EVALUATING RECHARGE PARAMETER SENSITIVITIES IN THE PRECIPITATION-RUNOFF MODELING SYSTEM

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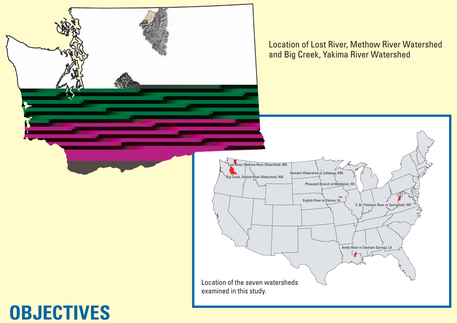
BACKGROUND

Ground-water recharge estimation methods vary from extremely complex to relatively simple. Most commonly used techniques, however, are limited by the scale of application. The methods either measure at a point or site scale and must be extrapolated to a larger area, or they measure a large area with no way to scale down to a local area. Another method category that can be used to estimate ground-water recharge includes process-based models that compute distributed water budgets on a watershed scale (Steuer and Hunt, 2001; Cherkauer, 2004). To date, these models have not been evaluated to determine which model parameters are the dominant controls in determining ground-water recharge. An understanding of the watershed-model parameters that control recharge estimates will help hydrologists focus on the compilation of the most relevant data in studies of regional ground-water recharge.

Seven existing watershed models, including two in Washington and five from distinctly different humid regions of the United States, were examined for this study. Parameter sensitivities were determined using a non-linear regression computer program to generate a suite of diagnostic statistics. Those statistics measure the amount of information provided by the data. This evaluation will identify by region the most important model parameters for determining ground-water recharge and also will compare and contrast the hydrologic system responses to those parameters.



Location of Lost River, Methow River Watershed and Big Creek, Yakima River Watershed

Location of the seven watersheds examined in this study.

OBJECTIVES

The general objective of this study is to determine which watershed model parameters are the dominant controls in determining ground-water recharge. Specific objectives are to determine if:

1. Regional differences exist across the United States in the sensitivity of ground-water recharge in humid-area basins to watershed-model parameters
2. Specific computer model chosen to simulate recharge affects parameter sensitivities
3. Modeler bias can affect ground-water estimates and parameter sensitivities

The results of this study will help focus data collection efforts in future studies requiring regional estimates of ground-water recharge. An understanding of parameter sensitivities and correlation will make the calibration process more efficient. Future studies also will benefit from an understanding of regional differences in ground-water recharge processes.

MODELS USED IN THE STUDY

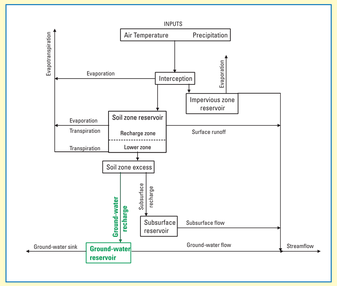
The Precipitation-Runoff Modeling System (PRMS) is a deterministic, processed-based, distributed-parameter modeling system designed to analyze the effects of precipitation, climate, and land use on streamflow and general basin hydrology (Leavesley and others, 1983). The Modular Modeling System (MMS), developed by Leavesley and others (1996), is a framework for the development and application of models. Existing PRMS models can be modularized and brought into MMS.

UCODE (Poeter and Hill, 1998) is a computer program that uses non-linear regression to estimate parameter sensitivities. The diagnostic statistics generated by UCODE can be used to measure the amount of information provided by the data. Three statistics presented here are the dimensionless scaled sensitivities, composite scaled sensitivities, and parameter correlation coefficients. A complete discussion of these statistics is given in Hill (1998) and Poeter and Hill (1998).

Dimensionless scaled sensitivities indicate the importance of an observation to the estimation of a parameter or, conversely, the sensitivity of the simulated equivalent of the observation to the parameter. In general, parameters with large dimensionless scaled sensitivities are more important to the simulation.

Composite scaled sensitivities indicate the information content of all the observations for the estimation of a parameter. In general, parameters with large composite scaled sensitivities are more important to the simulation.

Parameter correlation coefficients indicate parameters that cannot be uniquely estimated. Correlation coefficients range from -1.0 to 1.0. Absolute values close to 1.0 indicate a possible high degree of correlation.



Schematic diagram of the conceptual Precipitation-Runoff Modeling System.

MMS main interface menu showing the selected modules and the information flow among the modules.

PROCEDURE

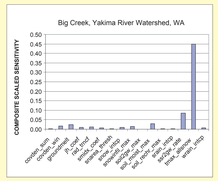
The importance of 15 parameters to ground-water recharge estimates were examined for five calibrated watershed models -- Amite River near Denham Springs, LA; English River near Kalona, IA; and S. Branch Potomic River near Springfield, WV (G. Leavesley, U.S. Geological Survey, written commun., 2004); Pheasant Branch near Middleton, WI (Steuer and Hunt, 2001); and Hamden Watershed near Callaway, MN (K. Vining, U.S. Geological Survey, written commun., 2004). An additional parameter, groundmelt, also was examined for the Big Creek, Yakima River Watershed, WA (Mastin and Vaccaro, 2002) and the Lost River, Methow River Watershed, WA (Ely, 2003).

