Texas A & M University and U.S. Bureau of Reclamation

Hydrologic Modeling Inventory

Model description Form

June 1999

Name of Model: OTIS

Model Type: Water Quality / Solute Transport

Model Objective(s):

OTIS is a mathematical simulation model used to characterize the fate and transport of water-borne solutes in streams and rivers. OTIS is often used with data from field-scale tracer experiments to quantify the hydrologic parameters affecting solute transport. Additional applications include analyses of nonconservative solutes that are subject to sorption processes and/or first-order decay.

Established method for quantifying instream mixing based on tracer- injection data in streams and small rivers. Used extensively by stream ecologists to document stream/hyporheic zone interactions.

Agency and Office: U.S.G.S., Water Resource Division

Technical Contact and Address: Rob Runkel, USGS, MS 415, Denver Federal Center, Denver CO 80225; runkel@usgs.gov

Model Structure or Mathematical Basis:

The governing equation underlying the model is the advection-dispersion equation with additional terms to account for transient storage, lateral inflow, first-order decay and sorption. Spatial derivatives in governing equation are approximated using standard finite difference methods. Resulting equations are solved using the Crank-Nicolson method as described by Runkel and Chapra (Water Resources Research, 1993, 1994). Mathematical limitations associated with solution scheme are well- documented (i.e. numerical constraints increase for highly advective systems).

Model Parameters:

The model computes solute concentrations at user-defined times and locations using the following user-supplied information:

a) System Configuration (Number and length of reaches)
b) upstream boundary conditions (solute concentration at x=0)

c) hydrology (flow and stream cross-sectional area)
d) mixing parameters (dispersion coefficient, transient storage parameters).
e) first-order reaction rates and/or sorption parameters (reactive solutes only)

Items a) and b) are typically defined by the investigator. Items c) and d) are often obtained using tracer-injection methods.

Spatial Scale Employed in the Model: user-defined

Temporal Scale Employed in the Model: user-defined

Input Data Requirements:
Observed data obtained from tracer-dilution studies are used to estimate the mixing parameters described above.

Computer Requirements:

Executable versions of the model are available for personal computers (DOS, Win 3.1, Win 95, Win NT, Linux) and Unix workstations (Sun-OS, Sun-Solaris, IBM-AIX, DEC, DGUX). Source code for compilation under other operating systems is also available.

Model Output:

Parameter Estimation / Model Calibration:

OTIS may be used in conjunction with data from field-scale tracer experiments to quantify the hydrologic parameters affecting solute transport. This application typically involves a trial-and-error approach wherein parameter estimates are adjusted to obtain an acceptable match between simulated and measured tracer concentrations.

A modified version of OTIS, OTIS-P, couples the solution of the governing equation with a nonlinear regression package. OTIS-P determines an 'optimal' set of parameter estimates that minimize the squared differences between the simulated and measured concentrations, thereby automating the parameter estimation process.

Model Testing and Verification:

Model Sensitivity:

Model Reliability:

Model Application / Case Studies:

(see http://webserver.cr.usgs.gov/otis/documentation/applications/)

Morrice, J.A., H.M. Valett, C.N. Dahm, and M.E. Campana, 1997, Alluvial Characteristics, Groundwater-surface water exchange and hydrological retention in headwater streams, Hydrological Processes, v. 11, p. 253 - 267.

Moyer, D.L., Dahm, C.N., and Valett, H.M., 1998, Effects of livestock grazing on solute transport and nutrient retent ion in four stream ecosystems: North American Benthological Society, 46th Annual Meeting.

Harvey, J.W., and Fuller, C.C., 1998, Effect of enhanced manganese oxidation in the hyporheic zone on basin-scale geochemical mass balance: Water Resources Research, v. 34, no. 4, p. 623-636.

Laenen, A., and Bencala, K. E., 1997, Transient storage assessments of dye-tracer injections in the Willamette River Basin, Oregon [Abstract] : American Society of Limnology and Oceanography Annual Meeting, February 10-14, Santa Fe, NM

Runkel, R.L., McKnight, D.M., and Andrews E.D., 1998, Analysis of transient storage subject to unsteady flow: Diel flow variation in an Antarctic stream: Journal of North American Benthological Society, v. 17, no. 2, p 143-154.

Tate, C.M., Broshears, R.E., and McKnight, D.M., 1995, Phosphate dynamics in an acidic mountain stream: Interactions involving algal uptake, sorption by iron oxide, and photoreduction: Limnology and Oceanography, v. 40, no. 5, p. 938-946.

Valett, H.M., J.A. Morrice, C.N. Dahm, and M.E. Campana, 1996, Parent lithology, surface-groundwater exchange, and nitrate retention in headwater streams, Limnol. Oceanogr., v. 41, no. 2, p. 333-345.

Documentation:

Runkel, R.L., 1998, One dimensional transport with inflow and storage (OTIS): A solute transport model for streams and rivers: U.S. Geological Survey Water-Resources Investigation Report 98-4018. 73 p.

Runkel, R.L. and S.C. Chapra, 1993, An efficient numerical solution of the transient storage equations for solute transport in small streams, Water Resources Research, v. 29, no. 1, p. 211-215.

Runkel, R.L. and S.C. Chapra, 1994, Reply to "Comment on An efficient numerical solution of the transient storage equations for solute transport in small streams by Dawes and Short", Water Resources Research, v. 30, no. 10, p. 2863-2865.

Other Comments: additional info at http://webserver.cr.usgs.gov/otis