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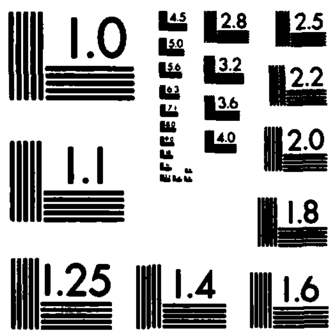
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ESL-TR-82-13

AD-A133454

FEASIBILITY STUDY FOR AN AIR FORCE ENVIRONMENTAL MODEL AND DATA EXCHANGE

Volume III Appendix F: Model Review and Index- Water Models

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JULY 1983

FINAL REPORT
MARCH 1981 - FEBRUARY 1983

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

AIR FORCE ENGINEERING AND SERVICES CENTER

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1. REPORT NUMBER: ESL-TR-82-13	2. GOVT ACCESSION NO.: AD-A133454
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): FEASIBILITY STUDY FOR AN AIR FORCE ENVIRONMENTAL MODEL AND DATA EXCHANGE: Appendix F, Model Review and Index - Water Models (Volume III of IV)	5. TYPE OF REPORT & PERIOD COVERED: Final Report, March 1981 - February 1983
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Stewart McKenzie, Larry Milask, Roger Long	8. CONTRACT OR GRANT NUMBER(s): WQ1Y03, Task 6
9. PERFORMING ORGANIZATION NAME AND ADDRESS: General Software Corporation, Suite 380 Metroplex, 8401 Corporate Drive, Landover, Maryland 20785	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: JON: 21039009, PE: 63723F
11. CONTROLLING OFFICE NAME AND ADDRESS: Engineering and Services Laboratory (AFESC/RDVS), HQ Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403	12. REPORT DATE: July 1983
	13. NUMBER OF PAGES: 186
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Executive Office of the President, Council on Environmental Quality, 722 Jackson Place, N.W., Washington D.C. 20006	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Availability of this report is specified on reverse of Front Cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Applications
Databases
Data Base Management
Environmental
Environmental Management
Environmental Protection
Models
Mathematical Models

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study assesses Air Force needs and capabilities for environmental consequence modeling, Air Force model application capabilities, and proposes resources available to overcome identified deficiencies. Needs for environmental information and analytical techniques were studied, and strategies proposed by which the modeling capabilities could evolve toward a comprehensive environmental information network, user community, and data exchange. The recommended information network would be known as the "Air Force Environmental Model and Data Exchange" (AFEMDEX). The technical report consists of four volumes. (continued)

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Volume 1: MODEL AND DATA REQUIREMENTS WITH RECOMMENDATIONS. The study recommends evolution of a computer-based network to enhance Air Force access and exchange of environmental information, and to match models with required data sources for effective application. The AFEMDEX network development is proposed in three evolutionary stages: (1) coordination; (2) information exchange; and (3) networking. Coordination would involve linking existing Air Force modeling needs to existing modeling resources in the Air Force and elsewhere, plus establishing a network of model support and use centers for operational modeling. Information exchange would involve developing techniques for transporting model data, analytical techniques and computer software from one model center to another, and promoting the distribution of coordinated hardware for a distributed network of model support centers. Network application involves the full linkage of distributed modeling computers into an integrated network. Other Air Force environmental information needs that could be addressed by AFEMDEX include: a hazardous chemical information system with chemical auditing, tracking, and disposal and accident planning; an improved environmental law information system; improved techniques for environmental data capture, storage, transportation, formatting, management and interpretation; computer cartography and site design aids; management information systems for facility planning, construction and operation; and a computer bibliographic reference database for environmental literature of special interest to the Air Force.

Volume 2: AIR FORCE NEEDS AND CAPABILITIES SURVEY. The survey instrument, survey results, and result analyses which constituted the Air Force needs and capabilities fact-finding task are presented. Air Force agencies which require, or desire environmental information or model application were surveyed to define operational needs and capabilities. Evaluation of present Air Force capabilities, plus capabilities of other federal agencies available to the Air Force, is discussed. A listing of existing environmental models which may be applicable to satisfying mission needs, with a preference rating, is presented.

Volume 3: MODEL REVIEW AND INDEX - WATER MODELS. A brief introduction to water models, by application category, precedes an extensive directory of water quality and quantity models. Reviews of models presented include (in general): (1) model name; (2) sponsor/developer; (3) contact; (4) model availability; (5) model abstract; (6) citation references; (7) current user; (8) implementation hardware/software; (9) input requirements; (10) output products; (11) synopsis of major parameters.

Volume 4: MODEL REVIEW AND INDEX - AIR, MULTIMEDIA AND OTHER MODELS, PLUS DATABASES. A brief introduction to air models, by application category, precedes an extensive directory of air quality models. The directory further provides reviews of multimedia, geology and soil, ecology, socioeconomic, exposure, noise, waste disposal, chemical spill, and traffic models. Further, a brief introduction to databases is followed by reviews for water, air, chemical and noise databases. Reviews of models presented include (in general): (1) model name; (2) sponsor/developer; (3) contact; (4) model availability; (5) model abstract; (6) citation references; (7) current user; (8) implementation hardware/software; (9) input requirements; (10) output products; (11) synopsis of major parameters.

PREFACE

This report was prepared by General Software Corporation, 8401 Corporate Drive, Landover, Maryland, 20785 under subcontract from M/A-COM Sigma Data Computing Corp., 5515 Security Lane, Rockville, Maryland 20852 under Contract No. WQ1Y03, Task 6, with HQ AFESC/RDV, Tyndall Air Force Base, Florida 32403.

This report documents work performed between March 1981 and February 1983. Dr. Carol Graves of Sigma Data Computing Corp., was the Project Officer for the IAG with the President's Council on Environmental Quality. Mr. John Ficke was the Project Officer for the IAG with the President's Council on Environmental Quality. Mr. Larry Milask was the Project Manager and Mr. Stewart McKenzie the primary author for the IAG with General Software Corporation. Captains George W. Schlossnagle, and Glenn E. Tapio were Project Officers for the Air Force Engineering and Services Center (AFESC/RDVS).

The authors wish to thank the Air Force personnel who participated in the questionnaire/survey and gave valuable comments and suggestions which enabled this feasibility study to accurately reflect the USAF capabilities and needs.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

GLENN E. TAPIO, Capt, USAF
Project Officer

ROBERT E. BOYER, Col, USAF
Director, Engineering and Services Laboratory

MICHAEL J. RYAN, Lt Col, USAF, BSC
Chief, Environics Division

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SECTION I

INTRODUCTION

Modeling is a tool for making simulations of real events in order to study the processes involved and to predict future events and their effects. In principle, modeling techniques can be applied to any activity which can be described mathematically. Environmental modeling, in particular, can best be understood as the application of theoretical or empirical knowledge of natural processes to calculations of the distribution and concentration of chemical substances (whether natural or man-made).

Environmental models can range from simple algebraic equations solvable by nomograms or calculators, to complex differential equations which are solved by using advanced numerical techniques and large-scale computer systems. Environmental model data input requirements can range from totally defaulted (all necessary data supplied with the model) to situations where hundreds of magnetic tapes would be needed for data input.

The choice that an analyst makes in selecting a model is based on the time and budget available, the input data required, and the detail required for a study, as well as the study requirements, the models available and the computer hardware that is needed and available. In most cases, the choice is based on a compromise of these factors. A simple algebraic model may be sufficient to respond to the immediate needs of an accident, such as a chemical spill; but a study of effects of disposal of hazardous waste in geological structures requires a thorough understanding of geological structures and groundwater flow patterns of the sites. The latter case will involve drilling test wells, collecting thousands of data points and running scores of three-dimensional groundwater model simulations.

The development of environmental models is based either on theoretical or empirical foundations (or both), as well as assumptions associated with the solution of a set of equations or with an approach used with the model. Applications which violate these assumptions, or which compromise the foundation of the model, will produce results which may be erroneous at best and, at worst, cause irreparable damage when incorporated into a final decision.

SECTION II

MODEL SELECTION CRITERIA

The model selection criteria established for use in the study incorporated the present and future Air Force needs, as well as objective requirements which must be met in any operational modeling environment. In many cases, models were excluded because they failed to fulfill one or more of the selection criteria. The models recommended here for use by the Air Force met most of the following criteria:

- Operational Model
- User and Systems Documentation
- Standard Programming Language
- Validation Studies Conducted
- Approved and in Use by Regulatory Agencies
- Availability of Input Data
- Compatibility of Air Force Modeling Requirements
- Compatibility with Existing and Planned Air Force Computer Systems

Some exceptions were made to the quality of documentation and validation required in areas of urgent Air Force needs where few models existed such as heavier-than-air gas dispersion, and for models which could run on microcomputers or programmable calculators.

1. OPERATIONAL MODEL

Models which are Research and Development (R & D) tools were largely excluded (except as noted earlier). Models which are complete in terms of their computer code development and released by the authors or agency sponsoring development were recommended. R & D models are not appropriate to the applications environment of the U.S. Air Force and to the operational areas of the modeling network concept discussed here. As new model releases are made, it is proper that the library be updated with new model versions.

2. USER AND SYSTEM DOCUMENTATION

A model must be sufficiently documented that a new user (with some background in the physical sciences) could study the available manuals and learn how to run the model. Input and output data descriptions must be available and sample studies must be provided with the documentation or through references. System manuals describing the source code structure are desirable, especially if system modifications are necessary.

3. STANDARD PROGRAMMING LANGUAGE

The model must be written in a language which is readily supported by a wide range of computers. Specialized languages would not be known by a wide enough range of USAF personnel. This would cause problems in maintaining a library of models and associated personnel knowledgeable in a given specialized language.

4. VALIDATED STUDIES

A model may be operational, but not applied to actual studies. These criteria were used to ensure that at least one application to an actual study was made and that the model produced results which were deemed reasonable by the author of the model.

5. APPROVAL AND USE BY REGULATORY AGENCIES

These criteria were used to determine models either developed or used by regulatory agencies in enforcement activities. Use of models approved by regulatory agencies make analyses conducted by USAF personnel more easily compatible with agency regulations.

6. AVAILABILITY OF INPUT DATA

The biggest problem in applying environmental models is fulfilling input data needs. Some large federal water and air quality/quantity databases exist and can be used to obtain data. In other cases, the data must be gathered for a specific study by USAF personnel.

7. COMPATIBILITY WITH U.S. AIR FORCE MODELING REQUIREMENTS

The USAF modeling needs cover all media (air, water, soil, groundwater, biological and human systems), as well as planned and accidental releases of chemicals. Consequently, a library of models and modeling systems is needed to fill this requirement. Specific needs gathered from the survey were matched to specific modeling capabilities. (See Appendix B)

8. COMPATIBILITY WITH EXISTING AND PLANNED U.S. AIR FORCE COMPUTER SYSTEMS

The range of computer hardware existing in the U.S. Air Force which is available for use in modeling activities, can support a wide range of models. In some cases, significant software and data conversion costs may be incurred. Future computer system procurement will not change the latter conclusion, but will make conversion efforts easier and less costly because of the improved computer software available with new computer hardware.

Thousands of environmental models have been developed. The majority were developed primarily for atmospheric studies. Water quality/quantity models are second in number, followed by groundwater models and other specialized application models. The following sections discuss general features of water models and air models and list the models selected by GSC. Listings of other types are included.

SECTION III

WATER MODELS

1. TYPES OF WATER MODELS

Water models can be classified as descriptive models, physical models, analog models and mathematical models. In this study, only mathematical models are addressed and discussed. In addition to the above classification, models can be also classified into conceptual vs. empirical models, steady state vs. transient models, stochastic vs. deterministic models, and 1-, 2-, and 3-dimensional models. Distinctions between mathematical models can be made depending on the solution approaches. Approaches include analytical methods and numerical methods. Available numerical techniques are finite differences, finite element methods, method of characteristics and boundary integral methods.

Water models are classified here by function. . General water models can stimulate surface and groundwater quantity and quality. This general category is divided into general surface and ground water models which can model both quality and quantity.

Surface water models are divided into watershed and waterway models (each subdivided into quality/quantity, which may include quantity calculations, and water quantity models, which can only model physical water movement.

Groundwater models are also divided into quality and quantity models. Further distinctions are shown in Tables G-1 and G-2 and discussed below.

a. General Water Models

(1) General Surface Water. General surface water models include the simulation of both surface water quantity and water quality. These models can be further divided into two groups: watershed models and waterway models.

(a) Surface Watershed. Surface watershed models simulate transport of pollutant from nonpoint runoff and point sources in watersheds or water quality in water channels. Hydrologic processes, sediment and pollutant transport, or hydraulic characteristics of waterways are considered in these models, depending upon the detail of the model.

(b) Surface Waterway. Waterway models simulate the hydrodynamics (flow or diffusive transport) and water quality (including temperature) in a stream, river, estuary, lake, reservoir or coastal area.

(c) Surface Water Quality. Surface water quality models can be further divided into three groups: stream/river models, estuary models and miscellaneous models. Some of the miscellaneous models can be applied to streams, estuaries or lakes/reservoirs.

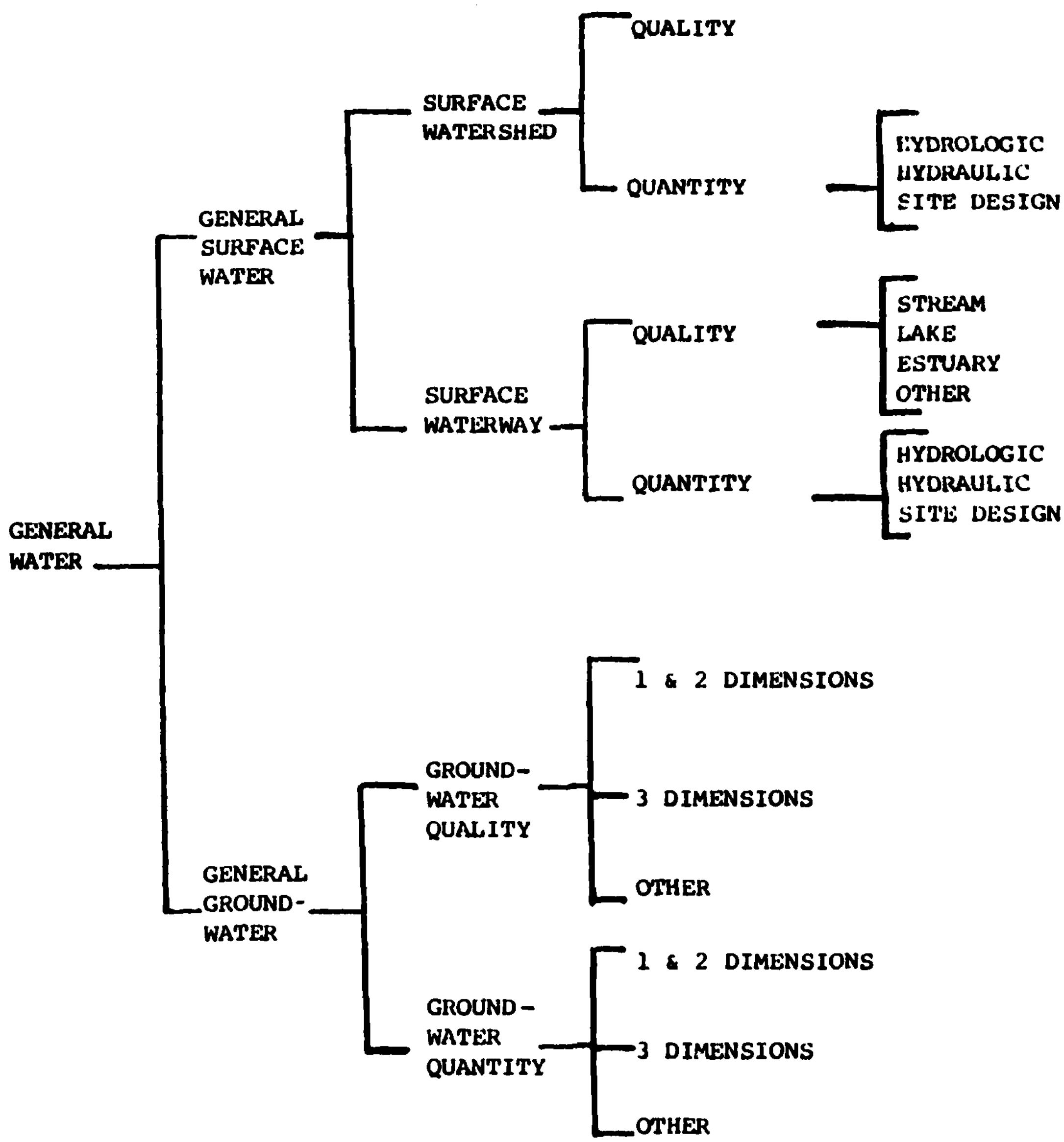
(d) Surface Water Quantity. Distinctions among surface water quantity models sometimes are difficult. However, they are classified into three groups: 1) models emphasizing simulation of hydrologic processes, 2) models emphasizing hydraulics/hydrodynamics, and 3) models related to data analysis/design. Models in Group 1 simulate water balance in watersheds, hydrographs, rainfall-runoff, etc. Models in Group 2 simulate flow velocities, wave dynamics, water surface profiles, etc. Models which are classified into Group 3 are related to hydraulic/hydrologic parameter determination, statistical analysis, water planning/design, etc. Nevertheless, this distinction among models is relative; for example, some models in Group 1 may also simulate the hydraulic characteristics for a waterway and models in Group 2, may also calculate the hydrologic balance for a river or watershed.

(2) General Groundwater. Eight general groundwater models are included in this index. They have the capability of simulating both the groundwater flow and mass transport in the subsurface system.

(a) Groundwater Quality. Groundwater quality models simulate chemical mass transport in the subsurface system. They can be classified into three groups according to the spatial dimensionality of a model: one and two-dimensional models, three-dimensional models and miscellaneuos models. The miscellaneous models are the ones which may be applicable to one-, two-or three-dimensional groundwater studies.

(b) Groundwater Quantity. Groundwater models simulate water flow in the saturated or unsaturated soil zones or both. Similar to groundwater quality models, they can be divided into three groups based on the spatial dimensionality of a model.

TABLE F-1. CLASSIFICATION OF WATER MODELS.



b. Summary of Models by Type

TABLE F-2. MODELS BY CATEGORY

Surface Watershed Quality

AFRUM
ARM II
NPS
WHTM
SWMM
STORM
HSPF
EPARRB
EPAURA
EPATLC
AGRUN
DEM
RECEIV II
WQRRS
HN
-- Time dependent, 3-D, hydrodynamic model
-- MIT Transient Network Model
EXPLORE-1

Groundwater Quality One and Two -D

SESOIL
GWMTM1
FEMWASTE
GWMTM2

Groundwater Quality

T3FEMA
-- 3-D Saturated-Unsaturated Transport Model
MMT-DPRW

Groundwater Quality Other

AT123D
-- Cleary Mass Transport Models

Groundwater Quantity One and Two -D

FEMWATER
-- Finite-Difference Model for Aquifer Simulation in Two - D
-- Dimensions with Results of Numerical Experiments
ISOQUAN 2
ISOQAD

Groundwater Quantity

FED3DGW
-- 3-D Saturated-Unsaturated Flow Model

Groundwater Quantity

Miscellaneous
-- Cleary Groundwater Flow Model (Models 8, 9, & 10)
-- Selected Digital Computer Techniques

Stream Quality

SSM
QUAL II
DOSAG-I
RWQM
DIURNAL
RIBAM
STREAM7B
SNSIM

Estuarine Quality

SEM
ES001

Other Surface Water Quality

WQAM
FEDBAK03
HAR03
-- Level IV - Receiving Water Quality (urban)
TTM
PLUME
-- Time-dependent, 3-D Transport

Surface Water Quantity

HEC1
-- Drainage Runoff Analysis
-- Open Channel Runoff Network
-- Chicago Hydrograph Method
Runoff Computations TR20
-- Storm Hydrograph and Flood
Routing
USDAHL-74
DORSCH
-- Flood Routing and Hydrograph
HYDROCOMP

Surface Water Quantity

DAMBRK
DWOPER Related
HEC 2 & CEPA Programs
--Backwater Analysis in Natural
Channel
--Backwater & Frontwater Curves
--Normal and Critical Depths
for Channels
ALLWET
THYSYS
WSP2
DAMS2

Surface Water Quantity

HEC4
EZRAT
-- Log Pearson Type 3 Analysis for
Regional Studies
-- Log Pearson Type 3 for Gaged Streams
-- Flood Routing by Muskingum Method
STRCH
WAS
SWAN

2. ALPHABETICAL LISTING OF WATER MODELS

a. Index of Water Models

(1)

Model acronym: **AFRUM**
Model name: Air Force Runoff Model
Sponsor: AFESC (Air Force Engineering and Service Center)
Developer: Dr. D.E. Overton, University of Tennessee at Knoxville and AFESC
Contact: NTIS
Contact address: 5285 Port Royal Road
Springfield, VA 22161
Availability: Public
Type of model: Surface Water General

Summary:

To predict storm water flow and quality for small watersheds.

Abstract:

The Air Force Runoff Model (AFRUM) is a storm water runoff simulation model designed to predict storm water flow and quality resulting from real or design storms for small watersheds generally limited to 2,000 acres or less. The principal model inputs are watershed area, land use characteristics, percent forested, percent impervious, and percent denuded. The input will also include either an observed hydrograph or an estimated Soil Conservation Service Curve Number (CN). The model is based upon 410 storms in 36 watersheds. Output is both tabular and graphical and provides the watershed hydrograph, pollutograph and discussion of model assumptions.

Document citation:

Overton, D.E., Schlossnagle, G.W., and Siebert, M.G., Air Force Runoff Model (AFRUM) User Manual Documentation, ESL-TR-80-29, Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403, July 1980.

Principal users: Air Force Engineering and Services Center
Current implementation: Mainframe Computer
Current hardware: CDC 6600
Software language(s): FORTRAN IV
Word size(s): The program requires 56K bytes of core capacity
Operating system(s): 6 CPU seconds to compile and execute
Number of subroutines: 10

Input requirements:

Accumulated storm rainfall at equal time intervals. Storm water discharge flow rates at equal time intervals, O.T. Watershed characteristics.

Output format:

Tabular and graphical output, including hydrograph, pollutograph and discussion of model assumptions.

Output complexity: Medium
Source program storage: 56K bytes of core capacity on CDC 6600
User manual: Yes
Date of first version: July 1980
Date of latest version: July 1980
Date of latest documents: July 1980
Machine interface: Plot subroutine uses a CALCOMP Electromechanical Plotter
Learning difficulty: Medium
Confidentiality: Public
Analytical Features for Model: Water Quality

Oxygen:	No
Water temperature:	No
DO level:	No
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time dependent input:	Yes
Changes in channel flow:	No
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	No
Evaporation and precipitation effects:	No
Time-variant pollution:	Yes
Point source:	No
Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	No
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

Analytical Features for Model: Surface Water Hydrology

Small watershed areas:	Yes
Large watershed areas:	No
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	Yes
Snowmelt considerations:	No
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Infiltration rates:	No

(2)

Model acronym: **AGRUN**

Model name: Agricultural Watershed Runoff Model

Sponsor: EPA

Developer: Water Resources Engineers, Inc.

Contact: Dr. Larry Roesner

Contact address: Camp Dresser and McKee, Inc.
762 Little River Turnpike, Annandale, VA 22003

Contact telephone: (703) 642-5500

Availability: May not be totally public

Type of model: Surface Water General

Summary:

Simulation of hydrology and channel pollutant loads for agricultural watersheds

Abstract:

MODEL OVERVIEW: The AGRUN model is a modification of the EPA Storm water. Management Model (SWMM) that dynamically simulates hydrology and channel pollutant loads for agricultural watersheds. This model can simulate storm runoff hydrographs and pollutographs for conservative water quality constituents which include: total suspended solids, nonsettleable suspended solids, TDS, BOD, COD, chlorides, SO,grease, total coliform, fecal coliform, NH_3, organic nitrogen, nitrite, and nitrate, phosphate, orthophosphate, mercury, copper, zinc, lead, chromium, cadmium and arsenic. AGRUN is one module of a larger set of compatible programs which includesa runoff model (AGRUN), a transport model and a receiving model.. AGRUN has an interface subroutine to connect it with the other two. This model uses the Universal Soil Loss Equation to compute the suspended solids source loading rates, and it assumes that there is no decreased BOD or conversion of nitrogen forms.

Document citation:

REFERENCES: Roesner, L.A., Zison, S.W., Monser, J.R., and Lyons, T.C. Agricultural Watershed Runoff Model for the Iowa Cedar River Basins, Prepared for the Environmental Protection Agency, Systems Development Branch, Washington, D.C. , by Water Resources Engineers, Inc., under Contract No. 68-0-0742., November 1975.

Principal users: Consulting firms, EPA

Assumptions:

The AGRUN model uses the Universal Soil Loss Equation to compute the suspended solids source loading rates and Horton's equation to compute infiltration rates. An iterative Newton-Raphson technique is the basis for the determination of water depth and outflow rates. Velocity computations are made on the basis that flow only occurs when the soil is above field capacity. The model assumes no decreased BOD and no conversion of nitrogen forms.

Current implementation: Mainframe computer

Current hardware: UNIVAC 1108

Software language(s): FORTRAN

Word size(s): 520 K

Input requirements:

The Agricultural Watershed Runoff Model requires a large card-image input data base. Input data for the model fall into seven categories: (1) input and program control data, (2) precipitation data, (3) drainage channel specifications, (4) land use hydrogeometric data, (5) watershed specifications, (6) soil characteristics and (7) output control information.

For each watershed subarea, the surface area, width, and slope must be specified. For each land use type specified for each subarea, the Manning "n," surface depression storage, and Horton infiltration coefficients must be entered as input data. Drainage channel specifications must include the length, invert slope and Manning number, plus the appropriate cross-section data.

If the user wishes to specify the additional data which will be used to compute the contribution of interflow to storm runoff, rather than by representing infiltration by the Horton equation alone, the following data are required for each subarea: (1) number of soil layers above the groundwater table, (2) depth of each soil layer, (3) soil permeability coefficient, (4) soil field capacity, (5) present field capacity available at the beginning of the storm, and (6) constant baseflow from the watershed. Constituents must be specified by user.

Output format:

Output produced by the model includes a printout of the input data, rainfall hydrographs, runoff hydrographs and a variety of charts representing the concentrations of the constituents.

Date of first version:	1975
Learning difficulty:	High
Geographic area:	Stream/river, rural
Analytical Features for Model:	Water Quality
Oxygen:	Yes
DO level:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	No
Radio-activity:	No
Salinity:	No
Conservative minerals:	Yes
Time dependent input:	Yes
Changes in channel flow:	Yes
Evaporation and precipitation effects:	Yes
Time variant pollution:	Yes
Nonpoint source:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	Yes
Flood routing:	No
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	No
Sedimentation and scour:	Yes
Water flow from a simulation:	No

(3)

Model acronym: **ALLWET**

Developer: U.S. Army Construction Engineering Research Lab; Michael Fuerst

Contact address: Department of the Army
Construction Engineering Research Laboratory
P. O. Box 4005
Champaign, Illinois 61820

Availability: Through the Department of the Army

Type of model: Surface Water Quantity

Summary: Determine the adequacy of an existing or proposed water distribution system.

Abstract:

The computer program, ALLWET, enables engineers and planners to determine the adequacy of an existing or proposed water distribution system, the effects upon a system of new demands and the adequacy of proposed design changes to a system. Input data includes a description of the nodes, pipes, nodal demands, valves, pumps and sources within the system.

ALLWET may be used in batch or timesharing (interactive) mode. In batch mode, ALLWET reads the input data from a keypunched deck submitted either with the job or from a disk file. After reading the data, ALLWET performs the analysis (i.e., calculates the nodal pressures and pipe flows within the system) and outputs the results at the remote job entry station. In interactive mode, ALLWET reads the data from a disk file. While at an interactive terminal, the user may make full or partial listings of the input data, revise the data, perform analyses, list full or partial analysis results, direct full listings of input data and analysis results to a remote job entry terminal and permanently store the revised data set. A digitizer, if available, permits the interactive user to more easily place new nodes in the system and to quickly identify portions of the system for which terminal printout is desired.

ALLWET permits four types of demands at each node and multiplicative factors for each demand type. In this way the effects of diurnal variations in flow patterns may be studied.

In calculating pipe flows and nodal pressures, ALLWET sets up and iteratively solves a system of nonlinear equations.

ALLWET was developed at the U.S. Army Construction Engineering Research Laboratory and is one member of the series of computer programs entitled Computer Evaluation of Utility Plans (CEUP).

Document citation:

Fuerst, Michael. ALLWET: A User's Manual, Department of the Army, Construction Engineering Research Lab, Champaign, IL. May 1980.

Principal users: Department of the Army

Assumptions:

If the input data reflects a physically unrealistic situation, then either unrealistic output may result or the pressure-flow calculations may terminate prematurely or not converge. Occasionally, even a properly modelled system may not converge.

Software language(s):	FORTRAN
Machine interface:	Interactive batch
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No
Water distribution system:	Yes

(4)

Model name: **Analytical Frequency Computation & Adjustment**

Developer: Goodkind & O'Dea, Inc.

Contact address: CEPA
Soc. for Computer
Applications in Engineering,
Planning, and Architecture, Inc.
358 Hungerford Drive
Rockville, MD 20850

Contact telephone: (301)762-6070

Type of Model: Surface Water Quality

Summary: Expand a stream record of the annual maximum flows.

Abstract:

Given a short record of the annual maximum flows for a given stream and a longer record for a neighboring, similar stream, this program will make a statistical analysis to expand the record to the shorter stream based on Exhibit 5 of Statistical Methods in Hydrology published by the Corps of Engineers, January 1962.

Current hardware: GA

Software language(s): FORTRAN

Word size(s): Min. memory size = 8K

Operating system(s): 1830 DMS

Lines of source code: 150

Input requirements: Heading Information, Skew, Gage numbers for short-and long-term records, Maximum annual flows for both short and long terms.

Output format:

- Headings
- Q and log Q by year
- Mean, Standard Deviation and Record Length for both short-and long-term records, abbreviated long-term record and adjusted short-term record.
- Statistical flows for the 10000-, 1000-, 100-, 20-, 10-, 3 1/3- and 2-year discharges based on the equivalent record equal to infinity.
- Calculated probabilities based on the equivalent length on record.

User manual: Yes

Analytical Features for Model: Surface Water Hydrology

Small watershed areas:	No	Snowmelt consideration:	No
Large watershed areas:	No	Continuous simulation of a storm event:	No
Rural land areas:	No	Continuous simulation in real time:	No
Urban land areas:	No	Sedimentation and scour:	No
Entire hydrographs:	No	Water flow from a simulation:	No
Flood routing:	No	Infiltration rates:	No
		Expand the stream record:	Yes

(5)

Model acronym: **ARM II**
Model name: Agricultural Runoff Model (Version II)
Sponsor: EPA
Developer: Hydrocomp, Inc.
Contact: Lee A. Mulkey
Contact address: US EPA Office of Research and Development, Environmental Research Laboratory, Athens, GA 30605
Contact telephone: (404) 546-3581
Availability: Public
Type of model: Surface water general
Summary: Simulate the movement and degradation of pollutants on agricultural land.

Abstract:

MODEL OVERVIEW: The Agricultural Runoff Management Model - Version II (ARM II) is a continuous simulation model that estimates the movement and degradation of pollutants on agricultural land surfaces. The model can be used to study pollutants including pesticides, nutrients and sediments. ARM II is an improved version of ARM I and the Pesticide Transport and Runoff (PTR) Model published in 1973. All of these models build upon the Stanford Watershed Model. The ARM II model has been tested at other sites throughout the United States. The model is recommended for use to estimate pollutant loads from agricultural fields. Applications include basin planning and evaluation of pesticides being considered for registration. ARM II was developed by Hydrocomp, Incorporated, for the U.S. Environmental Protection Agency.

Document citations:

Crawford, N.H. and A.S. Donigian, Jr., Pesticide Transport and Runoff Model for Agricultural Lands , Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C., EPA-660/2-74-013, 1973.

Donigian, A.S., Jr. and N.H. Crawford Modeling Pesticides and Nutrients on Agricultural Lands , Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, Georgia, EPA-600/2-76-043, 1976.

