Description of Analytical Tools

Name: DSM2 (Delta Simulation Model 2)

Contact Person: Tara Smith
Chief, Delta Modeling Section
Bay-Delta Office
California Department of Water Resources
1416, 9th Street, Room 215-7
Sacramento, CA 95814

Availability of Technical Support:

The Model and documentation (in a limited extent) are available via:

http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm

DSM2 is copyrighted by the State of California, Department of Water Resources. It is licensed under the GNU General Public License, version 2. This means it can be copied, distributed, and modified freely, and no one can restrict others in their ability to copy, distribute, and modify it. See the License for more details.

Categories: Surface water (Open Channel) hydraulics (Hydro), water quality (Qual), and particle tracking (DSM2-PTM)

Main Features and Capabilities:

Hydro

Finite difference implicit solution scheme
15 minute time-step
Irregular cross-cections
Weir and culvert gate structure
Model output includes stage, flow, and velocity at any location

Qual

Lagrangian Transport Model
15 minute time-step
Simulates multiple conservative and non-conservative constituents including dissolved oxygen, carbanoceous BOD, phytoplankton, organic nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, organic phosphorus, dissolved phosphorus, TDS and temperature
Includes advection and dispersion transport components
Model output includes concentration of any constituents simulated at any location
Capable of conducting finger-printing studies

PTM

Tracks individual Particle Movements
15 minute time-step
Includes deterministic and random movement
Model output includes the status of the particles injected
Graphical animation

Applications: DSM2 has been in use since 1997. It has been used as a tool to recreate historic flow conditions, forecast future conditions and evaluate various planning alternatives in the Sacramento-San Joaquin Delta. DSM2 has also been used as a forecasting tool to evaluate short and long term effects of specified changes in the Delta.

Calibration/Validation/Sensitivity Analysis: The first calibration was performed in 1997. In 2000, a second more rigorous calibration/validation was performed. The results are available online via a clickable map:

http://modeling.water.ca.gov/delta/studies/validation2000/map.html

Peer Review: A very limited Peer-Review was conducted by Professor Sobey From UC Berkeley with a contract from CWEMF (California Water and Environmental Modeling Forum). The results are no longer available on-line.

Anatomy of DSM2:

DSM2 is a river, estuary, and land modeling system.

River - Can simulate riverine systems, and has been extended from Sacramento to Shasta Dam. Also has been tested with high flow/stage simulations for flood modeling.

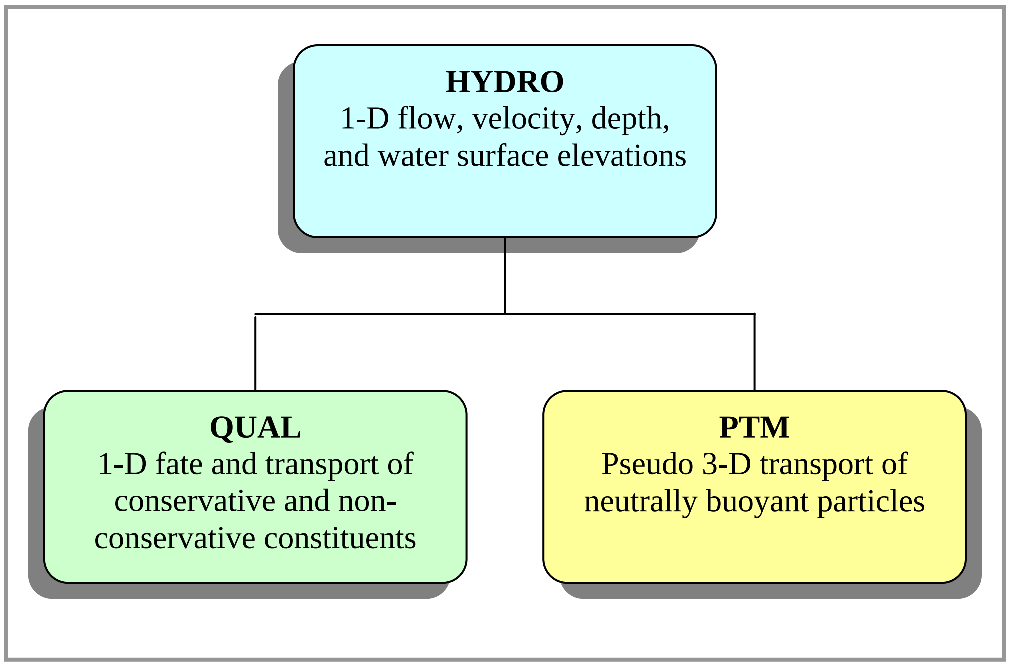
Estuary - Completely flexible estuary model; stages and flows may be specified at boundary and internal points.

