IV. PROJECT SUMMARY

Title: Groundwater Flow and Heat Transport in Wetlands: Transient Simulations and Frequency-Domain Analysis.

Project I.D.: UW-WRI #99-WLA-1

Investigators:
Principal Investigator – Hector R. Bravo, Associate Professor, Department of Civil Engineering and Mechanics, University of Wisconsin-Milwaukee (UWM).
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Period of Contract: July 1, 1998 to June 30, 2000.

Background/Need:
Reliable estimates of inflows to a wetland and hydrogeologic parameters can be crucial for understanding wetland hydrology as well as the sustainability of constructed wetlands. Yet inflows are spatially heterogeneous and time-dependent, and their characterization is not trivial. Groundwater models are one method for scaling point measurements up to the site scale, but the information provided by measured heads is frequently insufficient to find unique parameter values. That insufficiency can be overcome by including flux data or by jointly inverting head and temperature measurements.
Including heat transport in the model could result in different time scales than are traditionally considered dominant in groundwater flow. Frequency analysis of head and temperature data can characterize these time scales and facilitate the model construction.

Objectives:
The objectives of this project were: 1) to use a set of synthetic models to demonstrate the utility of including temperature data with traditional head data to constrain estimation of parameters important for groundwater flow modeling, 2) to use frequency-domain analysis to characterize a head and temperature data set collected at a wetland in Wilton, Wisconsin, and relate this characterization to proper model construction, and, 3) to apply the approach to simulating flow and heat transport at the Wilton wetland.

Methods:
The procedure consists in an optimization component and a simulation component. In the optimization module the unknown parameters are the flux across the water table and hydraulic conductivity; the objective is the minimization of a weighted sum of squared differences between measured and predicted heads and temperatures; and the constraints are the governing equations and boundary conditions in the simulation component. In the simulation module the primary unknowns are pressure and temperature; the governing equations express flow and energy balance; the set of boundary conditions includes the flux across the water table. The procedure was developed using hypothetical models and applied to the Wilton wetlands. The hypothetical models included a one-dimensional steady flow and transient heat transport model, and two dimensional steady state section models. The Wilton model is a two dimensional steady flow and transient heat transport model.
A univariate frequency domain analysis of water level, groundwater temperature and land surface data was done to uncover relevant time scales in those variables. The relative importance of heat conduction and advection was investigated through a bivariate analysis of land surface and groundwater temperature data.

Results and Discussion:
Synthetic and field models that did not converge to an optimal parameter set when only head data were used did converge when head and temperature data were used. The study demonstrated the viability of estimating groundwater inflows averaged over periods of the order of days by using average values of hydraulic head along with hourly temperature data. While the true values of the hydraulic conductivity and flux across the water table at the Wilton field site are unknown, the coupled inversion methodology produced estimates that were consistent with field measurements.
Harmonic analysis of groundwater temperature data showed that most of its variance is explained in terms of the annual cycle. That analysis showed consistency, at the yearly level, between land surface temperature and groundwater temperature at all depths. For frequency components other than the yearly cycle the significance of frequency relations decreases for records at deeper depths. In other words, the relative importance of heat conduction from and to the land surface decreases rapidly with depth.

Conclusions/Implications/Recommendations:
Joint inversion of head and temperature data is an effective method to estimate simultaneously hydraulic conductivity and inflow to wetland systems. While the computational effort required for the procedure increases for analysis of transient flow, time-and-frequency-domain analyses of head and groundwater temperature data can limit modeling time periods to those that provide the best return in parameter estimation.
The methodology should have wide applicability in areas where the groundwater-wetland interaction influences the temperature distribution of the shallow groundwater system and in areas where there is sufficient annual and/or daily temperature fluctuation. However, due to the larger data sets required, the reduced utility in multi-layer systems, and the additional uncertainty resulting from the additional thermal parameters needed to simulate the coupled system, these methods will complement rather than supersede calibration methods that use measured heads to estimate hydraulic conductivity and flux. They are expected to be of special use in systems where flux data are not readily available.

Related Publications:

Bravo, H.R., F. Jiang and R.J. Hunt, 2001. Using groundwater temperature data to constrain parameter estimation in a groundwater flow model of a wetland system, submitted to *Water Resources Research*.

Bravo, H.R., F. Jiang and R.J. Hunt, 2001. Parameter estimation for a groundwater flow and heat transport model of a wetland system: Selection of time scales through frequency domain analysis, submitted to XXIX IAHR Congress, Beijing, China.

Bravo, H.R., F. Jiang and R.J. Hunt, 2000. Improving wetland simulations by coupling groundwater flow and heat transport modeling, Proc. of the 4th International Conference Hydro Informatics 2000, Theme EW1, Cedar Rapids, Iowa.

Bravo, H.R., F. Jiang and R.J. Hunt, 2000. Analisis de temperatura del agua subterranea en el dominio de frecuencia y estimacion del aporte a bañados, Proceedings of the XIX Latin American Congress on Hydraulics, p. 437-446, Cordoba, Argentina.

Jiang, F., 2000. Calibration of model for ground water flow and heat transport in wetlands, M.S. Thesis, University of Wisconsin-Milwaukee.

Key Words: Groundwater Modeling, Wetlands, Heat Transport, Time-Series Analysis.

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