Science of the Total Environment 466–467 (2014) 871–880

Contents lists available at ScienceDirect

Science of the Total Environment

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

Developing a flow control strategy to reduce nutrient load in a reclaimed multi-reservoir system using a 2D hydrodynamic and water quality model

Yongeun Park [a], Kyung Hwa Cho [b], Joo-Hyon Kang [c], Seung Won Lee [a], Joon Ha Kim [a,*]

[a] School of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST), 261 Cheomdan-gwagiro, Buk-gu, Gwangju 500-712, South Korea
[b] School of Urban and Environmental Engineering, Ulsan National Institute of Science and Technology (UNIST), 100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulsan 698-805, South Korea
[c] Department of Civil and Environmental Engineering, Dongguk University-Seoul, Seoul 100-715, South Korea

HIGHLIGHTS

- 2D hydrodynamic and water quality model was used to predict the pollutant load.
- Sensitivity analysis and global optimization method were used to develop the model.
- The reduction of nutrient loads was calculated using the flow increase scenario.
- The TN and TP loadings were reduced by 27.2% and 6.6% under the optimal flow.
- This study suggested operational strategies for managing a multi-reservoir system.

ARTICLE INFO

Article history:
Received 12 March 2013
Received in revised form 2 July 2013
Accepted 13 July 2013
Available online xxxx

Editor: Simon Pollard

Keywords:
Integrated reservoirs
Water quality modeling (CE-QUAL-W2)
Pattern search algorithm
Sensitivity analysis
Flow control

ABSTRACT

Blocking the natural bi-directional flow in an estuarine system using an artificial dyke has commonly caused serious water quality problems. In the southwestern part of South Korea, a parallel triple-reservoir system was constructed by blocking the mouth of three different rivers (Yeongsan, Okcheon, and Kumja), which were then interconnected using two open channels. This system has experienced a deterioration in water quality due to pollutants accumulated from the upper watershed, and has continually discharged pollutant loads to the outer ocean. Therefore, the objective of this study is to establish an effective dam operation plan for reducing nutrient loads released from the integrated reservoir. In this study, the CE-QUAL-W2 model, which is a 2-dimentional hydrodynamic and water quality model, was applied to predict the pollutant load released from each reservoir in response to different flow scenarios for the interconnecting channel. The model was calibrated using two novel methods: a sensitivity analysis to determine meaningful model parameters, and a pattern search to optimize the parameters. From the scenario analysis using flow control, it was determined that the total nitrogen (TN) and total phosphorus (TP) loadings could be reduced by 27.2% and 6.6%, respectively, under the optimal channel flow scenario by regulating the chlorophyll-a concentration in the reservoir. The results confirm that effective dam operation could contribute to a decrease in pollutant loads in the receiving seawater body. As such, this study suggests operational strategies for a multi-reservoir system that can be used to reduce the nutrient load being discharged from reservoirs.

1. Introduction

Diking of estuarine and tidal flows has been an extensive practice in downstream rivers used to effectively manage coastal areas (Hood, 2004), as it plays an important role in the supply of freshwater resources in agricultural areas, preventing floods, etc. (Wetzel, 2001). However, the viability of estuarine dams has encountered critical tradeoffs between the maintenance of the current and severe water quality degradation. An estuarine dam blocks the mouth of a river, and thus incurs adverse effects in a waterbody, including eutrophication, accumulation of pollutants, a decrease in biodiversity, and estuarine stratification, among others (Lamping et al., 2005). For example, thermal and saline stratification result in degradation of water quality such as decreasing the dissolved oxygen in water at the bottom of the river and in the sediment, increasing the nutrient concentration in the river, and increasing the amount of heavy metals released from the bottom sediment (Borsuk et al., 2001; Wetzel, 2001). Above all, the contaminated discharge of an estuarine dam can incur detrimental effects on coastal water quality. As the receiving waterbody, coastal waters receive a

* Corresponding author. Tel.: +82 62 715 3277; fax: +82 62 715 2434.
E-mail address: joonkim@gist.ac.kr (J.H. Kim).

0048-9697/$ – see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.scitotenv.2013.07.041