding a prevalent and expensive problem in and around the city of Houston. In addition, the quality of water in local watersheds and in the Galveston Bay Estuary is extremely important for

regional fisheries, wildlife, and recreational use of the bay. The estuary is a nursery for many regionally important species of fish and shellfish, and serves as a migrational stop for waterfowl and other migratory birds. Between 1990 and 2008, four seafood safety advisories were issued for Galveston Bay because of chemical contamination. In addition, biological contaminants (primarily bacteria) are a concern, especially with respect to recreational use of the bay and some bay tributaries.

The Clean Water Act was develop to protect the integrity of waters of the United States—our nation's navigable and interstate water resources and waters that are important to the integrity of navigable and interstate waters. Wetlands that are adjacent to navigable waters or abut relatively permanent non-navigable tributaries of navigable waters are within the regulatory authority of the Clean Water Act (USEPA, 2007). However, wetlands exist that do not meet the above criteria but do posses the potential to affect downstream waters for significant portions of the year. Currently, most forested wetlands on the Texas Gulf Coast are assumed to be hydrologically isolated from waters of the United States because they discharge water intermittently and therefore probably do not contribute significant volumes of flow to influence downstream waters. However, there is very little quantified hydrologic data to substantiate this assumption.

Forested wetlands, though easily overlooked, are potentially very important for detention of floodwaters and for early removal of water and sediment borne contaminants in stormflow. Since 1955, over 97,000 acres of coastal forested wetlands in Texas have been lost to development (TPWD, 1996). Development has affected forested wetland systems in two ways. They have either been drained and filled for conversion to residential, industrial, or agricultural use or they have been converted to deepwater aquatic systems—as a result of subsidence from groundwater pumping—such that that they no longer provide the same ecological functions. It is important that we promptly develop an understanding of the nature of water fluxes through these wetland systems to determine their hydrologic capacity to perform critical ecological functions.

Objectives

The hydrology of forested wetlands on the Texas Gulf Coast is not well documented. In particular, only limited work has been done to define water budgets and to evaluate the hydrological connectivity of these wetlands to other systems. As noted by Rodriguez-Iturbe et al. (2007), the study of wetland ecohydrology is a fairly recent endeavor, and quantified information including soil water profiles and plant transpiration is needed for the development of new scientific frameworks. The objective of the proposed study is to develop a better understanding of wetland ecohydrology by (1) quantifying components of a water budget for a forested wetland watershed in southern Harris County and (2) determining whether or not the wetland is hydrologically connected to adjacent waterways.

Materials/Methodology

The study watershed (Figure 1) was located southeast of Houston, Texas at the Armand Bayou Nature Center. Any water discharged from the watershed flows into a channel that is directly connected to Armand Bayou, which is navigable. Armand Bayou in turn flows into Clear Lake, which ultimately flows into Galveston Bay and then the Gulf of Mexico. The watershed boundary encompasses 8 hectares (20 acres), approximately 25% of which is covered by wetland depressions. Much of the remainder of the watershed also meets the technical criteria for wetlands—evidence of reducing soil conditions, hydrophytic, vegetation, and/or wetland hydrology (Mitsch and Gosselink, 2007). Average annual rainfall in the watershed is approximately 1330 mm/yr. Some of the more prevalent tree species in the watershed include willow oak (*Quercus phellos*), swamp red oak (*Quercus pagodafolia*), water oak (*Quercus nigra*), and Chinese tallow (*Triadica sebufera*).

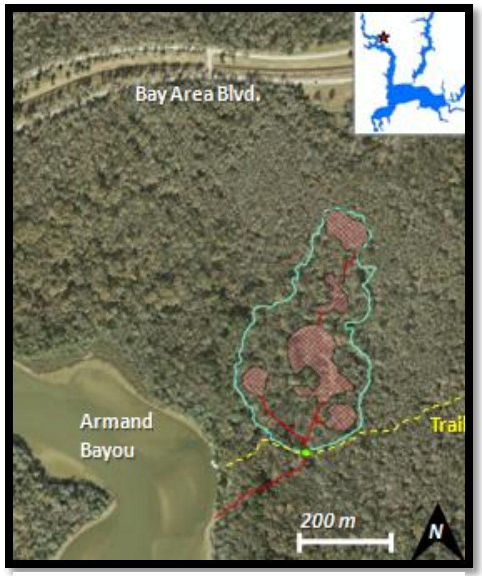

Figure 1 - Location of the study watershed and outlet (green dot) in relation to Armand Bayou, Bay Area Blvd., and Clear Lake (see inset).