Donigian, A.S., Jr., D.C. Beyerlein, H.H. Davis, Jr., and N.H. Crawford. Agricultural Runoff Management (ARM) Model - Version II, Refinement and Testing , Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, Georgia, EPA-600-3-77-098, 1977.

Donigian, A.S., Jr., and H.H. Davis, Jr. Agricultural Runoff Management (ARM) Model User's Manual: Versions I and II, Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, Georgia, EPA-600/3-78-080, 1978.

Principal users: EPA

Assumptions:

BASIC ASSUMPTIONS: Both water and pollutant transport and transformation descriptions used in the model are based on the principle of conservation of mass. Movement of water through the soil from surface to groundwater is modeled empirically. A key assumption in the model is that runoff water from the simulated watershed is derived from all locations within the watershed. Thus, it is impossible to identify the specific location as the source of a fractional load of the watershed. Degradation kinetics are also modeled empirically. All pollutant transformations are approximated by a series of first-order rate expressions. Volatilization is lumped with chemical and microbial degradation to form one rate expression for the removal and degradation of pesticides in the soil. Arrhenhius' equation corrections of specific transformation rate are assumed to adequately approximate temperature effects on nutrient cycling in soils. Detachment of sediment particles from the soil and transport of these particles between absorbed and dissolved phases takes place instantaneously.

Current implementation:	Mainframe computer
Current hardware:	Mainframe IBM 370/168 HP-3000 Series II
Software language(s):	FORTRAN
Word size(s):	Program: 360K bytes (90,000 words) on IBM 370/168, FORTRAN H compoler program execution: requires up to 230K bytes (57,500 words) storage.
Number of subroutines:	6
Input requirements:	

INPUT: Rainfall records. Inputs include:

Control parameters that specify amount of information printed as output, operations as to whether nutrient cycles and pesticide dynamics or just pesticide dynamics are to be simulated and definition of the period to be simulated.
Hydrology parameters that specify rates of water movement and nominal soil moisture storage capacity parameters.

Snowmelt parameters that specify snowmelt rates and snowpack characteristics.

Sediment parameters that define soil properties which determine sediment load response to rainfall events.

Pesticide parameters that determine rates of degradation of pesticides in soil and absorption partition between soil and dissolved phases.

Soil parameters that define topographical characteristics of the land surface and soil properties.

Nutrient parameters that define the timing and amount of fertilizer application and calculation of time intervals for nutrient transformation.

Nitrogen and phosphorus parameters that define reaction rates and nutrient storage.

Chloride storage parameter.
Output format:

Outputs produced by the model included the echo of the input data set, the concentration of pesticides and nutrients in the soil and runoff, and loads of nutrients, pesticides, and sediment in runoff. Nutrient concentrations are reported in terms of the various forms present in the cycle. For both pesticides and nutrients, concentrations and loads of dissolved and suspended materials are reported separately. Some selection is available as to the frequency of printout. Monthly and yearly summaries are also provided.

User manual:	Yes
Date of first version:	1973
Date of latest version:	1978
Date of latest documents:	March 1978
Learning difficulty:	High
Confidentiality:	Public
Geographic area:	Rural (nonurban)
Analytical Feature for Model:	Chemical Spills

(6)

Model acronym:	AT123D
Model name:	Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System
Sponsor:	Oak Ridge National Laboratory/Dept. of Energy
Developer:	Dr. G.T. Yeh, ORNL
Contact:	Dr. G.T. Yeh
Contact address:	Oak Ridge National Laboratory, Rm. 203, Bldg. 1505, Oak Ridge, Tennessee 37830
Contact telephone:	(615) 574-7285
Type of Model:	Groundwater quality
Summary:	A generalized model for groundwater aquifer quality simulation

Abstract:

A generalized analytical transient, one-, two- and/or three-dimensional (AT123D) computer code is developed for estimating the transport of wastes in a groundwater aquifer system. It contains 450 options: 288 for the three-dimensional case, 72 for the two-dimensional case in the X-y plane, 72 for the two-dimensional case in the x-z plane and 18 for the one-dimensional case in the longitudinal direction. These are the combinations of three types of wastes, eight sets of source configurations, three kinds of source releases, and four variations of the aquifer dimensions. Three types of the wastes are radioactive waste, chemicals, and heat. The eight types of source configurations are a point source, a line source parallel to the x-axis, a line source parallel to the y-axis, a line parallel to the z-axis and a volume source. Three kinds of source releases are instantaneous, continuous and finite duration releases. Four variations of the aquifer dimensions are finite depth and finite width, finite depth and infinite width, infinite depth and finite width, and infinite depth and infinite width. The mechanisms of transport included in the analysis are advection, hydrodynamic dispersion, adsorption, decay /degeneration and waste losses to the atmosphere. Boundary conditions included Dirichlet, Neumann, mixed type and/or radiation boundaries. Fifty sample cases are provided to illustrate the application of AT123D to various situations.

Current implementation:	Mainframe computer		
Current hardware:	IBM 360		
Software language(s):	FORTRAN		
Number of subroutines:	6		
User manual:	Yes		
Analytical Features for Model:	Groundwater quality		
Solution:	Yes	Unsaturated element:	No
Finite element solution:	No	Differentials across element:	No
Steady state:	Yes	Variable flow rates across boundary:	No
Nonsteady state:	Yes	Material transport:	Yes
One aquifer:	Yes	1-D, 2-D, 3-D	Yes
Leakage between aquifers:	No		
Semipermeable and non-permeable aquifers:	No		
Stream aquifer interaction:	No		
Saturated element:	Yes		

(7)

Model name: Backwater Analysis in Natural Channel

Developer: John Pai

Contact: Society for Computer Applications in Engineering, Planning, and Architecture, Inc.

Contact address: 358 Hungerford Drive, Rockville, MD 20850

Contact telephone: (301)762-6070

Type of model: Surface Water Quantity

Summary: Calculating water surface elevation and its related hydraulic parameters.

Abstract:

This program will solve the water surface elevation and its related hydraulic parameters for both normal and critical flow condition in a natural channel. Bernoulli and continuity equations are used. Supercritical and subcritical conditions will occur as needed to satisfy those requirements. Up to five different yearly discharges can be processed in a single pass. Effects due to variation of dischargers between sections have been taken into consideration.

Current implementation: Mainframe computer

Current hardware: IBM 1130

Software language(s): FORTRAN

Word size(s): Min. memory size 8k

Input requirements:

For each section the input will need: No. of segments, no. of subsegments in each segment, tolerance for trail procedure, expansion coeff., contraction coeff., no. of frequency, station location, frequency no., frequency year, discharge and starting elevation, For each subsegment, the input will need: subsegment no., elevation, roughness coeff., and width.

Output format: Water surface elevation, velocity, water depth for critical flow condition and normal flow condition.

User manual: Yes

Analytical Features for Model: Surface Water Hydrology

Small watershed areas: No

Large watershed areas: No

Rural land areas: No

Urban land areas: No

Entire hydrographs: Yes

Flood routing: No

Snowmelt considerations: No

Continuous simulation of a storm event: No

Sedimentation and scour: No

Water flow from a simulation: Yes

Automatic time interval generation: No

Infiltration rates: No

(8)

Model name: Backwater and Frontwater Curves
Developer: R. Jankowski
Contact: Society for Computer Applications in Engineering, Planning, and Architecture, Inc.
Contact address: 358 Hungerford Drive, Rockville, MD 20850
Contact telephone: (301) 762-6070
Type of model: Surface Water Quantity
Summary: Computing the water surface profile in a natural channel.

Abstract:

This program will compute the water surface profile in a natural open channel using the standard step method. Backwater (subcritical) and frontwater (supercritical) flow profiles can be handled by a newly formulated convergence technique. Up to 10 subareas with varying friction coefficients can be considered in each cross section. Islands and bridge piers can be handled. Up to 100 cross sections and 20 sets of discharge and initial water surface elevation may be specified in one run.

Current implementations: Mainframe computer
Current hardware: IBM 1130
Software language: FORTRAN
Word size(s): Min. memory size 16k
Operating system(s): DM2

Input requirements:

The input consists of the stationing, geometry, friction and eddy coefficients, and flow in each section of the channel. English or metric units may be used. Control parameters may be specified to control the accuracy of the energy balance and the amount of output. The calculations can be directed in either the upstream or downstream direction.

Output format:

The output consists of the water elevation, area, velocity, velocity head, friction, slope and total energy at each section. If specified, the conveyance area, wetted perimeter, hydraulic radius and velocity will be printed for each subarea. Froude numbers, conjugate depths, jump losses, critical depth and normal depth are computed where applicable.

Analytical Features for Models:	Surface Water Hydrology		
Small watershed areas:	No	Continuous simulation of a storm event:	No
Large watershed areas:	No	Continuous simulation in real-time:	No
Rural land areas:	No	Sedimentation and scour:	No
Urban land areas:	No	Water flow from a simulation:	Yes
Entire hydrographs:	No	Automatic time interval generation:	No
Flood routing:	No	Infiltration rates:	No
Snowmelt considerations:	No		

(9)

Model name: **Chicago Hydrograph Method Runoff Computations**
Developer: C. Keifer, J.P. Harrison, T. Hixson
Contact address: CEPA
Soc. for Computer
Applications in Engineering,
Planning,. and Architecture, Inc.
358 Hungerford Drive
Rockville, MD 20850
Contact telephone: (301)762-6070
Type of model: Surface Water Quantity
Summary: Analyzes storm runoff gravity flow to open channels.

Abstract:

The program analyzes the effects of storm runoff gravity flow to a network of open channels of an urban-type drainage area. The program will determine the effects of storm runoff on the analysis of an existing system of open channels or design of closed conduits. Storm runoff is determined for each drainage area using the Chicago Hydrograph Method. In order to determine the runoff from a drainage area, a rainfall pattern is selected for analysis. The pattern may be either an actual storm or a design-storm pattern of specific frequency. The average rainfall intensity is reduced by aerial distribution to produce the adjusted average intensity curve for the drainage area. Abstractions are made to the adjusted average intensity curve due to infiltration and depression storage for both the impervious and pervious area. The two unit hydrographs developed give the average supply to overland flow. Both hydrographs are routed overland on impervious and pervious strips. Storage in routing is created due to detention of flow on the surface. After routing, the hydrographs are combined according to the relative percent of imperviousness to give the total inflow to the gutter. The combined runoff hydrograph from overland flow is routed in the gutter to attain the total runoff hydrograph from the drainage area and the total inflow to the inlet. The inlet runoff hydrograph is added to flow in the open channel and is routed to the next inlet or to a point of intersection with another open channel.

Validations: Low
Current implementation: Mainframe computer
Current hardware: IBM 1130; CHI 2130
Software language(s): FORTRAN
Operating system(s): 1130 Monitor; DNA TSO
Lines of source code: 1100

Input requirements:

Synthetic or actual storm definitions, number of junctions and drainage areas, junction network description and drainage area characteristics: area, length of sewer, imperviousness, slope diameter, gutter constant, etc.

Output format:	Hydrograph values at each inlet, total hydrograph values at specific points of interest in the network of conduits.
User manual:	Yes
Learning difficulty:	Low
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	Yes
Entire hydrographs:	Yes
Flood routing:	No
Snowmelt considerations:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No

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Model name: Cleary Groundwater Flow Models (Models 8, 9, 10)
Sponsor: Nassau-Suffolk Regional Planning Boatd/EPA
Developer: R.W. Cleary, Princeton University
Contact: Dr. Robert W. Cleary
Contact address: Water Resources Program
Department of Civil Engineering
Princeton University
Princeton, N.J. 08540
Type of model: Groundwater Quantity
Summary Simplified, analytical groundwater flow models.

Abstract:

These models are based on the groundwater flow equation. The solutions are all analytical and have been derived by integral transform methods. The final solution is in closed form.

These models have been developed especially for the practicing professional dealing with problems in groundwater hydrology and may be used as primary tools of analysis.

Document citation:

R.W. Cleary, Groundwater Pollution and Hydrology, Report No. 78-WR-15, Water Resources Program, Princeton University.

Principal users: Consulting firms and academic institutes.
Assumptions: Simplified, analytical models. The models may be used as primary tools of analysis where costs or lack of a data base preclude the use of sophisticated numerical models.
Feasible implementation: Programmable calculator, mini, micro computers
Software language(s): FORTRAN
Word size(s): Memory is minimal.
Output format: Tabular format.
User manual: Yes
Date of latest documents: 1978
Learning difficulty: Low
Analytical Features for Model: Groundwater
Exact solution: Yes
Finite element solution: No
Steady state: Yes
Nonsteady state: Yes
One aquifer: Yes
Leakage between aquifers: No
Stream aquifer interaction: No
Saturated element: Yes
Unsaturated element: No
Differentials across element: No
Variable flow rates across boundary: No

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Model name: Cleary Mass Transport Models (Models 1-7)
Sponsor: Nassau-Suffolk Regional Planning Board/EPA
Developer: R.W. Cleary, Princeton University
Contact: Dr. Robert W. Cleary
Contact address: Water Resources Program
Dept. of Civil Engineering
Princeton University
Princeton, NJ 08540
Availability: Distributed to the short course attendees
Type of model: Groundwater quality
Summary: Groundwater pollutant transport analytical models.
Abstract:
The models are based on the convective-dispersive mass transport equation. The solutions are all analytical and have been derived by integral transform methods. In most cases, the final solution is in closed form. In some models, however, part of the solution is in integral format which is evaluated by a variable point (up to 256 points) Gauss quadrature scheme. These models have been developed especially for the practicing professional dealing with problems in groundwater pollution and hydrology and may be used as primary tools of analysis.

Document citations:

Cleary, R.W., Groundwater Pollution and Hydrology - Mathematical Models and Computer Programs, Princeton University, Princeton, N.J.

Principal users: Academic institutes and consulting firms

Assumptions:

These models are simplified, analytical models. In some cases, they cannot handle complex groundwater systems with inhomogeneity. The models may be used as primary tools of analysis where loss or lack of a data base preclude the use of sophisticated numerical models.
Feasible implementation: Microcomputers, minicomputer, mainframe computer
Software language(s): FORTRAN
Word size(s): Minimal
Output format: Tabular format
Date of latest documents: 1978
Learning difficulty: Low
Analytical Features for Model: Groundwater
Exact solution: Yes
Finite element solution: No
Steady state: Yes
Nonsteady state: Yes
One aquifer: Yes
Leakage between aquifers: No
Stream aquifer interaction: No
Saturated element: Yes
Unsaturated element: Yes
Differentials across element: No
Variable flow rates across boundary: No
Pollutant transport simulation: Yes
Flow simulation: No

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Model name: **Computer model of Two Dimensional Solute Transport and Dispersion in Groundwater**

Sponsor: USGS

Developer: L.K. Konikow and J.D. Bredehoeft

Contact: U.S. Geological Survey
Reston, VA 22092

Availability: Public through USGS

Type of model: Groundwater general

Summary: Simulate the groundwater flow and solute transport

Abstract:

This report presents a model that simulates solute transport in flowing ground water. The model is both general and flexible in that it can be applied to a wide range of problem types. It is applicable to one- or two-dimensional problems involving steady state or transient flow. The model computes changes in concentration over time caused by the processes of convective transport, hydrodynamic dispersion and mixing (or dilution) from fluid sources. The model assumes that the solute is nonreactive and that gradients of fluid density, viscosity, and temperature do not affect the velocity distribution. However, the aquifer may be heterogeneous and (or) anisotropic.

The model couples the groundwater flow equation with the solute-transport equation. The digital computer program uses an alternating-direction implicit procedure to solve a finite-difference approximation to the groundwater flow equation, and it uses the method of characteristics to solve the solute-transport equation. The latter uses a particle-tracking procedure to represent convective transport and a two-step explicit procedure to solve a finite-difference equation that describes the effects of hydrodynamic dispersion, fluid sources and sinks, and divergence of velocity. This explicit procedure has several stability criteria, but the consequent time-step limitations are automatically determined by the program.

The report includes a listing of the computer program, which is written in FORTRAN IV, and contains about 2,000 lines. The model is based on a rectangular, block-centered, finite-difference grid. It allows the specification of any number of injection or withdrawal wells and of spatially varying diffuse recharge or discharge, saturated thickness, transmissivity, boundary conditions, and initial heads and concentrations. The program also permits the designation of up to five nodes as observation points, for which a summary table of head and concentration versus time is printed at the end of the calculations. The data input formats for the model require three data cards and from seven to nine data sets to describe the aquifer properties, boundaries, and stresses.

The accuracy of the model was evaluated for two idealized problems for which analytical solutions could be obtained. In the case of one-dimensional flow, the agreement was nearly exact; but in the case of plane radial flow, a small amount of numerical dispersion occurred. An analyses of several test problems indicate that the error in the mass balance will be generally less than 10 percent. The test problems demonstrated that the accuracy and precision of the numerical solution is sensitive to the initial number of particles placed in each cell and to the size of

the time increment, as determined by the stability criteria. Mass balance errors are commonly the greatest during the first several time increments, but tend to decrease and stabilize with time.

Document citations:

L. F. Konikow and J.D. Bredehoeft, Computer Model of Two-dimensional/solute Transport and Dispersion in Groundwater, USGS, 1978.

Principal users:	USGS, consulting firms.
Current implementation:	Mainframe computer
Current hardware:	Honeywell 60168
Software language(s):	FORTRAN IV
Lines of source code:	2,000
Number of subroutines:	9
User manual:	Yes
Systems documentation:	Yes
Date of first version:	1978
Date of latest documents:	1978
Learning difficulty:	medium
Analytical features for Model:	
Exact solution:	No
Finite element solution:	No
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Stream aquifer interaction:	No
Saturated element:	Yes
Unsaturated element:	No
Differentials across element:	No
Variable flow rates across boundary:	No
Finite difference:	Yes
Flow:	Yes
Mass transport:	Yes
Method of characteristics:	Yes
1-D:	Yes
2-D:	Yes

(13)

Model acronym: **DAMS2**

Model name: Structure Site Analysis

Sponsor: U.S. Dept. of Agriculture

Developer: U.S. Dept. of Agriculture

Contact: National Technical Information Service
Available on magnetic tape as PB233 777

Contact address: USDA, Soil Conservation Service, Wash. D.C.

Availability: Public

Type of Model: Surface water quality

Summary: For hydraulic and hydrologic analyses of floodwater-retarding structure sites.

Abstract:

DAMS2 is a revision of a FORTRAN IV computer program (DAMS, issued November 1967) that facilitates the hydraulic and hydrologic analyses of floodwater-retarding structure sites. The program uses the sites' storage-discharge capacities to floodroute inflow hydrographs through a potential reservoir. Storage and discharge capacity may be computed by the program or loaded as input data. Inflow hydrographs may be actual or developed from any storm rainfall distribution. The program will compute embankment quantities if desired. The input data for a job is printed out as it is loaded and edited for such things as invalid characters in the data fields, missing data required for a run and unreasonably large or small data values where possible. A liberal amount of user options and program control is provided for greater application flexibility.

Document citations:

Mackay, R.E. DAMS2 - Project Formulation - Structure Site Analysis, User's Guide, USDA Soil Conservation Service, Washington, D.C., March 1971. (Available through NTIS, PB-233776.)

Principal users: SCS Soil Conservation Service

Validations: (Has undergone extensive field use) medium.

Assumptions:

Only one structure site at a time may be held in core storage, but by updating the structure data an unlimited number of sites may be studied in one computer run. A maximum of 20 points may be used to describe the sites' elevation-surface area or elevation-surface area-discharge-storage volume relation. A maximum of 99 points may be used to define the sites' centerline profile.

Up to five user-defined rainfall distribution tables of up to 300 co-ordinates each may be held in core storage at one time. Any one of these, plus the standard SCS 6-hour design distribution, defined by the program, may be used for design or simulation runs.

A maximum of 300 points may be specified to define inflow hydrographs developed by the program. This limitation also applies to hydrographs supplied by the user for routing through the structure. Only one user-supplied hydrograph may be held in storage at any one time. Following the control word to route that hydrograph, another may be inserted by the update procedure. In addition, one user-supplied dimensionless unit hydrograph of up to 100 coordinates may be held in storage at the same time.

An emergency spillway rating relation may be defined by the user with a maximum of 12 points (discharges) at uniform stage increments above the emergency spillway crest.

Up to 10 user-supplied centerline profiles for the emergency spillway inlet channel may be described with a maximum of seven coordinates each The first coordinate (0,0), located at the control section, is set by the program. The six additional points are supplied by the user.

In developing the emergency spillway rating, the program assumes that the exit channel slope is steep enough for a control section to exist at the downstream end of the inlet channel. There is no provision in the program to accurately compute spillway flow characteristics which flow is subcritical in the exit channel.

Current implementation:	Mainframe computer
Current hardware:	Unknown
Software language(s):	FORTRAN IV
Input requirements:	Numerical and character formatted--data must be in correct columns. Input information is provided on computer cards.
Input databases:	Some data is included with the model most is supplied by the user.
Output format:	Printed tables and hydrograph printer plots, computer card output is available.
User manual:	Yes
Systems documentation:	Yes
Date of first version:	Nov. 1967 (DAMS)
Date of latest documents:	March 1971
Machine interface:	Batch
Learning difficulty:	Medium
Output interpretation difficulty:	Medium
Analytical Features for Model:	Surface Water Hydrolog
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	Yes

Urban land areas:	Yes
Entire hydrographs:	No
Flood routing:	Yes
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym: **DAMBRK**

Model name: National Weather Service Flood Forecasting Model

Sponsor: National Weather Service

Developer: D.L. Fread, NWS

Contact address: Office of Hydrology
National Weather Service
NOAA
Silver Spring, MD 20910

Type of model: Surface Water Quantity

Summary:

The DAMBRK model attempts to represent the current state of the art in understanding of dam failures and the utilization of hydrodynamic theory to predict the dam-break wave formation and downstream progression.

Abstract:

The model consists of a breach component which utilizes simple parameters to provide a temporal and geometrical description of the breach. A second component computes the reservoir outflow hydrograph resulting from the breach via a broad crested weir-flow approximation, which includes effects of submergence from downstream tailwater depths and corrections for approach velocities. Also, the effects of storage depletion and upstream inflows on the computed outflow hydrograph are accounted for through storage routing within the reservoir. The third component consists of a dynamic routing technique for determining the modifications to the dam-break flood wave as it advances through the downstream valley, including its travel time and resulting water surface elevations. The dynamic routing component is based on a weighted, four-point nonlinear finite-difference solution of the one-dimensional equations of unsteady flow which allows variable time and distance steps to be used in the solution procedure. Provisions are included for routing supercritical flows, as well as subcritical flows, and incorporating the effects of downstream obstructions such as road-bridge embankments and/or other dams.

Model data requirements are flexible, allowing minimal data input when it is not available while permitting extensive data to be used when appropriate.

Document citations:

Fread, D.L. DAMBRK: The NWS Dam-Break Flood Forecasting Model. National Weather Service, Office of Hydrology, Silver Spring, MD. February 1981.

Brown, R.J., and Rogers, D.C. "A Simulation of the Hydraulic Events During and Following the Teton Dam Failure." Proceedings, Dam-Break Flood Modeling Workshop, U.S. Water Resources Council, Washington, D.C., 1977 pp. 131-163.

Fread, D.L., "Numeric Properties of Implicit Four-Point Finite Difference Equations of Unsteady Flow." NOAA Tech. Memo. NWS HYDRO-18, U.S. Dept. of Commerce NOAA, National Weather Service, 1974 pp. 39.

Fread, D.L., "Discussion of Comparison of Four Numerical Methods for Flood Routing." Journ. Hydraul. Div. ASCE, 101, HY3, March 1975, pp. 565-567.

Fread, D.L. "The Development and Testing of a Dam-Break Flood Forecasting Model." Proceedings, Dam-Break Flood Modeling Workshop, U.S. Water Resources Council, Washington, D.C., 1977, pp. 164-197.

Keefer, T.N., and Simons, R.K.,"Qualitative Comparison of Three Dam-Break Routing Models." Proceedings, Dam-Break Flood Modeling Workshop, U.S. Water Resources Council, Washington, D.C., 1977 pp. 292-311.

Principal users:	National Weather Service
Current level:	Mainframe computer
Current hardware:	IBM 360/195
User manual:	Yes
Date of latest documents:	February 1981
Learning difficulty:	Medium
Output interpretation difficulty:	Low
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	Yes
Flood routing:	Yes
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	No
Infiltration rates:	No
Dam-break wave predictions:	Yes

(15)

Model acronym: DORSCH
Model name: Dorsch Consult Hydrograph Method
Contact address: Dorsch Consult.
Munich, Germany
Availability: Proprietary
Type of model: Surface Water Quantity
Summary: Simulate time-varying runoff from basis with open channels.
Abstract:

The Dorsch model simulates the time-varying runoff from several basins which may include pipe networks and open channels. The flow routing sequence is based on the dynamic wave equation. Detention basins and other diversion structures can be analyzed. The model is limited to the simulation of a single-storm event. Storm runoff is computed separately for pervious and impervious areas accounting for depression storage where it is warranted. In pervious areas, infiltration is computed by either Holton's or Horton's technique. Rainfall access from both pervious and impervious areas is routed through open channels and/or pipes using a finite-difference solution of the dynamic wave equation. The model can be used to analyze the effects of various hydraulic structures such as drop structures, detention basins and overflow diversion structures. The data requirement for this complete, but complex model is quite extensive. The Dorsch model is proprietary and has been used extensively in Germany. Model testing on basins of up to 50 acres have shown good agreement between measured and computed hydrographs.

Document Citations:

Dorsch-Consult Ltd. Pollution of Receiving Water Bodies from Combined and Storm Sewer Systems. Dorsch-Consult Ltd., Toronto, Canada, June 1973.

Schelling, D.R.; Sternberg, Y.M., Highway Stormwater Management Models: Final Report. Department of Natural Resources, Silver Spring, MD, Dec. 1976.

Principal users: Has been used extensively in Germany
Current implementation: Mainframe computer
Current hardware: IBM 360/50
UNIVAC 1108
CDC 6600
Software language(s): FORTRAN IV
Systems documentation: Yes
Learning difficulty: High
Analytical Features for Model: Surface Water Hydrology
Small watershed areas: Yes
Flood routing: Yes
Continuous simulation of a storm event: Yes
Continuous simulation in real time: Yes
Water flow from a simulation: Yes
Infiltration rates: Yes

(16)

Model name:	**Deep Well Disposal Model**
Developer:	Intera Environmental Consultants, Inc.
Contact:	D.B. Grove
Contact address:	U.S. Geological Survey, National Center, Mail Stop 411, 12201 Sunrise Valley Dr. Reston, VA 22092
Contact telephone:	(713)496-0993
Availability:	NITS No. PB-256903
Type of model:	Groundwater general
Summary:	Simulate unsteady, three-D groundwater flow and pollutant transport in aquifer.

Document citations:

Intercomp Resource Development and Engineering, Inc. A Model for Calculating Effects of Liquid Waste Disposal in Deep Saline Aquifer: Part I - Development; Part II - Documentation. U.S. Geological Survey. Water Resources Investigation 76-61. (Available through NTIS: PB-256903).

Intera Environmental Consultants, Inc. Revision of the Documentation for a Model for Calculating Effects of Liquid Waste Disposal in Deep Saline Aquifer. U.S. Geological Survey. (Available through NTIS: PB122542).

Principal users:	Consultants
Current implementation:	Mainframe computer
Current hardware:	CDC 6600, IBM 370/158, DEC PDP10
Software language(s):	FORTRAN IV
Word size(s):	42K (decimal) words
Lines of source code:	9115
User manual:	Yes
Date of first version:	1975
Date of latest version:	1979
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	No
Steady state:	No
Nonsteady state:	Yes
Saturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	Yes
Pollutant transport:	Yes
Finite diff.	Yes

(17)

Model acronym: DEM
Model name: Dynamic Estuary Model
Sponsor: Public Health Service
Divison of Water Supply and Pollution Control
Developer: Water Resources Engineers
Contact: Robert B. Ambrose
Contact address: EPA, Athens Environmental Research Lab
College Station Road
Athens, GA 30613
Contact telephone: (404) 546-3545
Availability: Public
Type of model: Surface Water General

Summary:

An estuary simulation of tidal characteristicsand water quality in an estuary.

Abstract:

The DEM is a "real-time" link-node model that simulates the unsteady tidal flow and dispersive characteristics of an estuary. The model can be applied to estuaries in which vertical stratification is either absent or limited to relatively small areas. It can accommodate both conservative and nonconservative constituents. Constituents which have been modeled include salinity, tracer dye, dissolved solids, DO, BOD, total nitrogen, temperature, organic nitrogen, ammonia, nitrite, nitrate, phosphates, chlorophyll A, and coliform bacteria. Given the necessary kinetics and rates, the model could also treat parameters such as pesticides, heavy metals, and organic compounds. The DEM is often linked to the Tidal Temperature Model (TTM) for heat budgets. Ecological Processes such as algal dynamics, nutrient transport, sediment oxygen demand, coliform die-off, and first-order kinetics have been expressed in the model. Higher-order kinetics are available on some versions.

Document citation:

California Water Resources Control Board. Final report - San Francisco Bay - Delta Water Quality Control Program, Preliminary Abridged Edition, 1969.

Feigner, K.D. and Harris, H.S. Documentation Report, FWQA Dynamic Estuary Model, Report to U.S. Department of the Interior, Federal Water Quality Adminstration, 1970.

Finnemore, E.J.,Grimsrud, G.P. and Owen, H.J. Evaluation of Water Quality Models: A Management Guide for Planners, Report to Environmental Protection Agency, Office of Research and Development, Washington, D.C. 1976.

Genet, L.A., Smith, D.J. and Sonnen, M.B., Computer Program Documentation for the Dynamic Estuary Model. Report by Water Resources Engineers, Inc., Walnut Creek, California, to U.S. Environmental Protection Agency, System Development Branch, Washington, D.C., 1974.

Water Resources Engineers, Inc. A Hydraulic Water Quality Model for Suisun and San Pablo Bays. Report to U.S. Department of the Interior, Federal Water Pollution Control Administration, Southwest Region.

Water Resources Engineers, Inc. A Water Quality Model of the Sacramento - San Joaquin Delta, Report by WRE to U.S. Public Health Service, Region IX, 1965.

Water Resources Engineers, Inc. Computer Program Documentation for the Dynamic Estuary Model, Report by WRE to Florida Department of Pollution Control, Tallahassee, Florida, 1974.

Water Resources Engineers, Inc. Validation and Sensitivity Analyses of Stream and Estuary Models Applied to Pearl Harbor, Hawaii, Report by WRE, Walnut Creek, California, to U.S. Environmental Protection Agency, Systems Development Branch, Washington, D.C., 1974.

Principal users: EPA, State of California

Assumptions:

The model assumes that vertical stratification is either absent or limited to relatively small areas. It does not handle wind stress or tidal flats exposed at low tide. Other hydrodynamic processes assumed negligible include longitudinal density gradients, coriolis acceleration, and bottom slope. The instantaneous mixing of residual discharge throughout junctions is also assumed.

Current implementation: Mainframe Computer
Current hardware: Mainframe IBM 370/168
Software language(s): FORTRAN IV

Word size(s):

129 junctions and 131 channels, need 130K of main storage

Operating system(s):

The DEM is written in FORTRAN IV. The hydraulic component of the model requires two files, either on disk or tape. The cost of a 50-hour four tidal cycles) hydraulic simulation on an IBM 370/168 is approximately $40. The quality component of DEM requires from four to seven files, depending on the output options desired. A quality program with six constituents can be run on a digital computer with 200K to 400K of main storage. The cost of a 1000-hour (80 tidal cycles) quality simulation for six constituents and 129 junctions can range from $40 to $75. The DEM requires 5 to 20 man-weeks of effort for data preparation and output interpretation, one programmer, and one environmental engineer with experience in water quality modeling.

Input requirements:

The DEM requires a large input data base on disk, tape, and/or cards. Parameters which need to be specified include headwater and tributary flows, wastewater flows and loadings, water withdrawals, seaward tidal conditions, channel and junction geometry, bottom roughness of each channel, constituent concentrations at boundaries, and decay rates for nonconservative constituents. Physical data pertaining to channels and junctions can be obtained from navigational charts since direct measurements are seldom available.

