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Natural Resources Conservation Service

Conservation Effects Assessment Project (CEAP)
CEAP-Wetlands Conservation Insight

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Soil Influences on Water Balance in Wetlands May Impact Wetland Effectiveness in Achieving Different Restoration Objectives

Summary

This analysis indicates there is less interaction between surface water and groundwater in wetlands with low permeability subsurface soils than in wetlands with high permeability subsurface soils. In a paired-comparison study of two depressional wetlands in the Coastal Plain of the Chesapeake Bay watershed, the wetland with low permeability demonstrated water level dynamics that were more independent of groundwater level than those observed in the wetland with high permeability subsurface soils. Groundwater levels had little impact on surface water levels when subsurface soils were of low permeability. In contrast the wetland with highly permeable subsurface soils showed a more consistent relationship between surface water level and groundwater level, and greater contribution of groundwater to wetland surface water.

These results have implications for conservation planning and wetland restoration. In areas undergoing frequent heavy rainfall events or those where groundwater recharge to increase downstream resilience to drought is an objective, restored wetlands sited on highly permeable subsurface soils may be most appropriate. In contrast, wetland restoration over low permeability soils may yield a higher carbon holding capacity and may be more effective at nitrogen removal via denitrification because of the potential for the wetland to maintain surface water for longer periods of time.

Background

Wetland restoration practices may be necessary to restore ecosystem functions in cases where wetlands have been lost or degraded (Zhao et al. 2016). Wetland hydrology is a critical component in wetland restoration because hydrologic conditions impact various aspects of wetland biogeochemical and ecological function, such as nutrient removal and carbon cycling (Sharifi et al. 2013, Fenstermacher et al. 2014).

Wetland water balance is one way to characterize hydrologic conditions in wetlands and is assessed by quantifying the sources of water entering a wetland and pathways for water exiting the wetland. Precipitation levels, evapotranspiration (ET), groundwater recharge/discharge, spillage, and inflow from upslope drainage areas all impact wetland water balance.

The relative importance of groundwater in wetland water balance varies depending on hydrogeomorphic characteristics. For example, wetlands in the prairie pothole region have been found to influence groundwater less, while those in the Coastal Plain of the Chesapeake Bay watershed (CBW) exhibit strong interactions with groundwater (Van der Kamp and Hayashi 2009, Lee et al. 2018).

In wetland interactions with groundwater, water can flow in either direction. During winter seasons, groundwater levels (GWL) of wetland contributing areas have been observed to become higher than wetland surface water levels (SWL), causing groundwater to flow into wetlands (McLaughlin and Cohen 2013). In contrast, groundwater recharge occurs when water flows vertically from wetlands down into groundwater (Rains et al. 2006). This downward vertical water movement is strongly influenced by soil permeability.

Vertical water movement is constrained in soils with low permeability, resulting in longer standing water on the land surface

