Integrated Water Flow Model (IWFM): A Tool For Numerically Simulating Linked Groundwater, Surface Water And Land-Surface Hydrologic Processes

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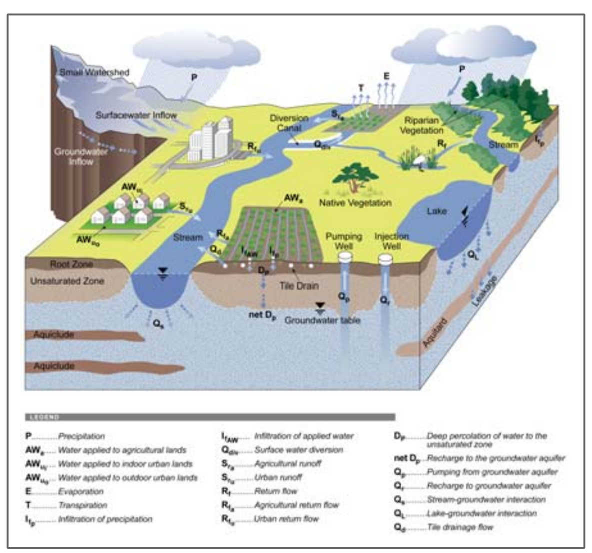
What is IWFM?

- Comprehensive, water resources management and planning tool developed by the California Department of Water Resources (CADWR, 2005)
- Simulates groundwater flow, surface flows and interaction between surface and subsurface flow processes using fully coupled conservation equations
- Land-use based simulation of surface runoff processes; agricultural (with user-specified crop types), urban, native vegetation and riparian vegetation lands can be simulated
- Simulates agricultural water demands based on crop acreages and agricultural management practices
- Computes stream diversions and groundwater pumping to meet the agricultural and urban water demands
- Database management using HEC-DSS files as well as ASCII text files
- Written in Fortran 95 using object-oriented programming concepts for ease of maintenance and extensibility
- Public domain source code and example problems available for download from California Department of Water Resources' IWFM web site



Additional Information

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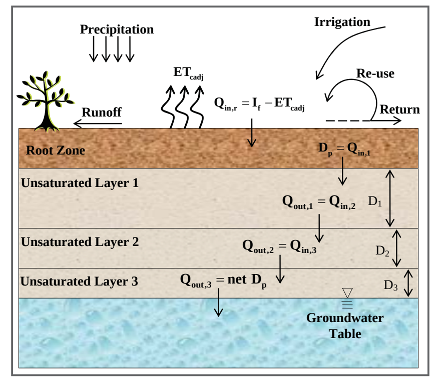
Vadose Zone Module

- Physically based routing of precipitation and irrigation water through root zone and multiple layers of unsaturated zone



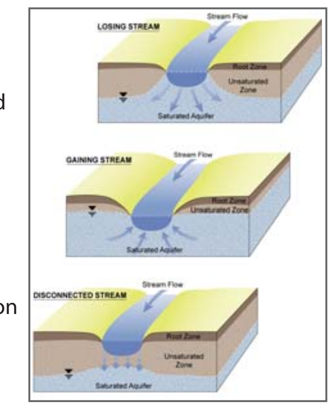
- Simulation of
  - Infiltration due to precipitation and irrigation
  - Surface runoff generated by precipitation and irrigation
  - Moisture-dependent ET using the FAO Paper 56 method
  - Non-point recharge to groundwater due to precipitation and irrigation
  - Re-use of irrigation return flow
  - Agricultural water demand based on available soil moisture, precipitation, crop ET requirement, crop acreage, basin irrigation efficiency and irrigation return flow re-use factor
- Pumping and stream diversions as sources of water to meet agricultural and urban water demands
- For planning studies, dynamic adjustment of pumping and/or stream diversions to meet the projected water demands

Groundwater Module

- Quasi 3-dimensional simulation of flow for a combination of confined, unconfined and leaky aquifer layers separated by aquitards
- Simulation of
  - Changing aquifer conditions; e.g. a confined aquifer becoming unconfined due to excessive pumping
  - Subsidence
  - Pumping from multiple aquifer horizons
  - Recharge: point (e.g. injection wells) and non-point (e.g. spreading basins, recharge due to precipitation and irrigation)
- Use of
  - Galerkin finite element method and fully implicit scheme for the spatial and temporal discretization
  - Newton- Raphson method for the linearization of the system of equations
  - Point SOR or Generalized Preconditioned Conjugate Gradient methods for matrix inversion

