Available online at www.sciencedirect.com
ScienceDirect
Environmental Modelling & Software 22 (2007) 1184–1195
Environmental Modelling & Software
www.elsevier.com/locate/envsoft

CITY DRAIN © – An open source approach for simulation of integrated urban drainage systems

Stefan Achleitner*, Michael Möderl, Wolfgang Rauch

Unit of Environmental Engineering, Institute of Infrastructure, Faculty of Civil Engineering, University of Innsbruck, Technikerstr. 13, 6020 Innsbruck, Austria

Received 10 March 2005; received in revised form 13 May 2006; accepted 9 June 2006
Available online 24 August 2006

Abstract

In the last years design procedures of urban drainage systems have shifted from end of pipe design criteria to ambient water quality approaches requiring integrated models of the system for evaluation of measures. Emphasis is put on the improvement of the receiving water quality and the overall management of river basins, which is a core element of the Water Framework Directive (WFD) as well.

Typically, it is not necessary to model the whole variety of effects on the receiving water but to focus on the few dominating ones. Only pollutants and processes that have a direct and significant influence on the selected impacts need to be described quantitatively, whereas all other processes can be neglected. Hence, pragmatism is required to avoid unnecessary complexity of integrated models. This is as well true for software being used in daily engineering work, requiring simplicity in handling and a certain flexibility to be adjusted for different scenarios.

CITY DRAIN © was developed to serve these needs. Therefore it was developed in the Matlab/Simulink © environment, enabling a block wise modelling of the different parts of the urban drainage system (catchment, sewer system, storage devises, receiving water, etc.). Each block represents a system element (subsystem) with different underlying modelling approaches for hydraulics and mass transport. The different subsystems can be freely arranged and connected to each other in order to describe an integrated urban drainage system. The open structure of the software allows to add own blocks and/or modify blocks (and underlying models) according to the specific needs.

The application of CITY DRAIN is shown within the integrated modelling case study Vils/Reutte. Further additional applications for CITY DRAIN, including batch simulations, real time control (RTC) and model based predictive control (MBPC) are presented and discussed.

Keywords: CITY DRAIN ©; CSO; Integrated urban drainage modeling; Receiving water; RTC; Sewer system; Simulink ©; Water quality

Software availability

Name of the software: CITY DRAIN
Contact Address: Stefan Achleitner, Wolfgang Rauch, Unit of Environmental Engineering, Institute of Infrastructure, Faculty of Civil Engineering, University of Innsbruck, Technikerstr. 13, 6020 Innsbruck, Austria. Tel.: +43 512 507 6921; fax: +43 512 507 2911. stefan.achleitner@uibk.ac.at, wolfgang.rauch@uibk.ac.at.
Year first available: 2005
Software requirements: MATLAB Release 12 (or higher)
Program Language: Matlab/Simulink
Program Size: ~10 MB.
Availability: Freeware, contact developer

1. Introduction

The aspect of improving ambient water quality, based on the overall management of river basins gained importance during the last years (Blöch, 1999). The emphasis is being put on the improvement of the receiving water quality as well as on river basins management as requested also by the European water framework directive (WFD). Both aspects require a change in the design procedures for urban drainage systems.

* Corresponding author: Tel.: +43 512 507 6930; fax: +43 512 507 2911.
E-mail address: stefan.achleitner@uibk.ac.at (S. Achleitner).

1364-8152/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envsoft.2006.06.013

Reason is that the application of design rules based on emission criteria does not necessarily lead to an improvement of the water quality (Lau et al., 2002; Lijklema, 1995). Thus a shift is recently experienced from end of pipe design criteria to ambient water quality approaches (Achleitner et al., 2005). For the application in practice, software tools are required that are capable of modeling urban drainage systems (including the receiving water) in an integrated manner. Rainfall as the elementary input source is of irregular occurrence in intensity and duration, which leads to the need of long term simulations for being capable of a systems performance.

