Modeling in Water Resources

An overview

Popular computer models in water resources

How to classify water related computer models

How to develop the model

How to extract and analyze data

How to represent the model output

Classification of Models

- Surface Water Modeling
  - Hydraulic
  - Water Quality
  - Sedimentation
  - Pipe Network Analysis
- Storm Water Modeling
  - Hydrologic
  - Drainage
- Ground Water Modeling
  - Flow & Transport
  - Water Quality

Definitions

Watershed

In the technical sense, a watershed refers to a divide that separates one drainage area from another drainage area. However, in the United States and Canada, the term is often used to mean a drainage basin or catchments area itself. Watersheds drain into other watersheds in a hierarchical form, larger ones breaking into smaller ones or sub-watersheds with the topography determining where the water flows. Understanding geomorphology is essential in understanding how watersheds interconnect.

Time of concentration

Time of concentration is a fundamental watershed parameter. It is used to compute the peak discharge for a watershed. The peak discharge is a function of the rainfall intensity, which is based on the time of concentration. Time of concentration is the longest time required for a particle to travel from the watershed divide to the watershed outlet.

Definitions

Stochastic Modeling

"Stochastic" means being or having a random variable. A stochastic model is a tool for estimating probability distributions of potential outcomes by allowing for random variation in one or more inputs over time. The random variation is usually based on fluctuations observed in historical data for a selected period using standard time-series techniques. Distributions of potential outcomes are derived from a large number of simulations (stochastic projections) which reflect the random variation in the input(s).Its application initially started in physics (sometimes known as the Monte Carlo Method).

Stochastic Modeling can also be defined as collections of random variables indexed by a parameter such as time and space [are known as STOCHASTIC PROCESSES (or RANDOM or CHANCE PROCESSES)].

Definitions

Hydrologic Modeling

When you try to model Rainfall, Runoff, Outflow & Inflow etc. hydrologic parameters.

Hydraulic Modeling

When you try to model Flow, Velocity and Discharge of a river or network of rivers.

Water Quality Modeling

When you try to model Water Quality Indices (WQI) or Pollutant Concentration (P) or Water Quality Parameters

Pipe Network Analysis

When you try to model pressure, head, velocity and hammering in a network of pipe lines

Flow and Transport Modeling

When you try to model flow and transport of chemicals under the earth surface

Sediment Modeling

When you try to model sediments i.e. deposits in the path of river

Definitions

Surface Water Modeling

When you try to model some hydrologic parameter of water bodies above surface (Rivers, Ponds, Lakes)

Storm Water Modeling

When you try to model Rainfall, Runoff, Evapo-Transpiration etc climatic parameters. (Storm remind us of some climatic catastrophes)

Ground Water Modeling

When you try to model some water related parameters of water available under the earth crust.

Drainage Modeling

When you try to model parameters related to rivers like discharge, reservoir inflow & outflow etc.

Hydrologic Models & Software

- StormNET® is the most advanced, powerful, and comprehensive stormwater and wastewater modeling package available for analyzing and designing urban drainage systems,stormwater sewers, and sanitary sewers. StormNET is the only model that combines complex hydrology, hydraulics, and water quality in a completely graphical, easy-to-use interface.Cost for the basic 10 unit inlets is $ 995.00(http://www.bossintl.com)

- Watershed Modeling System is also a sophesticated software that help engineers to fed data directly from map files and represent the ouput on map with contour or 3d elevation.It supports nearly all the models available in the Storm Water Modeling like HEC,HECHMS,HSPF,Rational,TR55 etc.(www.scientificsoftwaregroup.com).Costs more than $5000

- HYSIM is a hydrological simulation model (rainfall-runoff model) which uses rainfall and potential evaporation data to simulate the hydrological cycle (surface runoff, percolation to groundwater and river flow) on a continuous basis.(http://www.watres.com/software/sf-hysim.html)[Free]