Output format:

The model is capable of producing a wide variety of outputs. Output options available are: (1) maximum and minimum flows, heads, and velocities, as well as net flows, over a tidal cycle for the model network, (2) maximum, minimum, and average constituent concentrations for each junction over a complete tidal cycle (or other specified averaging interval), (3) "slack water" and "snapshot" tables of constituent concentration at desired time intervals throughout the simulaton, and (4) line-printer plots of both spatial and temporal concentration profiles.

Output complexity:	Medium
User manual:	Yes
Learning difficulty:	Medium
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym: DIURNAL
Model name: Receiving Water Model
Sponsor: EPA
Developer: Hydroscience, Inc.
Contact: Thomas Henry
Contact address: US EPA, Region 3 Water Division
Curtis Bldg, 6th & Walnut St.
Philadelphia, PA 19106
Contact telephone: (215)597-8048
Availability: Public
Type of model: Surface Water Quality
Summary: To predict the diurnal variations in DO for a stream.

Abstract:
DIURNAL is a one-dimensional (horizontal plane) receiving water quality model. The model represents the physical processes of advection and dilution and simulates receiving water quality changes in dissolved oxygen. Coupled chemical reactions can predict the diurnal fluctuations during periodic steady-state conditions. The model was developed by Hydroscience, Inc., of Westwood, New Jersey.

Document citations:

Di Toro, Dominic, and O'Connor, Donald J.,"Photosynthesis and Oxygen Balance in Streams." Journal of the Sanitary Engineering Division, ASCE, April 1970, pp. 547-571.

Principal users: EPA and consulting firms
Validations: High

Assumptions:

The solution analysis is an extension of the technique based on the continuity equation for dissolved oxygen which includes the diurnal time-variable effect of photosynthetic oxygen production. The analysis considers the temporal as well as spatial distributions. The periodic extension of the photosynthetic oxygen production is expressed as a Fourier series.

Current implementations: Mainframe computer
Current hardware: Any digital computer
Software language(s): FORTRAN IV (G)
Word size(s): 40k core

Input requirements:

Input information is basically of three types: initial conditions definition, individual segment characteristics definition and discharge information. Initial conditions data include system description (number of sections, element length, river mile at the head of the system) and quality description (upstream BOD, upstream NBOD and Fourier coefficients of upstream DO). The individual segment data include the following: section length, velocity, temperature, reaeration rate and decay rates (carbonaceous and nitrogenous). Other information includes bottom demand, hours of daylight, maximum photosynthetic rate, respiration, time of sunrise, stream flow and segment elevation. Discharge information includes, DO, flow, BOD and NBOD. Segment characteristics and discharge information are repeated for each segment modeled.

Output format:

DIURNAL produces a tabular printout of section parameters and dissolved oxygen response. The section parameters include: length, velocity, temperature, flow, reaeration and decay rates, benthic rates and photosynthesis and respiration rates. The DO response table includes hourly dissolved oxygen values, for 24 hours, for the beginning and the end of the segment and any intermediate point designated by the print interval.

User manual:	No
Date of first version:	1970
Learning difficulty:	Low
Geographic area:	Stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	Yes
Radioactivity :	No
Salinity:	No
Conservative minerals:	No
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state :	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	No
Estuarine Models:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: DOSAG-I
Model name: Dissolved Oxygen Sag Model
Sponsor: Texas Water Development Board
Developer: Water Resource Engineers, Inc.; Texas Water Development Board
Contact: Tom Barnwell
Contact address: US EPA Environmental Research Lab
Center for Water Quality Modeling
College Station Road, Athens, GA 30605
Availability: Public
Type of Model: Surface Water Quality

Summary:

A stream water quality model to predict dissolved oxygen.

Abstract:

DOSAG-I is a mathematical model developed to predict the steady-state dissolved oxygen concentrations in streams and canals resulting from a specified set of streamflow, wasteload, and temperature conditions. The model will determine the streamflow required to maintain a specified dissolved oxygen goal and will search the system for available storage to achieve the goal. The model can be used to estimate mean monthly dissolved oxygen levels over a full year. Both carbonaceous and nitrogenous oxygen demands are included, and up to five degrees of treatment for both can be specified. It is one of two programs that the Texas Water Quality Development Board and the EPA have for use in stream quality simulation studies. The other program, QUAL-I, is designed to be used as a complement to DOSAG-I.

Document citations:

Texas Water Development Board. DOSAG-I - Simulation of Water Quality in Streams and Canals: Program Documentation and User's Manual. Report by TWDB Systems Engineering Division, Austin, TX 1972.

Finnemore, D.J.; Grimsrud. G.P.; and Owen, H.J., Evaluation of Water Quality Models: A Management Guide for Planners. Prepared for the Environmental Protection Agency, Office of Research and Development, Washington, D.C., under Contract No. 68--01-2641, July 1976.

Principal user: EPA, consulting firms, Texas Water Development Board
Validation: High

Assumptions:

The model assumes constant stream velocity throughout each reach and assumes first-order decay only. The Streeter-Phelps equation is used to calculate dissolved oxygen concentration, and the computation of atmospheric reaeration is based on the Fickian law of diffusion. A Lagrangian solution technique is used to solve the dissolved oxygen equations.

Current implementation: Mainframe computer
Software language: FORTRAN IV (G level)
Word size(s): 27k words minimum

Input requirements:

The following are required for input and calibration needs: reach length, mean velocity, mean discharge, mean depth (per reach), average reach temperature, residual discharge inflows, withdrawals and groundwater inflows, residual inputs (as BOD) and dissolved oxygen concentration in each reach. For verification of the model, streamflows, stream velocity and observed constituent concentrations throughout the modeled area are required.

Output format:

Output from the model consists of a tabular printout of the concentration of dissolved oxygen for each reach, BOD (carbonaceous and nitrogenous) at the start and end of each reach, an echo of all input data, and a final summary.

Output complexity:	Low
User manual:	Yes
Systems documentation:	Yes
Learning difficulty:	Low
Geographic area:	Stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	No
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

(20)

Model name: **Drainage Runoff Analysis**
Developer: John Pai
Contact: CEPA
Contact address: Soc. for Computer Applications in Engineering, Planning, and Architecture, Inc. 358 Hungerford Drive Rockville, MD 20850
Contact telephone: (301)762-6070
Type of model: Surface Water Quantity
Summary : Determines the rainfall runoff from rainfall intensity-duration curves.

Abstract:

This program determines the rainfall runoff at an area where local rainfall intensity-duration curves are available. Five frequencies of 5, 10, 20, 25 and 50 can be solved in one pass. Rational formulas and unit-hydrograph methods are used.

Current implementation: Mainframe computer
Current hardware: IBM 1130
Software language(s): FORTRAN
Word size(s): Min. memory size = 8K

Input requirements:

Control section numbers, stations, elevations, channel factor downstream and number of contributory areas. Area number, C-factor, area, overland distance, overland elevation, overland factor, channel distance, channel elevation and channel factor.

Control section for which Q is required, list of all upstream control points and list of required frequencies.

Output format:

For each control section analyzed:
1) Maximum concentration time
2) Intensity for each frequency
3) Composite hydrograph ordinates for each frequency
4) Peak discharge for each frequency

User manual: Yes
Analytical Features for Model: Surface Water Hydrology
Small watershed areas: Yes
Large watershed areas: Yes
Rural land areas: Yes
Urban land areas: Yes
Entire hydrographs: Yes
Flood routing: No
Snowmelt considerations: No
Continuous simulation of a storm event: No
Continuous simulation in real time: No
Sedimentation and scour: No
Water flow from a simulation: Yes

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Model acronym: **DWOPER**
Model name: Dynamic Wave Operational Model
Sponsor: National Weather Service
Developer: D.L. Fread, NWS
Contact: D.L. Fread, Research Hydrologist
Contact address: Hydrologic Research Laboratory, W23, National Weather Service, NOAA, Silver Spring, MD 20910
Type of model: Surface water quality
Summary: A dynamic wave flood routing model

Abstract:

An operational hydrodynamic model (DWOPER) developed by the Hydrologic Research Laboratory of the National Weather Service is being placed in operational use by River Forecast Centers on a number of major river systems where storage routing methods are inadequate due to the effects of backwater, tides, and mild channel bottom slopes. The model is based on the complete one-dimensional St. Venant equations and belongs to the category of dynamic wave flood routing models. A weighted four-point nonlinear implicit finite-difference scheme is used to obtain solutions to the St. Venant equations via a Newton-Raphson iterative technique.

DWOPER has a number of features which make it applicable to a variety of natural river systems for real-time forecasting. It is designed to accommodate various boundary conditions and irregular cross sections located at unequal distances along a single multiple-reach river or several such rivers having a dendritic configuration. It allows for roughness parameters to vary with location and stage or discharge. Temporally varying lateral inflows, wind effects, bridge effects, off-channel storage, weir-flow channel bifurcations are included among its features. Time steps are chosen solely on the basis of desired accuracy,since the implicit finite difference technique is not restricted to the very small time steps of explicit techniques due to numerical stability considerations. This enables DWOPER to be very efficient as to computational time for simulating slowly varying floods of several days duration. An efficient automatic calibration procedure for determining optimum Manning n - stage or discharge relationships from observed data is provided as an option in DWOPER. Data handling requirements for day-to-day river forecasting are minimal due to extensive data management features utilizing disk or tape storage. Operationally, card coding is only required to update hydrograph files with the most recent observations. Applications of DWOPER to several large river systems have demonstrated its operational efficiency, accuracy and utility. The model is currently being extended to account for effects of channel sinuosity and flood plains (Fread, 1976), sediment transport (Chen and Simons, 1975) and bank storage on unsteady flows in alluvial rivers. Also, it has been coupled to an unsteady temperature transport model (Bowles, et al.,1977) for development as a river temperature forecasting model.

Document citations:

Fread, D.L. "Technique for Implicit Dynamic Routing in Rivers with Major Tributaries." Water Resources Research, Vol. 9, No. 4, 1973b, pp. 918-926.

Fread, D.L. Numerical Properties of Implicit Four-Point Finite Difference Equations of Unsteady Flow. NOAA Technical Memorandum NWS HYDRO Vol. 18, NOAA, March 1974, p. 88 .

Fread, D.L. National Weather Service Operational Dynamic Wave Model. National Weather Service, NOAA, Silver Spring, MD, April 1978.

Principal users:	National Weather Service
Validation:	High
Current implementations:	Mainframe computer
Current hardware:	IBM 360/195
User manual:	Yes
Date of latest documents:	April 1978
Continued enhancement:	Yes
Geographic area:	Many locations to different rivers.
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	Yes
Flood routing:	Yes
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Infiltration rates:	No
Dynamic wave prediction:	Yes

(22)

Model acronym: **EPA RRB**
Model name: Nonpoint Runoff Model for a Rural Setting
Sponsor: EPA
Developer: EPA
Contact: Howard A. True
Contact address: EPA Region 4 Ambient Monitoring Section
College Station Road, Athens, GA 30613
Contact telephone: (404)546-3139
Availability: Public
Type of model: Surface Water General

Summary:

Simulation of erosion and pollutant loads to a water body.

Abstract:

MODEL OVERVIEW: EPARRB is addressed as Planning Model "B" of a three-model group. This model calculates erosion and delivered sediment to a body of water using the "Universal Soil Loss Equation." The delivered sediment is converted to pollutant loads based on loading factors and is combined with litter and animal/fowl droppings loads to produce daily/monthly/annual and period loads to bodies of water. An unlimited number of land units of unlimited size can be used and grouped in several ways. Most of the physical characteristics of land units and loading rates are randomly selected from user determined distributions. Single-storm sedimentation reports can be produced by precalculating the storm Erosion-Index(EI) value. This process is basically a large area rural planning model.

Document citation:

True, Howard A. Nonpoint Assessment Processes. April 1976, Revised April 1977.

Assumptions:

BASIC ASSUMPTIONS: The model assumes that all areas have slope percentages that allow reasonable erosion to take place. Extremely flat and highly pervious areas could not be assessed with this process. It is assumed that the required topographic information can be obtained from soil surveys or other sources. Confidence in process results depends on the accuracy of the basic data.

Current implementation: Mainframe computer
Current hardware: IBM, CDC, UNIVAC etc.
Software language(s): FORTRAN
Word size(s): 120k
Operating System(s): Printer, any 132 characters per line model

Input requirements:

Input consists of seven area cards to provide report headings and general setup information, a state group composed of a state card, followed by land unit card groups, each containing nine data cards. There is no limit on number of state groups or number of land units in a state group.

Output format:

Output consists of a single report, giving land unit identification and calculated erosion, sediment, litter, nutrients (N,P,K,BOD,TOC) and acid-quantities for the period specified, or as daily loadings.

Geographic area:	Lake, stream/river, nonpoint: urban and rural
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	No
DO level:	No
Benthal oxygen:	No
Phosphorous:	Yes
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Changes in channel flow:	No
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	No
Point source:	No
Nonpoint source:	Yes
Steady state:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	No
Flood routing:	No
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	Yes
Sedimentation and scour:	Yes
Water flow from a simulation:	No

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<u>Model acronym:</u> **EPATLC**
<u>Model name:</u> Reporting and Projection Planning Model-Point and Nonpoint
<u>Sponsor:</u> EPA
<u>Developer:</u> EPA
<u>Contact:</u> Howard A. True
<u>Contact address:</u> Ambient Monitoring Section, S&E Division
EPA Region 4, College Station Rd
Athens, GA 30613
<u>Contact telephone:</u> FTS 250-3139
<u>Type of model:</u> Surface Water Quality
<u>Summary:</u> A planning model for point and nonpoint sources.

<u>Abstract:</u>

EPATLC is addressed as Planning Model "C" of a three-model group. This model will combine point and nonpoint loads for reporting purposes. It will also perform projections by changing treatment levels for point sources and land use percentages for nonpoint sources (i.e. municipal, industrial and any other) and output from EPAURA "A" and EPARRB "B." Process runs provide non-point information for up to five land uses.

FUNCTIONAL CAPABILITIES: EPATLC was designed to provide a composite report of pollutant loads from both point and nonpoint sources for current conditions. The process was expanded to allow changes in tratment rates for point sources and changes in land use for nonpoint sources so that the modification of current conditions provides for a projected report being made for some future year. Each parameter of interest produces a separate report. Three sets of loads are calculated if data ranges are stated; these loads are lowest, highest and most probable. The most probable load is developed by randomly sampling the values between the input extremes. This report shows the relationship between point and nonpoint loads and could indicate the feasiblity of advanced waste treatment effectiveness.

<u>Document citation:</u>

True, Howard A. <u>Nonpoint Assessment Processes</u>. April 1976, Revised April 1977.

<u>Principal users:</u> EPA

<u>Assumptions:</u>

This model is a technical assistance process for simplified reporting and projecting waste and potential nonpoint pollutant loads for an area and its component subareas. The model assumes that required information is available and merely requires manipulation according to changing criteria.

<u>Current implementation:</u> Mainframe computer
<u>Current hardware:</u> IBM, CDC, UNIVAC
<u>Software language(s):</u> FORTRAN, JCL/JES
<u>Word size(s):</u> 120k core

Input requirements:

The model input requires four cards of area data for a particular parameter and an unlimited number of four-card land unit groups for this parameter. These are multiple produced for each parameter.

Output format:

Output consists of a single point and nonpoint. Nonpoint summary report is produced for each parameter.

User manual:	No
Systems documentation:	No
Analytical Features for Model:	Water Quality
Changes in channel flow:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Point source:	Yes
Nonpoint source:	Yes
Steady state:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

Model acronym: EPAURA
Model name: Nonpoint Runoff Model for a Single-Storm Event
Sponsor: EPA
Developer: EPA
Contact: Howard A. True
Contact address: US EPA Region 4, Ambient Monitoring Section
College Station Road, Athens, GA 30631
Contact telephone: (404) 546-3139
Availability: Public
Type of model: Surface Water General
Summary: Calculating nonpoint loading from a storm

Abstract:

EPAURA is addressed as Planning Model "A" of a three-model group. This model calculates the "first flush" load to a body of water from a specified storm event. The storm can be of any intensity and duration, but only the first 15 minutes of rainfall will be utilized and routed to a common mixing point. Loading factors for up to 40 parameters are used in conjunction with curb miles or areal extents to produce storm loadings for up to 20 subareas and route each area separately to a body of water. The mixed slug loading can be used as input to other models or an equivalent daily load can be calculated, based on a storm frequency analysis.

Document citation:

True, Howard A., Nonpoint Assessment Processes, April 1976, Revised April 1977.

Principal users: EPA

Assumptions:

The model assumes an antecedent period adequate to allow buildup of pollutants. The model assumes that 15 minutes of rainfall at the specified intensity will run off as a slug and carry virtually all of the accumulated pollutants on the impervious surfaces with it.

Current implementation: Mainframe computer
Current hardware: Any mainframe with greater than 120K core.
Software language(s): FORTRAN JCL/JES
Word size(s): Any mainframe with greater than 120K core.

Input requirements:

The input consists of 40 parameter factor cards to provide loading rates, two cards describing the receiving body of water, one card for each subarea containing control information, a total area card and one or more storm cards containing required storm parameters.

Output format:

Output consists of a report for each subarea for up to 40 parameters, a total area report and a receiving mixing report showing arrival time of each slug and new concentrations for all parameters involving bodies of water.

User manual:	Yes
Date of first version:	April 1976
Date of latest documents:	April 1977
Geographic area:	Lake, stream/river, nonpoint urban
Analytical Features for Model:	Water Quality
Oxygen:	Yes
DO level:	Yes
Time dependent input:	Yes
Time-variant pollution:	Yes
Point source:	No
Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	Yes
Entire hydrographs:	No
Flood routing:	No
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	No
Sedimentation and scour:	Yes
Water flow from a Infiltration rates:	No

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Model acronym: ES001

Model name: Estuarine Water Quality Model

Sponsor: Federal Water Pollution Control Administration/EPA

Developer: Hydroscience, Inc.

Contact: George A. Nossa; Laura Livinston

Contact address: EPA Environmental Systems Section
26 Federal Plaza, NY, NY 10278

Contact telephone: (212)264-9850

Availability: Public need to contact EPA, Region II

Type of model: Surface Water Quality

Summary: A steady-state, one-dimensional, estuarine, BOD-DO water quality model.

Abstract:

ES001 is a steady-state, one-dimensional, estuarine water quality model which simulates BOD and DO variations. It was prepared by the EPA to improve upon and document some water quality models developed for the EPA by Hydroscience, Inc., and it is particularly useful for the rapid evaluation of a number of varying estuary and wasteload conditions. Based on the law of conservation of mass, the program is designed to model the BOD-DO deficit system but it is capable of modeling analogous systems of sequential reactions of two substances having first-order kinetics, like that of a nitrogen reaction with ammonia and nitrate. The model is assumed to be at steady state and to be tidally averaged.

Document citations:

Chapra, S.C., and Gordimer, S. Documentation of ES001, A Steady-state, One-Dimensional, Estuarine Water Quality Model, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, New York, NY, September 1973.

Finnemore, E.J. Grimsrud, G.P. and Owen, H.J. Evaluation of Water Quality Models: A Management Guide for Planners, Prepared for the Environmental Protection Agency, Office of Research and Development, Washington, D.C., under Contract No. 68-01-2641, July 1976.

Principal users: EPA

Assumptions:

ES001 handles only steady-state flows and discharges, and it does not consider flow velocity or quality variations with depth or within stream cross sections. The model assumes only first-order kinetics for BOD and DO, and it utilizes a matrix inversion technique for the solution of simultaneous differential equations which are derived from the law of conservation of mass.

Current implementations: Mainframe computer

Current hardware: IBM 370

Software language(s): FORTRAN IV

Word size(s): 245k

Input: 2-6 man-weeks are needed for data preparation and programming.

Input requirements:

The ES001 requires a large amount of input data in card-image form. Initial input/calibration needs include: estuary cross-sectional data, segment length, water depth, net flow, reservoir outflows, estuary volume, tidal exchange coefficient, dispersion coefficient, constituent concentration for all system inflows, temperatures, benthic oxygen demand, algal photosynthesis, respiration, and other rate coefficients, residual inputs from point sources, uniform waste input, salinities at seaward boundaries, tidal exchange coefficients, and temperature correction factors. Constituent concentrations through the system and observed salinity patterns are needed for verification.

Output format:

Output information provided by the model includes a tabular printout of the input data, BOD concentration and DO deficits at 10 equidistant points per segment, and a number of matrices (DO deficit matrix, BOD matrix and inverted DO deficit matrix.)

User manual:	Yes
Date of latest documents:	1973
Geographic area:	Estuary, New York Harbor complex, Raritan and Hudson rivers.
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	No
Reservoir and lake:	No
Estuarine:	Yes
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: EXPLORE-1
Sponsor: EPA
Developer: Battelle-Northwest Labs
Contact: Robert B. Ambrose, Jr.
Contact address: EPA Athens Environmental Research Lab
Center for Quality Modeling, College Station Road
Athens, GA 30613
Contact telephone: (404) 546-3546
Availability: Public
Type of model: Surface Water Quality
Summary: Predict hydrodynamics and water quality for rivers.

Abstract:

MODEL OVERVIEW: EXPLORE-1 is a comprehensive mathematical water quality model to be used in river basin planning and water resource studies. This generalized river basin water quality model can predict the hydrodynamics and water quality dynamics for rivers and those well-mixed estuaries where dispersion is negligible. The EXPLORE-1 model is an extended and modified version of the Storm Water Management Model, receiving water component, which was developed for studies of DO/BOD dynamics. The model is capable of simulating a number of hydraulic regimes in either a dynamic or steady-state mode, and it has been set up, calibrated, and verified on a portion of the Williamette River Basin, consisting of major tributaries. EXPLORE-1 was developed by Battelle-Northwest Laboratories for the EPA.

Document citation:

Thackston, E.L., and Krenke, P.A. "Reaction Predictions in Natural Streams." ASCE, Proc. Journal of the Sanitary Engineering Division, Vol. 965, No. SA1, Paper 6407, February 1969 pp. 65-94.

Feigner, K.D. and Harris, H.S. Documentation Report: FWQA Dynamic Estuary Model. U.S. Department of the Interior, Federal Water Quality Administration, July 1970.

Callaway, F.J., Byram, K.V.; and Ditsworth, G.R. Mathematical Model of the Columbia River from the Pacific Ocean to Bonneville Dam-Part I. Federal Water Pollution Control Administration, Pacific Northwest Water Laboratory, November 1969, pp. 155.

Metcalf & Eddy, Inc., Storm Water Management Model. Vol. 1-4. Palo Alto, California; University of Florida, Gainesville, Florida; and Water Resources Engineers, Inc. Walnut Creek, CA.

Principal users: EPA and consulting firms

Assumptions:

The overall model formulation is partitioned into two basic modules which can be operated sequentially: 1) a hydrodynamics module and 2) a mass transport and water quality submodels module. The hydrodynamics module is formulated on conservation of mass and momentum principles. The mass transport and water quality submodels module is formulated from the expressions for species continuity, i.e., mass balance of a particular constituent or species. For any biotic or abiotic substance, the general mass transfer expression is the sum of the individual forms of mass transfers. Diffusion is assumed to be negligible, and mass transfer is partitioned into simple transport and water quality kinetics.

Current implementation:	Mainframe computer
Current hardware:	IBM 370, UNIVAC 1100
Software language(s):	FORTRAN
Word size(s):	44k-UNIVAC 1100, 220k-IBM

Input requirements:

Junction and channel data are required for the hydrodynamics module. Junction input data include: the average water surface elevation for the junction point, the water surface area associated with the junction point, any significant inflows to the junction point from small streams, tributaries, or other sources, any significant outflows from the junction point, the average elevation of the bottom of the river or estuary for the junction point, the cartesian coordinates of the junction point (necessary only if the effect of wind stress on channel flow is being calculated). Required input channel data include: channel length, channel width, average elevation of the channel bottom, manning coefficient for the channel, initial velocity in the channel.

Input for the water quality program includes upstream node specification, reach boundaries, source node specification, BOD constants, benthic BOD constants, TOC constants, toxic constants, DO production by phytoplankton, DO production by benthic plants, reaeration constants, phosphorous constants, nitrogen constants, algae constants, number of constant sources, constant source values, time-varying source values, reach temperatures, constant upstream node concentrations, and time-varying upstream node concentrations.

Output format:

Output produced by the model includes an echo of the input data and BOD and loading rates for each of the constituents modeled.

User manual:	Yes
Geographic area:	Estuary, lake stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	Yes
Coliforms:	No
Chlorophyll-A:	Yes
Radioactivity:	No
Salinity:	Yes
Conservative minerals:	No
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and pre- Time-variant pollution:	Yes
Point source:	Yes

Steady state:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Mixing zones:	No
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Water flow from a simulation:	Yes
Infiltration rates:	No

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Model acronym:	**EZRAT**
Model name:	An EZRA Curve Computation Program
Developer:	Tony Supinski, David M. Lynch
Contact:	Society for Computer Applications in Engineering, Planning and Architecture, Inc.
Contact address:	358 Hungerford Drive, Rockville, MD 20850
Contact telephone:	301-762-6070
Type of model:	Surface Water Quantity
Summary:	Computes EZRA curves data for hand plotting.

Abstract:

Computes EZRA curves data for hand plotting. The plot of the EZRA curves for the section of consideration will yield a graphical determination of backwater elevations; the initial elevations may be varied without additional computations.

Current implementation:	Mainframe computer
Current hardware:	IBM 1130
Software language(s):	FORTRAN
Word size(s):	Min. peripherals 8k

Input requirements:

Discharge values (2), areas per part (LOB, MC, ROB) per stage for each section, wetted perimeters per part per stage for each section, roughness coefficients for each part, velocity coefficients for each part.

Outut format:

Echo of input, listing of reach energy head per stage (Z1 + F(Z1)), velocity head and state of flow, part data by stage (optional), velocity, discharge, average velocity, hydraulic gradient.

User manual:	Yes
Systems documumentation:	Yes
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	NO
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No
Other: Graphical determination of backwater elevation:	Yes

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Model acronym: **FE3DGW**

Model name: Finite-Element Three-Dimensional Groundwater Flow Model

Sponsor: Battelle Pacific NW Labs

Developer: S.K. Gupta, F.W. Bond, C.R. Cole

Contact: C.R. Cole

Contact address: Water & Land Resources Dept. Battelle Pacific NW Labs P.O. Box 999, Richland, WA 99352

Contact telephone: (509)376-8451/8449

Type of model: Groundwater quantity

Summary: 3-D simulation of flow in multilayered groundwater basin.

Document citations:

Gupta, S.K., Cole, C.R. and Bond, F.W., Finite-Element Three-Dimensional Groundwater (FE3DGW) Flow Model - Formulation, Program Listing and User's Manual, Rept. PNL-2939, Battelle Pacific NW Laboratories, Richland, WA, 1979.

Gupta, S.K., and Pinder, G.F., Three-Dimensional Finite-Element Model for Multilayered Groundwater Reservoirs of Long Island, New York, Water Resources Program, Dept. of Civil Eng., Princeton Univ., Princeton, N.J., 1978.

Gupta, S.K., Tanji, K.K. and Luthin, J.N., A Three-Dimensional Finite-Element Groundwater Model. Contribution No. 152, California Water Resources Center, University of California, Davis, CA 1975.

Gupta, S.K. and Tanji, K.K. Computer Program for Solution of Large, Sparse, Unsymmetric Systems of Linear Equations. Internal. J. for Num. Meth. in Eng., Vol. 11, pp. 1251-1259, 1977.

Gupta, S.K., Morrisey, M.W., Lonezak, J. and Tanji, K.K. Conversion of Irregular Finite-Element Grid Data to Regular Grid for Three-Dimensional Computer Plotting. Water Resources Research, Vol. 12(4), 1976.

Gupta, S.K., Cole, C.R., Kincaid, C.T. and Kaszeta, F.E., Description and Applications of the FE3OCW and CF EST Three-Dimensional Finite-Element Models. Battelle Pacific NW Laboratories, Richland, WA. No date.

Cole, C.R. and Gupta, S.K., A Brief Description of the Three-Dimensional Finite-Element Groundwater Flow Model Adopted for the Waste Isolation Safety Assessment Program. Rept. PNL-2652, Battelle Pacific NW Laboratories, Richland, WA, 1978.

Gupta, S.K. and Tanji, K.K., A Three-Dimensional Galerkin Finite-Element Solution of Flow Through Multiaquifers in Sutter Basin, California. Water Resources Research, Vol. 12121, 1978.

Gupta, S.K., Morrisey, M.W., Lonezak, J. and Tanji, K.K., Computer Program for Three-Dimensional Plottings from Irregular Finite-Element Grid, Water Science and Eng. Papers 4010, Dept. of Water Science and Eng., Univ. of California, Davis, CA, 1976.

Principal users: Research labs

Current implementation: Mainframe computer

Current hardware:	PDP 11/45
Software language(s):	FORTRAN IV
Word Size(s):	32K 16-bytes-words
User manual:	Yes
Date of first version:	1975
Date of latest version:	1979
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite-element solution:	Yes
Steady State:	Yes
	Yes
One Aquifer:	Yes
Leakage between aquifers:	Yes
Semipermeable and Nonpermeable aquifers:	Yes
Stream aquifer interaction:	Yes
Saturated element:	Yes
Unsaturated element:	No
Differentials across element:	Yes
Variable flow rates across boundary:	No
Finite diff.	No
Mass transport	No

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Model acronym: FEDBAKO3
Model Name: Water Quality Feedback Model
Sponsor: EPA, Region II
Developer: Nossa, G.A., Laura Livingston
Contact: George A. Nossa; Laura Livingston
Contact address: US EPA Information System Branch
26 Federal Plaza, NY, NY 10278
Contact telephone: (212)264-9850
Availablity: Public
Type of model: Surface Water Quality

Summary:

Compute distribution of water quality variables with nitrification.

Abstract:

FEDBAKO3 is used to compute the steady-state distribution of water quality variables undergoing consecutive reactions with feedback and following first-order kinetics. The program has been developed in a general form but is specifically applicable to the reactions observed by nitrogenous species and the associated dissolved oxygen uptake in the natural environment. The basis for this model is the theory of conservation of mass. The approach used to solve the equations is a finite-difference scheme developed by Thomann, which has been shown to be a very effective tool in the field of water quality management.

Document citations:

Nossa, G.A. , "FEDBAKO3 A Computer Program for the Modeling of First Order Consecutive Reactions with Feedback Under a Steady State Multidimensional Natural Aquatic System." Environmental Modeling and Simulation, USEPA Office of Research and Development, Washington, DC July 1976.

Nossa, G.A. FEDBAKO3 - Program Documentation and Users Guide, USEPA, Region II, New York, NY, November 1978.

Principal user: EPA

Assumptions:

The model assumes steady-state conditions in an aquatic environment. It is based on the theory of conservation of mass and utilizes a finite-difference scheme for the solution of the general estuarine advection/dispersion equation. Reactants are assumed to undergo consecutive reactions with feedback and first-order kinetics.

Current implementations: Mainframe computer
Current hardware: IBM 370
Software language(s): FORTRAN IV (G or H) level
Word size(s): 140k

Input requirements:

FEDBAKO3 requires the input of the physical characteristics of the system to be evaluated,(namely, the geometry, temperature, hydrologic characteristics, reaction schemes, and corresponding reaction rates.)

Output format:	FEDBAKO3 produces the calculation of BOD deficit and nitrification.
User manaul:	Yes
Systems documentation:	Yes
Date of latest documents:	1978
Learning difficulty:	Medium
Geographic area:	Estuary, lake, stream/river, marine.
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady State:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	No

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Model acronym: **FEMWASTE**

Model name: A Finite-Element Model for Waste Transport Through Porous Saturated-Unsaturated Media

Sponsor: Dept. of Energy

Developer: G.T. Yeh

Contact: G.T. Yeh

Contact address: Room 203, Bldg. 1505, Oak Ridge National Laboratory Oak Ridge, TN 37830

Contact telephone: (615) 574-7285

Type of model: Groundwater Quality

Summary: A two-dimensional, transient, finite-element porous media model for quality simulation.

