Journal of Environmental Management 90 (2009) 1824–1832

Contents lists available at ScienceDirect

Journal of Environmental Management

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

# An innovative modeling approach using Qual2K and HEC-RAS integration to assess the impact of tidal effect on River Water quality simulation

Chihhao Fan [a,*], Chun-Han Ko [b], Wei-Shen Wang [c]

[a] Department of Safety, Health, and Environmental Engineering, Ming Chi University of Technology, 84 Gung-Juan Rd, Taishan, Taipei County 24301, Taiwan
[b] School of Forest and Resources Conservation, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd, Da-An District, Taipei 10617, Taiwan
[c] Graduate School of Biochemical Engineering, Ming Chi University of Technology, 84 Gung-Juan Rd, Taishan, Taipei County 24301, Taiwan

ARTICLE INFO

*Article history:*
Received 27 December 2007
Received in revised form
4 August 2008
Accepted 24 November 2008
Available online 1 January 2009

*Keywords:*
Water quality modeling
Qual2K
Streeter-Phelps
HEC-RAS
Tidal river

ABSTRACT

Water quality modeling has been shown to be a useful tool in strategic water quality management. The present study combines the Qual2K model with the HEC-RAS model to assess the water quality of a tidal river in northern Taiwan. The contaminant loadings of biochemical oxygen demand (BOD), ammonia nitrogen ($NH_3$-N), total phosphorus (TP), and sediment oxygen demand (SOD) are utilized in the Qual2K simulation. The HEC-RAS model is used to: (i) estimate the hydraulic constants for atmospheric re-aeration constant calculation; and (ii) calculate the water level profile variation to account for concentration changes as a result of tidal effect. The results show that HEC-RAS-assisted Qual2K simulations taking tidal effect into consideration produce water quality indices that, in general, agree with the monitoring data of the river. Comparisons of simulations with different combinations of contaminant loadings demonstrate that BOD is the most import contaminant. Streeter-Phelps simulation (in combination with HEC-RAS) is also performed for comparison, and the results show excellent agreement with the observed data. This paper is the first report of the innovative use of a combination of the HEC-RAS model and the Qual2K model (or Streeter-Phelps equation) to simulate water quality in a tidal river. The combination is shown to provide an alternative for water quality simulation of a tidal river when available dynamic-monitoring data are insufficient to assess the tidal effect of the river.



## 1. Introduction

The prudent utilization of water resources has been an important issue in public policy for decades, and much effort has been expended in developing effective water management strategies to ensure sufficient high-quality water supplies (Ning et al., 2001; Elshorbagy and Ormsbee, 2006; Eatherall et al., 1998; Horn et al., 2004). In this regard, water quality modeling is increasingly recognized as a useful tool for acquiring valuable information for optimal water quality management.

Over the years, several water quality models have been developed for various types of water bodies (such as rivers, lakes, reservoirs, estuaries, and so on). Some of these models have included basic water quality indices (such as dissolved oxygen and biochemical oxygen demand), whereas others have included more sophisticated water quality criteria (such as eutrophication levels and toxicity impacts). For example, Thayer and Krutchkoff (1967) applied a 3-dimensional algorithm to advanced water quality spatial analysis, and Pelletier et al. (2006) confirmed the applicability and flexibility of the QUAL2Kw framework for simulation of river water quality.

However, Lindenschmidt (2006) has suggested that complex models are not necessarily the most useful models. This is because abundant monitoring data are required for the estimation, calibration, and verification of model parameters, and some complex simulation models can involve multiple parameters that have never been previously measured or reported. In some instances, these parameters have been estimated by other algorithms. For these reasons, the use of complicated models for water quality simulation is problematical, and the simulated results might not be as reliable as they are purported to be.

Given these circumstances, the utilization of basic water quality models has become a preferable option, and several successful examples have been reported in the literature (Mahamah, 1998; Drolc and Koncan, 1996). However, the application of basic water quality models has certain limitations. In particular, transport phenomena in rivers are often estimated with simplified assumptions, and parsimonious models can be incapable of accurate assessments of complex hydrodynamics (such as tidal effects in rivers).

Against this background, the present study investigates the applicability of a basic model to water quality simulation of a tidal river. The Qual2K model was selected for the study because of its

* Corresponding author. Tel.: +886229089899x4656; fax: +886229080783.
*E-mail address:* dillon@mail.mcut.edu.tw (C. Fan).

0301-4797/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2008.11.011

wide applicability and ease of use. The model calculates water quality indices using various combinations of contaminant loadings including biochemical oxygen demand (BOD), ammonia nitrogen ($NH_3$-N), total phosphorus (TP), sediment oxygen demand (SOD), oxygen consumption by algae growth, and so on. Because Qual2K does not consider tidal effects in its calculations, the HEC-RAS model is employed in this study to assess the impact of tidal effect on water quality simulation. Using these models, simulated results are compared with monitoring data from the Keelung River in northern Taiwan. This river was selected for the study because more than two million people live in its catchment area and the river water is employed for domestic water supply.

This paper represents the first report of this innovative use of combined models for water quality simulation in a tidal river.

