# DEVELOPMENT AND EVALUATION OF A COMPONENT-BASED WATERSHED MODEL USING THE OBJECT MODELING SYSTEM

**James C. Ascough II, Research Hydrologic Engineer, USDA-ARS-NPA Agricultural Systems Research Unit, Fort Collins, CO 80526 USA, jim.ascough@ars.usda.gov; Olaf David, Research Associate, Dept. of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO 80523 USA, olaf.david@colostate.edu; George H. Leavesley, Research Associate, Dept. of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO 80523 USA, george@usgs.gov; Peter Krause, Professor, Dept. of Geography, Friedrich-Schiller University, Jena, Germany, p.krause@uni-jena.de; Sven Kralisch, Research Associate, Dept. of Geography, Friedrich-Schiller University, Jena, Germany, sven.kralisch@uni-jena.de; Lajpat R. Ahuja, Soil Scientist, USDA-ARS-NPA Agricultural Systems Research Unit, Fort Collins, CO 80526 USA, laj.ahuja @ars.usda.gov**

**Abstract** The Object Modeling System (OMS) currently being developed by the USDA-ARS Agricultural Systems Research Unit and Colorado State University (Fort Collins, CO) provides a component-based environmental modeling framework which allows the implementation of single- or multi-process modules that can be developed and applied as custom-tailored model configurations. The 5-year ARS Conservation Effects Assessment Project (CEAP) Watershed Assessment Study (WAS) Project Plan provides detailed descriptions of research studies at 14 benchmark watersheds in the United States. In order to satisfy the requirements of CEAP WAS Objective 5 ("develop and verify regional watershed models that quantify environmental outcomes of conservation practices in major agricultural regions"), a new watershed model development approach is needed that can take full advantage of OMS modeling framework capabilities for assembling appropriate modules into a model customized to a specific problem and scale of application for a region. The European J2000 model **(**Krause et al., 2006) was selected to provide the initial components for a regionalized watershed model that satisfies the CEAP Objective 5 requirements. J2000 (referred to hereafter as J2K) is an object-oriented, modular hydrological system for fully distributed simulation of the water balance in large watersheds and catchments. The specific objectives of this study were to: 1) implement J2K hydrological modeling components under the OMS, 2) assemble a new modular 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 model for estimating daily and average monthly stream flow.

The Cedar Creek watershed (CCW) in northeastern Indiana was selected for application of the OMS-based watershed model. The CCW is located within the St. Joseph River Basin (41$^{o}$10'10'' to 41$^{o}$32'38'' N and 84$^{o}$53'49'' to 85$^{o}$19'44''W) and covers Noble, DeKalb, and Allen Counties. The OMS-J2K simulation period in this study was 1997 through 2005. Daily precipitation, solar radiation, wind speed, relative humidity, and maximum/minimum air temperatures for these years were obtained from the NOAA National Climate Data Center (NOAA-NCDC, 2004) for the Garret and Waterloo weather stations within the CCW. Regionalization pre-processors in OMS-J2K automatically distributed the climate data from the two gauges over the watershed. Historical measured data for Cedar Creek stream flow gauge 04180000 (41°13'08"N, 85°04'35"W) were supplied by the USGS for the 9-year period from January, 1997 to December, 2005. Initial model parameter values were taken from simulation studies successfully applying

J2K to watersheds in Germany and elsewhere exhibiting physical characteristics (e.g., topography, size, and agricultural land use) very similar to the CCW. Since the J2K model has not previously been applied in the United States, the initial parameter values represent an attempt at establishing a reasonable input parameter set without resorting to a detailed calibration procedure. The Nash-Sutcliffe model efficiency ($E_{NS}$) and percent bias (PBIAS) statistical evaluation coefficients were used to evaluate the overall correspondence of simulated output to measured values for daily and average monthly stream flow.

In general, the OMS-J2K model underestimated stream flow on a daily time-step as shown by a negative value for PBIAS (-18.55%). The $E_{NS}$ value of 0.46 for daily stream flow is considered unsatisfactory according to Moriasi et al. (2007) (although the PBIAS value is acceptable since it is under 25%). The $E_{NS}$ coefficient increased to 0.60 for average monthly stream flow with the PBIAS value for average monthly stream flow remaining the same as for daily stream flow. The initial uncalibrated simulation results exhibited a rather large overprediction of ET across the watershed (data not shown) in addition to a systematic underprediction of stream flow across all time scales. Therefore, modifications were made to input parameters related to evapotranspiration, soil water storage, and soil water lateral flow and all simulations re-run using the modified parameter values. All statistical evaluation coefficients for daily stream flow improved substantially for the modified parameter set, in particular, the $E_{NS}$ coefficient increased from 0.46 to 0.58 and PBIAS decreased from -18.55% to -8.59% (the OMS-J2K model still underestimated stream flow). The $E_{NS}$ coefficient for average monthly stream flow improved for the modified parameter set ($E_{NS}$ = 0.68) as compared to the initial parameter set ($E_{NS}$ = 0.60). Average monthly improvement was of similar magnitude as the improvement in daily stream flow. The range of relative error (e.g., PBIAS) and $E_{NS}$ values for uncalibrated daily stream flow predictions in this study (for both parameter sets) are similar or better than others reported in the literature for various watershed models.

The results show that the OMS-J2K prototype 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 regionalized model for the CEAP initiative that is able to quantify the impact of conservation practice implementation on water quantity and quality at the watershed scale. In particular, the fully-distributed topological routing scheme employed by OMS-J2K (thus allowing the simulation of lateral processes important for the modeling of runoff concentration dynamics) is much more robust than quasi-distributed routing schemes used by other watershed scale natural resource models (e.g., SWAT). The largest advantage of the OMS-J2K routing approach is a process-oriented view of spatial watershed characteristics that drive hydrological behavior. With a fully-distributed routing concept, higher spatial resolution in combination with the lateral transfer of water between HRUs and stream channel reaches can be considered a very important advancement (in hydrological modeling) towards deriving suitable conservation management scenarios for CEAP.