Hydrologic Models & Software

- RainOff helps in modelling effective rainfall, recharge, water storage, runoff, drainage and discharge relations in hydrological catchment areas (watersheds) using the concept of a nonlinear reservoir.Recently a Windows version (RainOffW) has been developed and made available for downloading.(http://www.waterlog.info/software.htm)[FREE]

- Vflo™ provides high-resolution, physics-based distributed hydrologic modeling for managing water from catchment to river basin scale. Improved hydrologic modeling capitalizes on access to high-resolution quantitative precipitation estimates from model forecasts, radar, satellite, rain gauges, or combinations of multi sensor products.(www.scientificsoftwaregroup.com)

- HECHMS is a software that automates the running of HECHMS model which is popular for its capability of predicting Runoff hydrograph. [FREE]

Hydrologic Models & Software

- TR-20, Technical Release No. 20: Computer Program for Project Formulation Hydrology (TR-20) is a physically based watershed scale runoff event model. It computes direct runoff and develops hydrographs resulting from any synthetic or natural rainstorm. Developed hydrographs are routed through stream and valley reaches as well as through reservoirs. Hydrographs are combined from tributaries with those on the main stream stem. Branching flow (diversions), and baseflow can also be accommodated. (http://www.waterengr.com/)

- TR-55, Urban Hydrology for Small Watersheds - Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States.(http://www.waterengr.com/)

- Rational Equation Calculator The Rational equation is the simplest method to determine peak discharge from drainage basin runoff. (http://www.lmnoeng.com/Hydrology/rational.htm)

Hydrologic Models & Software

- Hydrologic calculations for Peak Discharge, Runoff Depth, Runoff Curve Number, Time of Concentration, and Travel Times based on TR-55 model.A simple free online calculator. (http://www.lmnoeng.com/Hydrology/hydrology.htm)

- SMADA - Stormwater Management and Design Aid - This software is a complete hydrology package included as a number of separate executable files. These programs work together to allow hydrograph generation, pond routing, storm sewer design, statistical distribution and regression analysis, pollutant loading modeling, matrix calculation, and others. These programs are useful in both classroom and professional applications. Extensive on-line documentation is available for all programs. (http://www.waterengr.com/)

- SWMM Storm Water Management Model version 4.4 - This Rainfall Runoff Model was developed by the US Environmental Protection Agency, Oregon State University and Camp, Dresser & McKee, Inc. It is a large, complex model capable of modeling the movement of precipitation and pollutants from the ground surface through pipe and channel networks, storage treatment units, and finally to receiving waters. Both single event and continuous simulation can be performed on catchments having storm sewers and natural drainage, for prediction of flows, stages and pollutant concentrations.(http://www.waterengr.com/)

Hydrologic Models & Software

- HydroCAD is a Computer Aided Design tool used by Civil Engineers for modeling stormwater runoff. HydroCAD provides a wide range of commonly used drainage calculations including: SCS, NRCS, SBUH runoff hydrographs. Rational Method with automatic IDF curves, Hydrograph routing through ponds & reaches, Automatic pond storage calculations, including embedded storage chambers, Easy management and reporting of multiple rainfall events, Runs on any Windows PC - No other CAD software required [PAID] .(http://www.hydrocad.net/index.htm)

Hydraulic Models & Software

- RiverCAD® is a sophisticated river modeling software that completely supports HEC-RAS and HEC-2 within AutoCAD or its own stand-alone CAD environment. RiverCAD makes it even easier to compute water surface profiles for modeling bridges, culverts, spillways, levees, bridge scour, floodway delineation, floodplain reclamation, stream diversions, channel improvements, and split flows. RiverCAD reads and writes data from the latest versions of HEC-RAS and HEC-2.Cost : $ 6,180.00(http://www.bossintl.com)

- Surface Water Modeling System(SMS) is also a sophesticated software that help engineers to fed data directly from map files and represent the ouput on map with contour or 3d elevation. It supports nearly all the models available in the Surface Water Modeling like RMA,FEWMS,RMA2 etc.and can completely develop generic customized models without any code. Costs more than $3000(www.scientificsoftwaregroup.com)