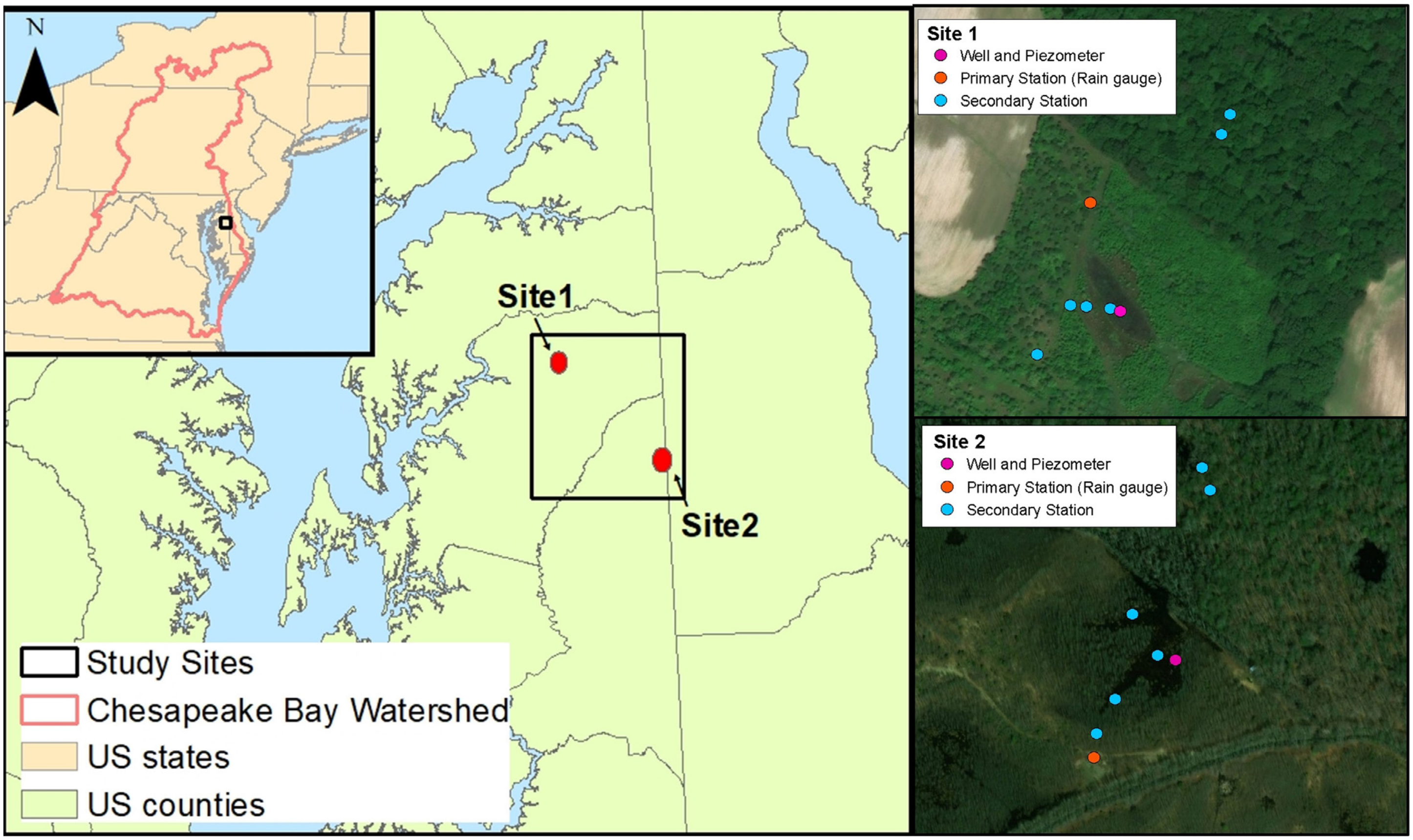

Figure 1. The two study sites (left) and placement of sensors in each site (right). Note: the red dots indicate approximate locations of the two sites. The outline of the Chesapeake Bay Watershed is shown in the inset in the top left corner.

and increased lateral flow (Rassam et al. 2006, Pyzoha et al. 2008). Soils with high permeability, on the other hand, promote downward movement (infiltration) of water. Soil characteristics can therefore have impacts on wetland water balance and in turn on the ecosystem services and functions provided by those wetlands.

This study explores how surface water and groundwater interactions vary with soil hydraulic conditions (e.g., low vs. high soil permeability) in the Mid-Atlantic Coastal Plain. In addition, implications of wetland soil characteristics on wetland restoration and management are discussed.

Assessment Approach

In high permeability soils, SWL are expected to vary in a consistent manner with GWL due to their strong interactions. To test this, two depressional wetlands located within the Coastal Plain of the CBW were selected for this study (Fig. 1). The two wetlands have distinct subsurface soil hydraulic conditions, in that wetland #1 has low soil permeability and #2 has high soil permeability.

Wetland-groundwater interactions were quantified by comparing the SWL and GWL for the two wetlands over time. SWL and GWL were monitored from January 1, 2016, to December 31, 2016, using a groundwater well and piezometer, respectively. In addition, the number of days with surface water present was compared between the two wetlands. Because low permeability soils impede surface water loss via infiltration, the wetland with the low permeability subsurface soils was expected to have more days with standing water than the wetland with high permeability subsurface soils.

Findings

Daily SWL and GWL are represented in Fig. 2 for both wetlands. The observed daily SWL and GWL ranged from -0.4 to 0.4 meter and from -1.5 to 0.3 meter at wetland #1, and from -0.8 to 0.4 and from -1.1 to 0.3 at wetland #2, respectively. Thus, the difference in range of variation between SWL and GWL was large at wetland #1 (1 m) relative to wetland #2 (0.2 m), due to less variation of SWL and more variation in GWL at wetland #1.

