Water Budget of a Surficial Aquifer in the Lower Coastal Plain: ACE Basin, SC

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ABSTRACT. South Carolina has the most extensive acreage of marshes than any other state on the East Coast. Salt marshes, in particular, support a collection of unique and sensitive ecosystems providing environmental and economic value to the coastal community. However, the ecological viability may be threatened due to sea level rise and land use stressors. Sea level rise has impacted groundwater resources in confined aquifers, but what is not well understood is the impact on freshwater resources of the surficial aquifers in the coastal zone. Furthermore, advancement landward of the marsh will follow sea level rise as the salt marsh system attempts to accrete sediment and transition previous maritime forest and other upland locations into coastal marsh. Sea level rise, coupled with topographic barriers between marsh and uplands as well as increased demand for shoreline development limits the space available for natural marsh retreat resulting in the issue of “shoreline squeeze”. This research seeks to identify the current state of an undeveloped tidal salt marsh located on Edisto Island, SC by analyzing the groundwater dynamics along the marsh transition unit (MTU).

The marsh transition unit is located between the marsh and upland maritime forest and is generally characterized by an elevation gradient. There is currently a limited amount of information on hydrological processes occurring across the MTU, although this narrow strip of transitional land is significant for the future preservation of salt marshes. This research seeks to expand knowledge on the groundwater dynamics of the MTU and its interaction with the upland maritime forest. It is hypothesized that the resiliency of surficial groundwater resources is a function of topography and soil drainage (permeability and depth to water table) and that groundwater dynamics will vary on water budget as well as topographic position and distance to the tidally dominant saltwater creek. The objectives of this study are to (A) determine the budget of fresh water at the site and (B) identify the groundwater dynamics as a function of season and response to storm events. We will present results of groundwater and runoff dynamics from a network of shallow wells in the upland and fringing salt marsh at Big Bay Creek behind Edisto Island. This project makes use of data collected for the National Estuarine Research Reserve System System-Wide Monitoring Program (SWMP). The results of this study will assist in determining how sea level rise may affect tidal salt marshes as well as marsh migration or transition of upland habitat. Furthermore, this research will be useful for coastal resource managers to identify pathways of future marsh relocation.

INTRODUCTION

South Carolina has the most extensive acreage of marshes than any other state on the East Coast at 344,500 acres (Wenner, 2010). Salt marshes, in particular, support a collection of unique and sensitive ecosystems providing environmental and economic value to the coastal community. Storm protection, carbon sequestration, nutrient transformation, and fisheries support are a few of the benefits provided by healthy tidal salt marshes (Kirwan and Megonigal, 2013). However, their ecological viability may be threatened due to sea level rise and land use stressors such as coastal development. Furthermore, saltwater intrusion resulting from sea level rise may disrupt the hydrologic balance between the salt marsh and fresh upland groundwater system.

An area of primary significance in this study is the interaction between the marsh transition unit (MTU) and upland systems. The MTU is significant because it is the initial area available for landward marsh movement during erosional processes, such as sea level rise (Doar, 2011). Prior studies show the capability to determine landward mobility of the marsh through dynamics driving MTU's such as salinization, elevation, and tidal inundation (Gardner et al., 2002). A study at North Inlet, SC by Gardner et al. (2002) found that the upland border of the marsh is already transforming into available marsh space from increases in salinity and tidal fluctuations. The same study points out a gap in knowledge about the groundwater flow dynamics that occur along the MTU, particularly along areas of differing elevation gradients (Gardner et al., 2002). In this study at Edisto Beach, SC, groundwater monitoring methods aim to expand knowledge on the groundwater dynamics occurring across the uplands and MTU.

Furthermore, this research analyzes the baseline groundwater dynamics of an undeveloped tidal saltmarsh at Edisto Beach State Park, SC an Ashepoo, Combahee, and Edisto (ACE) Basin National Estuarine Research Reserve System (NERRS) site. The goal is to provide understanding into the future impacts on the marsh from sea level rise and in turn saltwater intrusion. This site location is significant because it represents a relatively undeveloped soft-coast saltmarsh and upland system. This study site will reflect ecological dynamics that occur on natural, undisturbed salt marshes similar to this one.

PROJECT DESCRIPTION

The groundwater system being studied at this site is the surficial aquifer within the South Carolina Lower Coastal Plain region. This aquifer is unconfined so it is mainly subjected to infiltration of precipitation and areal recharge, as well as atmospheric pressure effects (SC DNR, 2009). Although a majority of groundwater systems contain fresh water, surficial aquifers in close proximity to tidal systems may contain saltwater (SC DNR, 2009). This study focuses on the area of marsh known as the MTU, which is similar to the high marsh, classified as only being flooded during very high tides twice a month from new and full moon phases (NOAA Ocean Service Education, 2008). Additionally, this study spotlights the upland maritime forest bordering the marsh. In order to understand the relationship of groundwater movement between this tidal-upland zone, groundwater monitoring wells were installed and executed as a triangulated network. The use of groundwater monitoring wells in the maritime forest and MTU zone allowed for data collection of various groundwater variables over a 12-month time period in order to highlight the monthly and seasonal dynamics, as well as to ensure recordings of storm events. The objective of this research is to calculate the freshwater budget for the watershed, which will help to understand the influence of the surficial aquifer on the upland and marsh interface.