Abstract:

A two-dimensional transient model for the transport of dissolved constituents through porous media originally developed at Oak Ridge National Laboratory (ORNL) has been expanded and modified. Transport mechanisms include: convection, hydrodynamic dispersion, chemical sorption and first-order decay. Implementation of quadrilateral isoparametric finite elements, bilinear spatial interpolation, asymmetric weighting functions, several time-marching techniques and Gaussian elimination are employed in the numerical formation. A comparative example is included to demonstrate the difference between the new and original models. Results from 12 alternative numerical schemes of the new model are compared. The waste model is compatible with the water flow model developed at ORNL for predicting convective Darcy velocities in porous media which may be partially saturated.

Document citations:

Yeh, G.T. Transport and Dispersion of Pollutants in Surface Impoundments: A Finite Difference Model. ORNL-5521, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.

Yeh, G.T. and Strand, R.H. FEMWASTE: User's Manual of a Finite-Element Saturated-Unsaturated Porous Media. ORNL/TM-7316, Oak Ridge Natl. Laboratory Oak Ridge, TN 1981.

Desai, C., and Abel, J. Introduction to the Finite Element Method: A Numerical Method for Engineering Analysis. Van Nostrand Reinhold, New York 1972.

Duguid, J.O., and Reeves, M. Material Transport in Porous Media: A Finite-Element Galerkin Model, ORNL-4928. Oak Ridge National Laboratory, Oak Ridge, TN p. 198, 1976.

Reeves, M. and Duguid, J.O. Water Movement Through Saturated-Unsaturated Porous Media: A Finite-Element Galerkin Model. ORNL-4927, Oak Ridge National Laboratory, Oak Ridge, TN pp. 232, 1975.

Yeh, G.T., and Ward, D.S. FEMWATER: A Finite-Element Water Flow Through Saturated-Unsaturated Porous Media. ORNL-5567, Oak Ridge National Laboratory, Oak Ridge, TN 1979.

Yeh, G.T. and Ward, D.S. FEMWASTE: A Finite-Element Model of Waste Transport Through Saturated-Unsaturated Porous Media. ORNL-5601, Oak Ridge National Laboratory, Oak Ridge, TN pp. 198, 1976.

Principal users:	Research laboratories, and consulting firms.
Current implementation:	Mainframe computer
Current hardware:	IBM
Software language(s):	FORTRAN
User manual:	Yes
Systems documentation:	Yes
Date of first version:	1979
Date of latest version:	1979
Date of latest documents:	1979
Learning difficulty:	Medium
User support:	Yes (615)574-7285
Geographia area:	Saturated-unsaturated porous media
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite-element solution:	Yes
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Semipermeable and non-permeable aquifers:	Yes
Stream aquifer inter-action:	Yes
Saturated element:	Yes
Unsaturated element:	Yes
Variable Flow rates across boundary:	No
Numeric solution (Finite Diff.):	No
Statistics consideration:	No
Toxic substances:	Yes
Mass transport:	Yes

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Model acronym: **FEMWATER**

Model name: Finite-Element Model of Water Flow Through Saturated-Unsaturated Porous Media

Sponsor: Dept. of Energy

Developer: G.T. Yeh

Contact: Dr. G.T. Yel

Contact address: Room 203, Bldg. 1505, Oak Ridge National Laboratory, Oak Ridge, TN 37830

Contact telephone: (615)574-7285

Type of model: Groundwater quality

Summary: A two-dimensional water quality model for saturated-unsaturated porous media.

Abstract:

Upon examining the "Water Movement Through Saturated-Unsaturated Porous Media: A Finite-Element Galerkin Model," it was felt that the model should be modified and expanded. The modification is made in calculating the flow field in a manner consistent with the finite element approach in evaluating the moisture content increasing rate within the region of interest, and in numerically computing the nonlinear terms. With these modifications, the flow field is continuous everywhere in the flow regime, including element boundaries and model points, and the mass loss through boundaries is much reduced. Expansion is made to include four additional numerical schemes which would be more appropriate for many situations. Also, to save computer storage, all arrays pertaining to the boundary condition information are compressed to smaller dimension. To ease the treatment of different problems, all arrays are variably dimensioned in all subroutines. This report is intended to document these efforts. In addition, in the derivation of finite-element equations, matrix component representation is used, and believed to be more readable than the matrix representation in its entirety. Two identical sample problems are simulated to show the difference between the original and revised models.

Document citations:

Desai, C.S., and Abel, J.F. Introduction to the Finite-Element Method. Litton Educational Publishing, Inc., New York, 1972.

Reeves, M., and Duguid, J.O. Water Movement Through Saturated-Unsaturated Porous Media: A Finite-Element Galerkin Model. ORNL-4927, Oak Ridge National Laboratory, Oak Ridge, TN pp. 232, 1975.

Yeh, G.T., and Ward, D.S. FEMWASTE: A Finite-Element Model of Waste Transport Through Saturated-Unsaturated Porous Media. ORNL-5601, Oak Ridge National Laboratory, Oak Ridge, TN, 1979.

Principal users: Research laboratories and consulting firms.

Current implementation: Mainframe computer

Current hardware: IBM

Software language(s): FORTRAN IV

User manual: Yes

Date of first version: 1979

Date of latest version: 1979

User support: Yes (615)574-7285

Analytical Features for Model:	Groundwater
Exact solution:	No
Finite-element solution:	Yes
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Semipermeable and non-permeable aquifers:	Yes
Stream aquifer interaction:	Yes
Saturated element:	Yes
Unsaturated element:	Yes
Differentials across element:	Yes
Variable flow rates across boundary:	Yes
Numeric solution (Fin.Diff):	No
Statistics consideration:	No
Toxic substances:	Yes

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Model name: Finite-Difference Model for Aquifer Simulation in Two Dimensions with Results of Numerical Experiments
Sponsor: USGS
Developer: P.C. Trescott, G.F. Pinder and S.P. Larson
Contact: Jeffery P. Schubert
Contact address: Argonne National Lab
Energy & Environmental Systems Division
9700 S. Cass Avenue
Argonne, IL 60439
Contact telephone: FTS 972-3416
Availability: Public through USGS
Type of model: Groundwater Quantity
Summary description: Simulate groundwater flow in an aquifer.

Abstract:

The model developed by the U.S. Geological Survey will simulate groundwater flow in an artesian aquifer, a water-table aquifer, or a combined artesian and water-table aquifer. The aquifer may be heterogeneous and anisotropic and have irregular boundaries. The source term in the flow equation may include well discharge, constant recharge, leakage from confining beds in which the effects of storage are considered, and evapotranspiration as a linear function of depth to water. The theoretical development includes presentation of the appropriate flow equations and derivation of the finite-difference approximations (written for a variable grid). The documentation emphasizes the numerical techniques that can be used for solving the simultaneous equations and describes the results of numerical experiments using these techniques. Of the three numerical techniques available in the model, the strongly implicit procedure, in general, requires less computer time and has fewer numerical difficulties than do the iterative alternating direction implicit procedure and line successive overrelaxation (which includes a two-dimensional correction procedure to facilitate convergence).

Document citation:

Trescott, P.C., Pinder, G.F., and Larson, S.P. Finite-Difference Model for Aquifer Simulation in Two Dimensions with Results of Numerical Experiments. U.S.G.S., Tech of Water-Resources Inv., Book 7, Ch. C1, p. 116, 1976.

Principal users: USGS, Consulting firms, research laboratories, Universities
Current implementation: Mainframe computer
Current hardware: IBM 370/195
Software language(s): FORTRAN
Word size(s): 300K core
Operating system(s): OS/MVT
User manual: Yes
Systems documentation: Yes
Date of first version: 1976
Learning difficulty: Medium
Geographic area: Unrestricted

Analytical Features for Model:	Groundwater
Exact solution:	No
Finite-element solution:	No
Steady state :	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Semipermeable and nonpermeable aquifers:	Yes
Saturated element:	Yes
Unsaturated element:	No
Variable flow rates across boundary:	Yes
Finite difference:	Yes

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Model name:	**Flood Routing and Hydrographs**
Sponsor:	Hewlett-Packard
Developer:	Hewlett-Packard
Availability:	Public/Purchase
Type of model:	Surface water quantity
Summary:	Calculate either a unit hydrograph or a soil conservation service hydrograph.

Abstract:

This program calculates either a unit hydrograph or a soil conservation service hydrograph from a given peak time (time of concentration) and peak flow. Any time interval can be selected. The program will also route a given hydrograph through a given dam, calculating an outflow hydrograph from given storage conditions and a given outflow structure.

Document citations:

HP-67/HP-97 User's Library program #01442D by Lawrence Busack

Pennsylvania State University. Hydrologic and Hydraulic Analysis for Small Watersheds. Penn State University, University Park, PA, 1974.

U.S. Department of Interior, Bureau of Reclamation, Design of Small Dams, GPO, Washington, D.C., 1974.

U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook Section 4 - Hydrology, GPO, Washington, D.C., 1972.

Principal users:	Users of HP-41C calculator
Current implementation:	Programmable calculator
Current hardware:	HP calculator HP-41C
User manual:	Yes
Systems documentation:	Yes
Date of latest documents:	Feb. 1981
Learning difficulty:	Low
Output interpretation difficulty:	Low
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	Yes
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No

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Model name: Flood Routing by Muskingum Method
Developer: Robert Jankowski
Contact: Society for Computer Application in Engineering Planning and Architecture, Inc.
Contact address: 358 Hungerford Drive
Rockville, MD 20850
Contact telephone: (301) 762-6070
Type of model: Surface Water Quantity
Summary: Flooding routing by Muskingum method and generating an output hydrograph

Abstract:

This program will determine the optimum values for the coefficients of the equations used in the Muskingum Method of Flood Routing. The computer fits a least-square line of regression repeatedly to the data until it determines the optimum solution. A calculated output hydrograph is generated.

Feasible implementation: Mainframe computer
Current hardware: IBM 1130
Software language(s): FORTRAN
Word size(s): Min. memory size = 4K
Operating system(s): DM2

Input requirements:

The input consists of an observed inflow hydrograph at the head of the reach and the corresponding outflow hydrograph at the tail. The time interval between observations is also input.

Output format:

The output consists of the desired optimized coefficients and a calculated outflow hydrograph to aid in determining the "closeness" of the fit. Intermediate output is printed, if specified.

Analytical Features for Model:	Surface Water Hydrology		
Small watershed areas:	No	Automatic time interval generation:	No
Large watershed areas:	No	Infiltration rates:	No
Rural land areas:	No		
Urban land areas:	No		
Entire hydrographs:	Yes		
Flood routing:	Yes		
Snowmelt considerations:	No		
Continuous simulation of storm event:	No		
Continuous simulation in real time:	No		
Sedimentation and scour:	No		
Water flow from a simulation:	No		

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Model acronym: GWMTM1
Model name: One-Dimensional Groundwater Mass Transport Model
Sponsor: Nassau-Suffolk Regional Planning Board
Developer: R.W. Cleary
Contact: Prof. Robert W. Cleary
Contact address: Princeton Associates
P.O. Box 2010
Princeton, NJ 08540
Contact telephone: (609)924-4163
Availability: Through Princeton Associates
Type of model: Groundwater quality
Summary: A one-dimensional, unsteady state, analytical, groundwater quality model.

Abstract:

GWMTM1 is a deterministic, one-dimensional, unsteady state, analytical model which simulates constituent concentration in groundwater systems. It is based on the convective-dispersive mass transport equation modified for first order decay. The analytical solution is based on a semi-infinite medium with the following surface boundary condition: C = Coexp (-ot); this allows the surface concentration to be constant or expotentially varying (e.g., through dilution processes). It is typically applied in case of vertical infiltration of waste waters. The soil may be saturated or unsaturated (provided the moisture content is constant); the vertical seepage velocity must be constant.

Document citations:

Cleary, R.W. Final 208 Report to the Nassau Suffolk Regional Planning Board, Hauppauge, New York, December 1977.

Principal users: Long Island, NY, throughout the country

Assumptions:

The model assumes a homogeneous soil and a constant seepage velocity. The constant seepage velocity requirement is met under steady, saturated conditions or steady, constant moisture content, unsaturated conditions.

Current implementation: Minicomputer, mainframe computer
Current hardware: Mainframe IBM 350/91, minicomputer using less than 100K core
Software language(s): FORTRAN IV
Word size(s): Disc storage 100K core
Operating system(s): 1/2 hr. learning time

Input requirements:

Data input as FORTRAN statements. The model requires only four pieces of data: the dispersion coefficient, the kinetic decay constant, the seepage velocity and the surface constant (if the surface concentration is not constant.)

Output format:

Concentrations are printed out at any number of specified (read in as data cards) space and time positions. It is a very simple model to operate.

User manual:	Yes (simple)
Learning difficulty:	Low
Geographic area:	Groundwater pollution sites throughout this country
Analytical Features for Model:	Groundwater
Exact Solution:	Yes
Finite element solution:	No
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	No
Stream aquifer interaction:	No
Saturated element:	Yes
Unsaturated element:	No
Differential across element:	No
Variable flow rates across boundary:	No
One dimensional:	Yes
Numerical, finite diff.:	No

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Model acronym: GWNTM2

Model name: Two-Dimensional Groundwater Mass Transport Model

Sponsor: Nassau-Suffolk Regional Planning Board

Developer: R.W. Cleary, Princeton Associate

Contact: Prof. Robert W. Cleary

Contact address: Princeton Associates, P.O. Box 2010, Princeton, New Jersey 08540

Contact telephone: (609) 924-4163

Type of model: Groundwater quality

Summary: An analytical, unsteady-state, two-dimensional groundwater pollutant transport model

Abstract:

MODEL OVERVIEW: GWMTM2 is based on an analytical solution to the unsteady-state, convective-dispersive mass transport equation which describes the concentration distribution in two-dimensional groundwater systems. The model accounts for advection, dispersion in two dimensions, first-order decay and an exponentially decaying, Gaussian boundary condition. The model can be used as an excellent test of available two-dimensional, unsteady state, numerical models; the degree of numerical models; the degree of numerical dispersion and oscillations for different numerical solution schemes can be easily determined. In addition to exactly checking numerical models, this Gaussian boundary condition model is a valuable tool for estimating the two-dimensional (areal or vertical cross section) concentration pattern down gradient from sanitary landfills, wastewater lagoons or other groundwater pollution sources.

Document citations:

Cleary, R.W., Final 208 Report to the Nassau-Suffolk Regional Planning Board, Hauppauge, New York, December, 1977.

Principal users: Long Island, NY, consulting firms

Assumptions:

The model is applicable where there is a unidirectional, constant-seepage velocity and the dispersion coefficients (longitudinal and lateral) are constants. This presumes steady, horizontal flow in the homogeneous aquifer.

Current implementation: Mini and mainframe computers

Current hardware: Mainframe IBM 360/91, minicomputer using less than 100K core

Software language(s): FORTRAN IV

Word size(s): Disc storage 100K core

Input requirements:

System parameters are inputted as FORTRAN statements in the main program. Space and time positions where concentration predictions are desired are inputted as data cards. The program is user-oriented requiring the punching of less than 10 cards for parametric information.

User manual:	Yes (through Princeton Associates)
Geographic area:	Nassau-Suffolk County, N.Y., landfills, groundwater pollution sites

Analytical Features for Model:	Groundwater
Exact solution:	Yes
Finite element solution:	No
Steady state:	No
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	No
Stream aquifer interaction:	No
Saturated element:	Yes
Unsaturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	No
Numeric solution:	No
Statistics consideration:	No
Toxic Substances:	Yes

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Model acronym:	**GWSIM-II**
Sponsor:	State of Texas
Developer:	Tommy R. Knowles
Contact:	Tommy R. Knowles
Contact address:	Texas Department of Water Resources P.O. Box 13087 Austin, TX 78758
Contact telephone:	(512)475-3681
Availability:	Available $25.00
Type of model:	Groundwater general
Summary:	A transient two-D model of water levels and quality in aquifer.

Document citations:

Texas Dept. of Water Resources, Data Collection and Evaluation Section: GWSIMII-Groundwater Simulation Program: Program Documentation and User's Manual. Report UM-16. Austin, TX.

Assumptions:	The flow submodel of GWSIM-II is based on Prickett-Lonnguist flow model "PLASM" version 1971
Current implementation:	Mainframe computer
Current hardware:	Mainframe UNIVAC 1100
Software language(s):	FORTRAN IV (G)
User manual:	Yes
Date of first version:	May 1978
Date of latest version:	August 1981
User support available:	Yes
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	No
Steady state:	Yes
Nonsteady state:	Yes
Semipermeable and non-permeable aquifers:	Yes
Stream aquifer inter-action:	Yes
Saturated element:	No
Differentials across element:	Yes
Variable flow rates across boundary:	Yes
Pollutant transport:	Yes
Numeric sol. (Finite diff.):	Yes
Two-D horizontal:	Yes

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Model acronym: HAR03

Model name: Water Quality Model

Sponsor: EPA

Developer: EPA Region II

Contact: George A. Nossa; Laura Livingston

Contact address: U.S.EPA Environmental Systems Section
Information Systems Branch, 26 Federal Plaza
NY, NY 10278

Contact telephone: (212)264-9850

Availability: Public/Contact EPA Region II

Type of Model: Surface Water Quality

Summary: A steady state, multidimensional, water quality model for natural aquatic systems.

Abstract:

HAR03 is a computer program for the modeling of water quality parameters in steady-state multidimensional natural aquatic systems. The technique underlying the program is based on the Law of Conservation of Mass, and the program can handle up to two variables reacting in a feed-forward fashion with first-order kinetics. The computer program from which HAR03 evolved was developed by Hydroscience, Inc., for the Massachusetts Water Resources Commission. HAR03 utilizes a numerical solution technique to a convective-diffusion equation for mass transport decay and source terms.

Document citations:

Chapra, S.C., and Nossa, G.A. Documentation for HAR03: A Computer Program for the Modeling of Water Quality Parameters in Steady State Multidimensional Natural Aquatic Systems, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, New York, NY, October 1974.

Principal user: EPA

Assumption:

In an application of HAR03, it is assumed that the variables and parameters input do not vary from tidal cycle to tidal cycle. The reaction coefficients are assumed to follow first-order kinetics, and each individual segment of the system is assumed to be completely mixed. An orthogonal system segmentation for multidimensional systems is used.

Current implementation: Mainframe computer

Current hardware: IBM 370

Software language(s): FORTRAN IV G or H

Word size(s): 184k

Input requirements:

HAR03 requires a large input data base in card image form. JCL cards are required, as are cards to describe the general system being modeled. The general system cards include data for the interface parameters, the length, depth, temperature and volume of the system. These must be followed by specific constituent cards which include data on: the number of boundaries, B.C. concentrations, photosysnthetic rates, benthal rates and loads, and other parameters for the constituents being modeled. The geometric configuration for each section is also required, as well as CBOD and NBOD removal rates, deoxygenation rates and loads.

Output produced by the model includes: printouts of the input systems parameters, section temperatures, volumes and depths, chloride boundary load, BOD rates and loads, correction factors, deoxygenation and reaeration rates, and BOD-DO deficits for each section in the system.

User manual: Yes

Geographic area: Estuary, lake, stream/river, marine. HARO3 has found various applications.

Analytical Features for Model:	Water Quality
Toxic substance:	No
Nitrogen:	Yes
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Conservative Minerals:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	No

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Model acronym: HEC-1

Model name: Flood Hydrograph Package

Sponsor: U.S. Army Hydrologic Engineering Center(HEC)

Developer: Leo R. Beard

Contact: The Hydrologic Engineering Center

Contact address: U.S Army Corps of Engineering Center
Gog 2nd St.
Davis, CA 95616

Contact telephone: (916)440-2105
448-2105

Availability: A Memorandum of Understanding with the Hydrologic Engineering Center (HEC), Davis, CA, is a prerequisite. Software through Digital Equipment Corp.

Type of model: Surface Water Quantity

Summary description: A single-storm event flood runoff model.

Abstract:

This model is a composite of a number of computer programs simulating the runoff resulting from a single recorded or hypothetical storm. The program's main feature is its ability to generate runoff hydrographs, and combine and route them in a single computer run. The capabilities of the program include:

1. Hydrograph generation based on a unit hydrograph approach including unit hydrographs computed from time-area curves.

2. Hydrograph combining and routing through channels and reservoirs via a number of alternate methods.

3. Rainfall, snowfall, snowpack, and snowmelt determinations.

4. Optimization of areal and loss rate parameters, snowmelt parameters, and routing parameters based on recorded data.

5. Designing flood computations for system design problems.

6. Computations of relative damage due to channel or reservoir development or flood magnitudes.

The input data requirements are somewhat extensive and complicated. The program was geared toward the Corps of Engineer's techniques but it has been used by planners and designers concerned with flood runoff analysis. The program is somewhat complex and implementation may require considerable time and effort.

Principal users: U.S. Army Corps of Engineers, Consulting firms

Current implementation: Mainframe computer

Current hardware: PDP-11

Software language(s): FORTRAN IV

Word size(s): 32K words of core

Operating system(s): RSX-11M, Requires 4-switch disk (or tape, etc) units.

Input requirements:

Input to HEC-1 includes the basin topology (showing subbasin connections and routing reaches), precipitation applied to a subarea (three methods of determination are available), precipitation loss rates, the unit hydrograph corresponding to duration of rainfall excess, base flow controls, and stream and reservoir routing.

Output format:

HEC-1 output can include a graphical display of intermediate or summary hydrographs and precipitation for a modeled basin. Other output may be rainfall and snowmelt losses and excess, subbasin outflow hydrographs, and route hydrographs. The routine for evaluating reservoir and channel development plans for one or more locations includes computation of average annual dollar benefits at each damage center for each plan of development, as well as for existing conditions.

User manual:	Yes
Date of first version:	March 1969 - Rev. January 1973
Learning difficulty:	High
User support:	Yes, from HEC
Debugging maintenance:	Yes
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	Yes
Flood routing:	Yes
Snowmelt considerations:	Yes
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Infiltration rates:	No

(40)

Model acronym: HEC-2 (HP-3000)
Model name: Surface Water Profiles
Sponsor: US Army Corps of Engineers, Hydrologic Engineering Center
Developer: USACE, HEC
Contact: HEC
Contact address: Corps of Engineers
609 Second Street
Davis, CA 95616
Contact telephone: (916) 440-2105
Availability: Public
Type of model: Surface water quantity
Summary: Computing river's water surface profiles for steady, gradually varied flow.

Abstract:

The program computes water surface profiles for steady, gradually varied flow in rivers of any cross section. Flow may be subcritical or supercritical. Various routines are available for modifying input cross-section data; for example, for locating encroachments or inserting a trapezoidal excavation on cross sections. The water surface profile through structures such as bridges, culverts and weirs can be modeled. Variable channel roughness and variable reach length between adjacent cross sections can be accommodated. Printer plots can be made of the river cross sections and computed profiles. Input may be in either English or Metric units.

Document citations:

Eichert, Bill S. Water Surface Profiles (HEC-2). The Hydrologic Engineering Center, U.S. Army Corps of Engineers, Dec. 1968, Rev. Sept. 1971.

Principal users: Consulting firms and HEC, US ACE

Assumptions:

The method used is the step method,which is generally like Method 1, U.S. Army Corps of Engineers, Engineering Manual EM 1110-2-1409, 7 December 1959 - Backwater Curves in River Channels. Bridge losses are based on energy and momentum principles, and weir and orifice formulas. Critical depth is based on minimum energy.

Current implementation: Mainframe computer
Current Hardware: HP-3000
Software language(s): FORTRAN
Operating system(s): MPE III with MORCOM
User manual: Yes
Date of first version: Dec. 1968
Date of latest version: July 1979 by Boyle Engineers
User support: Yes
Analytical Features for Model: Surface Water Hydrology
Small watershed areas: No
Large watershed areas: No
Rural land areas: No
Urban land areas: No
Entire hydrographs: Yes
Flood routing: No

Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym: HEC-4
Model name: HEC-4 Monthly Streamflow Simulation
Sponsor: U.S. Army Corps of Engineers
Developer: Hydrologic Engineering Center (HEC)
Contact: Leo R. Beard and H.E. Kubik
Contact address: The Hydrologic Engineering Center
U.S. Army Corps of Engineers
609 Second Street
Davis, CA 95616
Contact telephone: (916)440-2105 FTS 448-2105
Availability: Memorandum of Understandingw/HEC is a prerequisite
Type of model: Surface Water Quality
Summary: Generate a reference of hypothetical monthly streamflows

Abstract:

This program will analyze monthly streamflows at a number of interrelated stations to determine their statistical characteristics and will generate a sequence of hypothetical streamflows of any desired length having those characteristics. It will reconstitute missing streamflows on the basis of concurrent flows observed at other locations. It will also use the generalized simulation model for generating monthly streamflows at ungaged locations based on regional studies.

The mean, standard deviation and skew coefficients of the logarithms are computed for each station and each month. Each flow is converted to a normalized standard deviation using an approximation of the Pearson Type III distribution. Missing and generated values are computed by a multiple-regression equation which includes a random component whose influence is proportional to the unexplained error. The previous month is one of the independent variables so as to preserve the serial correlation.

Document citations: Contact HEC for info on program 723-X6-L
Principal users: U.S. Army Corps of Engineers
Validations: Medium or high

Assumptions:

The program is dimensioned for a maximum of 10 stations, but more stations can be intercorrelated by multipass operations. Input is limited to 100 years of monthly flows. Station numbers should be three digits or less (can be four digits by changing input format and generated values cannot exceed 999,999 units.

Current implementation: Mainframe computer
Current hardware: CDC 6600, IBM 7094, IBM 360
Software language(s): FORTRAN IV
Word size(s): 60K words of storage on CDC 6600
Operating system(s): Double precision is recommended when using IBM360
Date of first version: July 1967
Date of latest version: Rev. January 1971
User support: Yes, through HEC
Analytical features for Model: Surface Water Quality

Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	Yes
Flood routing:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No
Streamflow generation monthly:	Yes
Statistics:	Yes

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Model acronym:	**DSHEC (HEC SUPPORT)**
Model name:	Digitized Cross Section for HEC2
Developer:	M. Marquez
Contact:	Society for Computer Applications in Engineering, Planning, and Architecture, Inc.
Contact address:	358 Hungerford Dr., Rockville, MD 20850
Contact telephone:	762-6070
Type of model:	Surface Water Quantity

Abstract:

This program creates X1 and GR cards for HEC programs. This is done by digitizing points along the cross section and inputting the elevation of each point. The data must be digitized starting downstream and working upstream. The left and right sides of the cross sections are determined by looking downstream.

Currrent hardware:	PRIME
Software language(s):	FORTRAN
Operating Systems:	PRIMOS
Lines of source code:	250
User manual:	Yes
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym: HECPH (HEC SUPPORT)
Model name: HEC-2 Punch Program
Sponsor: HEC, U.S.Army Corps of Engineers
Developer: S.W. Lewis; C.B. Richardson
Contact: Society for Computer Applications in Engineering, Planning, and Architecture, Inc.
Contact address: 358 Hungerford Drive, Rockville, MD 20850
Contact telephone: (301)762-6070
Type of Model: Surface Water Quantity
Summary: Compute river's water surface profiles for steady, gradually varied flow.

Abstract:

HECPH reduces field notes (one point for each station), lists reduced cross sections (maximum 100 stations for each cross section) in tabular form on printer, and punches title cards, X1 cards and GR cards for later use in HEC-2 Corps of Engineers Water Surface Profiles Program.

The program reads cards, calculates the ground elevation, and stores the card input and calculated data on a temporary file. The temporary file is then read and/or printed and/or punched, as desired. The file is presently set up to handle a maximum 1000-card input.

The title card is for identification purposes only, to be used in locating the start of cross sections for different streams. The title card must be removed before using the punched cards in a HEC-2 program.

The X1 cards are punched with the identification "X1," the cross-section ID as found in the field books and the total number of stations used in the cross section. The punched X1 cards require modification prior to their use in a HEC-2 program. Refer to HEC-2 documentation for X1 format and for other information required.

The GR cards are punched in the correct format for use in the HEC-2 program without modification.

Current implementations: Mainframe computer
Current hardware: META-4
Software language(s): FORTRAN
Operating system(s): DNS, TSO
Lines of source code: 600
User manual: Yes
Analytical Features for Model: Surface Water Hydrology
Small watershed areas: No
Large watershed areas: No
Rural land areas: No
Urban land areas: No
Entire hydrographs: Yes
Flood routing: No
Snowmelt considerations: No
Continuous simulation of a storm event: No
Continuous simulation in real time: No
Sedimentation and scour: No
Water flow from a simulation: Yes
Automatic time interval generation: No
Infiltrarion rates: No

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Model acronym:	REORDR (HEC SUPPORT)
Model name:	Cross-Section Reorder
Contact:	Society for Computer Applications in Engineering, Planning, and Architecture, Inc.
Contact address:	358 Hungerford Dr. Rockville, MD 20850
Contact telephone:	(301)762-6070
Availability:	Proprietary, CEPA
Type of model:	Surface Water Quantity
Summary:	To reverse the order of the cross sections for a HEC-2 data file.

Abstract:

This program takes a HEC-2 data file and the reverse order of the cross sections by changing the X1 groups. It will reverse it upstream if you are going downstream and vise versa. This program will not change any of the values of the file.

Current hardware:	PRIME
Software language(s):	FORTRAN
Operating system(s):	PRIMOS
Lines of source code:	50
User manual:	Yes
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym:	HECST (HEC SUPPORT)
Model name:	Storage Behind a Cross Section
Developer:	Goodkind and O'Dea, Inc.
Contact:	Society for Computer Applications in Engineering, Planning, and Architecture, Inc. (CEPA)
Contact address:	358 Hungerford Drive, Rockville, MD 20850
Contact telephone:	301-762-6070
Availability:	Through CEPA
Type of Model:	Surface Water Quantity
Summary:	Computation of the storage capacity behind selected HEC-2 cross sections.

Abstract:

This program computes the storage capacity behind selected HEC-2 cross sections. At bridges, elevations and corresponding discharges are input. The storage at each of these elevations is output on cards in a form compatible with TR20 input.

Current implementations:	Mainframe computer
Current hardware:	General Automation
Software language(s):	FORTRAN
Operating system(s):	1830 DMS
Lines of source code:	150

Input requirements:

Station, elevation vs. storage, for each section. Elevation discharge and storage behind bridges, TR20 Number 3 cards.

Output format:	Dischargers, TR20 Number 3 cards, elevations at structures, HEC-2 input deck.
User manual:	Yes
Analytical Features for Models:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	N
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Automatic time interval rates:	No
Other: Compute storage capacity:	Yes

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Model name:	**Hierarchical Modeling for the Planning and Management of a Total Regional Water Source System**
Developer:	Y.Y. Haimes, P. Das, Y. Dreizin, H.L. Garay
Contact:	Y.Y. Haimes
Contact address:	Center for Large-Scale Systems and Policy Analysis Case Institute of Technology, Case Western Reserve University, Cleveland, OH 44106
Type of model:	Water general
Summary:	A groundwater and surface water management model
Document citations:	

Haimes, Y.Y., Hierarchial Modeling for the Planning and Management of a Total Regional Water Supply System, Joint Consideration of the Supply and Quality of Ground and Surface Water Resources, Water Resources Progress, Systems Engineering Dept., Case Inst. of Technology, Case Western Reserve Univ., Cleveland, OH, 1976.

Principal users:	University
Current implementation:	Mainframe computer
Current hardware:	Mainframe UNIVAC 1108, GE 4060
Software language(s):	FORTRAN V, FORTRAN II
User manual:	Yes
Date of first version:	1976
Date of latest version:	1976
Learning difficulty:	High
User support available:	No
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	No
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Semipermeable and nonpermeable aquifers:	Yes
Stream aquifer interaction:	Yes
Saturated element:	Yes
Unsaturated element:	No
Differentials across element:	Yes
Variable flow rates across boundary:	Yes
Confined aquifer:	Yes
Optimization method	Yes
Num-Solu. (finite diff.):	Yes
Two-D horizontal:	Yes

Model acronym: HM

Model name: Enhanced Hydrodynamical-Numerical Model for Near Shore Processes

Sponsor: EPA

Developer: Compass Systems, Inc.