As anticipated, the daily temporal dynamics of SWL and GWL at wetland #2 were consistent (Fig. 2b). Unexpectedly, surface water was present in both wetlands for a similar number of days (Fig. 3). However, it was also found that the groundwater contribution to wetland surface water differed between the two wetlands, as indicated by the number of days with GWL above the lowest soil surface level within the wetland (48 days at wetland #1 versus 215 days at wetland #2). These observations indicate that wetland #1 has high potential to hold surface water without contributing to groundwater, while surface levels in wetland #2 were often maintained through groundwater contributions.

Implications

These results have implications for wetland restoration aimed at achiev-

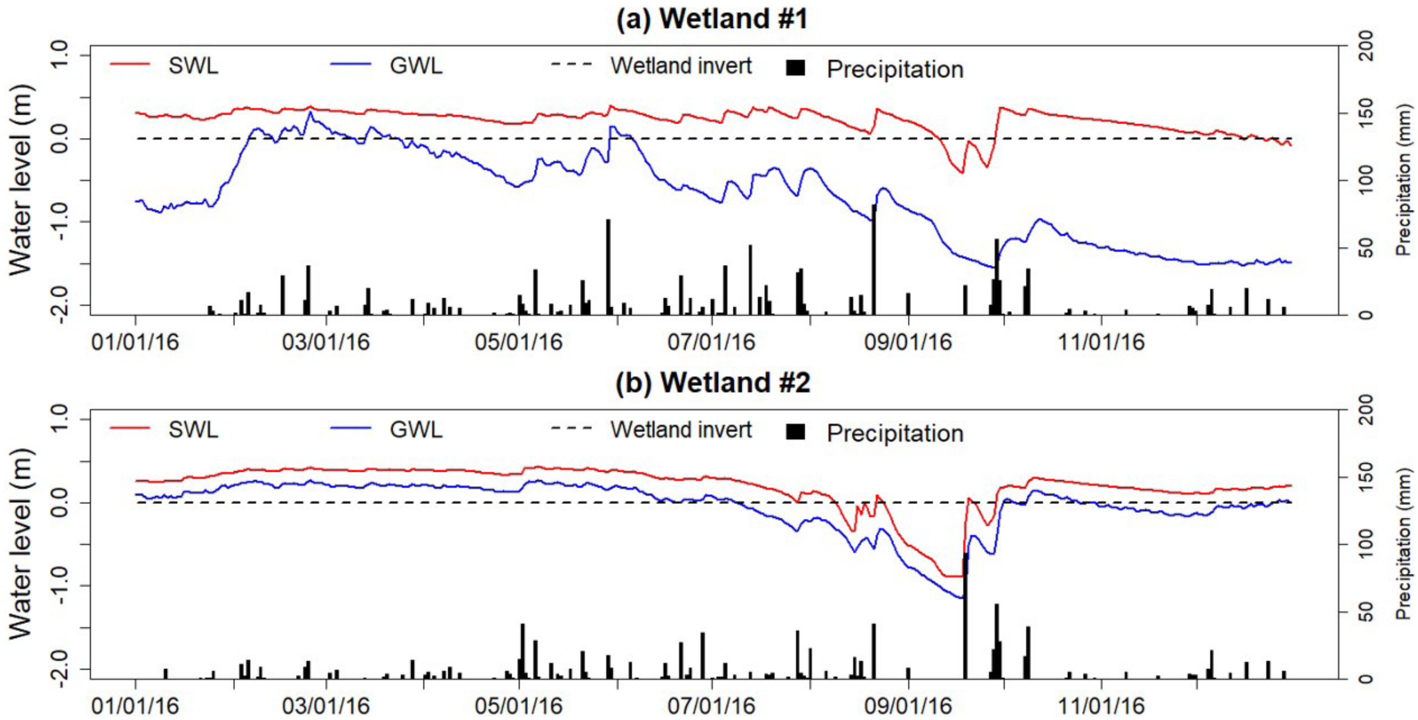

Figure 2. Surface water level (SWL) and groundwater level (GWL) in daily time steps at wetlands #1 (a) and #2 (b). Wetland #1 has a low-permeable subsurface soil, whereas wetland #2 has a high-permeable subsurface soil.

ing specific wetland-mediated ecosystem services. The influence of soil hydraulic properties on wetland hydroperiod (how long water stands on the soil surface) will have a strong influence on storm water storage capacity and groundwater recharge, as well as the vegetation community possible as an endpoint of restoration.