Additionally, the main goal of this study is to discover the baseline data of the groundwater dynamics that occur in the surficial aquifer at this marsh-upland interface. In order to satisfy this goal, the relationship among topography, evapotranspiration, tidal amplitude and duration were identified. We hypothesize that groundwater dynamics will mimic the topography of the watershed and salinity will decrease with distance to the saltwater source, Big Bay Creek.

METHODS

The study site for this project is located in a maritime forest and adjacent undeveloped tidal saltmarsh along Big Bay Creek at Edisto Beach State Park located within the ACE Basin, South Carolina. A series of six triangulated wells were installed in the uplands and MTU; three in the uplands and three in the MTU (Figure 1). Solinst levelogger instruments were deployed in each well, which allowed for 30-minute data collection of water temperature (C), electrical conductivity (µS/cm), water level (cm), and barometric pressure (Kpa) from June 6, 2013 to May 5, 2014. For the purposes of this study, all electrical conductivity readings were converted to salinity (ppt).

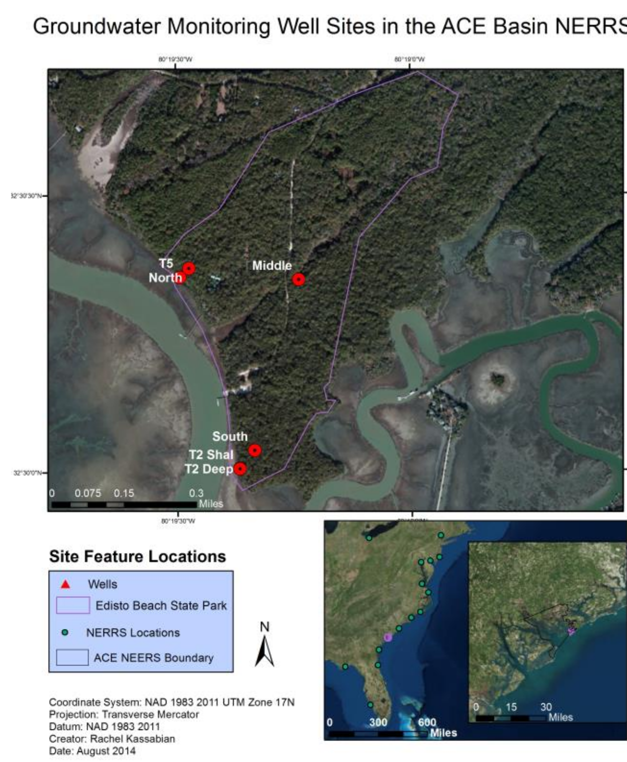

Figure 1. Site Map including NERRS Boundaries and well locations.

In order to calculate the water budget, precipitation and air temperature data were retrieved from a nearby weather station at Bennett's Point, SC through the NERRS Centralized Data Management Office (CDMO) and converted into daily readings. The Hamon method was used to calculate potential evapotranspiration due to its accuracy when analyzing sensitivity of the hydrologic cycle (Lingling et al, 2013). A coefficient of 1.2 was used in the Hamon Evapotranspiration calculation (Lu et al, 2005). The water budget data was calculated for both weekly and monthly rates using the formula:

$$\Delta S = P - PET + \Delta G$$

Where ΔS is change in storage, P is precipitation, PET is potential evapotranspiration, and ΔG is change in groundwater. Runoff was not included in this calculation due to the presence of sandy soils at this site and the lack of flood-inducing storms.

Additionally, it was necessary to determine the topography of the site through LIDAR and traditional field surveying methods in order to delineate the watershed and compare groundwater level at mean sea level. Soil characterization at each well site was also determined during well installation by grab samples every other foot. Determining the soils and topography help uncover the groundwater pathways within the watershed.

RESULTS

A water gain/loss model was created depicting the precipitation and potential evapotranspiration conditions at this site. This model is significant because it represents the relationship between the main freshwater input (precipitation) and the main water output (evapotranspiration) thus providing insight into water storage change at this site. This model utilized the temperature based Hamon potential evapotranspiration method. As seen in Figure 2, the difference between precipitation and potential evapotranspiration showed a generally negative change in storage to the watershed over the 12-month study period. A water loss situation generally occurred when precipitation was low and potential evapotranspiration rates were high. Conversely, water gain situations occurred when precipitation rates were high and potential evapotranspiration rates were comparatively lower. Negative trends in this model were present for ten out of the twelve months studied. The months of September 2013, October 2013, and May 2014 experienced water loss greater than 50 mm/month. Alternatively, November 2013 April 2014 were the only months representing a positive change in water storage based off of the model. In particular, April 2014 experienced comparatively high rain events causing the precipitation rate to exceed the potential evapotranspiration rate.

Individually, precipitation rates over the study period were greatest during the spring and summer months and lowest in the fall and winter. Evapotranspiration rates were also the greatest during the summer months when daylength and temperature were at their peak.