Contact: Richard J. Callaway

Contact address: EPA-Corvallis Research Lab
Marine & Freshwater Ecology Branch
200 S.W. 35th Street, Corvallis, OR 97330

Contact telephone: (503) 757-4703

Availability: Public

Type of model: Surface Water Quality

Summary: Simulation of hydraulics and temperature for coastal areas.

Abstract:

MODEL OVERVIEW: The Hansen type multilayer Hydrodynamical Numerical (HN) model described by Bauer has been used successfully to study the dynamics of numerous coastal areas. The optimized version of the HN model combines the vertically integrated single-layer HN model originally developed by Professor W. Hansen, University of Hamburg, Germany, and the multilayer multiple-open boundary HN model proposed by Hansen and developed by Dr. T. Laevastu.

Document citation:

Bauer, R.A. and Stroud, A.D. Enhanced Hydrodynamical-Numerical Model for Near Shore Processes. In Press, prepared by Compass Systems, Inc., San Diego, California, for Corvallis Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, Oregon. EPA Contract 68-03-2225.

Bauer, R.A. Description of the Optimized DPRF Multilayer Hydrodynamical-Numerical Model. ENVPREDRSCHFAC Tech. Paper No. 15-74, Environmental Prediction Research Facility, Monterey, California, 1974.

Hansen, W. Hydrodynamical Methods Applied to Oceanographic Problems, In Proceedings of the Symposium on Mathematical-Hydrodynamical Methods of Physical Oceanography, Institute Fur Meereskunde der Universitat Hamburg, West Germany, 1962. pp. 25-34.

Laevastu, T. and Stevens, P. Application of Numerical Hydrodynamical Model in Ocean Analysis/Forecasting. FNWC Tech. Note No. 51, Fleet Numerical Weather Central, Monterey, California, 1969.

Laevastu, T. and Rabe, K. A Description of the EPRE Hydrodynamical Models in Ocean Analysis/Forecasting, FNWC Tech. Note No. 51, Fleet Numerical Weather Central, Monterey, California, 1969.

Laevastu, T. A Vertically Integrated Hydrodynamical Numerical Model (W. Hansen Type), Model Description and Operating/Running Instructions. Part 2 of a series of four reports. ENVPREDRSCHFAC Technical Note No. 2-74, Environmental Prediction Research Facility, Monterey, California, 1974.

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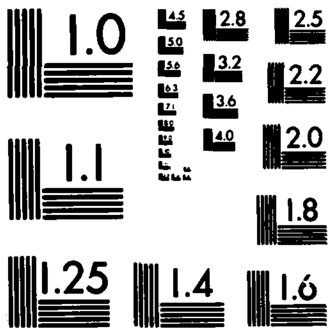
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1.6
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2.2
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2.8
3.2
3.6
4.0

Crawford, N.H. and Donigian, A.S. Jr. Pesticide Transport and Runoff Model for Agricultural Lands. EPA 600/2-74-013. Environmental Research Laboratory, Athens, GA 30613, 1973.

Crawford, N.H. and Lindsey, R.K. Digital Simulation in Hydrology: Stanford Watershed Model IV. Stanford Univ. Tech. Rep. No. 39, Stanford Univ., Palo Alto, CA, 1966.

Donigian, A.S., Jr., Beyerlain, D.C., Davis, H.H., Jr., and Crawford, N.H. Agricultural Runoff Management (ARM) Model Version II; Refinement and Testing. EPA-600/2-77-098. Environmental Research Laboratory, Athens, GA 30613, 1977.

Donigian, A.S., Jr. and Crawford, N.H. Modeling Pesticides and Nutrients on Agricultural Lands. EPA 600/2-76-083. Environmental Research Laboratory, Athens, 1976.

Donigian, A.S., Jr. and Crawford, N.H. Modeling Nonpoint Pollution From the Land Surface. EPA-600/3 -76-083. Environment Research Laboratory, Athens, 1976.

Donigian, A.S., Jr. and Crawford, N.H. Simulation of Nutrient Loadings in Surface Runoff with the NPS MODEL. EPA-600/3-77-065. Environmental Research Laboratory, Athens, GA, 30613, 1977.

Donigian, A.S., Jr. and Crawford, N.H. User's Manual for the Nonpoint Source (NPS) Model. Unpublished report. Environmental Research Laboratory, Athens, GA 30613, 1979.

Donigian, A.S., Jr. and Davis, H.H. User's Manual for Agricultural Runoff Management (ARM) Model EPA-600/3-78-080. Environmental Research Laboratory, Athens, GA 30613, August 1978.

Hydrocomp, Inc. Hydrocomp Simulation Programming: Operations Manual. 2nd Edition, Hydrocomp, Inc., Palo Alto, CA, 1969.

Leytham, K.M. and Johanson, R.C. Watershed Erosion and Sediment Transport Model. EPA-600/3-79-028. Environmental Research Laboratory, Athens, GA 30613, 1979.

Negev, M. A Sediment Model on a Digital Computer. Standford Univ. Tech. Per. No. 76. Stanford Univ., Palo Alto, CA, 1967.

Principal users: EPA and consulting firms.

Assumptions:

BASIC ASSUMPTIONS: In a model as comprehensive as HSPF, it is difficult to list all the assumptions made in its development. The watershed hydrologic algorithms generally follow the assumptions made in the Stanford Watershed Model. The agricultural chemical algorithms that were derived from the ARM and NPS are described elsewhere in this catalogue. Stream routing uses the kinematic wave approximation and the water quality algorithms use first-order kinetics, except in the plankton algorithms where Monod growth kinetics are incorporated.

Module PERLND simulates a previous land segment with homogeneous hydrologic and climatic characteristics. The simulation of snow accumulation and melt is based on an energy balance approach. Water movement is modeled along three flow paths--overland flow, interflow and groundwater flow--in the manner of the Stanford Watershed Model. Erosion processes include sediment detachment by rainfall splash, man's influence and transport by overland flow. Scour in rills and gullies is also considered. Water quality constituents may be simulated in the fashion of the NPS model using simple relationships with sediment and water yield or by using the detailed algorithms for pesticides and nutrients as in the ARM model.

Module IMPLND is designed to simulate impervious land segments where little or no infiltration occurs. Algorithms are similar to PERLAND except that no water movement occurs by interflow or groundwater flow. Solids are simulated using accumulation and removal relationships in the manner of urban models such as SWMM and STORM. Water quality constituents are simulated using empirical relationships with solids and water yield.

Module RCHRES simulates the processes that occur in a single reach of an open channel or a completely mixed lake. Hydraulic behavior is modeled using the kinematic wave assumption. The outflow of an element may be distributed across several targets that might represent normal outflows, diversions, and multiple gates on a reservoir. Temperature is simulated using a heat balance approach. Sediments may be simulated as two components--washload, and sandload. Power relationships to flow predict transport capacity and scour. Deposition of the sandload is modeled. Conservative and nonconservative constitutents are simulated in a manner that allows maximum user flexibility. The primary dissolved oxygen and biochemical oxygen demand balances are simulated in the traditional manner, with provisions for decay, settling, benthal sources, reaeration, etc. The primary nitrogen balance is modeled as sequential reactions from ammonia through nitrate. Deni'ification is also considered. Both nitrogen and phosphorus are considered in modeling three types of plankton-phyplankton, zooplankton and attached algae. Dissolved oxygen is considered in modeling plankton and the nitrogen cycle. Hydrogen ion activity (ph) is calculated considering carbon dioxide, total inorganic carbon and alkalinity.

HSPF's utility modules are designed to give the user maximum flexibility in managing simulation input and output. COPY is used to manipulate time series. The user can change the form of the time series during the COPY operation. A 5-minute rainfall record may be aggregated to an hourly time interval, for example. The PLTGEN module creates a specially formatted sequential file for later access by a stand-alone plot program. DISPLY takes a time series and summarizes the data in a neatly formatted table. Aggregation of the basic data is also possible. DURANL performs a duration and excursion analysis on a time series and computes some elementary statistics. It can answer questions like: "How often does dissolved oxygen stay below 4 mg/l for 4 consecutive hours?" The GENER module is used to transform a time series (A) to produce a new series (C). For example, this module is useful if one wants to compute the mass outflow of a constituent from the flow and concentration.

Current implementation: Minicomputer, Mainframe computer
Current hardware: Mainframe IBM PRIME, HP3000, HARRIS
Software language(s): FORTRAN
Operating system(s):

Disc storage 12 files, printer any model, card reader/punch

Input requirements:

INPUT: Data requirements to run HSPF can be quite extensive and depend on the state variables selected for simulation. Tables 1 and 2 (attached) list the time series and parameter inputs possible for HSPF. As a minimum, precipitations and evapotranspiration records are required for simulations. Many parameters can be defaulted, but defaults are not provided for the more sensitive, site-specific parameters.

Output format:

System output can be obtained at several levels, from a detailed printout of system state variables and parameter values at every time step to yearly summaries. Printout formats compatible with output interval are provided. An interface file for plotters is provided and a stand-alone program for CALCOMP plotters is available.

Source program storage:

128/c bytes of instructions and data storage on virtual memory machines or about 250K with extensive overlaying on overlay-type machines.

User manual:	Yes
Systems documentation:	Yes
Date of first version:	April 1980
Learning difficulty:	High
User support:	Yes
Geographic area:	Lake, stream/river, urban, rural (nonurban)
Analytical Features for Model:	Surfce Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	Yes
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	Yes
Sedimentation and scour:	Yes

Water flow from a simulation:	Yes
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorohpyll-A:	Yes
Radioactivity:	Yes
Salinity:	No
Conservative minerals:	Yes
Time dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Respiration:	Yes
Waste treatment plant input:	Yes

Evaporation and precipitation effects:	Yes
Time-variant pollution:	Yes
Point source:	Yes
Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: HSPF

Model name: Hydrological Simulation Program-FORTRAN

Sponsor: EPA

Developer: Hydrocomp, Inc.

Contact: Thomas O. Barnwell

Contact address: EPA Athens Environmental Research Lab
Center for Water Quality Modeling
College Station Road
Athens, GA 30613

Contact telephone: (404) 546-3585

Availability: Public, User's manuals are available

Type of model: Surface Water General

Summary: A simulation of watershed hydrology and comprehensive water quality.

Abstract:

HSPF is a comprehensive package for simulation of watershed hydrology and water quality developed for the U.S. Environmental Protection Agency (EPA). Simply put, the simulation model uses such information as the time history of rainfall, temperature and solar radiation; such characteristics of the land surface as land use patterns and soil types; and agricultural practices to simulate the processes that occur in a watershed. The result of this simulation is a time history of the quantity and quality of the runoff. Flow rate, sediment load, and nutrient and pesticide concentrations are predicted. The model then takes these results and information about the stream channels in the watershed, and simulates the processes that occur in these streams. This part of the simulation produces a time history of water quantity and quality at any point in the watershed--the inflow to a lake, for example. HSPF includes a data management system to process the large amounts of input data for the simulations and equally large amounts of simulation output. Computer routines are provided to statistically analyze the data to ease resource problems. The key attribute that makes it applicable to such a wide variety of water resource problems is its ability to simulate the continuous behavior of time-varying physical processes and provide statistical summaries of the results.

Document citation:

Johanson, R.C.,; Imhoff, J.C.; and Davis, H.H. User's Manual for the Hydrologic Simulation Program-FORTRAN (HSPF). EPA 600/9-80-015. Environmental Research Laboratory, Athens, GA 30613, 1980.

Barnwell, T.O., and Johanson, R.C. HSPF: A Comprehensive Package for Simulation of Watershed Hydrology and Water Quality. Presented at: Nonpoint Pollution Control: Tolls and Techniques for the Future, Gettysburg, PA, June 1980.

Grimsrud, G.P., Franz, D.D., Johanson, R.C., Crawford, N.H. Executive Summary for the Hydrologic Simulation Program--FORTRAN (HSPF). In Pres. Environmental Research Laboratory, Athens, GA 30613, 1980.

Anderson, E.A. "Development and Testing of Snowpack Energy Balance Equations." Water Resources Research, 4(1):19-37, 1968.

Laevastu, T. A Multilayer Hydrodynamical -Numerical Model (W. Hansen Type), Model Description and Operation/Running Instruction. Part 2 of a series of four reports. ENVPREDRSCHFAC Technical Note No. 2-74, Environmental Prediction Research Facility, Monterey, California, 1974.

Principal users: EPA

Assumptions:

The Hydrodynamical-Numerical model is an explicit numerical difference scheme based on leapfrog integration of the two dimensional Eulerian form of the hydrodynamical equations through time to obtain a dynamical boundary-value solution of tidal order. Advection is simulated by the method of moments, a quasi-Lagrangian method which maintains information on the zero, first-and second-order moments of the concentration in each cell of the grid mesh. In order to introduce the random element for utilization of Monte Carlo methods, the total velocity for a particular fluid particle is assumed to be composed of a mean flow velocity component and a turbulent flux velocity component. The HN model provides the mean flow velocity and the Monte Carlo scheme provides the turbulent flux velocity. Dispersion is thus modeled by simulating the diffusion process stochastically within the background fluid in motion. The Pedersen-Prahm thermal advection scheme has been chosen since it is a conservative scheme without the pseudodiffusion of Eulerian difference methods. In order to model the heat budget effect on the thermal discharge as it is transported by the currents throughout the region, the Laevastu thermal techniques were selected.

Current implementation: Mainframe computer
Current hardware: Mainframe CDC 3300 and CDC 6500

Input requirements:

Input to the HN model includes grid and mesh size; system geometry, bathymetry, and boundaries; average latitude; Coriolis factor, tidal data; wind values; outfall sources and winds; storm surge, and river inflow. Control cards and library directives are necessary for the selection of subroutines.

Output format:

Output provided by the model includes computer printouts of the input variables and contour plots.

User manual:	Yes
Geographic area:	Stream/river, wetlands
Analytical Features for Model:	Water Quality
Oxygen:	No
Water temperature:	Yes
DO level:	No
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	No
Chlorophyll A:	No
Radioactivity:	No
Conservative minerals:	Yes

Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and pre-time-variant pollution:	No
Point source:	Yes
Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	No
Analytical Features for Model:	Surface Water Hydrology
Snowmelt considerations:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Infiltration rates:	No
Other:	Capability to simulate diffusion process.

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Model acronym: HYDROCOMP
Model name: Hydrocomp Simulation Model
Developer: Hydrocomp International, Inc.
Contact address: Hydrocomp International, Inc.
Palo Alto, CA
Availability: Proprietary
Type of model: Surface Water Quantity
Summary: Simulation of a watershed and open-channel networks.

Abstract:

The Hydrocomp Simulation Model: The Hydrocomp model is an improved version of the Stanford Watershed Model, originally developed for nonurban basins. The routing component included pipe and open channel networks. Precipitation from several rain gauges serves as input and empirical equations include a number of empirical coefficients which must be determined by calibrating the model with measured data. Overland and open channel flow is routed by means of the kinematic wave equation. The geometries of the channel and flood plain are assumed to be trapezoidal. Diversion structures and reservoirs can be simulated, if diversion hydrographs and rating curves are provided as input. Because of the parametric nature of this model, sufficient data must be available for calibration of the model and coefficient evaluation. Hydrocomp is a proprietary model and has been tested and applied to both urban and non-urban basins with good results.

Documentation Citations:

Hydrocomp Internaland, Inc. Hydrocomp Simulation Programming Operator's Manual. Palo Alto, CA., February 1972.
Crawford, N.H. Linsley, R.K. Digital Simulation in Hydrology: Stanford Watershed Model IV. Stanford University, Department of Civil Engineering, Technical Report No. 39, Palo Alto, CA, July 1966.
Schelling, D.R., Sternberg, Y.M. Highway Storm Water Management Models: Final Report. Department of Natural Resources, Silver Spring, MD, December 1976.

Principalusers: Hydrocomp, Inc., Universities
Current implementation: Mainframe computer
Current hardware: IBM 360/370
Software language(s): PL/1
User manual: Yes
System documentation: Yes
First version: 1972
Learning difficulty: High
Analytical features for model: Surface Water Hydrology
Small watershed areas: Yes
Large watershed areas: Yes
Rural land areas: Yes
Urban land areas: Yes
Sedimentation and Scour: Yes
Water flow from a simulation: Yes
Infiltration rates Yes

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Model name:	ISOQUAD
Developer:	G.F. Pinder and E.O. Frind, Princeton University
Contact:	G. F. Pinder
Contact address:	Dept. of Civil Engineering, Princeton University Princeton, NJ 08540
Contact telephone:	(609)452-4602
Availability:	Contact G.F. Pinder
Type of model:	Groundwater quantity
Summary:	Simulate two -dimensional confined and unconfined groundwater flow.
Principal users:	Consultants and universities.
Current implementation:	Mainframe computer
Current hardware:	IBM 360/91, IBM 370/158
Software language(s):	FORTRAN IV
User manual:	Yes
Date of first version:	1974
Date of latest version:	1974
User support available:	Yes
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	Yes
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Semipermeable and nonpermeable aquifers:	Yes
Saturated element:	Yes
Unsaturated element:	No
Confined aquifer:	Yes
Unconfined aquifer:	Yes
2-D:	Yes
Pollutant transport:	No

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Model name:	ISOQUAD-2
Sponsor:	Princeton Univ.
Developer:	G. F. Pinder
Contact:	George F. Pinder
Contact address:	Dept. of Civil Engineering, Princeton University, Princeton, NJ 08540
Contact telephone:	(609)452-4602
Type of model:	Groundwater quantity
Summary:	Solve two-D convective-dispersive trans. equation
Principal users:	University, consultants
User manual:	Yes
Date of first version:	1977
Date of latest version:	1977
User support available:	No
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	Yes
Steady State:	Yes
Nonsteady State:	Yes
One aquifer:	Yes
Stream aquifer interaction:	No
Saturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	No
Confined aquifer:	Yes
Unsaturated element:	No

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Model name: **Level III - Receiving Water Quality Modeling for Urban Storm Water Management**

Sponsor: EPA

Developer: Dr. M.A. Medina, Dept. of Civil Engineering, Duke University

Contact: Dr. Miguel A. Medina

Contact address: Department of Civil Engineering, Duke University, Durham, N.C.

Contact telephone: (919)684-2434

Availability: Public through Duke University

Type of model: Surface Water Quality

Summary: A simplified, continuous, receiving water quality model

Abstract:

Level III-Receiving is a simplified, continuous, receiving water quality model that can be used as a planning guide to permit preliminary screening of area-wide wastewater treatment strategies. The model was designed to interface with hourly continuous urban catchment hydrologic simulation models such as STORM or SWMM. A large number of urban pollution control alternatives can be simulated and evaluated in terms of their impact on receiving water quality. Evaluation is accomplished by evaluating either classical dissolved oxygen sag curves or cumulative frequency curves of dissolved oxygen concentration. The model computes a minimum inter event time to define statistically independent storm events.

Document citations:

Medina, M.A., Jr., Level III: Receiving Water Quality Modeling for Urban Stormwater Management. EPA-600/2-79-100, U.S. Environmental Protection Agency, Cincinnati, OH 45268, 1979.

Principal users: EPA

Assumptions:

Assumptions typical of models limited to interim planning are made, including:

Temporal steady-state conditions prevail; i.e. all system parameters and inputs (other than storm water inputs) are constant with respect to time.

Natural system parameters (such as flow, velocity, depth, deoxygenation and reaeration rates, and longitudinal dispersion) are spatially constant throughout each time step.

All waste inflows occur at one point;

The effects of various natural biological processes (algal photosynthesis and respiration, benthal stabilization) are incorporated into a background quality reflected by an upstream DO deficit. Any benthic buildup is incorporated in the BOD decay rate.

Waste treatment facilities operate at constant efficiency, independent of hydraulic and organic loadings, for the entire period of simulation.

Current implementation: Mainframe computer
Current hardware: Mainframe IBM 370/165, Amdahl 470-V6/II
Software language(s): FORTRAN
Word Size(s): Disc storage 100K bytes on IBM 370/165

Input requirements:

Program input consists of STORM/SWMM output and data cards organized into 5 major card groups. Card Group I controls the execution of the three major subprograms. Card Group II controls the auto-correlation analysis of hydrologic time series. Card Group III contains input data common to both the wet-weather and dry-weather flow models. Card Group IV contains the wet-weather flow model input, and Card Group V is specific to the dry-weather flow model.

Output format:

Program output consists of tables and plots describing system response, including correlograms of time series, frequency histograms or cumulative frequency curves of DO concentrations, and tables of DO concentrations at specified locations.

User manual: Yes
Geographic area: Stream/River
Analytical Features for Model: Water Quality, Toxic Substance Nitrogen
Oxygen: Yes
DO level: Yes
Phosphorous: No
Coliforms: No
Chlorophyll-A: No
Radioactivity: No
Salinity: No
Time dependent input: Yes
Changes in channel flow: No
Aeration: Yes
Respiration: No
Photosynthesis: No
Waste treatment plant input: Yes
Evaporation and precipitation effects: No
Time-varient pollution: Yes
Point source: Yes
Nonpoint source: Yes
Steady state: Yes
Unsteady state: Yes
Stream and river: Yes
Reservoir and lake: No
Estuarine: No
Ocean inlet: No
Dam computation: No
Mixing zones: No

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Model name: Log Pearson Type 3 Analysis for Gaged Streams
Developer: Goodkind & O'Dea, Inc.
Contact address: CEPA
Soc. for Computers
Applications in Engineering,
Planning, and Architecture, Inc.
358 Hungerford Drive
Rockville, MD 20850
Contact telephone: (301)762-6070
Type of model: Surface Water Quantity
Summary: Compute a discharge-frequency relationship based on a statistical analysis.

Abstract:

Given the maximum observed or recorded discharges of a gaged stream for a continuous period of water years, this program will compute a discharge-frequency relationship based on the Log-Pearson, Type 3 Statistical Analysis.

Current hardware: GA
Software language(s): FORTRAN
Operating system(s): 1830 DMS
Lines of source code: 200
Input requirements: Heading Information, Skew, Water Year and Maximum Stream Discharge

Output format:

Log of the mean and standard deviation and the calculated skew for the entered discharges.

Table of Flows for the following statistical frequencies of occurrence 10000, 1000, 100, 20, 10, 3.33 and 2 years (length of record equals infinity). Expected possibilities for the length of record equalling the input number of years.

User manual: Yes
User support: Yes
Analytical Features for Model: Surface Water Hydrology
Entire hydrographs: No
Flood routing: No
Snowmelt considerations: No
Continuous simulation of a storm event: No
Continuous simulation in real time: No
Sedimentation and scour: No
Water flow from a simulation: No
Automatic time interval generation: No
Infiltration rates: No
Compute a discharge-frequency relationship: Yes

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Model name:	**Log Pearson Type 3 Analysis for Regional Studies**
Developer:	Goodkind & O'Dea, Inc.
Contact:	CEPA
Contact address:	Soc. for Computers Applications in Engineering, Planning, and Architecture, Inc. 358 Hungerford Drive Rockville, MD 20850
Contact telephone:	(301)762-6070
Type of model:	Surface Water Quantity
Summary:	Develop a discharge frequency relationship based on a statistical anaylsis.

Abstract:

Given the drainage area, skew and map coefficients from the mean and standard deviation; or given the logs of the mean and standard deviation, and the skew of an ungaged, natural stream, this program will develop a discharge frequency relationship based on a Log Pearson Type 3 Statistical Analysis.

Current hardware:	GA
Software language:	FORTRAN
Word size(s):	Min. memory size = 8K
Operating System(s):	1830 DMS
Lines of source code:	200

Input requirements:

Heading Information
No. of years of record
Drainage Area, Skew and Map Coefficients mean, standard deviation and skew.

Output format:

Input verification
Flows and log Q for the following probability percentages .01, .1, 1., 5., 10., 30. and 50 based on the length of record equalling infinity.

Discharges for the following recurrence intervals 2, 5, 10, 25, 50, 100, 200 and 500.

User manual:	Yes		
Analytical Features for Model:	Surface Water Hydrology		
Entire hydrographs:	No	Water flow from a simulation:	No
Flood routing:	No	Infiltration rates:	No
Snowmelt considerations:	No	Develop a discharge-frequency relationship:	Yes
Continuous simulation of a storm event:	No		
Continuous simulation in real time:	No		

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Model acronym:	MAGNUM
Model name:	Magnum
Sponsor:	Dept. of Energy
Developer:	Rockwell International
Contact:	Robert G. Baca, Staff Scientist
Contact address:	Basalt Waste Isolation Project, Rockwell Hanford Operations, Energy Systems Group, P.O. Box 800, Richland, WA 99352
Contact telephone:	(509) 376-6896
Type of model:	Groundwater
Summary:	Simulate two-dimensional groundwater flow and heat transport in fractured-porous rock systems.

Abstract:

The MAGNUM model is a two-dimensional finite-element code designed to simulate groundwater flow and heat transport in fractured-porous rock systems. The theoretical framework of the model is based on concepts for porous continua for discrete conduits. In particular, a "dual porosity" approach is used to represent the continuous rock mass, whereas flow-through discrete channels are described in terms of Poiseuille flow in planar conduits. The governing equations and finite-element solution techniques are presented in the paper by Baca, et al. (1981). The principal features of the MAGNUM code are as follows:

- Continuous rock mass represented with isoparametric finite elements, line elements are embedded along the sides of two-dimensional elements to represent flow and heat transport.
- Model accommodates complex stratigraphic features with variable media properties.
- Computer code provides options for coupled or uncoupled solutions.
- Provides flow field calculations for input to pathline and transport.

Document citations:

Baca, R.G., Arnett, R.C., and King, I.P. Numerical Modeling of Flow and Transport Processes in a Fractured Porous Rock System, RHO-BWI-SA-113, Proceedings of 22nd U.S. Symposium on Rock Mechanics, Massachusetts Institute of Technology, Cambridge, MA, 1981.

Principal users:	Rockwell International, Dept. of Energy
Current implementation:	Mainframe computer
User manual:	In preparation
Systems documentation:	No, in preparation
Analytical features for Model:	Groundwater

Exact solution:	No	Saturated element:	Yes
Finite-element solution:	Yes	Heat transport:	Yes
Steady state:	No	Simulate fractured-porous rock systems:	Yes
Nonsteady state:	Yes		
One aquifer:	Yes	Flow calculation:	Yes
Stream aquifer interaction:	No		

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Model acronym:	MAGNUM 3-D
Model name:	Magnum 3-D
Developer:	Rockwell International
Contact:	Robert G. Baca, Staff Scientist
Contact address:	Basalt Waste Isolation Project, Rockwell Hanford Operations, Energy Systems Group, P.O. Box 800, Richland, WA 99352
Contact telephone:	(509) 376-6896
Availability:	Public through Rockwell International
Type of model:	Groundwater general
Summary:	Simulate three-dimensional groundwater flow.

Abstract:

A special version of the MAGNUM model has been developed which solves the full three-dimensional form of the groundwater flow equations. The model is based on the theory of porous media and is designed for analysis of flow patterns in large-scale groundwater basins. Some of the important features of the model are as follows:

- Model permits the use of various three-dimensional isoparametric finite elements, e.g., tetrahedrons and parallepipeds.
- Model can consider different types of boundary conditions, e.g., specific head and/or fluxes.
- Provides a three-dimensional flow field for input to pathline and transport models.

Document citations:

Baca, R.G., Arnett, R.C., and King, I.P. Numerical Modeling of Flow and Transport Processes in a Fractured Porous Rock System. RHO-BWI-SA-113, Proceedings of 22nd U.S. Symposium on Rock Mechanics, Massachusetts Institute of Technology, Cambridge, MA, 1981.

Baca, R.G., Langford, D.W., and England, R.L. Analysis of Host Rock Performance for a Nuclear Waste Repository Using Coupled Flow and Transport Models. RHO-BWI-SA-140, Rockwell Hanford Operations, Richland, WA, 1981.

Principal users:	Dept of Energy, Rockwell International
Validations:	Has been benchmarked with other codes and known analytic solutions.
Assumptions:	The present version of MAGNUM 3-D is limited to isothermal conditions.
Current implementation:	Mainframe computer

User manual:	No	Saturated element:	Yes
Systems documentation:	No	Unsaturated element:	Yes
Analytical features for Model:	Groundwater	Differential across element:	Yes
Exact solution:	No	Variable flow rates across boundary	Yes
Finite-element solution:	Yes		
Steady state:	No	3-D	Yes
Nonsteady state:	Yes	Groundwater flow	Yes
One aquifer:	Yes	Mass transport	No
Stream aquifer interaction:	No		

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Model Name:	**M.I.T. Transient Water Quality Network Model**
Sponsor:	EPA
Developer:	R.M. Parsons Lab. for Water Resources and Hydrodynamics
Contact:	Richard J. Callaway
Contact address:	US EPA Corvallis Environmental Research Lab 200 S.W. 35th Street Corvallis, OR 20036
Contact Telephone:	(503)757-4703
Availability:	Public
Type of Model:	Surface Water General
Summary:	A one-dimensional, real-time water quality and hydrodynamic model for estuaries

Abstract:

The M.I.T. Transient Water Quality Network Model is a one-dimensional, real-time, nitrogen cycle model which can be used for nitrogen-limited, aerobic estuarine systems. The model solves one-dimensional continuity and momentum equations to generate the temporal and spatial variations in the tidal discharges and elevations. This information is used in solving conservation-of-mass equations for the water quality variables, which include salinity temperature, carbonaceous BOD, nitrogen cycle variables, DO, and fecal coliform.The model combines the work of many investigators and has undergone a great deal of modification. It was originally developed at the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics at the Massachusetts Institute of Technology, and its broadest application has been the St. Lawrence River and Estuary. The model is intended to be used in engineering decisions regarding the degree of eutrophication due to distributed and point source loadings in estuaries.

Document citation:

Chow, V.T. Open Channel Hydraulics, McGraw Hill, NY. 1959.

Dailey, J.E. and Harleman, D.R.F. Numerical Model for the Prediction of Transient Water Quality in Estuary Networks. Technical Report No. 158, R.M. Parsons Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, M.I.T., October 1972.

Gunaratnum, D.J. and Perkins, F.E. Numerical Solution of Unsteady Flows in Open Channels. Technical Report No. 127, R.M. Parsons Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, M.I.T. July 1970.

Harlemann, D.R.F.; Brocard, D.N.; and Najarian, T.O. A Predictive Model for Transient Temperature Distributions in Unsteady Flows. Technical Report No. 175, R.M. Parsons Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, M.I.T., November 1973.

Harleman, D.R.F. and Thatcher, M.L. Longitudinal Dispersion and Unsteady Salinity Intrusion in Estuaries. La Houille Blanche/No. 1/2 - 1974.

Henderson, F.M. Open Channel Flow, MacMillan Co., N.Y., 1966.

Larsen, P.A. Hydraulic Roughness of Ice Covers. JHD, ASCE 99, HYI, January 1973.

Najarian, T.O., and Harleman, D.R.F. A Real-Time Model of Nitrogen-Cycle Dynamics in an Estuarine System. Technical Report No. 204, R.M. Parsons Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, M.I.T., July 1975.

Surveyer, Nenniger & Chenevert, Inc., and Carrier, Trottier, Aubin, Hydrodynamic and Water Quality Simulation Model: Cornwall-Montmagny Section, Report to Department of Environment, Canada, Mardh 1973.

Surveyer, Nenniger & Chenevert, Inc., and Carrier, Trottier, Aubin; (in French) Hydrodynamic and Water Quality Simulation Model: Cornwall-Montmagy Section. Report to Service de Protection de l'Environment Quebec, March 1974.

Thatcher, M.D. and Harleman, D.R.F. Mathematical Model for the Prediction of Unsteady Salinity Intrusion in Estuaries. Technical Report No. 144, R.M. Parson Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, M.I.T., February 1972.

Thatcher, M.L.; Pearson, H.W.; and Mayor-Mora, R.E. Application of a Dynamic Network Model to Hydraulic and Water Quality Studies of the St. Lawrence River. 2nd Annual Symposium of the Waterways, Harbours and Coastal Engineering Division, ASCE, San Francisco, September 1975.

Harleman, D.R.F.; Dailey, J.E.; and Thatcher, M.L.; Najarian, T.O.; Brocard, D.N.; and Ferrara, R.A. User's Manual for the M.I.T. Transient Water Quality Network Model. Report for U.S. Environmental Protection Agency, Office of Research and Development, Corvallis Environmental Research Laboratory, Corvallis, Oregon. U.S. EPA-600/3-77-010, January 1977.

