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A fast mobile early warning system for water quality emergency risk in ungauged river basins

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ABSTRACT

Environmental decision support system (EDSS) has become an important research topic in the fields of water environment protection and emergency early warning. Most existing systems require plenty of measured data, which are typically unavailable in ungauged basins. In order to develop an early warning system that can work with few measured data, a mobile environment decision support system (MEWSUB) for early warning and emergency assessment in ungauged river basins was developed. A one-dimensional water quality model was built for the system and the terrain module and pollutant module were developed for terrain digitization and pollutant release process data generation. MEWSUB can quickly create water quality model input files, simulate the temporal release of pollutants, and display the results in a dynamically rendered map and trend line diagram via HTML5. The system has been used successfully to support early warning efforts during accidents on several ungauged rivers in China.

Software and data availability

Software Name	MEWSUB
Developers	This paper's authors, Hydroco Science and Technology Ltd
Hardware Requirements	Smartphone or tablet with GPS
Software Requirements	the APP on Android 4.0 and above or IOS6 and above, browser supporting HTML5.
Programming Language	Java, Fortran
Download instructions	Requires authorization.
Availability and cost:	Android APP may be requested free of charge by e-mailing the author (wangyonggui@whu.edu.cn); or directly browser (http://115.28.11.12:8085/ewup/) with account name and password.

1. Introduction

The sudden water pollution accidents have taken place more frequently around the world in recent years. The water environment emergency risks have caused heavy damage to humans' daily lives and the natural environment. These water environment pollution incidents suddenly or unexpectedly occur, that may lead to catastrophic environmental problems and grave social consequences. After water quality accidents, it is important to warn downstream areas after the water pollution accident. For downstream locations, in order to evaluate the pollutant impact and carry out emergency actions in a timely, accurate and reasonable manner, it is necessary to gain answers to four important questions about when the pollutant will arrive at sensitive sites downstream, what the peak value of the pollutant will be, how large the pollution areas will be, and how long the pollutant concentration value will remain at or above the security value (herein called 2W2H questions) (Hou et al., 2014).

With the development of GIS and distributed environmental numerical models (e.g., hydrodynamic and water quality models),

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these 2W2H questions can be answered easily. Early warning systems (EWS) for emergency response of sudden water pollution accidents coupled with GIS and water quality models have been studied and put into practical application in many countries (e.g., the British raw water quality monitoring system established by Severn Trent Water company on the Trent River (Adams et al., 2006), the American water quality early warning system managed by the Ohio River Valley Water Sanitation Commission on the Ohio River (Grayman et al., 2001), and the Chinese drinking water quality early warning and control system (Hou et al., 2013)). These early warning systems can be applied to real-time alarm monitoring and emergency response (Song et al., 2013); water quality EWS can provide important and essential pollution warning information for the adjustment of treatment operations to clean pollutant or decrease the contamination concentration and protect human lives (Quansah et al., 2010). Most of these existing systems are based on client-server architecture software approaches, and few have a Web services structure. With abundant input data, they can be used for precisely simulating contaminant transport. These EWS need a large number of measured data for numerical computation, but many of these data may be unavailable in ungauged river basins. Ungauged river basins abound in developing countries and often have high occurrences of water pollution. A new framework for water quality early warning to answer the 2W2H questions in ungauged river basins is urgently needed, especially in China.

Due to the rapid economic development and the growth of agriculture, industry and social construction activities, China has many occurrences of river water pollution contamination events, such as the nitrobenzene spill accident in the Songhua River in 2005 (Hu et al., 2009; Zhang et al., 2011), the odorous tap water crisis in Wuxi in 2007 (Zhang et al., 2010b), and the phenol leakage incidents in the Qiantang River in 2011 (Hou et al., 2014). This series of water pollution accidents attracted great attention from the government and academia, which prompted the development of a rapid and effective emergency response framework and building up the capability of early accident detection (Zhang et al., 2011). Early warning systems for water emergency risk have become an important research topic in water environment protection and risk assessment fields. Although many systems like DEWS (Hou et al., 2013), WPMS_ER (He et al., 2011), EWS-FDWQ (Li et al., 2009) and FDEWS (Li et al., 2006) are designed to address specific problems in a specific water body, they may still require large, spatially distributed inputs for their coupled complicated numerical models.