- AquaDyn Hydrodynamic Simulation Package allows the complete two-dimensional description and analysis of hydrodynamic systems of open channels rivers, lakes, or estuaries. (http://www.waterengr.com/)

Hydraulic Models & Software

- The RIPRAP Design System is a powerful stream bank protection design software. The RIPRAP Design System determines sizing, layer thickness and gradation of rock riprap to protect streams from scour utilizing seven different methods. (http://www.waterengr.com/)

- Coastal Hazard Analysis Modeling Program, Version 1.1-CHAMP is a program for performing coastal hazard assessments of fine-scale wave phenomena associated with hurricane storm surges or northeaster flooding effects. These methodologies include storm-induced erosion treatments, wave height analyses, and wave runup analyses. CHAMP allows the user to enter data, perform coastal engineering analyses, view and tabulate results, and chart summary information for each representative transect along a coastline within a user-friendly graphical interface. (http://www.waterengr.com/)

- Quick-2, Version 2.0, is the latest version of a hydraulic analysis program used to compute water-surface elevations in open channels of all types.(http://www.waterengr.com/)

Pipe Network Analysis
Models & Software

WaterCAD is a robust and comprehensive water distribution modeling solution that can be customized with additional modeling platforms and modules as your modeling requirements grow. [PAID](www.bentley.us)

HAMMER is the industry's #1 transient analysis and water hammer modeling solution. HAMMER demystifies the complex science of water hammer and transient analysis and puts the power to perform this critical work in your hands. [PAID](www.bentley.us)

SewerGEMS has built-in support for SewerCAD. This close compatibility allows users to apply full hydrodynamic analysis against system models that are mapped and managed using SewerCAD. Use SewerCAD to investigate and analyze in greater detail the effects of system surcharging, overflows, and treatment bypasses that might occur during extreme wet weather events. SewerGEMS adds the ability to model direct runoff into combined sewer systems, as well as model and calibrate for RDII (Rainfall Derived Infiltration and Inflow). SewerGEMS also features ready integration with ArcGIS. [PAID](www.bentley.us)

Pipe Network Analysis
Models & Software

PumpBase finds the best pumps for your fluid conveyance application using 40 criteria from 1000's of curves.(http://www.waterengr.com/)

Pipe Network (Hardy Cross) is a program which uses the iterative Hardy-Cross algorithm to determine the flow and pressure loss in each leg of a series-parallel pipe network.(http://www.engineering-software.com/pr/sku27543.htm).Cost : $89

Ground Water Models & Software

SVFlux 2D/3D - Finite element seepage analysis software. Perfomr 2D and 3D flow analysis in unsaturated or saturated soil.(www.scientificsoftwaregroup.com)[Public Domain]

Visual MODFLOW is the proven standard for professional 3D groundwater flow and contaminant transport modeling using MODFLOW-2000, MODPATH, MT3DMS and RT3D. (www.scientificsoftwaregroup.com)[PAID]

SaltModW a mathematical, numerical simulation model describing the relations between agriculture, crop rotation, irrigation, rainfall, potential and actual evaporation (evapotranspiration), climate, hydrology, depth and level of water-table, capillary rise, deep percolation, soil salinity and subsurface drainage by drains or wells, and reuse (conjunctive use) of ground and drain water from wells. It includes farmers' responses to water logging and soil salinity.Recently a Windows version (SaltModW) has been developed and made available for downloading. (http://www.waterlog.info/software.htm)[FREE]

Ground Water Models & Software

SegReg can be used for segmented linear regression, i.e. regression in segments, using a breakpoint (break-point) or threshold value, which serves for example to analyse the relation between plant growth or crop production in agriculture versus soil salinity and depth of watertable in agricultural land.Recently a Windows version (SegRegW) has been developed and made available for downloading.
(http://www.waterlog.info/software.htm)[FREE]

WellDrain calculates the spacing of wells, the shape, depth, and level of the watertable in vertical drainage systems using pumped wells. Like EnDrain, it permits aquifers with various different properties and, in addition, fully/partially penetrating wells.Recently a Windows version (WellDrainW) has been developed and made available for downloading.
(http://www.waterlog.info/software.htm)[FREE]

