A COMPONENT-BASED DISTRIBUTED WATERSHED MODEL FOR THE USDA CEAP WATERSHED ASSESSMENT STUDY

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INTRODUCTION

The specific objectives of this study were to: 1) implement hydrological modeling components under the Object Modeling System (OMS), 2) assemble a new prototype watershed scale model for fully distributed transfer of water between land units and stream channels, and 3) evaluate the accuracy and applicability of the modular watershed prototype model for estimating stream flow. The watershed selected for application of the prototype watershed model was the Cedar Creek watershed (CCW) in northeastern Indiana, USA. The prototype model was applied without calibration, thus eliminating any ambiguities pertaining to the use of different optimized model parameter values. The study is unique in that it represents the first attempt to develop and apply a complex natural resource system model using the OMS.

OBJECT MODELING SYSTEM (OMS)

The Object Modeling System (OMS) is a comprehensive modeling framework that helps streamline the development of integrated natural resource system models for current and future model delivery (David et al. 2002) using a component-oriented modeling approach. OMS is implemented in the Java programming language on top on the NetBeans application platform. OMS modeling components can be characterized as system and scientific components. System tools such as a Component Builder and Model Builder support model development where various scientific components can be assembled into a complex model. The model can then be executed using the OMS Runtime Environment. Modular frameworks for model development like OMS are well-suited for studies such as this requiring complex simulation component technology integrated into a common, collaborative, and flexible system.

OMS-BASED CEAP PROTOTYPE WATERSHED MODEL

The J2K modeling system (Krause et al., 2006) was used for the simulation of the hydrological dynamics of the Cedar Creek Watershed in Indiana. J2K is a modular, spatially distributed hydrological system which implements hydrological processes as encapsulated process components. J2K operates at various temporal and spatial aggregation levels throughout the watershed. For example, runoff is generated at the Hydrologic Response Unit (HRU) level with subsequent calculation of runoff concentration processes (through a lateral routing scheme) and flood routing in the channel network. HRUs for the CCW were delineated by GIS overlay techniques using spatial data layers (e.g., elevation, slope, aspect, land use, soil type, and hydrogeology), thus creating a topologically connected pattern of single land units with similar data features. The J2K model had previously been implemented only in the JAMS (Jena Adaptable Modelling System) modular modeling framework (Kralisch and Krause, 2006). Therefore, the following J2K modeling resources were transferred to the OMS framework: 1) 40+ J2K Java scientific source components for watershed scale hydrological processes including overland flow, infiltration, ET, soil water movement, groundwater storage, and flood routing; and 2) ASCII data input files for hydrogeology, soils, land use, HRU routing, and channel reach routing that are referenced from the J2K model XML (Extensible Markup Language) input file.

RESULTS AND DISCUSSION

Two input parameter sets were developed for OMS-J2K evaluation: 1) a "base parameter set" with parameter values taken from previous simulation studies where J2K was applied to watersheds with characteristics similar to the CCW; and 2) an "adjusted parameter set" with modifications to input parameters related to ET, soil water storage, and soil water lateral flow. Table 1 shows model performance for daily, monthly, and annual stream flow response using both parameter sets and the following model evaluation statistics: Nash-Sutcliffe model efficiency (E_{NS}), coefficient of determination (R^2), Root Mean Square Error (RMSE), and percent bias (PBIAS). Comparisons of daily, average monthly, and annual average simulated and observed flows for the 1997-2005 simulation period using the base parameter set resulted in evaluation coefficients ranging from 16 to 20% for PBIAS, 1.98 to 8.23 m^3 s^{-1} for RMSE, and 0.47 to 0.55 for E_{NS}. All statistical evaluation coefficients for daily, average monthly, and average annual stream flow improved substantially for the adjusted parameter set (e.g., PBIAS, RMSE, and E_{NS} coefficients ranged from 9 to 10% for PBIAS, 1.02 to 6.06 m^3 s^{-1} for RMSE, and 0.62 to 0.65 for E_{NS}). The range of relative error (e.g., PBIAS) and E_{NS} values for uncalibrated stream flow predictions in this study were similar (base parameter set) or better (adjusted parameter set) than others reported in the literature. The study is unique in that it represents the first attempt to develop and apply a complex natural resource system model under the OMS. In addition, this study represents the first time that J2K hydrological process components have been evaluated on a watershed in the United States. The results show that the prototype OMS-J2K watershed model was able to reproduce the hydrological dynamics of the Cedar Creek Watershed with sufficient quality, and should serve as a foundation on which to build a more comprehensive model to better assess water quantity and quality at the watershed scale.

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Table 1. Statistical evaluation for OMS-J2K simulated daily, average monthly, and average annual Cedar Creek Watershed stream flow (January, 1997 to December, 2005).

Evaluation coefficient	OMS-J2K statistical evaluation – base parameter set			OMS-J2K statistical evaluation – adjusted parameter set		
	Daily	Average monthly	Average annual	Daily	Average monthly	Average annual
E_{NS}	0.47	0.53	0.55	0.62	0.64	0.65
R^2	0.51	0.53	0.54	0.61	0.63	0.64
RMSE	8.23	4.01	1.98	6.06	2.77	1.02
PBIAS	20.21	16.49	15.67	10.17	10.13	9.40

Note: E_{NS} = Nash-Sutcliffe efficiency; R^2 = coefficient of determination; RMSE = root mean square error (m^3 s^{-1}); PBIAS = bias or relative error (%).