Journal of Hydrology: Regional Studies 4 (2015) 675–685

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

Simulating the effects of a beaver dam on regional groundwater flow through a wetland

Kathleen Feiner*, Christopher S. Lowry

University at Buffalo, 411 Cooke Hall, Buffalo, NY 14260, United States

A R T I C L E I N F O

Article history:
Received 6 May 2015
Received in revised form
25 September 2015
Accepted 6 October 2015
Available online 1 December 2015

Keywords:
Beaver dam
Ecological engineering
Capture zone delineation
MODFLOW
Analytic element modeling

A B S T R A C T

Study Focus: This research examines a wetland environment before and after the construction of a beaver dam to determine the hydrologic impacts on regional groundwater flow and quantify changes to the capture zone of a wetland pond. Increased hydraulic head behind a newly built beaver dam can cause shifts in the capture zone of a wetland pond. Changes in groundwater flux, and the extent of both the capture and discharge zones of this wetland were examined with the use of a groundwater flow model, created using MODFLOW.

New hydrological insights for the region: The construction of a beaver dam resulted in minimal changes to regional groundwater flow paths at this site, which is attributed to a clay unit underlying the peat, disconnecting this wetland from regional groundwater flow. However, groundwater discharge from the wetland pond increased by 90%. Simulating a scenario with the numerical model in which the wetland is connected to regional groundwater flow results in a much larger impact on flow paths. In the absence of the clay layer, the simulated construction of a beaver dam causes a 70% increase in groundwater discharge from the wetland pond and increases the surface area of both the capture zone and the discharge zone by 30% and 80%, respectively.

1. Introduction

The North American beaver (*Castor canadensis*) can act as an ecosystem engineer in low gradient streams, having complex and lasting effects through dam building and stream diverting activities (Rosell et al., 2005; Jones et al., 1997). A newly constructed beaver dam can change both the distribution of water in a stream system and the groundwater/surface water interactions directly surrounding the dam (Lautz et al., 2006; Hester and Doyle, 2008; Janzen and Westbrook, 2011). Beavers can have an especially large impact in areas with low topographic gradients where flooding caused by damming can have a widespread effect, such as wetlands and streams with well-connected floodplains (Johnston and Naiman, 1987; Pollock et al., 2003; Westbrook et al., 2006).

Wetlands perform many important function, such as serving as intermediaries between surface water and groundwater, filtering sediments and transforming nutrients, such as nitrogen and phosphorus, from surface runoff (Mitsch et al., 2005). In addition, wetlands act as major terrestrial sinks of carbon, holding large quantities in their soils (Bridgham et al., 2006). By storing water, wetlands also serve to decrease flood peaks and reduce the risk of flooding downstream (Zedler and Kercher, 2005). They also provide an essential habitat for many plant and animal species, including beavers.

* Corresponding author.
E-mail addresses: feinerk853@gmail.com (K. Feiner), cslowry@buffalo.edu (C.S. Lowry).

http://dx.doi.org/10.1016/j.ejrh.2015.10.001
2214-5818/

Wetlands have historically been altered by both natural and anthropogenic processes, causing a reduction in wetland function and associated ecological services. It has been reported that nearly 50% of natural wetlands worldwide have been destroyed (Mitsch and Gosselink, 2011). As a result, there has been an increased interest in the restoration of degraded stream and wetland environments (Lave et al., 2010). Restoration of streams and wetlands is now a multi-million to billion dollar industry (Bernhardt et al., 2005; Zedler and Callaway, 1999). Current research focuses on both the impacts of new restoration techniques (Ernst et al., 2010; Moore et al., 2014) as well as outcomes of previous restoration (Zedler and Callaway, 1999). As ecological engineers, beavers play a potential role in stream and wetland restoration by slowing down stream flows and reconnecting the water table to land surface. Because of this, beavers are utilized as a low cost restoration tool (UBMP, 2010; Brown et al., 2011). In addition to changes in surface water flows, understanding how a beaver dam changes groundwater flow in a wetland is a necessary step in determining whether or not the addition of a beaver dam can be used as an effective restoration technique. Quantifying the hydrologic change that result from the construction of a dam will lead to a better assessment of potential ecological impacts within a study area.