Environmental monitoring and science research in developing countries like China lags that in developed countries. Due to time and financial resource constraints to support monitoring stations in all waters, government and research institutions typically focus on demonstrations in big rivers and lakes. Numerous data may be collected in such areas, while little data are collected in other smaller rivers or channels. Insufficient terrain, hydrometeorological, pollution source and water quality parameter data needed for distributed models in China (Reckhow, 1994) is effectively putting a brake on the development and practical application of EWS (Burchard-Levine et al., 2014).

With the rapid development of industrial transfer (high polluting industries have been moved from the east China cities to west China cities or from the big cities to the small towns) and the construction of traffic routes in China, a number of ungauged river basins have become areas accepting traditional industry and have accepted many new factories. Most of these new factories are operated in a traditional industrial production style with high energy consumption and high pollution. Together with the impact of traffic lines and factories along rivers, these ungauged river basins face severe water quality threats from factory discharges and traffic accidents. In these areas, as the river water may be the main or even the only water source for life and production, once it is polluted, people's daily lives will be seriously impacted. Therefore, an effective tool that can answer the 2W2H questions and be applied in ungauged river basins is urgently needed. Using this tool for assistance, the environment management branch or the environment protection operator can simulate fate and transport of chemical pollution, create an emergency response plan for pollution cleanup, and inform the relevant people when to store adequate amounts of fresh water.

Furthermore, early warning and emergency planning involves significant work in the field, where computer equipment may not be readily available. Equipped with professional mobile systems, smartphones are strong candidates used for the work of field investigations, data collection and decision making (Dong and Li, 2014). Water pollution accident evaluation and early warning of the fate and flow distribution of contaminates and the rate and trend of water pollution in ungauged river basins is an example of such field work. In order to meet these requirements of convenient and rapid early warning of water environment emergency risks in ungauged rivers, this paper explores early warning technology of sudden water pollution accidents in ungauged rivers, proposes a framework for mobile water quality early warning systems, and presents its recent application in an ungauged river in China.

The paper is structured as follows: Section 2 analyzes related work about the risk in ungauged basins to identify the key points of early warning in ungauged basins. The One-dimensional water quality model for pollutant simulation, and the features of EWS and Web services technology for mobile early warning systems are also discussed in this section. Section 3 presents the architecture of MEWSUB as well as the main content and functions of the input files for the model and the system. The two technologies for digital terrain data generation and accident release data creation are described in Section 3.3. Section 3.4 describes the method to correct the model results, and Section 3.5 describes the output data from the system. A case study using the system for early warning in the Xin'an River of China is presented in the Section 4. Finally, the paper provides conclusions in Section 5.

2. Related work

2.1. Risk and early warning in ungauged river basins

Risk is defined as “the combined measure of the degree of detriment to society (in this case concerning people's health) caused by a defined event (or combination of events), and the probability of that event occurring” (McIntyre et al., 2003). These risks arise for numerous reasons such as unlawful or accidental pollution discharges (point discharges), transportation spills and chemical or radioactive spills. As pressure on water resources globally is rising, small catchments and tributaries of big rivers are becoming increasingly more important for water supply and economic development (Smakhtin, 2001). Numerous factories and transport lines have been built in these areas. Unfortunately, due to historical and current causes, the systematically recorded flow and environment data in these basins are often sparse or non-existent, and these phenomena are especially prominent in many developing countries (Niadas, 2005). These basins are ungauged or poorly gauged basins. An ungauged basin was defined in the “predictions in ungauged basins (PUB) project” by the International Association for Hydrological Sciences (IAHS) as “an ungauged basin is one with inadequate records (in terms of both data quantity and quality) of hydrological observations to enable computation of hydrological variables of interest (both water quantity or quality) at the appropriate spatial and temporal scales, and to the accuracy