The size of the watershed was determined using a handheld GPS unit while the watershed was saturated and runoff was occurring. Most of the watershed had a clearly discernible boundary (peak), but in some locations, the direction of runoff flow was used to determine the boundary. An elevated trail was identified as the southern boundary of the watershed, and equipment for monitoring discharge was located at the outflow culvert. Daily rainfall data was obtained from a set of the nearest available rain gauge within the watershed operated by the Harris County Office of Homeland Security and Emergency Management (Armand Bayou at Pasadena Lake). Where data from this rain gauge was unavailable, data from the Horespen Bayou at Bay area Boulevard was used in its place. Long-term average rainfall was determined using the nearest available official rain gauge maintained by the National Climactic Data Center (Hobby Airport, 1921 to present). Wetland surface discharge (runoff) was measured using a wier instrumented with a sonic water level recorder (Infinities USA, Inc.). Near-surface soil moisture was measured in situ at depths 0 mm, 100 mm, and 150 mm depths using soil moisture probes (Hydra Probe II, Stevens Water Monitoring). Finally, transpiration through trees in the watershed was measured using the heat dissipation sap flux method (see Granier, 1987).

Principal Findings

Here, results are reported from 3/1/2009 to 4/23/2010 in order to show some of the interesting results of this study that were not available prior to trees coming out of dormancy in during March 2010. Additionally, soil moisture sensors were not available for use until the later part of November 2009, and were subsequently installed during December of 2009. Instrumentation for monitoring rainfall and runoff were operational for the nearly all of the reporting period.

The 1,117 mm of rainfall received by the watershed during the study period was below-average compared to long-term average rainfall of approximately 1,330 mm/yr. Even so, it is clear that surface discharge to Armand Bayou (runoff) occurred during the study period. The first occurrence of runoff was 10/2/2009, and significant runoff was generated between 10/10/2009 and 1/27/2009 (Figure 2a). A total of 176 mm of surface runoff was measured, and surface runoff accounted for 14.9% of rainfall inputs.

Soil moisture (Figure 2b) was measured in two different soils. Surface soils in the wetland depressions are predominantly deep, heavy clays. Soils on the adjacent flats are typically loamy, and underlain by clay at 150-450 mm depth. The porosity of the soils in the depression was 0.45, whereas the average porosity of the surface soils on the adjacent flats was 0.41. If extrapolated over the entire watershed, it is capable of storing approximately 1400 m^3 within the upper 150 mm of soil for the depressions and approximately 3700 m^3 within the upper 150 mm of soil for the adjacent flats. This means that the upper 150 mm of soil in the watershed is capable of containing a maximum of 63 mm of rainfall at any given time. Perhaps the most interesting observation with regard to soil moisture is that the soils were essentially saturated from December up through late March or Early April, after which the soils began to rapidly depart from saturation.

Interestingly, transpiration began to increase around the same time (see *T. sebufera* and *Q. phellos*, Figure 2c: other trends are similar but less detectable at the given scale). Measured average sap flux density ranged from 2.13 x 10^{-5} m/s (*Q. pagodafolia*) to 3.52 x 10^{-4} m/s (*Q. phellos*). The lower end of the range falls in line with published values (Granier 1987), however, values in the upper range do not; this suggests that data for *Q. pellos* and *T. sebufera* may require more sophisticated data treatment to produce reliable results.