Land - Includes effects from land-based processes, such as consumptive use and agricultural runoff.

DSM2 can calculate stages, flows, velocities; many mass transport processes, including salts, multiple non-conservative water quality constituents, temperature, THM formation potential and tracking of individual particles.

-Conceptual Basis: Conceptually DSM2 simulates flow conditions and concentration of water quality constituents (conservative and non-conservative mass) and tracks movements of individual particles in a network of channels. Hydrodynamic

information (velocity, water level and flow rates) from hydrodynamic simulation is used as inputs to drive simulation of channel water quality and to track movements of individual particles in a network of channels. DSM2 consists of three modules: HYDRO, QUAL, and PTM. The relationship between HYDRO, QUAL and PTM is shown below as provided by DSM2 documentation and tutorial:
(**http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm**



HYDRO simulates one-dimensional hydrodynamics including flows, velocities, depth, and water surface elevations. HYDRO provides the flow input for QUAL and PTM. QUAL simulates one-dimensional fate and transport of conservative and non-conservative water quality constituents (11 constituents) including salts, water temperature, dissolved oxygen, and trihalomethane formation potential given a flow field simulated by HYDRO. PTM simulates pseudo 3-D transport of neutrally buoyant particles based on the flow field simulated by HYDRO. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae. DSM2 thus provides a powerful simulation package for analysis of complex hydrodynamic, water quality, and ecological conditions in riverine and estuarine systems.

-Theoretical Basis: Theoretical basis of DSM2-HYDRO is a pair of partial differential mathematical equations, known as Saint-Venant flow equations based on conservation of mass and momentum describing one-dimensional, unsteady and non-uniform flow in open channels. Flow rate and water level (unknown or dependent variables) are allowed to vary with time and space (independent variables) and by accounting for acceleration (inertia) terms in momentum equation, it provides a basis for “dynamic” simulation of unsteady, non-uniform flow. When acceleration terms are dropped from momentum equations, however, it results in a “diffusion-wave” simulation. Once unknown variables, i.e. flow rate and water levels, are solved at each time step, the average cross-section velocity is computed based on channel geometry information. Therefore, HYDRO hydrodynamics simulation provides flow, velocity and water level information needed to simulate water quality (QUAL) and particle tracking (PTM) in a network of riverine or estuarine channels.

DSM2-QUAL is based on one-dimensional advection-dispersion equation to simulate transport of water quality constituents in open channels. Mass balance equations are written for all constituents in each parcel of water to ensure conservation of mass. Flow field computed by HYDRO provides needed information for advection part of the transport process. Transport via dispersion is computed based on input dispersion coefficient and concentration gradient calculated during simulation. The process of chemical and biochemical transformations including interaction among various parameters, decay and growth are considered too.

DSM2-PTM is based on pseudo 3-dimensional movement of neutrally buoyant particles within channels. The individual particles can move in longitudinal, transverse and vertical directions. Longitudinal movement is governed by both transverse and vertical velocity profiles obtained by multiplying the average cross sectional velocity, provided by HYDRO, and factors reflecting the transverse and vertical position of the particle. These factors are used to adjust for slower movements of particles closer to the bottom or sides of the channel due to shear stress between moving fluid and channel boundary. Transverse, as well as vertical movement, is based on mixing across and along the depth of the channel, respectively. The mixing coefficient is a function of the water depth and the velocity in the channel. The higher the velocity and deeper the channel, the mixing will be greater.

-Numerical Basis: The numerical formulation and solution of partial differential equations of mass and momentum in HYDRO is based on a numerical technique called: Four-Point implicit finite difference scheme. In this scheme channel length is divided into discrete reaches and the partial differential equations are transformed into finite difference forms for the discrete reaches by integrating numerically in time and space. The resulting equations are then linearized over a single iteration in terms of incremental changes in unknown variables (flow rate and water level) using approximations from truncated terms of Taylor series. When the discretized equations are written for all computational cells at the current time and the next time lines, it forms a system of equations which are solved simultaneously using an implicit algorithm.