Ground Water Models & Software

AQUA3D - AQUA3D solves transient groundwater flow with anisotropic flow conditions. Solves transient transport of contaminants and heat with convection, decay, adsorption and velocity-dependent dispersion.(www.scientificsoftwaregroup.com)[PAID]

GMS supports both finite-difference and finite-element groundwater models in 2D and 3D including MODFLOW 2000, MODPATH, MT3DMS/RT3D, SEAM3D, ART3D, UTCHEM, FEMWATER, PEST, UTEXAS, MODAEM and SEEP2D.(www.scientificsoftwaregroup.com) [PAID]

ChemFlux is a contaminant transport software modeling package for modeling of mass transport, contaminant concentrations and plume migration.(www.scientificsoftwaregroup.com) [PAID]

Forest Hydrology Software

Simulistics develops and distributes Simile, modelling and simulation software for complex dynamic systems in the earth, environmental and life sciences. We use unique logic-based declarative modeling technology to represent the interactions in these systems in a clearly structured, visually intuitive way.(http://www.simulistics.com/products/index.htm) [FREE]

Model Development Methodology

1. Data Collection
2. Data Analysis
3. Model Development
4. Model Selection
5. Running Model
6. Model Validation
7. Prediction with the Model
8. Data Representation

Data Analysis & Collection
Software Tools

- Data analysis
  - SigmaXL : Complete Statistical Package. Come as excel addin. No programming.(www.**sigmaxl**.com)[PAID]
  - Analyze it for Excel : statistics software for statistical analysis and method validation.(http://www.analyse-it.com/) [PAID]
- Data extraction
  - Find graph : It extracts data from graphs and also performs many common statistical analysis.(http://www.regnow.com/softsell/nph-softsell.cgi?item=7266-2&affiliate=65113)
  - Solid Converter PDF to Word : Convert PDFs to Microsoft® Word or Excel documents for easy editing! Solid Converter PDF to Word converts tables, hyperlinks, rotated text, and more.Scan datasheets.Convert the image into pdf.Convert the pdf into excel .No need of typing.

Data Representation
Software Tools

- **Surfer** – Build 3d graphs, surface elevation, contour graphs, wireframes etc.
  Costs about $600.

- **Grapher** - Build 2d & 3d graphs, surface elvation, contour diagrams etc.
  Costs about $600.

- **Complex Grapher**

  Complex Grapher is a graphing calculator to create a graph of complex function. 3D function graphs and 2D color maps can be created with this grapher. You can input complex functions in the form of w=f(z) (where z=x+yi) directly before creacting graphs. Graphs can be copied and saved in the format of bitmap.Complex Grapher is a graphing calculator to create a graph of complex function. 3D function graphs and 2D color maps can be created with this grapher. You can input complex functions in the form of w=f(z) (where z=x+yi) directly before creacting graphs. Graphs can be copied and saved in the format of bitmap.Cost : $ 19.95

- **Function Grapher**

  Function Grapher is an easy-to-use software to create 2D, 2.5D, 3D function graphs, animations and table graphs. 2D Features: explicit, implicit, parametric, and inequality; Cartesian and polar coordinate systems; curve and animation; graph of inverse function and derivative function; parity; maximum, minimum, and inflexion; integral; root; the length of curve; tangent and normal; curvature circle; intersection; line plot; scatter plot; stem plot; step plot; curve smoothing; graph of limit, series and ordinary differential equation. 3D Features: cartesian, cylindrical, and spherical coordinate systems; 3D curve and surface; animation; graph of partial derivative functions; tangent line and normal plane of 3D curve; tangent plane and normal line of 3D surface; graph of 3D vector and vector operation; 3D surface based on table data; surface by rotation; material and light. Ability to create color map, contour plot and vector plot. Ability to move, zoom in, zoom out and rotate graphs. Ability to save graphs as pgp file or bmp file. Ability to save animation as AVI file.Cost : $34.95