Principle users: EPA, M.I.T. and Canadian Department of the Environment and Transport.

Assumptions:

The M.I.T. Transient Water Quality Network Model defines the geometry of the water body along a particular reach by interpolation between the cross-sectional data submitted by the user. The model pays strict adherence to the mass conservation principle as applied to the element nitrogen, and its ecosystem model is coupled with a real-time hydrodynamic transport system as opposed to a tidal average or slack tide approximation. The structure of the model was formulated such that the level of complexity would not be too complex to the point of diminishing returns, nor too simplified to the point where rate-governing parameters must be determined by curve-fitting the available field data. Carbonaceous BOD is handled as a first-order decaying substance in the classical manner.

<u>Current implementation</u>: Mainframe computer
<u>Current hardware</u>: Mainframe - any model
<u>Software languages(s)</u>: FORTRAN IV (H)
<u>Word size(s)</u>: Disc storage 256K for compilation; 226K for execution and 192K for plotting program.

<u>Input requirements</u>:

Input data is divided into nine groups. Card Group A includes information regarding solution options. Here it is stipulated which solutions (hydraulic and water quality) will be executed and which water quality parameters will be modeled. Time parameters stipulating the duration of the run and the time step of integration, and the network topology (identification and sequence of reaches) are also provided.

Card Group B provides the geometric information (i.e., the physical properties of the channel), and the computational mesh spacing and initial conditions required for the hydraulic solution. This group is repeated for each reach as given in Group A.

Card Group C provides values of rate coefficients for those water quality parameters being modeled. The coefficients may be specified for the entire network or may be specified for each individual reach. If the user does not wish to specify values, computational mesh spacing for water quality calculations and initial conditions for water quality parameters are also specified.

Card Group D describes the location, magnitude and quality of any lateral inflows being considered. Lateral inflows are considered for both the hydraulic and water quality solutions. Care Group E describes the same information for any injections (e.g., sewage treatment plant or waste heat discharge) of water quality parameters. Injections are considered only in the water quality solution. For hydraulic purposes they are considered passive; that is, they have no effect on the flow field in the receiving water. Care Group F stipulates the hydraulic boundary conditions to be applied at each node.

Card Group G allows the user to selectively view output from the hydraulic solution. Card Group H stipulates the water quality boundary conditions to be applied at each node in the network and Card Group I allows the user to selectively view output for the water quality solution. The sequence of the input cards is important to note. Certain card groups (D,E,F,G,H,I) for particular cases must be repeated several times corresponding to the number of periods for which the solution is executed.

<u>Geographic area</u>: Estuary, St. Lawrence River & Estuary, Canada.
<u>Analytical Features for Model</u>: Surface Water Hydrology
<u>Small watershed areas</u>: No
<u>Large watershed areas</u>: No
<u>Rural land areas</u>: No

Urban land areas:	No
Entire hydrographs:	Yes
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Infiltration rates:	No
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	No
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity::	No
Salinity:	Yes
Conservative minerals:	No
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Time-variant pollution:	Yes
Point source:	Yes
Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	No
Reservoir and lake:	No
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	No

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Model acronym:	**MMT-DPRW**
Model name:	Multicomponent Mass Transport Model - Discrete Parcel Random Walk Version
Developer:	S.W. Ahlstrom, H.P. Foote, R.J. Serne
Contact:	Battelle Pacific Northwest Laboratories, P.O. Box 999, Richland, WA 99352
Type of model:	Groundwater quality
Summary:	Predict transient three-D movement of contaminants in subsurface system.

Document citations:

Ahlstrom, S.W., and Foote, H.P. Multicomponent Mass Transport Model-Theory and Numerical Implementation (Discrete Parcel Random Walk Version), Report BNWL-2127, Battelle Pacific Northwest Laboratories, Richland, WA., 1976.

DPRW Transport Model User's Guide (Groundwater Version), (Internal documents). Battelle Pacific Northwest Laboratories, Richland, WA.

Principal users:	Research laboratory
Current implementation:	Mainframe computer
Current hardware:	DEC PDP 11/45
Software language(s):	FORTRAN IV, Macro II
Word size(s):	62K for 186x186 nodes
Operating system(s):	RSX-11D Real-Time Operating System, Mass storage requirements: 1 disk with 40 MB
User manual:	Yes
Date of first version:	1976
Date of latest version:	1976
Continued enhancement:	No
User support:	No
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	No
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Stream aquifer interaction:	No
Saturated element:	Yes
Unsaturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	No
Pollutant transport:	Yes
Discrete parcel random walk	Yes
Finite Diff.:	No

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Model name:	**Multipurpose**
Sponsor:	Princeton University
Developer:	G. McCracken; Voss; G.F. Pinder of Princeton Univ.
Contact:	G. McCracken
Contact address:	Dept. of Civil Engineering, Princeton University, Princeton, NJ 08540
Type of model:	Groundwater general
Summary:	To solve subsurface flow and transport
User manual:	Yes
Date of first version:	1976
Date of latest version:	1976
User support available:	No
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	No
Saturated element:	Yes
Unsaturated element:	Yes
2-D:	Yes
3-D:	Yes
Flow:	Yes
Transport:	Yes
Numeric sol. (Finite Diff):	Yes

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Model name: **Normal and Critical Depths for Channels**

Developer: Kevin Shea

Contact address: Society for Computer Applications in Engineering Planning and Architecture, Inc.

Type of model: Surface Water Quantity

Summary: Calculates normal and critical depths for irregular channels.

Abstract:

This program calculates normal and critical depths for irregular channels, using Manning's Equation. The channel is described as a series of offsets and elevations.

Current Hardware: GA 18/30

Software Language(s): FORTRAN

Lines of source code: 200

Input requirements: Water flow, Manning's "n," channel slope and channel description.

Output format:

Area, perimeter, velocity, radius and depth for both normal and critical depths. Also, a plot of the cross section showing normal and critical water lines.

User manual:	Yes
User support:	No
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No
Normal and critical depths to compute:	Yes

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Model acronym: NPS

Model name: Nonpoint Source Pollutant Loading Model

Sponsor: Environmental Research Laboratory of EPA-ORD

Developer: Hydrocomp Inc.

Contact: Lee A. Mulkey

Contact address: EPA, Environmental Research Lab
Office of Research and Development
College Station Road
Athens, GA 30613

Contact telephone: (404) 546-3581

Availability: Public

Type of model: Surface Water General

Summary: To simulate hydrologic response of a watershed including chemical transport.

Abstract:

The Nonpoint Source Pollutant Loading (NPS) Model is comprised of subprograms to represent the hydrologic response of a watershed, including snow accumulation and melt. The processes of pollutant accumulation, generation, and washoff from both pervious and impervious areas are based on sediment as a pollutant indicator. The calculated sediment washoff is multiplied by user-specified "potency factors" that indicate the pollutant strength of the sediment for each pollutant simulated. Both urban and rural areas can be simulated.

Initial testing of the NPS Model was performed on three urban watersheds in Durham, North Carolina; Madison, Wisconsin; and Seattle, Washington. The hydrologic simulation results were good, while the simulation of nonpollutants was fair to good. Sediment, BOD, and SS were the major pollutants investigated. A detailed user manual is provided to assist potential users in application of the NPS Model. Parameter definitions and guidelines for parameter evaluation and calibration are included. Possible uses of the NPS Model for evaluation of nonpoint pollution problems are discussed.

Document citation:

Donigian, A.S., Jr., and Crawford, N.H. Modeling Pesticides and Nutrients and Agricultural Lands. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA, EPA-600/2-76-043, 1976, pp. 317.

Donigian, A.S., Jr., and Crawford, N.H. Modeling Nonpoint Pollution from the Land Surface. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA, EPA-600/3-76-083, 1976, pp. 280.

Principal users: EPA, Consulting Firms

Assumptions:

Both water and pollutant transport descriptions are based on the principle of conservation of mass. The overall model is based on the Stanford Watershed Model. Water transported out of the watershed is assumed to be drawn from every portion of the watershed. Consequently, water and chemical constituents in runoff cannot be identified with any particular location within the watershed. The water balance calculations assumes that there are five water storage zones, namely, interception storage, upper zone storage, lower zone storage, active groundwater storage and inactive groundwater storage. During a storm event, rainfall is partitioned between these storages and also exported from the watershed by overland flow, interflow and base flow. Between storm events, export continues along with transfers between compartments. In addition, water is lost by evapotranspiration. Snow accumulation and melt are also modeled.

The rates of water export and intercompartment transfers are governed by empirical equations which contain constants requiring calibration for each application of the model. Where possible, guidance has been provided to show reasonable parameter estimates in various parts of the country. Calibration requires simultaneous rainfall and runoff records.

Sediment losses from previous surfaces are modeled in identical fashion as the ARM Verion I model. Two processes are described: detachment of fines and transport of fines. For impervious surfaces, sediment particulate accumulates and is removed according to empirical equations during dry weather periods. During storms, transport of sediment particles is defined by the same relationship as for sediment fines from previous surfaces.

Conservative constituent transport is assumed to move at a rate proportional to the rate of movement of sediment.

<u>Current implementation</u>: Mainframe Computer
<u>Current hardware</u>: Mainframe IBM 360, CDC 6000, Univac 1108, Honeywell, Series II
<u>Software language(s)</u>: FORTRAN IV

<u>Operating system(s)</u>:

As abstracted from the report documenting the NPS model, system resource requirements are as follows. The NPS Model is written in the IBM FORTRAN IV language. The "handy minimal language" concept was adopted to the extent possible to produce a reasonably compatible computer code for at least the following computer systems: IBM 360, UNIVAC 1108, CDC 6000 and Honeywell Series 32. However, present model operation has been limited to the IBM systems. The NPS model operates most efficiently in a two-step procedure. The first step involves the compilation of the program and the the storage of the compiled version on disk or magnetic tape. In the second step, the compiled model can operate a number of types of different input data with a single compilation.

<u>Lines of source code</u>: 6,000

<u>Input requirements</u>:

- Input parameter list includes the following:
- A set of control parameter values that defines frequency of printing of output, dates of simulation and whether snowmelt calculations are to be performed.
- A set of hydrology parameter values that specifies the nominal capacity of the storage zone and specific rates of water transport between zones and the rates of export of water by runoff and evapotranspiration.
- A set of parameter values that defines snow pack characteristics. A set of parameter values that defines sediment transport characteristics.

Output format:

Outputs commonly displayed are hydrographs for each storm, as well as base flow projected for dry weather periods; sediment loads and concentrations as a function of time, pollutant loads and concentrations as a function of time, dissolved oxygen concentration, and temperature as a function of time. An echo of the input data set is also printed along with storm, monthly, and annual summaries of the output data sets.

User manual:	Yes
Date of first version:	1976
Geographic area:	Urban, rural (nonurban)
Analytical Features for Model:	Water Quality
Oxygen:	No
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	No
Time-variant pollution:	Yes
Nonpoint source:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model name:	**Open Channel Runoff Network**
Developer:	L.G. Cullens
Contact address:	CEPA Soc. For Computer Applications in Engineering, Planning, and Architecture, Inc. 358 Hungerford Drive Rockville, MD 20850
Contact telephone:	(301)762-6070
Type of model:	Surface Water Quantity
Summary Description:	Computing runoff based on the rational formula.

Abstract:

An open-channel runoff network analysis system based on the rational formula to compute runoff (Q=CIA). The system basically reduces drainage area parameters to Q's to size trapezoidal shaped channels of a tree-type network. The system does not incorporate backwater analysis.

Current implementation:	Mainframe computer
Current hardware:	IBM 1130
Software language(s):	FORTRAN
User manual:	Yes
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Infiltration rates:	No

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Model name: **Selected Digital Computer Techniques for Groundwater Resource Evaluation**

Sponsor: Illinois State Water Survey

Developer: T.A. Prickett and G.G. Longquist

Contact: T.A. Prickett or C.G. Longquist

Contact Address: Illinois State Water Survey
Box 232
Urbana, Illinois 61801

Availability: We have purchased the report from NTIS. Public.

Type of Model: Groundwater Quantity

Summary: Generalized one-, two-, and three-dimensional groundwater flow model.

Abstract:

Generalized digital computer program listings are given that can simulate one-, two- and three-dimensional nonsteady flow of groundwater in heterogeneous aquifers under water table, nonleaky and leaky artesian conditions. Programming techniques involving time-varying pumpage from wells, natural or artificial recharge rates, the relationships of water exchange between surface waters and the groundwater reservoir, the process of groundwater evapotranspiration, and the mechanism of converting from artesian to water table conditions are also included.

The discussion of the digital techniques includes the necessary mathematical background, documented program listings, theoretical versus computer comparisons, and field examples. Also presented are sample computer input data and explanations of job setup procedures.

A finite difference approach is used to formulate the equations of groundwater flow. A modified alternating direction implicit method is used to solve the set of resulting finite difference equations.

The programs included are written in FORTRAN IV and will operate with any consistent set of units.

Document citations:

Prickett, T.A., and Lonnguist, C.G. Selected Digital Computer Techniques for Groundwater Resource Evaluation, Bull. 55, Ill. State Water Survey, Urbana, IL 1971.

Principal users: Illinois State Water Survey (by 1971)

Current implementation: Mainframe computer

Current hardware: IBM 360/75 with a G-level compiler
IBM 370/195

Software language(s): FORTRAN IV

Word size: IBM 370/195 - 350K core

Operating system(s): IBM 370/195 - OS/MVY

User manual: Yes

Date of latest documents: 1971

Machine interface: Batch

Learning difficulty:	Medium
Interpretation difficulty:	Medium
Analytical Features for Model:	Groundwater
Land spills:	No
Water spills:	No
Flammable material spills:	No
Oil spills:	No
Toxic chemical spills:	No
Exact:	No
Finite-element solution:	No
Steady state:	Yes
Nonsteady state:	Yes
Leakage between aquifers:	Yes
Saturated element:	Yes
Unsaturated element:	No
Numerical (finite-difference):	Yes

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Model acronym: PLUME
Model name: Outfall Plume Model
Sponsor: EPA Research Lab in Corvallis, Oregon
Developer: USEPA Pacific Northwest Water Lab
Contact: George A. Nossa, Laura Livingston
Contact address: EPA Information Systems Branch
26 Federal Plaza
New York, New York 10278
Contact telephone: (212) 264-9850
Availability: Public
Type of model: Surface Water Quality
Summary: Predict water quality of a plume from an outfall.

Abstract:

PLUME is a computer program which can be used to evaluate coastal waters, lakes or estuaries under consideration as disposal sites. It is designed to evaluate and/or predict the length of outfall needed to adequately dilute a proposed discharge in order to provide compliance with water quality standards. The model was developed by the U.S. EPA Environmental Research Laboratory in Corvallis, Oregon, and it has been used by the San Juan Field Office of the U.S. EPA to aid in location and analysis of ocean outfalls.

Document citations:

Baumgartner, D.J., and Trent, D.S. Ocean Outfall Design: Part I, Literature Review and Theoretical Development. Report of FWPCA, Washington, D.C., 1970.

Baugartner, D.J. and Trent, D.S. User's Guide and Documenation for Outfall Plume Model. Working Paper #80 by U.S. EPA Pacific Northwest Water Laboratory, Corvallis, OR.

Burchett, M.E., Tchobanglous, G.; and Burdoin, A.J. A Practical Approach to Submarine Outfall Calculations. Public Works, 5, 95, 1967.

Callaway, R.J. Computer Program to Calculate ERF. EPA Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon, 1973.

Guthrie, D.L. Documentation for Outfall: A Computer Program for the Calculation of Outfall Lengths Based upon Dilution Requirements. U.S. Environmental Protection Agency, San Juan Field Office, Santurce, Puerto Rico, 1975.

Principal Users: EPA, San Juan field office

Assumptions:

The model simulates the behavior of a buoyant, round effluent plume being discharged into a nonflowing water body where it considers the density differences between freshwater (with residuals) and saltwater masses. The model does not simulate the transport of discharged residuals by mechanisms other than mixing and dilution of fluids with different densities, and it assumes no water flow other than the plume-induced movement. A steady-state, stratified aquatic environment is assumed.

Current implementations: Mainframe computer

Current hardware: IBM 370/155
Software language: FORTRAN IV
Word Size(s): Disc storage 10K words of core storage

Input requirements:

Input to the PLUME program should be in card-image form. Initial setup/calibration needs include: (1) water temperature profile (with depth), (2) salinity or density profile (with depth), (3) effluent flow rate, (4) effluent density and (5) the outfall features such as the port diameter, number of discharge points, depth of discharge points, and the angle of the discharge points to the horizontal plane. The initial constituent concentration throughout the plume is needed for verification.

Output format:

The model provides a tabular printout of the following output information: (1) labeled input values, (2) constituent dilution along the plume centerline and (3) the depth at which the plume stabilizes.

User manual:	Yes
Geographic area:	Estuary, lake and marine
Analytical Features for Model:	Surface Water Quality
Feature:	Toxic Substance Nitrogen
Oxygen:	
Water temperature:	Yes
DO level:	No
Benthal oxygen	No
Phosphorous:	No
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Conservative minerals:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	No
Unsteady state:	No
Stream and river:	No
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	No
Dam computation:	No
Mixing Zones:	Yes

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Model acronym: POKFLO
Model name: PORFLO
Sponsor: Dept of Energy
Developer: Rockwell International
Contact: Robert G. Baca, Staff Scientist
Contact address: Basalt Waste Isolation Project
Rockwell Hanford Operations
Energy Systems Group
P. O. Box 800
Richland, WA 99352
Contact telephone: (509) 376-6896
Availability: Through Rockwell International
Type of model: Groundwater general
Summary: A finite difference model to simulate groundwater flow, heat and pollutant.

Abstract:

The PORFLO model is a finite difference code which has options for solution of groundwater flow, heat transfer and solute transport. The model is applicable to porous media or highly jointed rock systems which may be represented as an "equivalent porous continuum." The finite-difference method is based on a nodal point integration technique used in conjunction with an alternating direction implicit method. Major features of the PORFLO computer model are as follows:

- Computer code is easy and inexpensive to use.
- Numerical method ensures energy and mass consistency at the grid block level.
- A donor cell method is used to accommodate advection-dominated flow regimes.
- Model formulation accommodates planar axisymmetric coordinate systems.

Document citations:

Baca, R.G., Lanford, D.W., England, R.L., Analysis of Host Rock Performance for a Nuclear Waste Repository Using Coupled Flow and Transport Models. RHO-BWI-SA-140, Rockwell Hanford Operations, Richland, WA, 1981.

Draft documentation has been prepared to be issued in the near term.

Principal users: Dept. of Energy, Rockwell International
Current implementation: Mainframe computer
User manual: No, but soon will be
Systems documentation: No, but soon will be
Analytical Features for Model: Groundwater
Exact solution: No
Finite element solution: No
Steady state: No
Nonsteady state: Yes
One aquifer: Yes
Stream aquifer interaction: No
Saturated element: Yes
Numerical (finite difference): Yes
Groundwater flow: Yes
Neat transport: Yes
Solute transport: Yes

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Model acronym: QUAL-II
Model name: Stream Quality Model
Sponsor: EPA
Developer: Water Resources Engineers, Inc.
Contact: Thomas O. Barnwell
Contact address: EPA Athens Environmental Research Lab
Center for Water Quality Modeling
College Station Road, Athens, GA 30613
Contact telephone: (404) 546-3585
Availability: Public
Type of model: Surface Water Quality

Summary: Water quality simulation in branching stream systems and rivers.

Abstract:

QUAL-II is designed to simulate the dispersion and advection of conservative and reacting constituents in branching stream systems and rivers. Constituents modeled included conservative minerals, temperature, BOD, chlorophyll-A, phosphorus, NH_3, nitrate, nitrite, DO, coliform bacteria, radioactive material, and an arbitrary nonconservative material. It also considers nutrient cycles and algal growth. The program simulates the dynamic behavior of these constituents by numerical integration of the one-dimensional form of the advection-dispersion transport equation. Any branching stream system can be simulated.

Document citation:

Roesner, L.A., Giguere, P.R., Evenson, D.E. Computer Program Documentation for the Stream Quality Model QUAL-II, prepared for the Southeast Michigan Council of Governments by Water Resources Engineers, Inc., 710 South Broadway, Walnut Creek, CA 94596. Undated.

Principal users: EPA, academic institutes and consulting firms.
Validations: High

Assumptions:

QUAL-II assumes first-order kinetics and utilizes a simplified nutrient-algae cycle with Monod kinetics. Only constant inflows and point source discharges are considered, and each computational element is considered completely mixed. The model does not consider variation in depth or within stream cross section.

Current implementation: Mainframe computer
Current hardware:

Any digital computer with 45,000 words of memory or PDP II

Software language(s): FORTRAN
Word size(s): 45K words of memory

Input requirements:

QUAL-II requires an input data base in card-image form. Aside from the printed report, no additional requirements are imposed. The data required is varied and includes evaporation coefficients, oxygen uptake per unit of nitrogen and unit of algae, algal growth rates, nitrogen and phosphorus half-saturation constants, and reaction rate constants. Further input required is the identification of the computational elements and their hydraulic characteristics, and initial conditions of the system.

Output format:

The printed output includes a complete history of every quality parameter and temperature at each computational element. The hydraulic information provided includes flow, velocity and depth of each reach, as well as the head of the system. Water quality information provided includes the concentration of each quality component, temperature, and reaction rates at each computational element in the system.

Output complexity:	Low
User manual:	Yes
Systems documentation:	Yes
Learning difficulty:	Medium
User support:	Yes
Geographic area:	Estuary, lake, stream/river, upper Mississippi river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	Yes
Radioactivity:	Yes
Conservative minerals:	Yes
Changes in channel flow:	No
Aeration:	Yes
Respiration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Non point source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: RECEIV-II
Model name: Receiving Water Model
Sponsor: EPA
Developer: Water Resource Engineers and Raytheon Company
Contact: EPA
Contact address: U.S. EPA, ORD, Environmental Research Lab
College Station Road, Athens, GA 30613
Contact telephone: (404) 546-3685
Availability: Public
Type of model: Surface Water General
Summary: A two-dimensional water quantity and quality model for waterways.

Abstract:

RECEIV-II is a two-dimensional receiving water model for streams, rivers, estuaries, lakes and reservoirs. The model represents the physical processes of advection, dispersion and dilution, and it can simulate flow, tidal movements and water surface changes in a link-node network. Coupled and non-coupled chemical reactions can be simulated. Dissolved oxygen, BOD, coliforms, nutrients, salinity, conservative constituents, chlorophyll-A, and non-conservative constituents with first-order decay can be modeled. RECEIV-II is a modification of the receiving water module of the Storm Water Management Model (SWMM) developed by Water Resources Engineers, Metcalf and Eddy, and the University of Florida.

Document citation:

Metcal F. and Eddy, Inc., University of Florida, and Water Resources Engineers, Inc., Storm Water Management Model. Volumes 1-4, Report to U.S. Environmental Protection Agency, Washington, D.C. 1971 (EPA Report No. 11024DOC).

Stormwater Management Model User's Guide, Version II, for the U.S. Environmental Protection Agency - Report No. EPA-670/2-75-017. March 1975.

Vol. III - Documentation Report, Part I - RECEIV-II Water Quantity and Quality Model. Raytheon Company, New England River Basins Projects, Final Report, Dec 1974.

Principal users: U.S. Army Corps of Engineers
EPA Regions III and IV
Validations: High

Assumptions:

The model is based on deterministic assumptions and uses a finite-difference method as a solution technique. RECEIV-II assumes instantaneous mixing throughout each junction and it uses a two-dimensional channel network to simulate two-dimensional flow and transport.

Current implementation: Mainframe computer
Current hardware: Any digital computer with 400K bytes core
Software language(s): FORTRAN
Word size(s): 400K bytes of core
Operating system(s): Two magnetic tape storage

Input requirements:

INPUT: Input to the model for initial setup and calibration includes: constant headwater inflow rates; flow rate for each inflow (discharge, tributary, etc.) or withdrawal; tidal cycles and heights at the seaward boundary; widths and depths of each channel; initial flow velocities and water surface elevations throughout the system; initial constituent conservatives throughout the system; residual loading rates from discharges, tributaries, and headwaters; tidal exchange coefficient; meteorological data (wind speed, rainfall, and daily solar radiation); and first order decay rates for constituents. Input for verification of the model includes: net flow and velocities for each channel; data record of constituent concentration throughout the modeled system; and salinity data to establish concentration inputs at the seaward boundary.

Input databases: Coastal Guard data on tidal variations

Output format:

OUTPUT: The model produces a tabular printout of: maximum, minimum, and net flows for each tidal cycle; maximum, minimum, and average constituent concentrations in each channel at specified time intervals; and depth at each junction at specified time intervals. Hydrodynamic output (especially channel velocities) can be written onto magnetic tape or disk.

Source program storage:	400K bytes
Load module storage:	400K bytes
User manual:	Yes
Stystems documentation:	Yes
Date of first version:	1971
Date of latest documents:	1974
Machine interface:	Batch
Learning difficulty:	Medium
Geographic area:	
Analytical Feature for Model:	Surface Water Qualtiy
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A	Yes
Radioactivity:	Yes
Salinity:	Yes
Conservative minerals:	Yes
Time dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Respiration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	Yes
Time-variant pollution:	Yes
Point surface:	Yes

Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	Yes
Mixing zones:	Yes
Analytical Feature for Model:	Yes Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	
Urban land areas:	
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	Yes
Infiltration rates:	No
Analytical Features for	

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Model acronym: **REDEQUL.EPAK**
Model name: REDEQL.EPAK
Sponsor: EPA
Developer: EPA, Corvallis Environmental Research Laboratory
Contact: Michael Schock
Contact address: U.S. EPA, Municipal Environmental Research Lab
26 West Saint Clair Street
Cincinnati, OH 45268
Contact telephone: (513) 684-7236
Availability: Public
Type of model: Water General
Summary: Calculate equilibrium aqueous speciation as well as dissolved and solid concentrations.

Abstract:

A load module is maintained, along with a thermodynamic data deck, of the REDEQl.EPAK aqueous chemical equilibrium modeling program originally developed by Ingle, et. al at the Corvallis Environmental Research Laboratory (References 1 and 2).

This program can calculate equilibrium aqueous speciation, saturation states of solids, and calculate dissolved and solid concentrations following precipitation reactions. The program is useful for aquatic toxicology studies, nitration experiment modeling (determination of pH or complexation changes), water chemical evaluation for corrosion control treatments and determination of solubility controls on constituents in natural or drinking waters.

Document citation:

Ingle, S.E. et. al., A User's Guide for REDEQL.EPA, A Computer Program for Chemical Equilibria in Aqueous Systems. EPA-600/3-73-024,(1978).

Ingle, S.E. et. al. REDEQL.EPAK Aqueous Chemical Equilibrium Computer Program. Marine and Freshwater Ecology Branch, Corvallis Environmental Research Laboratory. Corvallis, Oregon. in press, 1980 .

Schock, Michael R. and Buelow, R.W. The Behavior of Asbestos-Cement Pipe Under Various Water Quality Conditions. A Progress Report. Part 2 - Theoretical Considerations. Submitted manuscript,.1980.

Schock, Michael R. Computer Modeling of Solid Solubilities as a Guide to Treatment Techniques. A paper given at the seminar "Corrosion Control in Water Distribution System," Cincinnati, Ohio, May 20-22 , 1980

Principal users: Drinking Water Research Division, U.S. EPA

Assumptions:

The major assumption is that the system in question is at equilibrium (or can be considered to be in a metastable state that can be treated as equilibrium). Temperature corrections to the equilibrium constants are done by the Van Hoff relation. Three solids and six complexes are allowed for each metal-ligard pair. Equilibrium constants can contain no more than one decimal place.

Mathematical and computational limitations are given in References 1 and 2. Charge balance is not required.

Current implementation:	Mainframe computer
Current hardware:	Mainframe IBM 370/168
Software language(s):	FORTRAN
Operating system(s):	Disk Storage 19 tracks, Magnetic tape storage Printer 132-position line printer or terminal Card reader/punch

Input requirements:

A program header card with input and output selections is included with each run. Ten cases can be considered in each run. Concentrations of each metal and ligand can be given in "mg/L" or "-log(molarity)." Cards are added to give carbon dioxide partial pressure, redox reactions to consider, solids to check saturation indices for, or for which to disallow precipitation, etc. A test data set is given in Reference 2.

Output format:

The model can output solid and aqueous speciation in units of "-log(molarity)." and give a table summarizing forms by percentage. Interaction capacities and intensities can be given. The ionic strength, saturation indices for numerous solids, the pH and several other parameters can be calculated.

User manual:	Yes
Date of first version:	1978
Geographic area:	Estuary, Lake, Stream/river, Marine
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No
Chemical equilibrium model:	Yes
Analytical Features of Model:	Water Quality
Oxygen:	No
Water temperature:	No

DO level:	No
Benthal oxygen:	No
Phosphorous:	Yes
Coliforms:	No
Chlorophyll-A:	No
Radioactive constituents:	No
Salinity:	No
Conservative Minerals:	Yes
Metals & liqands:	Yes
Changes in channel flow:	No
Aeration:	No
Respiration:	No
Photosyntheses:	No
Waste treatment plant input:	No
Evaporation and precipitation effects:	No
Time-variant pollutant:	No
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: **RIBAM**

Model name: River Basin Model

Sponsor: EPA

Developer: Raytheon, Co., Oceanographic and Environmental Svcs.

Contact: Donald Schregardus

Contact address: US EPA Region 5
Eastern District Office
25089 Center Ridge Road
Westlakes, OH 44145

Contact telephone: (216)835-5200

Availability: Public/EPA Region 5

Type of model: Surface Water Quality

Summary: A stream water quality model, expanded version of DOSAG

Abstract:

RIBAM is a modification of the DOSAG water quality model prepared by the Texas Water Development Board. The DOSAG model has been expanded to model 17 stream water quality parameters, sulfates, manganese, iron, total nitrogen, BOD, chlorophyll-A, dissolved oxygen, coliforms. The user supplies streamflow, waste discharge flows and concentrations, and stream physical characteristics. The model calculates the water quality profile for each water quality management alternative.

Document citations:

Ratheon Co., Oceanographic and Environmental Services. Documentation Report Beaver River Basin Model Project. Contract No. 68-01-0746, March 1973.

Raytheon Co., Oceanographic and Environmental Services, Expanded Development of BEBAM-A Mathematical Model of Water Quality for the Beaver River Basin, May 1974, Contract No. 68-01-1836.

Amendola, G.A.; Schregardus, D.R., Harris, W.H.; and Moloney, M.E. Mahoning River Waste Land Allocation Study. Sept 1977.

Principal users: EPA and consulting firm

Assumptions:

RIBAM assumes stream concentrations are either conservative within a segment or behave according to first-order reaction kinetics. Point source discharges are assumed to mix completely and instantaneously minimal. Within each segment, concentrations are calculated using an exact solution to the differential equation.

Feasible implementation: Mainframe computer

Current hardware: IBM 360, Univac 1110

Software Language(s): FORTRAN IV

Word size(s): Disc storage core - less than 100K bytes

Input requirements:

RIBAM requires as input stream physical characteristics (width, depth and velocity for each segment), upstream conditions (flow and concentrations), effluent flows and concentrations, stream reaction rates for each segment and segment temperatures.

Output format:

RIBAM provides a copy of all input data and a table summarizing computed stream concentrations for each constituent modeled. Stream concentrations are reported for upstream and downstream ends of each segment for all constituents, except dissolved oxygen for which maximum/minimum concentrations and their location are reported in addition to the above.

User manual:	Yes
Date of latest document:	1974
Learning difficulty:	medium
Geographic areas:	Mahoning River in eastern Ohio
Analytical Features for Model:	Water Quality
Feature:	Toxic Substance Nitrogen
Oxygen:	Yes
Water temperature:	
DO level:	Yes
Benthal oxygen:	
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	Yes
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: RWQM

Model Name: Receiving Water Quality Model

Sponsor: Hydrologic Engineering Center, U.S. Army Corps of Eng

Developer: Resource Analysis, Inc.