Based on the observed hydrological processes, wetlands with low permeability soils might be ineffective at curbing peak flow during consecutive heavy rainfalls relative to wetlands with high permeability soils. Low permeability soils limit water infiltration, potentially resulting in the maximum water capacity for a wetland being reached after a single rainfall event. In response to following rainfall events, spillage from the wetland can occur, exporting a large amount of water to downstream areas via surface flows.

In contrast, high permeability soils allow a wetland to drain water to groundwater, providing additional holding capacity for following rainfalls. Thus, wetland restoration planned for areas undergoing frequent heavy rainfall events should consider hydraulic soil conditions and might be better suited on high permeability soils.

Wetland restoration in soils that allow strong wetland-groundwater interactions could potentially mitigate the effects of drought on downstream areas. During dry periods, most downstream baseflows are supported by groundwater. An increased amount of water from wetlands to groundwater may contribute to sustaining downstream waters during dry periods. For improved water management using wetland restoration, locations with high permeability soils should be targeted for restoration activities.

In contrast, wetland restoration on low permeability soils may be more effective at increasing carbon holding capacity and nitrogen removal via denitrification relative to high permeability soils because of the potential for long hydroperiods (Busnardo et al. 1992, Altor and Mitsch 2008).

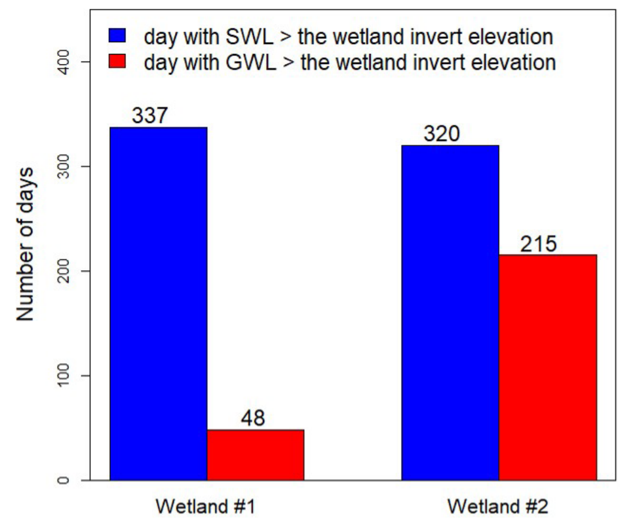

Figure 3. Number of days when surface water level (SWL) or groundwater level (GWL) exceeded the wetland bottom (i.e., the lowest soil surface level within the wetland).

The effect of soil permeability on plant communities and wildlife habitat should also be considered. Plants well adapted to long-standing water may be more suitable for restored wetlands with low permeability soils while wetland restoration for plant communities that prefer short periods of standing water may be more suited to high permeability soils (Correa-Araneda et al. 2012). Timing of inundation and vegetation community would also strongly influence the potential for amphibian breeding and other wildlife usage.

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Conservation Effects Assessment Project: Translating Science Into Practice

The Conservation Effects Assessment Project (CEAP) is a multiagency effort to build the science base for conservation. Project findings will help to guide USDA conservation policy and program development and help farmers and ranchers make informed conservation choices.

One of CEAP's objectives is to quantify the environmental benefits of conservation practices for reporting at the national and regional levels. Because wetlands are affected by conservation actions taken on a variety of landscapes, the Wetlands National Component complements the national assessments for cropland, wildlife, and grazing lands. The wetlands national assessment works through numerous partnerships to support relevant assessments and focuses on regional scientific priorities.

This project was conducted through collaboration among researchers with University of Maryland (UMD) College Park, the University of Newcastle, Australia and USDA-ARS Beltsville. Primary investigators on this project were Lee, S., McCarty, G.W., Moglen, G.E., Lang, M.W., Sadeghi, A.M., Green, T.R., Yeo, I.-Y., and Rabenhorst, M.C. This Conservation Insight was compiled by Drs. S. Lee, G. McCarty, and X. Li.

For more information, see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap, or contact Joseph Prenger (joseph.prenger@usda.gov).