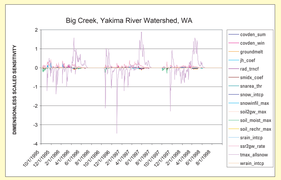
Scaled sensitivities are calculated by increasing and decreasing parameter values and calculating the derivative of the simulated value (recharge), with respect to the parameter. Correlation coefficients are calculated as the covariance between two parameters divided by the product of the standard deviation.

Parameter	Description
COVDEN_SUM	Vegetation cover density for summer
COVDEN_WIN	Vegetation cover density for winter
GROUNDMELT	Amount of snowpack water that melts each day to soils
JH_COEF	Monthly air temperature coefficient used in the Jensen-Haise potential Evapotranspiration computations
RAD_TRNCF	Transmission coefficient for short-wave radiation through the winter canopy
SMIDX_COEF	Coefficient in nonlinear contributing area algorithm
SNAREA_THRESH	Maximum snow water equivalent below which the snow covered area depletion curve is applied
SNOW_INTCP	Snow interception storage capacity for the major vegetation type on a Modeling Response Unit (MRU)
SNOWINFIL_MAX	Maximum infiltration rate for snowmelt, in inches per day
SOIL2GW_MAX	Amount of soil water excess for an MRU that is routed directly to the associated
SOIL_MOIST_MAX	Maximum available water holding capacity of soil profile, in inches
SOIL_RECHR_MAX	Maximum value for available water in the soil recharge zone, in inches ground-water reservoir, in inches per day
SRAIN_INTCP	Summer interception storage capacity for the major vegetation type on an MRU, in inches
SSR2GW_RATE	Coefficient to route water from the subsurface to ground-water reservoir
TMAX_ALLSNOW	Maximum temperature below which all precipitation is simulated as snow
WRAIN_INTCP	Winter rain interception storage capacity for the major vegetation type on an MRU, in inches

PRELIMINARY RESULTS (*subject to revision*)

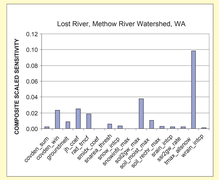
COMPOSITE SCALED SENSITIVITIES / DIMENSIONLESS SCALED SENSITIVITIES

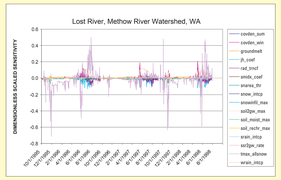




Parameter Correlation Coefficient

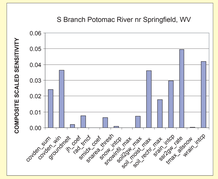
SMIDX_COEF SOIL_MOIST_MAX -0.94
SNOW_INTCP WRAIN_INTCP 0.94

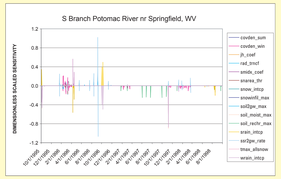




Parameter Correlation Coefficient

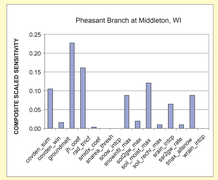
SOIL2GW_MAX SSR2GW_RATE -0.92

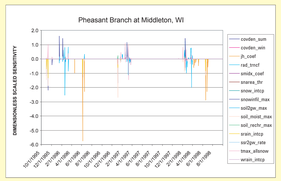




Parameter Correlation Coefficient

SRAIN_INTCP WRAIN_INTCP 0.98
SOIL_MOIST_MAX SOIL_RECHR_MAX -0.95
SOIL_MOIST_MAX WRAIN_INTCP -0.90
SOIL_MOIST_MAX SRAIN_INTCP -0.87
SOIL_RECHR_MAX WRAIN_INTCP -0.86



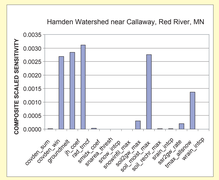


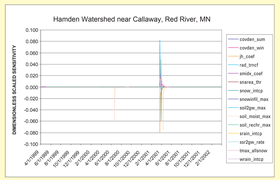
Parameter Correlation Coefficient

COVDEN_SUM SRAIN_INTCP -0.91

PRELIMINARY RESULTS (*subject to revision*)

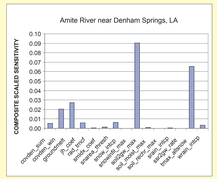
COMPOSITE SCALED SENSITIVITIES / DIMENSIONLESS SCALED SENSITIVITIES

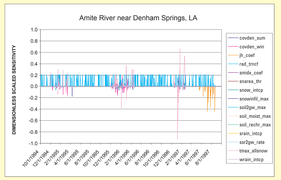




Parameter Correlation Coefficient

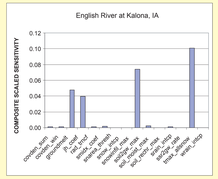
No parameter pair with an absolute value greater than 0.85

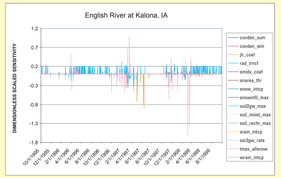




Parameter Correlation Coefficient

SOIL_MOIST_MAX SOIL_RECHR_MAX -0.93





Parameter Correlation Coefficient

SOIL_MOIST_MAX SOIL_RECHR_MAX -0.95

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