Stream Module

- Assumption of zero storage at a stream reach in computing stream flows; i.e. $Q_{in} = Q_{out}$
- Dynamic simulation of the state of the stream - aquifer interaction; i.e. hydraulically connected or disconnected



- Fully coupled stream and groundwater conservation equations
- Stream-aquifer interaction:

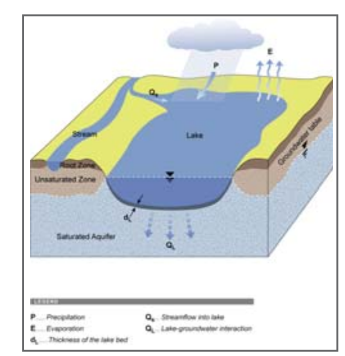
$$Q_s = C_s\,(h_s - h_g)$$

where Q_s is the stream-aquifer interaction (L^3/T); C_s is the conductance of stream bed material (L^2/T); h_s is the head in stream; h_g is the groundwater head

- Simultaneous solution of stream and groundwater equations results in the direct computation of stream - aquifer interaction
- Simulation of by-passes, and diversions for agricultural and urban water use

Lake Module

- Computation of lake storage as a function of
  - Precipitation
  - Evaporation
  - Inflows from streams, pumping
  - Lake-aquifer interaction
  - Lake outflow



- Dynamic simulation of the state of the lake-aquifer interaction; i.e. hydraulically connected or disconnected
- Fully coupled lake and groundwater conservation equations
- Lake-aquifer interaction:

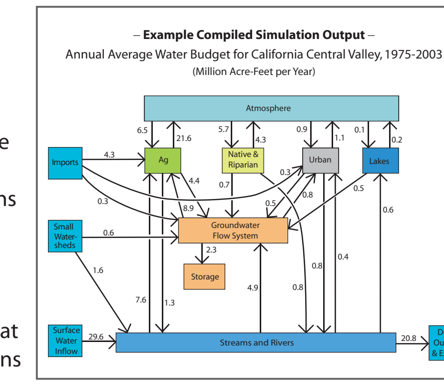
$$Q_L = C_L\,(h_L - h_g)$$

where Q_L is the lake-aquifer interaction (L^3/T); C_L is the conductance of lake bed material (L^2/T); h_L is the lake surface elevation; h_g is the groundwater head

- Simulation of ponding and draining conditions for managed water bodies (e.g. managed wetlands) by using time-series maximum lake elevation

Simulation Output Options

- Extensive set of output options for simulation results include



  - Groundwater, stream, tile drain, element face flow and boundary node flow hydrographs at selected locations
  - Vertical flow among aquifer layers
  - Groundwater budget at predefined subdomains
  - Detailed groundwater zone budget at arbitrarily grouped elements using a unique algorithm (Dogrul and Kadir, 2006)
  - Stream flow budget
  - Lake water budget
  - Root zone water budget
  - Agricultural and urban water demand and supply details
  - Stream diversions and delivery details
- Options to print simulation time-series results to ASCII text files or HEC-DSS files

Current Applications

- **C**alifornia **C**entral **V**alley **SI**mulation **M**odel (C2VSIM), by California Department of Water Resources
- West side of the California San Joaquin Valley (WESTSIM), by U. S. Bureau of Reclamation
- California Merced River Basin (MercedSim), by Lawrance Berkeley National Lab
- California Butte Basin Groundwater Model, by CDM
- California Solano County Model, by West Yost & Assoc.
- Oregon Walla Walla River Basin, by Oregon State University, Corvallis
- Studies on the impacts of climate change on California water resources using IWFM and logit functions coupled with CalSim-II, a reservoir operations model, by University of California, Berkeley

References

- California Department of Water Resources (CADWR). (2005). *Integrated water flow model (IWFM v2.3): Theoretical documentation*, Modeling Support Branch, Bay-Delta Office, Sacramento, CA.
- Dogrul, E. C., and Kadir, T. N. (2006). "Flow computation and mass balance in Galerkin finite-element groundwater models." *J. Hydraul. Eng.*, 132(11), 1206-1214.