Many studies have examined the ecological changes that occur when a beaver moves into a new habitat (Naiman et al., 1986; Townsend and Butler, 1996; Jones et al., 1997; Rosell et al., 2005). Some examine the hydrologic changes (Woo and Waddington, 1990; Gurnell, 1998; Hill and Duval, 2009), but few have numerically modeled these hydrologic changes (Lautz et al., 2006; Hester and Doyle, 2008; Janzen and Westbrook, 2011). Specifically, researchers have modeled changes in hyporheic flow patterns (groundwater/surface water mixing) on a small scale, within a 10-m radius around the beaver dam (Lautz et al., 2006; Hester and Doyle, 2008). These studies found that a beaver dam can increase the amount of hyporheic mixing that occurs in a stream near a dam, therefore influencing the biogeochemical and ecological functioning of the area directly surrounding the dam. However, there has yet to be a study conducted to numerically model the regional impacts that a beaver dam has on groundwater flow, including changes to a wetland's capture zone.

This research examines groundwater/surface water interactions in a wetland before and after the construction of a beaver dam to determine the hydrologic impacts on groundwater flow and quantify changes to the wetland capture zone. Water table and lake level measurements collected before and after the construction of a beaver dam were used to develop a three dimensional MODFLOW model (Harbaugh, 2005) that quantifies the changes in groundwater flow on a larger scale than what has previously been studied. The objectives of this research are to (1) quantify the hydrologic impacts of the construction of a beaver dam on regional groundwater flow and to (2) examine the transferability of how a beaver dam could impact other wetlands, using numerical simulations that vary hydrostratigraphy near the wetland.

1.1. Site description

This research focuses on the Beaver Meadow wetland site maintained by the Buffalo Audubon Society, located in the town of North Java, Wyoming County, New York. Beaver Meadow is located in the headwaters of the Buffalo River watershed (Fig. 1). Due to its dynamic history of beaver activity, Beaver Meadow offers a unique opportunity to study the effects of beavers on a wetland system. Beavers inhabited this site and maintained a beaver dam in the wetland pond until 2002, after which beavers were no longer present. Without maintenance by the beavers, the dam collapsed, resulting in a large drop in water level throughout the wetland which decreased the surface area of the wetland pond by 48%, based on aerial images taken before and after the collapse of the beaver dam. In August of 2011, beavers returned to the pond and built a new dam at the outlet of the pond, located at its southernmost point. This has caused the pond to increase in depth by about one meter (Lowry and Fienen, 2013) and extend aerially by about 50%, based on aerial image comparisons.

The areal extent of the Beaver Meadow wetland is 0.24 km^2 with a pre-dam surface water area of 0.09 km^2, which expanded to 0.19 km^2 with the construction of the beaver dam. The area surrounding the wetland is forested with fairly steep hills along the sides, restricting the wetland vegetation. The pond has a maximum depth of 1.5 m. There is no significant surface water inlet to the wetland (surface water flowing into the wetland enters via a low gradient floodplain with several small (10 cm) anastomosing channels) and a stream flows from the southern end of the pond. The field site receives approximately 1100 mm of precipitation annually.

Over time, peat has accumulated in the wetland, measuring up to 7 m thick. The wetland is underlain by kame deposits composed of layers of clay sand and gravel, with some proglacial fluvial deposits containing layers of sand, silt, clay, and gravel nearby. Directly below the wetland peat is a clay layer, which was observed at several locations while collecting peat cores, measuring peat depth, and installing piezometers. According to well logs obtained from the New York Department of Environmental Conservation, unconsolidated aquifer sediments are about 30 m thick below the Beaver Meadow wetland.

2. Methods

2.1. Instrumentation and data collection

In June 2011 (two months before the construction of the beaver dam), nested piezometers were installed in the Beaver Meadow wetland on the eastern and northern sides of the pond at 10 locations (Fig. 2) to quantify the hydraulic gradient within the wetland and to be used as observations for future numerical modeling. The piezometers were manually driven into the wetland peat using a hand held slide hammer and thoroughly flushed to ensure that the screens were not clogged. Eight of the ten locations contain a nest of three piezometers, the first was screened across the water table, the second at