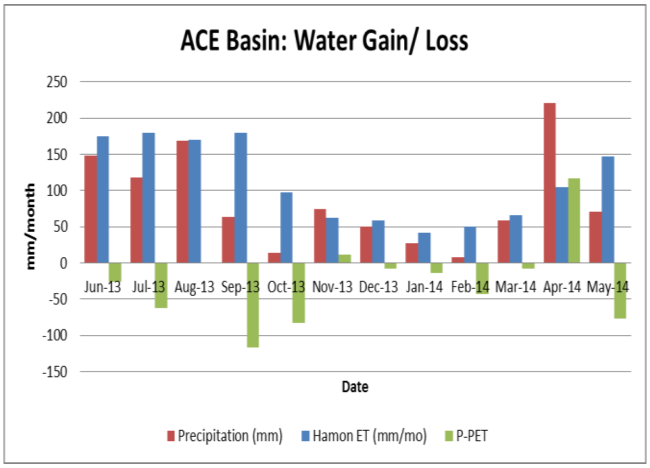

Figure 2. Generalized water gain/loss graph accounting for available precipitation input and potential evapotranspiration output.

Hydrographs for each well site were able to characterize the processes influencing groundwater level movement within the well, as well as the salinity variations for the study period. The north and south well hydrographs showed that groundwater level was affected primarily by evapotranspiration rates showing a diurnal water pattern (Figure 3). The middle well hydrograph revealed a slight tidal pattern despite its distance from the creek (Figure 3). The marsh well hydrographs all showed a tidal signature influencing water level (Figure 4). Salinity variations among all six wells showed that the north and south wells maintained similar freshwater readings (0.19 ppt and 0.28 ppt). Whereas the middle well maintained an average brackish water reading (9.92 ppt). The marsh wells recorded saline water averages for T5 (31.65 ppt), T2 deep (33.77 ppt), and T2 shallow (30.67 ppt).

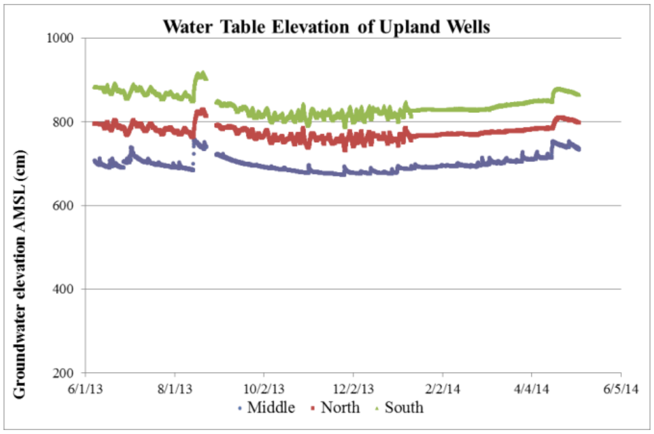

Figure 3. Water Table Elevation Hydrograph for the North, South, and Middle Upland Wells.

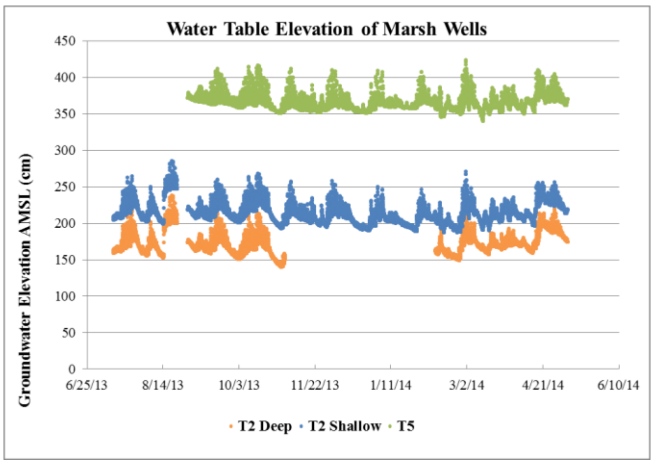

Figure 4. Water Table Elevation Hydrograph for T2 Deep, T2 Shallow, and T5 marsh wells.

DISCUSSION

The groundwater movement in the upland wells revealed that distance to creek is not a main factor affecting groundwater dynamics at this site, as seen in the middle well. The hydrograph for the middle well showed that although it is located the furthest away from the creek, a tidal signal is present. Comparatively, the north and south well groundwater levels, while closer to the creek, are mainly influenced by evapotranspiration patterns. Therefore, the hypothesis that the upland well groundwater will mimic evapotranspiration is challenged by these results. Furthermore, salinity at the middle well was consistently about 30 times higher than the north and south wells. The salinity levels of the middle well were also closer in relationship to the marsh wells, than the upland wells. The topography at the middle well may explain the uncharacteristic groundwater and salinity readings at this site. This well site is located in a lower elevation slough which extends to the creek, and perhaps allows for surface water to enter into the slough. Future research at this site may confirm this assumption through the installation and monitoring of a well at the slough-creek outlet. Also, the results of the water gain/ loss model will be further supported by the completion of a formal water budget.

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