## 2. Research setting

The Keelung River is a major river in the Taipei area of Taiwan. The river, which originates from the Snow Mountain of Taiwan at an elevation of approximately 3000 m, is 80 km in length and has a watershed area of approximately 501 square kilometres. The population living in the river's watershed has increased markedly in recent years in association with significant urban and economic development. Unfortunately, these developments have been accompanied by marked increases in contaminant loadings in the river, which, in combination with an inadequate sewerage system, has resulted in serious water pollution problems in the Keelung River.

To estimate the contaminant loadings in the Keelung River, the watershed area of the river has been divided into 41 pollution sub-divisions ('K1–K41') in accordance with topographical and geographical characteristics. In each sub-division, BOD, $NH_3$-N, and TP discharges due to domestic and industrial uses have been estimated under conditions of 60% sewerage-system coverage. The geographical location of the Keelung River and the pollution sub-divisions of the watershed are shown in Fig. 1. The BOD, $NH_3$-N, and TP loadings in each pollution sub-division are presented in Table 1.

According to the water quality monitoring protocol followed by the Taiwan Environment Protection Administration (EPA), BOD is the most important contaminant for analysis. Domestic sewage has been identified as the most significant source of BOD pollution, whereas the wastewater from pig farms is the least significant source. During the years between 2000 and 2006, BOD discharge due to domestic sewage, woodland non-point sources, industrial wastewater, and pig-farms wastewater were 41,698 kg/day,

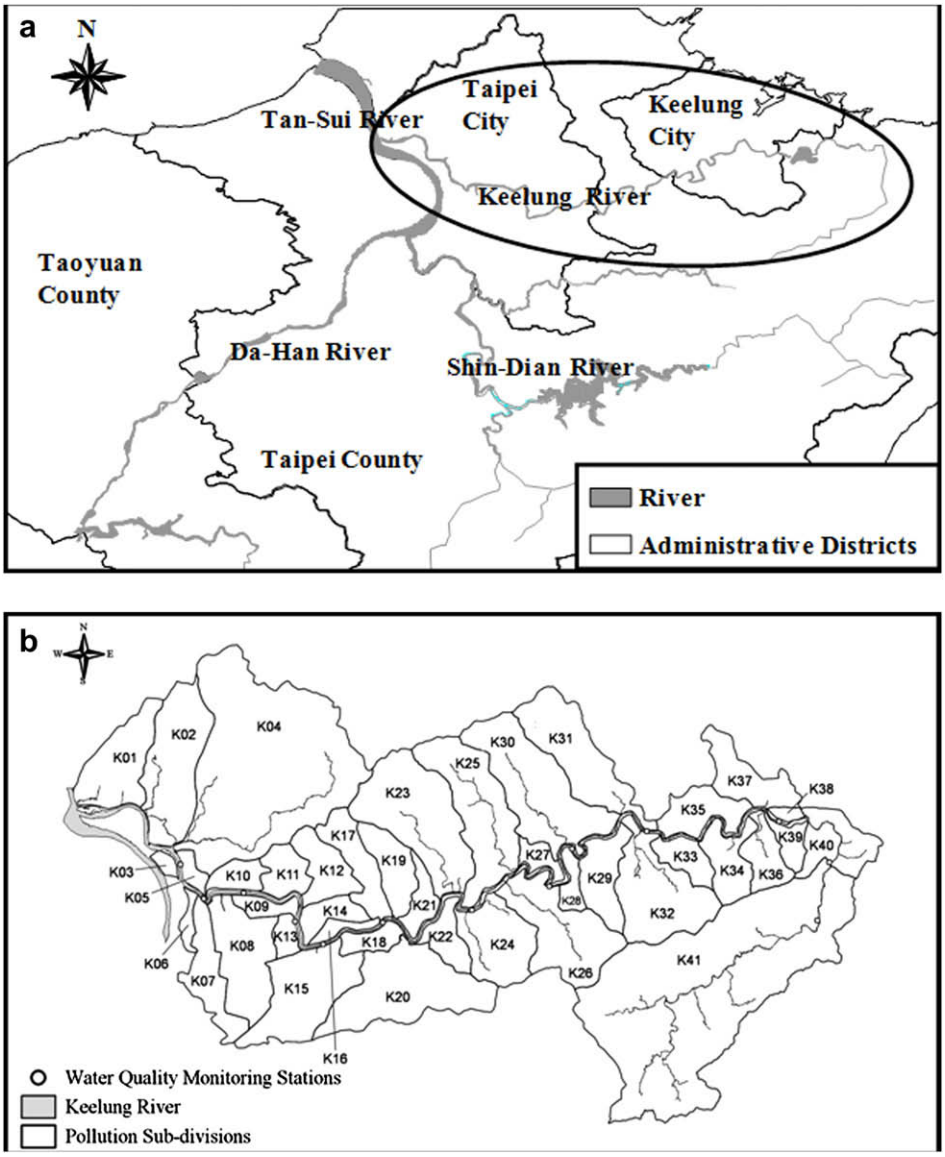


**Fig. 1.** Keelung River watershed: (a) geographical location; (b) pollution sub-divisions and locations of water quality monitoring stations.