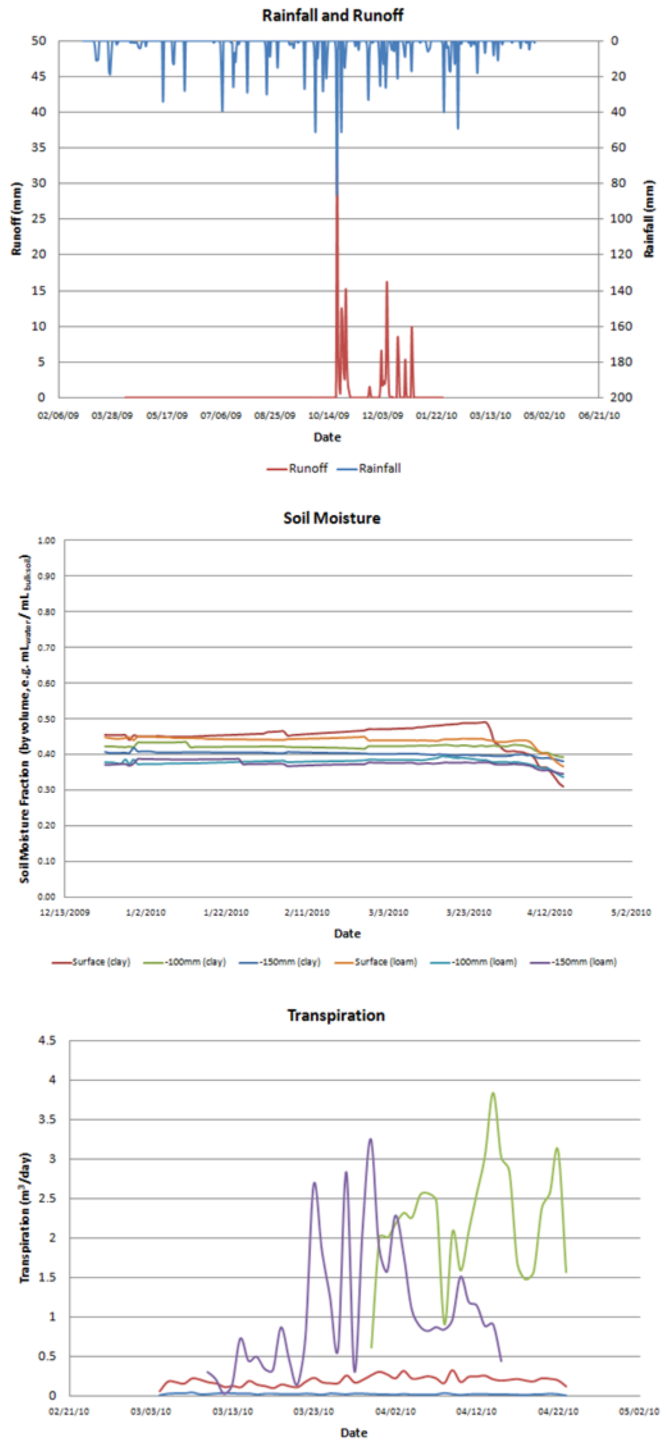

Figure 2 - Hydrologic fluxes for the wetland watershed, including (a) daily rainfall and runoff in mm (b) soil moisture in two surface soils, given as a volume fraction, and (c) measured transpiration from trees of four species given in m^3/day. Please note that x-axis (date) scales vary between plots.

Significance

The principle significance of these results is that they provide baseline data that will be useful for developing frameworks that will help regulators and policy makers make decisions based upon the best available data. These data show that wetlands on the Texas Gulf Coast are not hydrologically isolated, as assumed. Instead, they are capable of discharging substantial amounts of water downstream (14.9% of rainfall in this study, with below-average rainfall). Additionally soil moisture data indicated that wetland soils were at or near saturation from the time the sensors came online until late March-early April, when the forest regained its leaves and transpiration began to contribute significantly to water fluxes leaving the watershed.

References Cited

Granier, A (1987) Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. Tree Physiol. 3:309–320.

Mitsch WJ, JG Gosselink (2007) *Wetlands*, 4th ed (John Wiley & Sons, Hoboken, New Jersey).

Rodriguez-Iturbe I, P D’Odorico, F Laio, L Ridolfi (2007) Challenges in humid land ecohydrology: interactions of water table and unsaturated zone with climate, soil, and vegetation. Water Resources Research, 43.

TPWD (1997) *Texas Wetlands Conservation Plan*, (Texas Parks & Wildlife Department, Austin, Texas).

USEPA (2007) Clean water act jurisdiction following the U.S. Supreme Court's decision in Rapanos v. United States & Carabell v. United States.