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An integrated environmental model for a surface flow constructed wetland: Water quality processes

Zhen-Gang Ji[a,*], Kang-Ren Jin[b]

[a] Department of Civil Engineering, Catholic University of America, Pangborn Hall, Room G12, Washington, DC 20064, United States
[b] South Florida Water Management District, P.O. Box 24680, West Palm Beach, FL 33416, United States

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ABSTRACT

It is a challenge to apply coupled hydrodynamic, sediment, water quality, submerged aquatic vegetation (SAV), and emergent aquatic vegetation (EAV) models to the studies of constructed wetlands (CWs). So far, there are few published studies on CWs that included comprehensive SAV, EAV and nutrient cycling processes, had detailed model-data comparisons for multiple years, and were applied to support CWs management. Stormwater Treatment Areas (STAs) in south Florida are CWs that have been built to reduce phosphorus (P) concentrations from agricultural drainage waters and Lake Okeechobee discharges. The scale of this CWs project is unprecedented in terms of size, cost, and scientific challenges. The STA management needs models/tools to provide detailed spatial and temporal information to optimize the P removal efficiency and to predict the dynamic response of STAs under a variety of management conditions. Based on the Lake Okeechobee Environment Model (LOEM) developed in the past 15 years, the LOEM-CW water quality model is developed for simulating water quality processes in CWs. The coupled interactions of SAV and EAV with P variables are included in the LOEM-CW to ensure that the P cycling processes are represented realistically. The LOEM-CW is calibrated and verified with 6 years of measured data (2008–2013) at 6 locations in STA-3/4 Cells 3A/3B. Through graphic and statistical comparisons, it is shown that the model simulated P, nitrogen, and dissolved oxygen processes in the STA well. The model results illustrate that increasing water depth increases the retention time and decreases effluent TP concentration. By adjusting the existing outflow rates, the STA can be more efficient in removing P. It has been shown that the LOEM-CW can serve as a useful tool in wetland management.

1. Introduction

The Everglades, located in southern Florida, is one of the largest wetlands in the world (Fig. 1a). In the past decades, altered hydrologic regimes and excessive nutrients from agricultural drainage waters deteriorated the water quality in the area. Too much of the nutrients, especially phosphorus (P), promotes an overgrowth of plants and alters the habitat that Florida's native plants and animals need to thrive. Local, state, and federal initiatives have been taken to reduce P loadings in runoff from agriculture and other sources (Chimney and Goforth, 2001; Pietro et al., 2010; Paudel et al., 2010; Dierberg et al., 2012; Juston et al., 2013).

Constructed wetlands (CWs) have become a popular technology for treating wastewater and stormwater in the United States and other parts of the world (Kivaisi, 2001; Zhang et al., 2014; Vymazal, 2014; Wu et al., 2015). They can operate under a wide range of inflow rates, have internal water storage capabilities, and can remove/transform contaminants, including P, nitrogen (N), oxygen-demanding substances, and sediments. A constructed wetland (CW) can reduce contaminant concentrations through settling and biogeochemical processes. These processes, in turn, are closely associated with the hydrodynamic and water quality conditions of the wetland and its vegetation (Kadlec and Wallace, 2009; Reddy and DeLaune, 2009). In order to optimize the operation of a CW and to maximize the nutrient removal, it is essential to fully understand the hydrodynamic and water quality processes and the vegetation in the wetland.

In south Florida, six large-scale treatment wetlands, known as Stormwater Treatment Areas (STAs) (Fig. 1a), have been built to reduce P concentrations from agricultural drainage waters and Lake Okeechobee discharges. The STAs are situated between Lake Okeechobee and the Everglades Agricultural Area to the north and the Everglades Protection Area to the south (Fig. 1a). The scale of this CW project is unprecedented in terms of size, cost, and scientific

* Corresponding author.
E-mail addresses: zji@cua.edu (Z.-G. Ji), kjin@sfwmd.gov (K.-R. Jin).