DSM2-QUAL numerical solution is based on Branched Lagarangian Transport Model (BLTM) in which advection-dispersion equation is solved numerically using a Lagrangian coordinate system where computational nodes move with the flow. This method tends to reduce numerical errors associated with “fixed” Eulerian coordinates when solving transport equations. Because of the stability and accuracy of Lagarangian approach it was used for a network of channels with many branches and junctions. The current version of QUAL simulates about 11 constituents moving in as many as 30 branches connected at junctions. The HYDRO flow model provides the needed information to move the computational nodes with mean channel velocity in Lagarangian moving coordinate system thus accounting indirectly for advection part of the transport process. The dispersion part, however, is computed directly based on input dispersion coefficient and change in concentration gradient (2^{nd} partial derivative) computed during simulation. Reaction kinetics of the constituents can also be supplied as input by the user.

DSM2-PTM computes the location of an individual particle at any time step within a channel based on velocity, flow and water level information provided by HYDRO. The longitudinal movement is based on transverse and vertical velocity profiles computed from mean channel velocity provided by HYDRO. Mean channel velocity is multiplied by a factor which depends on particle's transverse location in the channel resulting in a transverse velocity profile resulting in slower moving particles closer to the shore. Mean channel velocity is also converted to vertical velocity profile using Von Karman logarithmic profile to account for slower particles closer to the channel bottom. The longitudinal movement is then the sum of transverse and vertical velocities multiplied by time step. Particles also move across the channel and in vertical direction along the depth due to mixing. A Gaussian random factor and mixing coefficients and the length of time step is used to compute the movement of particle in transverse and vertical direction.

Input and Output: HYDRO and QUAL require specifications of various input parameters. Geometry data for the Delta channels (cross sections, channel length, etc) are specified. The input geometry data are utilized to create the computational grid that represents the Delta. Locations of gates, barriers, and other flow control structures may also be specified. Initial conditions for flow and stage for a HYDRO simulation can be specified by one of two methods: 1) using a restart file that uses the simulation results from the final time step of a previous simulation as the initial conditions for a new simulation, or 2) using the initial conditions provided in one of the input files. Initial conditions for constituent concentrations for a QUAL simulation can be specified by one of three methods: 1) using a restart file that uses the simulation results from the final time step of a previous simulation as the initial conditions for a new simulation, 2) specifying initial concentrations in each channel in a user created input file (referred to as a "warm-start"), or 3) running a simulation that starts with a single concentration throughout the system as an initial condition and running DSM2 until the simulated concentrations are reasonable.

HYDRO provides output information on simulated flows, velocities, and water levels at designated locations throughout the Delta. QUAL provides simulated constituent concentrations at designation locations. Output time series can be specified at each computational time step (referred to as instantaneous results) or output data can be averaged over specified time intervals (15 minute, one hour, one day, etc). Output data can be provided in text or DSS format.

Data Management: DSM2's input structure is flexible, inputs are not required to be in a specific order. Input files are read in the order that they are specified in the main input file (dsm2.inp). If sections are repeated in the same file or in multiple input files, the information read last will supercede (overwrite) previously specified information. This allows the user to create a base set of files and overwrite only that information which changes for a particular simulation. In order to make processing and checking input data easier, the input data are typically specified in several different files. Input files are currently in text format. Time series input data can also be specified in DSS format (U. S. Army Corps' Hydrologic Engineering Center **D**ata **S**torage **S**ystem). The beginning of each section in a text input file is indicated by a keyword. For most sections, the second line of the section will be the field keywords, which tell the input system what data appears in which fields. The field keywords act as column headings for the data that follow. The data itself follows in the order indicated by the field keywords. Data are provided on as many lines as are necessary. The columns of data do not need to appear as columns on the screen. DSM2 will read the first value and associate it with the first keyword, the second value with the second keyword, etc. However, it may be easier for the user to interpret the input file if values are listed directly under the keyword with which they are associated. Sections must be closed by a line containing only the keyword END.

More information about the details of DSM2 can be found at:

http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2tutorialv122502.pdf