The schematic in Fig. 1 illustrates the main elements and information flow occurring. For simple systems – when the information flow follows the flow of water through the system-simultaneous calculation of the subsystems is not required. A sequential calculation of elements can be applied, transferring output from one element to another. Unless feedback fluxes occur, such as required for real time control (RTC), the simultaneous simulation of subsystems is not vital for a integrated modelling (Rauch et al., 2002).

2. Dominant processes and complexity of models

2.1. Principals

Software for integrated modelling may incorporate a variety of models covering hydraulics, mass transport, processes for conversion of matter etc. within the subsystems. Main objective is the prediction of the system performance including the receiving water quality. For choosing the appropriate models it is therefore vital to characterise the impacts onto the receiving water with regard to their type (hydraulic, chemical, bio-chemical, etc.) and duration (e.g. acute, delayed, accumulating).

Regarding the time scale for modelling not only the dynamics of the relevant processes in the drainage system itself are to be considered but also the duration of the impacts (and associated processes) in the receiving waters. E.g. acute pollution occurs instantly and requires short term modelling whereas accumulative effects in the receiving water can only be covered within a long term simulation effort. But also the stochastic

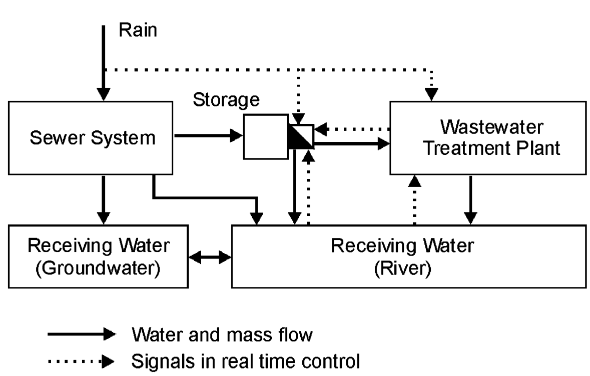

Fig. 1. Schematic on the main elements and information flow in an integrated model (redrawn from Rauch et al., 2002).

nature of rainfall as the source of impacts in an urban catchment needs to be considered. Single rain events are often source for acute effects in the receiving water such as hydraulic stress or pollutants entering the receiving water. The assessment of those is based on an evaluation of frequency, magnitude and duration of the impact (see e.g. Harremoës and Rauch, 1996) and thus requires a statistical interpretation. This again is possible only within the framework of long term simulation studies.

Overall the computation in CITY DRAIN © is based on an fixed discrete time steps approach where each subsystem uses the same time increments, usually being predetermined by the temporal resolution of the rain data used. Models implement for hydraulics and mass transport are formulated for discrete time steps Δt.

2.2. Computational aspects for hydraulics

Flow of water in both sewers and rivers is described by the continuity and momentum equations. The latter is known as the Navier-Stokes or Reynolds equation. The actual form of a hydrodynamic model depends on assumptions made on characterizing turbulence but for water quality purposes mostly the well-known, cross-sectionally integrated (1D) Saint Venant equations or approximations to these equations are used. Different levels of simplifications of the momentum equation are known for describing unsteady flow. Most simple approximation is the kinematic wave model being valid where backwater effects are negligible. All hydrodynamic equations have in common that they are demanding from a computational point of view. Therefore a variety of simpler conceptual models where developed (frequently denoted as hydrological models). These as well respect conservation of mass but use conceptual relations instead of momentum equations. The rapid simulation with conceptual models puts them in favour to hydrodynamic models regarding computational effort. Effects such as pressurized flow or backwater effects cannot be covered. For allowing long term simulations the blocks implemented in CITY DRAIN are based on purpose on simple conceptual models for hydraulics.

2.3. Computational aspects for transport and conversion of matter

For limiting the effort of simulation only relevant pollutants and processes need to be considered. Neglecting issues of secondary importance is required to avoid unnecessary complexity of models. Transport models describe in principle only the flow of soluble and conservative matter through the system. Effects such as physical or biological conversion processes (sedimentation, degradation, etc.) are considered by extension of the transport equations.

3. CITY DRAIN – implemented models

Basic idea was to create an open source toolbox for integrated modelling of urban drainage systems. For the use in