Contact: R.G. Willey

Contact address: Corps of Engineers, Hydrologic Engineering Center
609 Second Street, Davis, CA 95616

Contact telephone: (916) 440-3292

Availability: Public

Type of model: Surface Water Quality

Summary: Predict the impact of land surface runoff on stream water quality.

Abstract:

The Receiving Water Quality Model (RWQM) was developed by Resource Analysis, Inc.,for the U.S. Army Corps of Engineers' Hydrologic Engineering Center to interface with STORM (Storage Treatment Overflow Runoff Model). RWQM (HEC, 1979), when linked with the time history of storm and dry-weather flows generated by STORM, provides the capability to predict the impact of land surface runoff on stream water quality.

Document citations:

Receiving Water Quality Model. Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, CA 95616, 1979.

Abbott, Jess, and Willey, R.G. Pennypack Creek Water Quality Study, Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, CA 95616. 1979.

Principal user: HEC

Assumption:

RWQM simulates time-varying hydraulic and water quality conditions by utilizing the law of mass conservation for water and pollutant volumes. Stream routing uses the kinematic wave assumption. Water quality parameters are modeled using first-order kinetics.

Current implementation: Mainframe computer

Current hardware: IBM 370, CDC 7600

Software language: FORTRAN

Operating system: Disc storage and/or magnetic tape

Input requirements:

RWQM input is on cards and tape files. Input consists of, for each stream reach: Stream reach and segmentation, simulation controls, I/O controls, percentile curve limits and location, atmospheric temperature input, monthly stream equilibrium temperature, monthly heat transfer rate coefficients, reaction rate coefficients, reaction rate temperature modification bases, gauged baseflow information, stream hydraulic information, boundary conditions, tributary flows, point sources, nonpoint sources, volumetric sources and sinks, STORM runoff and dry weather flow, combined sewer overflows, storage releases and treated outflow, and initial conditions.

Output format:

RWQM offers a wide range of statistical output to both summarize and provide "snapshots" of simulated instream conditions. Long-term average, maximum, and minimum pollutant concentrations, temperatures, and flows are tabulated and frequency (percentile) curves can be computed. In addition, parameters profiles can be printed for any day or "pollutographs" for chosen locations.

User manual:	Yes
Date of latest documents:	1979
Geographic area:	Stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Time-dependent input:	Yes
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Evaporation and Precipitation effects:	No
Time-variant pollution:	Yes
Point source:	Yes
Nonpoint source:	Yes
Steady state:	Yes
Unsteady-state:	Yes
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocena inlet:	NO
Dam computation:	No
Mixing zones:	No

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Model name: 3-D Saturated-Unsaturated Transport Model
Developer: Genevieve Segal, Univ. of Waterloo, Ontario, Canada
Contact: E.D. Friend
Contact address: Department of Earth Sciences, University of Waterloo, Waterloo, Ontario Canada N5L3G1
Type of model: Groundwater quality
Summary: Transient, 3-D, solute transport simulation for saturated-unsaturated flow systems.

Document citations:

G. Segal. A Three-Dimensional Galerkin Finite Element Model for the Analysis of Contaminant Transport in Variably Saturated Porous Media: User's Manual. Dept. of Earth Sciences, Univ. of Waterloo, Waterloo, Ontario, Canada.

Principal users:	University
Current implementation:	Mainframe computer
Current hardware:	IBM 360/75
Software language(s):	Fortran IV
Word size(s):	Depends on problem.
Operating system(s):	3 scratch tapes or disks
User manual:	Yes
Date of first version:	August 1976
Date of latest version:	August 1976
Learning difficulty:	High
User support available:	No
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	Yes
Steady state:	Yes
Nonsteady state:	Yes
Saturated element:	Yes
Unsaturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	No
Mass transport:	Yes
Finite diff.	No

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Model name:	3-D Saturated - Unsaturated Flow Model
Developer:	M. J. Verge, Univ. of Waterloo
Contact:	E.O. Frind
Contact address:	Dept. of Earth Sciences, University of Waterloo Waterloo, Ontario, Canada N5L 3G1
Type of model:	Groundwater quantity
Summary:	Determine hydraulic head in 3-D saturated-unsaturated groundwater flow.

Document citations:

Verge, M.J. A Three-Dimensional Saturated-Unsaturated Groundwater Flow Model for Practical Applications. Ph.D thesis. Univ. of Waterloo, Waterloo, Ontario, Canada.

Current implementation:	Mainframe computer
Current hardware:	IBM 360/75
Software language(s):	Fortran IV
Word size(s):	225-600K bytes
User manual:	Yes
Date of first version:	October 1975
Date of latest version:	October 1975
Analytical features for Model:	Groundwater
Exact solution:	No
Finite element solution:	Yes
Steady state:	Yes
Non steady state:	Yes
One aquifer:	Yes
Saturated element:	Yes
Unsaturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	No
Finite-Diff.	No
Pollutant transport	No
3-D	Yes

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Model acronym: SEDMNT
Model name: SEDMNT
Sponsor: EPA
Developer: ORNL
Contact: D.M. Hetrick
Contact address: Oak Ridge National Laboratory, P.O. Box X, 4500N B224
Contact telephone: (615)576-7556
Availability: Public
Type of Model: Surface Water General
Summary: A stream channel sediment transport model using externally computed streamflow.

Abstract:

SEDMNT is a computer code written to model the movement of sediment through a stream channel. This model is based on the SEDONE model (Hetrick, Eraslan, and Patterson, 1979). SEDMNT was written to be incorporated in the Unified Transport Model (UTM) (Patterson et al., 1974). The mathematical model of SEDMNT consists of a system of coupled, ordinary differential equations for sediment concentration (by size class) which are solved by the Runge-Kutta-Gill integration scheme. Sediment of selected size classes is resident in the channel bed and enters the channel with stream flow. Transportation, erosion or deposition of sediment may occur for each size class depending on the amount of sediment present and the stream volume, velocity and turbulence. Input to the model includes flow data from the calling program (UTM) and initial sediment concentrations provided by the user. Output includes a listing of the input and calculated sediment concentrations for selected time steps.

Document citations:

Hetrick, D.M.; Patterson, M.R.; and Sjoreen, A.L. SEDMNT: A Sediment Transport Submodel Based on Principles for the Unified Transport Model. ORNL/TM-7831, 1982.

Principal users: EPA
Validation: Medium
Current implementation: Mainframe computer
Current hardware: IBM 3033
Software language(s): FORTRAN
Word size(s): 32 bit
Operating systems: OS/MVS
Lines of source code: 9000
Number of subroutines: 9
Input requirements: See ORNL/TM-7831
Output format: Sediment concentration by size class by compartment by time interval.
Source program storage: 96K
Load module storage: 146K
User manual: Yes
Date of first version: 1/82
Date of latest version: 1/82
Date of latest document: 1/82
Machine interface: Batch
Learning difficulty: Medium
User support: No

Debugging maintenance:	Yes
Continued enhancement:	No
Confidentiality:	Not sensitive
Update frequencies:	None yet
Analytical Features for Model:	Surface Water Hydrology
Small watershed area:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	?
Sedimentation and scour:	Yes
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym: **SEM**
Model name: Simulated Estuary Model
Sponsor: EPA
Developer: Hydroscience, Inc.
Contact: Robert B. Ambrose
Contact address: US EPA Environmental Research Lab
College Station Road, Athens, GA 30613
Contact telephone: (404) 546-3546
Availability: Public
Type of model: Surface Water Quality

Summary: Simplified, quality models for tidal rivers and estuaries.

Abstract:

The Simplified Estuary Model (SEM) is a one-dimensional, steady-state water quality model for the evaluation of uncoupled chemical reactions and BOD-DO deficits in tidal streams and rivers, and nonstratified estuaries. Constituents that can be modeled include BOD, DO, unspecified conservatives, and uncoupled nonconservatives with first-order decay (i.e., some nutrients). SEM was developed by Hydroscience, Inc. For the EPA as a "first cut" water quality planning tool to achieve estimates of ambient DO concentrations in estuaries downstream from point source residual inputs. The model requires no computer equipment, except for a hand calculator which is used to compute logs and exponentials.

Document citation:

Hydroscience, Inc. Simplified Mathematical Modeling of Water Quality. Report to Office of Water Programs, U.S. Environmental Protection Agency, Washington, D.C. (U.S. Government Printing Office No. 1972-484-486-/291), 1972.

Principal users: EPA
Validations: High

Assumptions:

The model considers only longitudinal variations and handles only point source residual inputs. It assumes a constant velocity for each reach, and assumes first-order decay rates for quality constituents.

Current implementation: Handbook, programmable calculator
Current hardware: Calculator

Input requirements:

The following input data is required for initial setup/calibration of the model: net river flow exclusive of tidal effects, flow velocities, average depths, distance from point source discharges, dispersion coefficients, cross-sectional area, constituent concentration, temperature and background DO for all stream inflows, loading rate for ultimate oxygen demand, deoxygenation coefficients, reaeration coefficients, salinities at the seaward boundary, Constituent concentrations throughout the modeled area are needed for verification of the model.

Output format:

Outputs from the model (through hand calculation) include constituent concentrations, maximum DO deficiency, and minimum DO concentrations.

Output complexity:	Low
User manual:	Yes
Learning difficulty:	Low
Geographic area:	Estuary
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	No
DO level:	Yes
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Conservative minerals:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	No
Reservoir and lake:	No
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	No

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Model acronym: **SESOIL**
Model name: Seasonal Soil Model
Sponsor: EPA
Developer: H. Bonazountas, Arthur D. Little, Inc.
Contact: Joan Leffler
Contact address: EPA, Office of Toxic Substances
Exposure Evaluation Division, 401 M Street, SW
Washington, D.C. 20460
Contact telephone: (202) 755-8060
Availability: Available through EPA in late 1981
Type of model: Groundwater quality
Summary: Describe water and pollutant transport in a unsaturated soil column

Abstract:

The SESOIL model describes the water transport, sediment transport, pollutant transport and soil quality within a user-specified soil column extending between the ground surface and the lower part of the saturated soil zone of a region. SESOIL is designated as seasonal because it analytically estimates the pollutant distribution in the soil column after a season (e.g. 1 year or 6 months) directly. It does not estimate pollution distribution indirectly (i.e., by summing up pollutant distribution estimates in the soil column after each major storm event) as existing models in the literature do. SESOIL is designed to simulate point or nonpoint pollutants from major land use categories such as urban areas and is sufficiently flexible to allow applications to various climate-soil-vegetational conditions and pollutant types. The analysis of SESOIL can consider time-dependent pollutant inputs to the soil column. The model simulates three major cycles: the water cycle, taking into account rainfall, infiltration, surface runoff, evapotranspiration, groundwater, and optionally snow pack/melt and vegetative interception; the sediment cycle, taking into account sediment resuspension due to wind and sediment washload from rainstorms; and the pollutant cycle which takes into account volatilization, absorption/desorption, degradation and biological transformation/uptake.

Document citations:

Bonazountas, M., and Scow, K.M. "Seasonal Solute Movement Model for the Unsaturated Soil Zone," Paper presented at the American Geophysical Union Fall Meeting, San Francisco, CA, December 3-7, 1979.

Principal users: OTS, EPA

Assumptions:

The fundamental water balance equation in the model sets infiltration equal to precipitation minus surface runoff, which is in turn equal to net evapotranspiration and groundwater recharge and loss. There is a fundamental pollutant mass balance equation for both the upper (unsaturated) and lower (saturated) soil zones, which can be solved for dissolved and sorbed pollutant concentrations.

Current implementation: Mainframe computer
Current hardware: Mainframe VAX 11/780
Software language(s): FORTRAN

Input requirements:

In order to avoid difficulties in calibration, SESOIL uses primarily theoretically derived subroutines based on physical principles, thereby limiting input data requirements. Model parameters can be determined independently either from laboratory experi ents or from past field measurements. SESOIL requires continuous (time-dependent) inputs for various parameters (e.g. rainfall, evapotranspiration) for a specific timestep. The model accepts input from the atmospheric regime as well as from point and nonpoint sources of pollutant discharges.

Output format:	Separate concentration estimates for pollutants are calculated for the upper and lower soil zones
User manual:	late 1981
Date of first version:	1981
Learning difficulty:	Medium
Geographic area:	Urban, rural (nonurban)
Analytical Features for Model:	Groundwater
Exact solution:	No
Finite element solution:	No
Steady state:	Yes
Non steady state:	Yes
Leakage between aquifers:	Yes
Semipermeable and nonpermeable aquifers:	Yes
Stream aquifer interaction:	No
Saturated element:	No
Unsaturated element:	Yes
Differentials across element:	No
Variable flow rates across boundary:	Yes
Numeric solution (finite diff.):	Yes
Statistics consideration:	Yes
Toxic substances:	Yes
1D:	Yes
2D:	No
3D:	No

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Model Name:	**Simultaneous Transport of Water and Reacting Solutes Through Multilayered Soil Under Transient Unsaturated Flow Conditions**
Contact:	Berge A. Gureghian
Contact Address:	Argonne National Laboratory Environmental Impact Studies Division 9700 S. Cass Avenue Argonne, IL 60439
Contact Telephone:	FTS 972-7791
Type of Model:	Groundwater General
Summary Description:	Simulate vertical movement of water and multi-solutes through multilayered soil.

Abstract:

The model is capable of predicting the one-dimensional (vertical) movement of water and multisolutes through multilayered soil systems under transient unsaturated flow conditions. The multilayered system was treated as a series of homogeneous layers and a 2-step implicit finite-difference method was used to solve the resulting set of flow equations. The mass transport equation was solved by the Crank-Nicholson method, an agricultural fertilization problem in which the sequential chemical reaction of ammonium to nitrite, to nitrate is described by first-order kinetics with linear or nonlinear absorption for ammonium. The pressure-based model considers both infiltration redistribution and evaporation. Cubic spline functions are used to describe the soil hydraulic properties.

Document citation:

Long Island Report

Unnamed paper presented at SSSA's Conference, Houston, TX, November 1976.

Unnamed paper presented at AGU's Conference, Washington, D.C. June 1977.

Current implementation:	Mainframe computer
Current hardware:	IBM 370/195
Software Language(s):	FORTRAN
Word size:	IBM 370/195; OS/MVT with 350 K core.
User manual:	No
System documentation:	No
Analytical Features for Model:	Groundwater

Exact solution:	No	Finite difference:	Yes
Finite Element solution:	No	Mass transport:	Yes
Steady state:	Yes	Flow prediction:	Yes
Nonsteady state:	Yes		
One Aquifer:	Yes		
Aquifers:	Yes		
Stream aquifer interaction:	No		
Unsaturated element:	Yes		

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Model acronym: SNSIM
Model name: Stream Network Simulation Program
Sponsor: EPA
Developer: Braster, R.E., S.C. Chapra, G.A. Nossa, EPA Region II
Contact: George A. Nossa; Laura Livingston
Contact address: US EPA Environmental Systems, 26 Federal Plaza NYC, NY 10278
Contact telephone: (212) 264-9850
Availability: Public
Type of model: Surface Water Quality
Summary: Steady state water quality simulation of a stream network.

Abstract:

SNSIM is a computer program for the steady-state water quality simulaton of a stream network. Its basis is an expanded form of the Streeter-Phelps equation, and it is designed to evaluate and/or predict the DO and the carbonaceous/ nitrogenous BOD profiles in a river or stream where the effects of dispersion can be assumed to be insignificant. This environmental model is ideal for the evaluation of various water treatment schemes, as its basic control variable is waste input.

Document citation:

Braster, F.E.; Chapra, S.C.; and Nossaq, G.A., Documentation for SNSIMI/2, A Computer Program for the Steady-State Water Quality Simulation of a Stream Network. U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, New York, New York, March 1978.

Principal users: EPA Region II
Assumptions:

This model typifies the sanitary engineering approach in that its emphasis is on relating man's waste inputs to the aquatic environment with the express purpose of managing the inputs and thus the water quality. An expanded form of the Streeter-Phelps equation is the basis of the SNSIM computer program, and the model is designed to evalute and/or predict the dissolved oxygen, and the carbonaceous/nitrogenous BOD profiles in a river or stream where the effects of dispersion can be assumed to be insignificant.

Current implementation: Mainframe computer
Current hardware: IBM 370/155
Software language(s): FORTRAN IV
Word size(s): 16k core

Input requirements:

SNSIM requires a large input data which must be in card-image form. For each reach, the following information should be provided: instream flow, instream carbonaceous demand, instrea- nitrogenous demand, instream DO deficit, increment size for a section output, an integer representing the reach number of the starting mile-point, the number of sections in the reach, the number of tributaries or reaches to be combined and the indicator which designates if the reaeration rate is to be input or computed.

A control variable which indicates if the stream depth, flow and velocity are to be computed by exponential correlation equations may also be used. Further, the section length, stream depth, stream velocity, waste or effluent flow at the head of the section, effluent COD, effluent NOD, effluent DO deficient, tributary flow at the head of the section, and the ratio of ultimate to d-day BOD are needed. In addition, the tributary COD, tributary NOD, the tributary DO deficit, water temperature, carbonaceous BOD deoxygenation rate, carbonaceous BOD decay rate, nitrogenous BOD decay rate, reaeration rate, algal oxygen rate, benthic oxygen demand, the carbonaceous and nitrogenous bank loads, and the altitude above sea level are required.

Output format:

Reports produced by the SNSIM program include the input parameters for each reach, as well as converted reaction rates, section number, section names, distance downstream, CBOD, NBOD, DO, flow, deficit components, and the total deficient for each reach.

Output complexity:	Low
Load module storage:	16k core, IBM 370/155
User manual:	Yes
Systems documentation:	Yes
Date of latest documents:	March 1978
Learning difficulty:	Low
Confidentiality:	Public
Geographic area:	Stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym:	SSM
Model name:	Simplified Stream Model
Sponsor:	EPA
Developer:	Hydroscience, Inc.
Contact:	Robert B. Ambrose
Contact address:	US EPA ORD Environmental Research Lab College Station Road, Athens, GA 30613
Contact telephone:	(404)546-3546
Availability:	Public
Type of model:	Surface Water Quality
Summary:	A simplified, one-dimensional, steady state water quality model for streams.

Abstract:

The Simplified Stream Model is a one-dimensional, steady state water quality model for the evaluation of conservatives, singular non-conservatives with first-order decay, and coupled BOD-DO deficits in streams, rivers, and shallow nonstratified lakes. It was developed by Hydroscience, Inc. for the EPA as a "first cut" planning tool to achieve estimates of ambient DO downstream from point sources. SSM requires no computer equipment except for a hand calculator which is used to compute logs and exponentials.

Document citations:

Hydroscience, Inc. Simplified Mathematical Modeling of Water Quality. Report to Office of Water Programs, U.S. Environmental Protection Agency, Washington, D.C. U.S. Government Printing Office No. 1971-444-367./392, 1971.

Hydroscience, Inc. Addendum to Simplified Mathematical Modeling of Water Quality. Report to Office of Water Programs, U.S. Environmental Protection Agency, Washington, D.C. U.S. Government Printing Office No. 1972-484-486/291, 1972.

Principal users:	EPA
Validations:	High

Assumptions:

The model considers only longitudinal variations and handles only point source residual inputs. It assumes a constant stream velocity for each reach and assumes first-order decay rates for quality constituents.

Current implementation: Handbook, Programmable Calculator

Input requirements:

For initial setup/calibration needs,the following input data is required: net river flow, flow velocity, depth, distance from point source discharges, constituent concentration, temperature , and background DO deficit for all stream inflows, loading rate for ultimate oxygen demand, deoxygenation coefficients. Constituent concentrations throughout the modeled area are required for model verification.

Output format:

Output from the model (through hand calculation) includes constituent concentrations and DO deficits.

Output complexity:	Low
User manual:	Yes
Date of first version:	1971
Date of latest version:	1972
Date of latest documents:	1971 & 1972
Learning difficulty:	Low
Geographic area:	stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	No
DO level:	Yes
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	Yes
Salinity:	Yes
Conservative minerals:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: STORM

Model name: Storage, Treatment, Overflow Runoff Model

Sponsor: Hydrologic Engineering Center (HEC) and EPA

Developer: Originally by Water Resources Engineers, Inc.

Contact: Arlen Feldman

Contact address: U.S. Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

Contact telephone: (916) 440-2329

Availability: Public

Type of model: Surface Water General

Summary description: A continuous simulation of the quantity and quality of runoff.

Abstract:

The Storage, Treatement, Overflow, Runoff Model (STORM) is a continuous simulation model that provides an analysis of the quantity and quality of runoff from urban or nonurban watersheds. STORM computes loads and concentrations of six basic water quality parameters and land surface erosion. The purpose of the program is to aid in the sizing of storage and treatment facilities so that the quantity and quality of storm water runoff and land surface erosion may be controlled. The original version of the model was completed in January 1973 by Water Resources Engineers, Inc., of Walnut Creek, California, for the Hydrologic Engineering Center (HEC) and the Environmental Protection Agency. Major additions since then include the ability to compute (or specify) the quantity and quality of dry weather flow. The program and its usage are described in the current HEC Storms User's Manual, dated August 1977.

Document citations:

Resource Analysis, Inc., Modifications to the STORM Program. January, 1975.

U.S. Soil Conservation Service, Urban Hydrology for Small Watersheds. TR No. 55, January 1975.

Principal users: Hydrologic Engineering Center and EPA.

Assumptions:

The model assumes that precipitation cannot be considered without the system, and a design storm cannot be defined by itself, but must be defined in the light of the characteristics of the storm water facilities. The approach used in the STORM model recognizes not only the properties of storm duration and intensity but also storm spacing and the storage capacity of the storm water system. In this approach, rainfall washes dust and dirt and the associated pollutants off the watershed. The resulting runoff is routed to the treatment storage facilities where runoff greater than the treatment rate is stored for treatment at a later time. If storage is exceeded, the untreated excess is wasted through overflow directly into the receiving waters. The magnitude and frequency of these overflows are important in a storm water study, so STORM provides statistical information on washoff, as well as overflows.. The quantity, quality and number of overflows are treated as functions of hydrologic characteristics, land use, treatment rate and storage capacity.

Current implementation:	Mainframe computer
Current hardware:	Mainframe IBM 360; CDC 6600; Univac 1108
Software language(s):	FORTRAN
Operating system(s):	Magnetic tape storage or disk Printer 132 position line printer or tape/disk(input)

Input requirements:

Input to the model includes job specifications, hourly precipitation record, daily temperature record, land use data including runoff parameters, pollutant accumulation and washoff data, and land surface erosion data. The hourly precipitation record and the daily temperature record are available on magnetic tape from the National Weather Service, Asheville, North Carolina.

Output format:

The two main types of output are statistical information on the quantity and quality of washoff and overflow, and pollutographs for selected individual events. The STORM program produces four output reports: quantity analysis, quality analysis, pollutograph analysis, and land surface erosion analysis. Input variables allow control of the level of printout which may be summary only, all events and/or detailed analysis of selected events. The quantity and quality reports also include average annual statistics of the rainfall/snowmelt; runoff; pollutant washoff; and the quantity, quality, and frequency of overflows to the receiving water. The land surface erosion report shows average annual values for sediment production and delivery to the receiving system.

User manual:	Yes
Systems documentation:	Yes
Date of first version:	1973
Date of latest documents:	1977
Learning difficulty:	High
Output interpretation difficulty:	High
Confidentiality:	Public
Geographic area:	Urban; rural (nonurban)
Analytical Features for Model:	Surface Water Hydrology
Large watershed areas:	Yes
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	Yes

Snowmelt considerations:	Yes
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	Yes
Sedimentation and scour:	Yes
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	No
Do level:	No
Benthal Oxygen:	No
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	No
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	Yes
Time-variant pollution:	Yes
Point source:	Yes
Nonpoint source:	Yes
Steady state:	No
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model name: Strom Hydrograph and Flood Routing

Developer: Kevin Shea

Contact address: Society for Computer Applications in Engineering Planning and Architecture, Inc.
358 Hungerford Drive
Rockville, MD 20850

Type of model: Surface water quantity

Summary: Programs calcuate the storm hydrograph and water surface elevations.

Abstract:

These two programs can be used separately or together. The storm hydrograph program calculates and plots the storm hydrograph from the excess precipitation values and the unit hydrograph. The flood routing program calculates the outflow and water surface elevations of a reservoir during a storm. The inflow values may be taken directly from the storm hydrograph program.

Current hardware: GA 18/30

Software language(s): FORTRAN

Lines of source code: 525

Input requirements:

Storm Hydrograph - Time Base, excess precipitation and unit hydrograph values, flood routing, reservoir characteristics, inflow data and type of spillway.

Output format:

Storm Hydrograph - Storm hydrograph and plot flood routing - outflow, water surface values and plot of inflow and outflow versus time.

User manual availability: Yes

Analytical Features for Model: Surface Water Hydrology

Entire hydrograph(s): Yes

Flood routing: Yes

Snowmelt considerations: No

Continuous simulation of a storm event: No

Continuous simulation in real time: No

Sedimentation and scour: No

Infiltration rates: No

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Model acronym: **STRCH**
Model name: Selection of Study Reaches
Developer: Goodkind & O'Dea, Inc.
Contact address: Society for Computer Applications in Engineering Planning and Architecture, Inc.
358 Hungerford Drive
Rockville, Maryland 20850
Contact telephone: (301)762-6070
Type of model: Surface Water Quantity
Summary: To calculate the flood hazard factor and zone of a river.

Abstract:

Based on the Corps of Engineers' method for Type 15 Flood Insurance Studies, this program calculates the Flood Hazard Factor and Zone of each reach of a river, providing that 80% of the entire reach falls within the allowable variations of the average difference in elevation in feet between the 10-year and 100-year floods.

Current hardware: General automation
Software language(s): FORTRAN
Operating system(s): 1830 DMS
Lines of source code: 500
Input requirements: 2 heading cards (80 chars. maximum card) and the difference in elevations in feet between the 10 and 100-year floods at even intervals.
Output format: Input verification, total and average differences in elevations, allowable variation and the FHF value and zone for each reach.
User manual: Yes
Systems documentation: Yes
Analytical Features for Model: Surface Water Hydrology
Small watershed areas: No
Large watershed areas: No
Rural land areas: Yes
Urban land areas: Yes
Entire hydrographs: No
Flood routing: Yes
Snowmelt considerations: No
Continuous simulation of a storm event: No
Continuous simulation in real time: No
Sedimentation and scour: No
Water flow from a simulation: No
Automatic time interval generation: No
Infiltration rates: No
Flood hazard factor and zone of each river's reach: Yes

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Model acronym: **STREAM 7B**
Model name: STREAM 7B
Sponsor: EPA
Developer: Resources Analysis, Inc.
Contact: Douglas A. Little
Contact address: US EPA Region I
JFK Federal Bldg, Boston, MA
Contact telephone: (617)223-5885
Availability: Public
Type of model: Surface Water Quality
Summary: A one-dimensional, steady state model to simulate BOD-DO in a stream/river.

Abstract:

Stream 7B is a one-dimensional steady-state model characterized by first-order reaction kinetics. It is primarily intended for use in the analysis of biochemical oxygen demand (BOD) and dissolved oxygen (DO), although it may be applied for any other parameter assumed to follow first-order reaction kinetics.

Document citation:

Resources Analysis, Inc. STREAM 7A User's Manual. March, 1978. Resource Analysis Addendum to STREAM 7A User's Manual Stream 7B, June, 1980.

Principal users: EPA
Assumptions:

Constant stream velocity, steady-state, first-order decay, reaeration by COVAR's method.

Current implementation: Mainframe computer
Current hardware: IBM 370/168 and others
Software language(s): FORTRAN IV
Word size(s): 300k bytes

Input requirements:

River NBOD oxidation rates, bottom sludge deoxygenation rates, dam reaeration rates, rapids reaeration rate, stream reaeration rates, NBOD settling rate, fecal coliform decay rate, optional constituent decay rate, time of travels, reach lengths, flows, distributed inflow, temperatures, waste discharges, algal production and respiration rates, mean reach depths.

Output format:

The purpose of this model is to calculate NBOD, CBOD, DO and fecal coliforms as well as an optional constituent at various points with a river system. Average algal photosynthesis and respiration can be modeled. Model can produce plots if desired.

Output complexity:	Low
User manual:	Yes
Date of latest documents:	1980
Learning difficulty:	Low
Geographic area:	stream/river
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Phosphorous:	No
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Respiration:	Yes
Photosynthesis:	Yes
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	Yes
Mixing zones:	No

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Model acronym: SWAN

Model name: Sewer Analysis

Developer: Charles Hodge

Contact address: CEPA
Society for Computer Applications in Engineering, Planning, and Architecture, Inc.
358 Hungerford Drive
Rockville, MD 20850

Contact telephone: (301) 762-6070

Availability: Through CEPA

Type of model: Surface Water Quantity

Summary: To analyze and plot an existing sewage collection network.

Abstract:

The Sewer Analysis System (SWAN) is a package of computer programs used to analyze and plot an existing sewage collection network, whether a storm, sanitary or combined. The system employs an elaborate configuration of data files, based on accurate field observations, which are used to store information about the network being investigated. Data may also be used to load the network and to define the weak points requiring later design. Profile plots may be developed from this information. Field observations may be used to verify flows as modeled by SWAN.

Document citation:

User manual available

Current hardware: Prime 400, IBM 1130 8K or 16K versions available on request - but only on tape.

Software Language(s): FORTRAN

Operating System(s): PRIMOS IV

Lines of source code: 6,000

Input requirements:

Data must be collected and entered into the data base. Sewer networks have to be described by their geometrics and require the following information: Length of each conduit between manholes, shape of conduit and dimensions, invert elevations at each manhole, Manning's N for each conduit and continuity of flow.

Two hydrological methods incorporated into this program could be used to determine the amount of rainfall entering a sewer network. The rational method uses rainfall intensity curves promulgated by local weather offices while the Chicago method utilizes hydrographs and generates time-dependent sufrace hydrographs for every manhole.

Output format:

Computer profile plot and table of sewer characteristics, computer printout of sewer geometrics, printout of domestic and storm loads, printout of backwater analysis of surcharge conditions, printout of hydrograph coordinates and hydrograph plot, and mass diagram plots.

User manual:	Yes
Analytical Features for	
	Surface Water Hydrology
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No
Analyze sewage collection network:	Yes

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Model acronym: SWMM
Model name: Stormwater Management Model
Sponsor: EPA
Developer: EPA
Contact: Douglas Ammon
Contact address: U.S. EPA Municipal Environmental Research Lab
26 West Saint Clair Street
Cincinnati, OH 45268
Contact Telephone: (513)684-7635
Availability: Public
Type of model: Surface Water General
Summary: Simulate water quantity and quality for storm water runoff and sewers.

Abstract:

The EPA Storm Water Management Model (SWMM) is a comprehensive mathematical model capable of simulating urban storm water runoff and combined sewer overflows including the spatial and temporal quality and quantity aspects of the precipitation/runoff (snowmelt) process, conveyance system transport, control measures and receiving water responses. The model operates in a continuous mode for detailed planning and receiving water analysis or in a single-event mode for indepth analysis. Two transport routines are available: One is based on a kinematic wave formulation, while the other is based on the complete St. Venant equations (i.e., WRE Transport) to include effects of backwater, flow reversal, surcharging, looped connections and pressure flow. Two receiving water models are included in SWMM: RECEIV and LEVEL III - RECEIVING. RECEIV is a dynamic model applicable to streams, rivers, estuaries, marshes/swamps and lakes. LEVEL III - RECEIVING is a simplified continuous model, applicable to streams or tidal rivers, that provides dissolved oxygen frequency information.

Document citation:

Metcalf and Eddy, Inc., University of Florida, and Water Resources Engineers, Inc. Storm Water Management Model, Volume I - Final Report. EPA Report 11024 FOC (NTIS PB 203 289), Environmental Protection Agency, Washington, D.C., July 1971.

Huber, W.C., Heaney, J.P., Medina, M.A., Peltz, W.A., Sheikh, H. and Smith, G.F. Storm Water Management Model User's Manual - Version II. EPA-670/2-75-017, Environmental Protection Agency, Cincinnati, Ohio, March 1975.

Heaney, J.P., Huber, W.C., Sheikh, H., Medina, M.A., Doyle, J.R., Peltz, W.A., and Darling, J.E. Urban Stormwater Management Modeling and Decision Making. EPA-670-2-75-022, Cincinnati, Ohio, May 1975.