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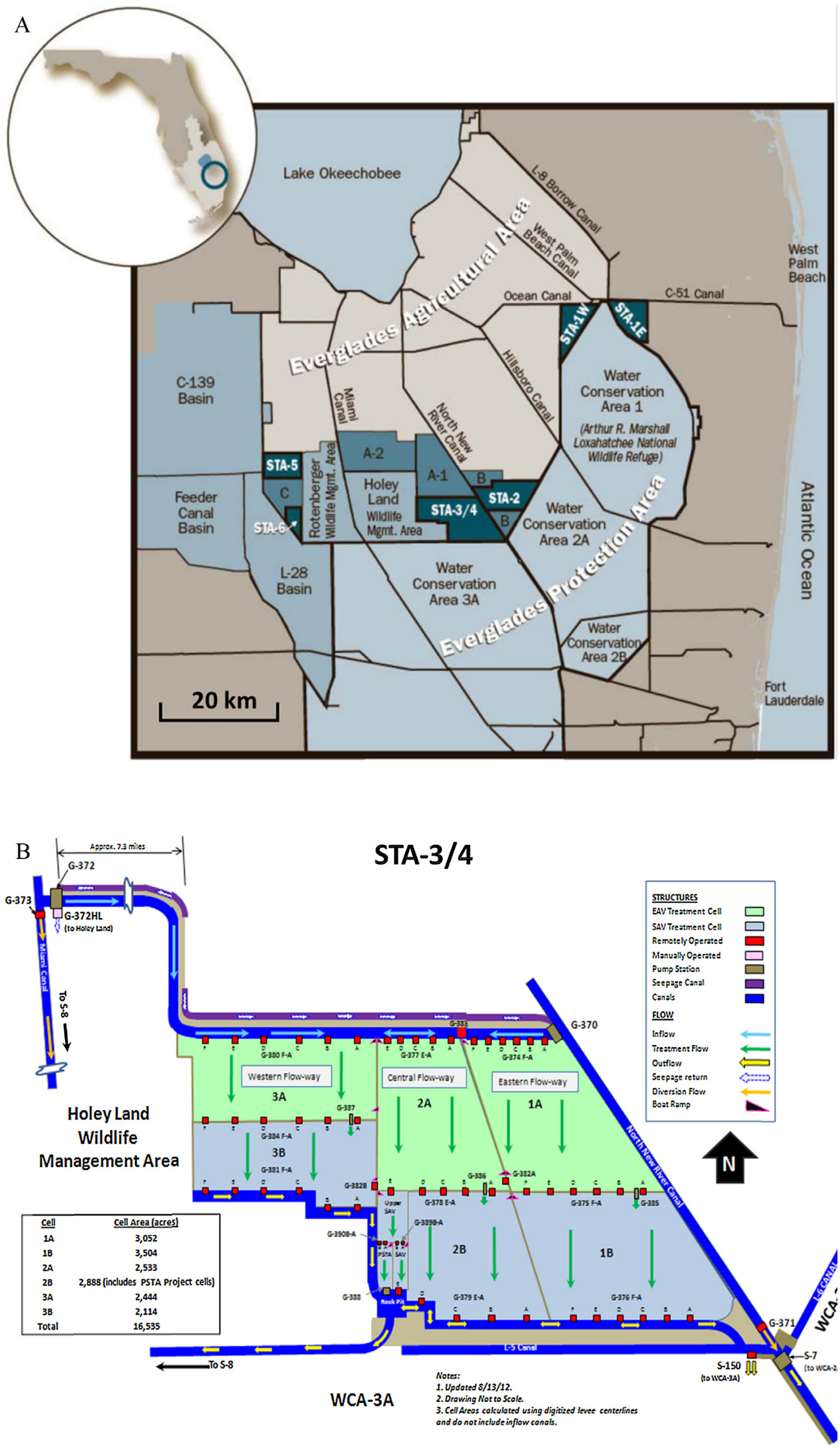

Fig. 1. (a) Location of the Everglades and Stormwater Treatment Areas (STAs). (b) Study area of STA-3/4 Cells 3A/3B.