Medina, M.A. Receiving Water Quality Modeling for Urban Stormwater Management: Level III. USEPA Report EPA-600/2-79-100, Environmental Protection Agency, Cincinnati, Ohio, August 1979.

Huber, W.C.; Heaney, J.P.; and Nix, S.J. Storm Water Management Model User's Manual - Version III. EPA Report, Environmental Protection Agency, Cincinnati, Ohio. Draft 1980.

Principal users: Consulting engineers, public agency engineers and university researchers

Assumptions:

BASIC ASSUMPTIONS: (1) Deterministic model; (2) surface quantity: iterative solution of coupled continuity and Manning equations, integrated form of Horton infiltration (infiltration rate proportional to cumulative infiltration, not time), or Green Ampt; (3) Surface gutter/pipe routing, nonlinear reservoir assuming water surface parallel to invert; (4) Channel/pipes: (a) original transport: implicit finite-difference solution to modified kinematic wave equation, (b) WRE transport: explicit finite difference solution of complete St. Venant equations, stability may require short time step; (5) Storage/sedimentation: modified Puls method requires table look-up for calculation of outflow; (6) Surface quality, quality routing and treatment: algebraic equations, no iterations required once flows and conduit volumes are known.

Current implementations: Mainframe computer

Current hardware: IBM 360/370, CDC 6600, Univac 1108, and AMDAHL 470

Software Languages: FORTRAN

Operating System:

Disc storage 90,000 words core storage plus five units to process magnetic tape storage or disc. Card reader/punch for tape or disc (input).

Input requirements:

Data input items are:

(1) Historical or synthetic precipitation record, uses National Weather Service precipitation tapes for continuous simulation, monthly evaporation rates for snowmelt: daily max-min (continuous) or time-step (single-event) temperatures, monthly wind speeds, melt coefficients and base melt (temperatures, snow redistribution fractions and areal depletion curves (continuous only), other melt parameters: (2) Surface quantity: area, imperviousness, slope, width, depression storage and Manning's roughness for pervious and impervious areas, infiltration parameters; (3) Channel/pipe quantity: linkages, shape, slope, length, Manning's roughness, WRE transport also requires invert and ground elevation, storage volumes at manholes and other structures, geometric and hydraulic parameters for weirs, pumps, orifices, storages, etc., infiltration rate; (4) Storage/sedimentation quantity: geometry, hydraulic characteristics of outflows; (5) Surface quality: land use, total gutter length, catchbasin volume and initial residuals concentrations, street sweeping interval, efficiency and availability factor, dry days prior to initial precipitation, user-supplied initial residuals surface loadings, exponential washoff coefficient or parameters for pollutant rating curve, linear or nonlinear surface accumulation rates; (6) dry-weather flow on basis of diurnal and daily quantity/quality variations; population density, other demographic parameters; (7) no input data required for channel/pipe quality routing; (8) storage/treatment: parameters defining exponential removal as function of residence time in storage/sedimentation, parameters for individual treatment options, e.g., particle size distribution, maximum flow rates, size of unit, chemical additions, optional dry-weather flow data when using continuous simulation; (9) Storage/treatment costs: ENR index, unit costs of excavation, land, power, chlorine, polymers, alum, interest rate and amortization period; (10) Data requirements for individual modules much less than for run of whole model, large reduction in data requirements possible by aggregating (lumping) of subcatchments and channel/pipes, especially useful for continuous simulation.

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Model acronym: **T3FEMA**

Model name: Transient, Three-Dimensional Finite Element for Simulating Material Transport in Saturated-Unsaturated Aquifers

Sponsor: Oak Ridge National Laboratory

Developer: G.T. Yeh, ORNL

Contact: Dr. G.T. Yeh

Contact address: Room 203, Bldg. 1505, Oak Ridge National Lab Oak Ridge, Tennessee 37830

Contact telephone: (615)574-7285

Type of model: Groundwater general

Summary: Simulate hydrodynamics and material transport for saturated-unsaturated porous media.

Abstract:

The Richards and advective-dispersion equations governing the pressure and concentration distributions, respectively, in any combined saturated-unsaturated porous media are employed for simulating the hydrodynamic variables (including matric potential, total head, moisture content, and velocity field) and temporal-spatial distributions of materials. The driving forces included in the hydrodynamics are the pressure gradient and gravitational acceleration. The mechanisms in the material transport are advection, dispersion, radioactive decay and degration by physical, chemical and biological processes. Three types of boundary conditions are considered in the solution of flow field. The Dirichlet, Neumann and variable conditions. On the other hand, Dirichlet, Neumann and Cauchy conditions are adopted for the material transport. The mixed first-and second-order elements are used to derive two sets of matrix equations. Gaussian elimination algorithm is used to solve the resulting system of algebraic equations iteratively with both over- and under-relaxation options. The model is verified by comparing its simulations with those obtained by analytical techniques. It is then validated against laboratory experimental data. Finally, it is demonstrated for typical prototype applications.

Principal users: Research laboratory

Current implementation: Mainframe computer

Current hardware: IBM 360

Software language(s): FORTRAN

User manual: Available in near future.

Analytical Features for Model: Groundwater

Exact solution:	No
Finite element solution:	Yes
Steady state:	Yes
Nonsteady state:	Yes
One aquifer:	Yes
Leakage between aquifers:	Yes
Semipermeable and nonpermeable aquifers:	Yes
Stream aquifer interaction:	No
Saturated element:	Yes
Unsaturated element:	Yes
Differential across element:	Yes
Variable flow rates across boundary:	Yes
Mass transport simulation:	Yes

Output format:

(1) Input data summary, including precipitation; (2) Hydrographs and pollutographs (concentrations and loads versus time) at any point in system on time-step or longer basis, no stages or velocities printed; (3) WRE transport also outputs elevation of hydraulic grade line; (4) Surcharge volumes and required flow capacity, original transport model will resize conduits to pass required flow (optional); (5) Removal in storage/treatment units, generated sludge quantities; (6) Summaries of volumes and residuals loads for simulation period, continuity check, initial and final pounds of solids in conduit elements; (7) Daily (optional), monthly, annual and total summaries for continuous simulation, plus ranking of 50 highest hourly precipitation, runoff and BOD values; (8) Line printer plots of hytographs, hydrographs, and pollutographs; (9) Costs of simulated storage/treatment options.

User manual:	Yes
Systems documentation:	Yes
Date of first version:	1971
Date of latest version:	1980 (Version III)
Date of latest documents:	1980 (draft)
Learning difficulty:	High
User support:	Yes
Continued enhancement:	Yes, semiannual meeting of the user's group are held in the U.S. and Canada.
Geographic area:	Estuary, stream/river, wetlands, environment, urban.
Water quality:	
Capability to monitor carbonaceaous and nitrogenous oxygen :	Yes
DO level:	Yes
Radioactive constituents:	No
Time-dependent input conditions:	Yes
Model changes in channel flow	Yes
Compute effects of aeration:	Yes
Compute evaporation and precipitation effects:	Yes
Time-variant pollution sources :	Yes
Nonpoint Source:	Yes
Unsteady conditions :	Yes
Stream and river models:	Yes
Reservoir and lake models:	No
Estuarine models :	Yes
Ocean inlet capabilities:	No
De. computation capabilities:	No
Compute effects of mixing zones :	No
Surface Water Hydrology:	
Analyze small watershed areas:	Yes
Analyze large watershed areas:	Yes
Analyze urban land areas:	Yes
Generate entire hydrograph(s):	Yes
Perform flood routing :	No
Perform snowmelt considerations :	Yes
Perform a cont. simulation in real time:	Yes
Compute effects of sedimentation/scour:	Yes
Record water flow from simulation:	Yes
Compute infiltration rates:	No

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Model name: Thermal Plume, Surface Discharge Model
Contact: Gary J. Marmer
Contact address: Argonne National Laboratory
Environmental Impact Studies Division
9700 S. Cass Avenue
Argonne, IL 60439
Contact telephone: FTS 972-3202
Type of model: Surface Water Quality
Summary: Describe three-dimensional surface-heated jet discharged to a deep water body.

Abstract:

This model describes the three-dimensional behavior of a heated jet discharged from a rectangular channel at the surface of a deep and wide body of homogeneous water that is either at rest or moving with a uniform and constant velocity. The magnitudes of the discharge angle, channel dimensions, discharge velocity and temperature are arbitrary. The jet velocity and temperature distributions at the outlet are assumed uniform and constant. Comments: The mathematical model is greatly idealized and is subjected to considerable limitations in the process of arriving at a mathematical solution.

Document citations:

Shirazi, M.A. and Davis, L.R. Workbook of Thermal Plume Prediction - v.2: Surface Discharge. U.S. EPA: EPA-R2-72-0056, May 1974.

Dunn, W.D.; Policastro, A.J. and Paddock, R.A. Surface Thermal Plumes: Evaluation of Mathematical Models for the Near and Complete Field, Argonne National Lab ANL/WR-75-3 Part 1, May 1975, Part 2, August 1975.

Principal users: Argonne National Lab
Oak Ridge National Lab
Environmental Protection Agency

Assumptions:

The mathematical model is greatly idealized and is subject to considerable limitations in the processes of arriving at a mathematical solution.

Current implementation: Mainframe computer
Current hardware: IBM 370/195
Software language(s): FORTRAN
Input requirements: Discharge densimetric Froude number, aspect ratio, ratio of exit to ambient velocity, discharge angle, surface heat exchange coefficient.
User manual: Yes
Systems documentation: Yes
Date of first version: 1974

Analytical Features for Model:	Water Quality
Oxygen:	No
Water temperature:	Yes
DO level:	No
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	No
Changes in channel flow:	No
Aeration:	No
Respiration:	No
Photosynthesis	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	No
Point Source:	Yes
Steady state conditions:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	Yes

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Model acronym: THYSYS

Model name: Texas Hydraulic System

Sponsor: Texas Highway Department, Division of Automation for Highway Hydraulic Design and Analysis

Contact: McConnell Douglas Automation Company

Contact address: Division of Automation
Field Coordination Service
State Department of Highways and Public Transportation
Austin, Texas 78701

Availability: Nonproprietary

Type of model: Surface Water Quantity

Summary: A computer system for highway hydraulic design and analysis

Abstract:

The system was developed by the Texas Highway Department, Divison of Automation for highway hydraulic design and analysis. It is composed of five major programs or subsystems as follows:

HYDRO - Computation or modification of peak flow for surface runoff. The user may select one of four methods: the rational method; a gaged analysis method which employs the major runoff history on a stream to determine peak flow; and two methods which employ regional analysis procedures tailored to the hydrology of Texas.

HYDRA - Used to compute water surface elevations and cumulative conveyance at stream cross section. This offers three options: the one-section method, the two-section method, and the multisection method. The system contains six basic program commands.

CULBRG - Makes use of peak flow determinations and water elevations from HYDRO and HYDRA to perform a complete design or analysis of hydraulic structures under highways. Numerous cases are available as options. The system contains 65 commands.

SEWER - An independent subsystem used to accomplish a complete design of a storm sewer network including runoff calculation, inlet and sewer network design. The system contains 14 commands.

PUMP - Subsystem to design and analyze pump stations used to lift storm water. The system is completely modular and contains a flexible program structure to which modifications can be easily added.

Document citation:

Schelling, D. Texas Hydraulic System - THYSYS. Texas Highway Department, Division of Automation, Austin, TX, 1970.

Principal users: Texas Highway Department

Software languages(s): FORTRAN

Number of subroutines: Twelve routines for the hydraulic design of bridge waterways and nine sewer design routines

Systems documentation: Yes

Date of first version: 1970

Learning difficulty: Low

Continued enhancement: Yes; 33 options were planned in each area

Analytical Features for Model: Surface Water Hydrology

Small watershed areas:	Yes	Flood routing:	No
Rural land areas:	Yes	Water flow from a simulation	Yes
Urban land areas:	Yes		
Entire hydrographs:	No		

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Model name: Time-dependent, Three-dimensional, Variable-density Hydrodynamic Model

Sponsor: Environmental Protection Agency

Contact: Dr. John F. Paul

Contact address: EPA Environmental Research Lab
Office of Research & Development
9311 Groh Road
Grosse Ile MI 48138

Contact telephone: (313) 226-7811

Availability: Public

User manual: Yes

Type of model: Surface Water General

Summary: A time-dependent, three-dimensional, variable-density model for simulating hydrodynamics and temperature.

Abstract:

The time-dependent, three-dimensional, variable-density hydrodynamic model was developed to describe the motion in thermal discharges, harbors, bays, lake basins, entire lakes, estuaries, etc. The model calculates velocities and temperature (salinity, also, if required) as a coupled set of time-dependent, nonlinear partial differential equations. The results of the model can be used as input to a transport model (described separately). The model has various versions (user-specified) such that the calculations can be performed with the water surface treated rigid-lid or as a free surface and with the bottom condition specified either as no-slip or slip.

Document citations:

Lick, W.J.; Paul, J. and Sheng, Y.P. "The Dispersion of Contaminants in the Near Shore Region." In: Modeling Biochemical Processes in Aquatic Ecosystems (R. Canale, ed.) Ann Arbor Science Publishers, Inc., pp. 93-112, 1976.

Paul, J.F. Modeling the Hydrodynamic Effects of Large Manmade Modifications to Lakes. Proc. of the EPA Conf. on Environmental Modeling and Simulation (W.R. Ott, ed.). EPA-600/9-76-016, pp. 171-175, 1976.

Paul, J.F. and Lick, W.J. A Numerical Model for Three-Dimensional, Variable-Density Jet. Report No. FTAS/TR73-92, School of Engineering, S.W.R.U., Cleveland, OH,1973A.

Paul, J.F. and Lick, W.J. A Numerical Model for Three-Dimensional, Variable Density Jet. Proc. 16th Conf. Great Lakes Res., LAGIR, pp. 818-830, 1973b.

Paul J.F. and Lick, W.J. A Numerical Model for Thermal Plumes and River Discharges. Proc. 17th Conf. Great Lakes Res., LAGIR, pp. 445-455, 1974.

Paul, J.R. and Lick, W.J. Report to Argonne National Laboratory on the Application of the Paul-Lick Model to Point Beach Unity 1 Outfall. Appears in appendix of Surface Thermal Pumes: Evaluation of mathematical models for the near and complete field (W.E. Dunn, A.J. Policastro and R.A. Paddock), ASL/WR-75-3, pp. 484-511, 1975.

Paul, J.F. and Lick, W.J. Application of Three-dimensional Hydrodynamic Model to Study Effects of Proposed Jetport Island on Thermocline Structure in Lake Erie. Report 17-6 of Lake Erie International Jetport Model Feasibility Investigation. U.S. Army Engineer Waterways Experimental Station Contract Report H-75-1, 1976.

Paul, J.F. and Lick, W.J. An Efficient, Implicit Method for Calculating Time-Dependent, Free-surface, Hydrodynamic Flows. Presented at the 22nd Conference on Great Lakes Research, Rochester, NY, 1979.

Paul, J.F. and Lick, W.J. Numerical Model for Three-Dimensional, Variable Density Rigid-lid Hydrodynamic Flows: Volume I. Details of the numeric model, in Preparation, 1980.

Paul, J.F., Richardson, W.L., Gorstko, A.B. and Matveyou, A.A. Results of a Joint USA/USSR Hydrodynamic and Transport Modeling Project. EPA-600/3-79-015, 1979.

Vasseur B., Finkquist, L. and Paul, J.F. Verification of a Numerical Model for Thermal Plumes SMHO Hydrology and Oceanography Report No. 24. 1980.

Principal users: GPA, Universities, Corps of Engineers, etc.

Assumptions:

The equations are derived from the time-dependent, three-dimensional equations for conservation of mass, momentum, energy and salinity. The principal assumptions are: 1) hydrostatic pressure variation; 2) rigid-lid or linearized free-surface approximation; 3) eddy coefficients to account for turbulent diffusion effects. The program for the model is modular in form so the last condition can be modified to account for various turbulence modeling schemes. The solution procedure is a modification of the simplified marker and cell technique.

Current implementation:	Mainframe computer
Current hardware:	Mainframe Cray, IBM 370/4300, Univac 1100, Vax 11/780
Software languages(s):	FORTRAN
Word size:	Disc storage 50K-1.5M words core storage
Operating system(s):	Magnetic tape storage 0-2 units to process high speed line printer if disc input not used

Input requirements:

Input to the model includes: complete specification of geometry and grid layout, topography and forcing functions. The latter includes wind (constant or spatial and temporal varying), inflows/outflows and heat specification at water surface. The initial conditions can be quiescent conditions, some user specified form or results from a previous calculation.

Output form:

The basic output of the program is a printed record of velocities, temperature, salinity and pressure, as desired. If results are stored (disc) or tape), separate programs are available to produce graphic output on either Tektronix or CALCOMP equipment. The plots available include time series of variables, and horizontal and vertical section plots of the variables.

User manual:	In preparation
Learning difficulty:	High
Confidentiality:	Public
Geographic area:	Estuary, lake, marine, Lake Huron, Lake Erie, Cleveland Harbor, Saginaw Bay, Great Lakes, Baltic Sea, Lake Baikal, Waukegan Harbor.
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	No
Urban land areas:	No
Entire hydographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Infiltration rates:	No
Analytical Features for Model:	Water Quality
Oxygen:	No
Water temperature:	Yes
DO level:	No
Benthal Oxygen:	No
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Conservative minerals:	No
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	No
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	No
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	No
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	Yes

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Model name: Time-dependent, Three-dimensional Transport Model
Sponsor: EPA
Developer: John Paul, EPA Research Lab/Duluth
Contact: Dr. Joun F. Paul
Contact address: EPA Environmental Research Lab
Office of Research and Development
9311 Groh Road
Grossee Ile, MI 48138
Contact telephone: (313) 226-7811
Availability: Public
Type of model: Surface Water Quality
Summary: A time-dependent, three-dimensional constituent transport simulation in various water bodies.

Abstract:

The time-dependent, three-dimensional transport model was developed to calculate the hydrodynamic transport of conservative and nonconservative substances in various water bodies. The model calculates the time-dependent concentration of the desired substance. Input to this model for velocities are results from the separately described hydrodynamic model. Various user-specified options permit application to conservative substances such as chloride and nonconservative substances such as suspended solids.

Document citation:

Lick, W.J.; Paul, J. and Sheng, Y.P. The Dispersion of Contaminants in the Near Shore Region. In: Modeling Biochemical Processes in Aquatic Ecosystem (R. Canale, ed.) Ann Arbor Science Publishers, Inc. 1976. pp. 93-112.

Paul, J.F. and Patterson, R.L. Hydrodynamic Simulation of Movement of Larval Fishes in Western Lake Erie and Their Vulnerability to Power Plant Entrainment. Proc. of the 1977 Winter Simulation Conf. (H.J. Highland, R.G. Sargent and J.W. Schmidt, ed.), WSC Executive Committee, 1977, pp. 305-316.

Paul, J.F.; Richardson, W.L. Gorstko, A.B. and Matveyev, A.A. Results of a Joint USA/USR Hydrodynamic and Transport Modeling Project. EPA-600/3-79-015, 1979.

Principal users:

EPA, various Federal agencies and Universities in this country and in Europe.

Assumptions:

The equations are derived from the time-dependent, three-dimensional equation for conservation of material. The main assumption is that eddy coefficients are used to account for turbulent diffusion effects. The program for the model is modular in form so this condition can be changed to incorporate various turbulance modeling schemes.

Current implementation: Mainframe computer
Current hardware: Mainframe Univac 1100, IBM 370/4300, VAX 11/780

Software language: FORTRAN
Word size: Disk storage 50k - 1.5m words core storage
Operating system:

Magnetic tape storage 0-2 units to process, high-speed line printer, card reader/punch is disk input not used.

Input requirements:

Input to the model includes: complete specification of geometry and grid layout (which can be obtained from hydrodynamic model), topography and forcing. The latter includes velocities (from hydrodynamic model), inputs/outputs and other things such as wind, depending on what is being modeled. The initial conditions can be user-specified or from results of previous calculation.

Output format:

The basic output of the program is a printed record of concentrations, as desired. If results are stored (disk or tape), separate programs are available to produce graphic output on either Tektronix or CALCOMP equipment. The plots available include time series and horizontal and vertical sections.

User manual: No
First version: 1976
Learning difficulty: Medium

Geographic area:

Estuary, lake, marine, Lake Erie and basins, Saginaw Bay, Sea of Azov, Lake Baikal, and Waukegan Harbor.

Analytical Features for Model:	Water Quality
Oxygen:	No
Water temperature:	Yes
DO level:	No
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time-dependent input:	Yes
Changes in channel flow:	No
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Time-variant pollution:	Yes
Point source:	Yes
Steady state:	Yes
Nonpoint source:	No
Unsteady state:	Yes
Stream and river:	No
Reservior and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	Yes

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Model acronym: **TR-20 (HP-3000)**
Model name: Watershed Project Formulation Program TR20
Sponsor: Soil Conservation Service
Developer: USDA, Soils Conservation Service
Contact: National Technical Information Service; Magnetic tape PB 233 779
Contact address: USDA, Soil Conservation Service, Washington, DC
Contact telephone: (202) 447-5157
Availability: Public
Type of model: Surface Water Quantity
Summary: Compute surface runoff from synthetic or natural rainstorm.

Abstract:

This simulation program computes surface runoff due to a given rainfall distribution, develops runoff hydrographs, and combines and routes these hydrographs. The program can accept two types of rainfall data; a dimensionless time distribution and a given total rainfall, or actual rainfall amounts for specified time periods. Excess rainfall is based on a technique developed by the Soil Conservation Service, which takes into account antecedent moisture conditions and land use practices. At first, the program computes a unit hydrograph and, from it, incremental runoff hydrographs are computed by applying the unit hydrograph to the rainfall excess computed over a specified incremental rainfall duration. Reservoir routing is done by using a conventional reservoir routing technique while channel routing is accomplished by the covex routing method.

Document citations:

U.S. Dept. of Agriculture, Computer Program for Project Formulation-Hydrology (TR-20). Soil Conservation Service, Engineering Division, Washington, DC, 1965. (NTIS, PB-233 778)

Principal user(s): Soil Conservation Service
Validation: Medium

Assumptions:

The computer will perform, in any one continuous operation: 1) Route through 60 structures and an unlimited number of variations for each structure, including the variation of haveing no structure (null structure); 2) Route through 120 stream reaches and an unlimited number of channel modifications for each reach; 3) Compute up to 300 ordinates of a hydrograph and print out the discharge and elevation for each; 4) Make an unlimited number of routings through a watershed including variations in rainfall amounts, rainfall duration and antecedent moisture condition; 5) Develop and route the runoff from nine different storm distributions. It will develop and route the runoff for any number of depths and durations for any storm distribution defined in dimensionless units; 6) Combine hydrographs from an unlimited number of tributaries and reach terminals.

Current implementations: Mainframe computer
Feasible implementations: Minicomputer
Current hardware: HP-3000, IBM 370
Software language(s): FORTRAN IV, IBM assembler
Word size(s): 32 bit

Operation system(s):	MPE
Input requirements:	Numerical; formatted
Output format:	Printed tables
Output complexity:	Medium
User manual:	Yes
Systems documentation:	Yes
Date of first version:	1964
Date of latest version:	1969
Date of latest documents:	1969
Machine interface:	Batch
Learning difficulty:	Medium
User support:	No
Analytical Features for Model:	Surface Water Hydrology
S 11 watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	Yes
Flood routing:	Yes
Snowmelt considerations:	No
Continuous simulation of a storm event:	Yes
Continuous simulation in real time:	Yes
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	Yes
Infiltration rates:	No

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Model acronym: TTM
Model name: Tidal Temperature Model
Sponsor: EPA
Developer: EPA Pacific Northwest Laboratory
Contact: Richard J. Callaway
Contact address: EPA Corvallis Environmental Research Lab
200 S.W. 35th Street, Corvallis, OR 97330
Contact telephone: (503)757-4703
Type of model: Surface Water Quality
Summary: To simulate heat budget of streams, shallow impoundments or estuaries.

Abstract:

The Tidal Temperature Model (TTM) is a derivative of the Dynamic Estuary Model (DEM) that can simulate the heat budget and dispersion characteristics of streams, well-mixed shallow impoundments, estuaries, and coastal waters. The model can accommodate constituents which may be conservative or nonconservative, have coupled or noncoupled reactions and which undergo first-order decay. The TTM was developed by the EPA Pacific Northwest Laboratory and has been applied to the Columbia River below the Bonneville Dam.

Document citations:

Callaway, R.J. and Byram, K.V. Mathematical Model of the Columbia River from the Pacific Ocean to Bonneville Dam, Part II: Input-Output and Initial Verification Procedures. Report by U.S. EPA Pacific Northwest Laboratory, Corvallis, Oregon, 1971.

Callaway, R.J., Byram, K.V. and Ditsworth, G.R. Mathematical Model of the Columbia River from the Pacific Ocean to Bonneville Dam, Part I. Theory, Program Notes and Programs. Report by FWQA Pacific Northwest Water Laboratory, Corvallis, Oregon, 1969.

Principal user: EPA and Pacific Northwest Research Laboratory.

Assumptions:

The TTM assumes that all inflows or withdrawals are constant, and it utilizes a simplified form of evaporation. One-dimensional channels are used to represent two-dimensional flow and transports. The model neglects wind stress and disregards lateral and vertical variation in channel cross-sectional area with tidal elevation change. It handles constant residual input rates which can be put in variable form, and it cannot simulate tidal flats that go dry.

Current implementation: Mainframe computer
Current hardware: Any digital computer
Software language(s): FORTRAN
Word size(s): 50k

Input requirements:

The Tidal Temperature Modal allows for a large input data base, written in card-image form. Parameters which can be specified include headwater flows, tributary flows, groundwater flows, water withdrawals, seaward tides, channel depths and widths, bottom roughness, constituents in freshwater inflows and at seaward boundaries, constituent concentrations throughtout the modeled area, the quality and quantity of point source residuals dischargers, net solar radiation, and wet and dry bulb temperatures.

Output format:

Output formats include tabular printouts and velocities written by the hydrodynamic module. Output information provided by the model includes summarized data (maximum and minimum values) for tidal cycles, flows, velocities, water depths, and constituents at each junction, channel velocities, junction depths, and constituents at user-specified periods.

User manual:	Yes
Systems documentation:	Yes
Geographic area:	Estuary, stream/river, wetlands, Columbia River below the Bonneville Dam.
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	No
Phosphorous:	No
Coliforms:	Yes
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	Yes
Time variant pollution:	Yes
Point source:	NO
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Dam computation:	No
Mixing zones:	No

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Model acronym: USDAHL-74
Sponsor: U.S. Dept. of Agriculture, Agriculture Res. Svc.
Developer: USDA Agricultural Research Service
Contact address: Agricultural Research Service, USDA
Washington, D.C.
Availability: Public
Type of model: Surface Water Quantity
Summary: A model to simulate watershed hydrology.
Abstract:
The USDAHL-74 model is concerned with agricultural watershed hydrology. The system considers rural land use categorization of soils, evapotranspiration, infilteration, and flood routing.

Citations:

Holtan, H.N., and Lopez, N.C. USDAHL-70 Model of Watershed Hydrology. USDA-ARS Technical Bulletin 1435, 84 pp., 1971.

Holtan, H.N. et al. USDAHL-74 Revised Model of Watershed Hydrology. USDA-ARS Technical Bulletin 1518, 99 pp., 1975.

Holtan, H.N.; Yaramanoglu, M. University of Maryland Version of the USDAHL Model of Watershed Hydrology (Using Minutes and Integers for Accuracy, Soil Moisture Constants for Convenience of Inputs, and Variable Routing Intervals for Economy of Operation. Univ. of Maryland, Dept. of Agricultural Engineering, College Park, MD.

Principal users: USDA, Universities
Current implementation: Mainframe computers
Current hardware: UNIVAC 1108, IBM 360/65
Software language(s): FORTRAN IV
Word size(s): 98K
Operating System(s): HASP
User manual: Yes
Systems documentation: Yes
Date of first version: 1975
Date of latest version: See refs. for USDAHL-70 and WOM version.
Learning difficulty: Medium
Analytical features for Model: Surface water hydrology
Large watershed areas: Yes
Rural land areas: Yes
Flood routing: No
Continuous simulation of a storm event: Yes
Sedimentation and scour: Yes
Water flow from a simulation: Yes

Flood routing:	No
Snowmelt considerations:	No
Continous simulation of a storm event:	No
Sedimentation and scour:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No
Data process:	Yes
Statistical:	Yes

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Model acronym: WAS

Model name: Water Analysis System to Process Data on Water Availability and Characteristics in the U.S., particularly for Regional Analysis

Developer: ORNL

Contact: Alf D. Shepherd

Contact address: Oak Ridge National Laboratory
Resource Analysis Group
Energy Division
P.O. Box X
Oak Ridge, Tennessee 37830

Contact telephone: (615) 483-8611, ext. 3-6739/FTS 850-6739

Type of Model: Surface Water Quantity

Abstract:

The water analysis system (WAS) has been developed in response to the high priority given water availability analysis in power plant siting. WAS is a composition of main programs and subroutines that process streamflow information from the United States Geological Survey (USGS) Daily-Value Water Tapes, which contain data from all stream gaging stations in the United States. The WAS programs enable the user to (a) delimit any region of the United States by state, county, size of drainage area, or latitude-longitude frame; (b) recall daily flow values from the USGS Water Tapes for all gaging stations within the study region; (c) compute low-flow recurrence frequencies and apply theoretical probability distributions; and (d) predict the reservoir drawdown capacity necessary to maintain any given rate of streamflow at any specified rate of consumption. The WAS procedure provides a valuable tool for energy facility siting in particular and is directly applicable to many water resource questions.

Document citation:

Jalbert, J.S., and Shepherd, A.D., A System for Regional Analysis of Water Availability. ORNAL/NUREG/TM-82, July 1977.

Principal users: Department of Energy
USGS

Current implementation: Mainframe computer

Current hardware: IBM 370/195
PDP 10

Software language(s): FORTRAN IV

Word size(s): 500k memory - IBM 370/195
10k memory - PDP 10

User manual: Yes

Systems documentation: Yes

Date of first version: 1976

Geographic area: National

Analytical Features for Model: Surface Water Hydrology

Small watershed areas: Yes

Large watershed areas: Yes

Rural land areas: No

Urban land areas: No

Entire hydrographs: No

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Model acronym: **WATEQ2**
Model name: WATEQ2
Sponsor: EPA
Developer: EPA
Contact: Michael Schock
Contact address: EPA, Municipal Environmental Research Lab
26 West Saint Clair Street
Cincinnati, OH 45268
Contact telephone: (513) 684-7236
Availability: Public
Type of model: Water General

Summary:

A chemical model for trace and major element speciation.

Abstract:

WATEQ2 is a chemical model for trace and major element speciation and the calculation of saturation states of minerals and other solids in drinking and natural waters. WATEQ2 is an expanded and revised version of the WATEQ model of Truesdell and Jones (see references). The purpose of the program is to calculate the equilibrium aqueous speciation of a water from analytical chemical data, and then the output can be applied to solve problems such as those relating to the identification of mineral controls on the solubility of elements, relationship of aqueous speciation to elemental toxicity toward fish and other aquatic organisms, determination of the tendency of a drinking water to mobilize toxic metals from the piping in homes and distribution systems, and solubility factors governing corrosion of materials in water.

Document citation:

James W. Ball, et al., Additional and Revised Thermochemical Data and Computer Code for WATEQ2 -- A Computerized Chemical Model for Trace and Major Element speciation and Mineral Equilibria of Natural Waters, USGS Water Resources Investigation WRI 73-116 (1980).

James W. Ball, et al. WATEQ2-"A Computerized Chemical Model for Trace and Major Element Speciation and Mineral Equilibria of Natural Waters," ch. 36 in Chemical Modeling in Aqueous Systems (E.A. Jenne, ed.) ACS Symposium Series 93 (1979).

Darrell K. Nordstorm, et al.,"A Comparison of Computerized Chemical Models for Equilibrium Calculations in Aqueous systems," Ch. 38 in Chemical Modeling in Aqueous Systems (E.A. Jenne, ed.), ACS Symposium Series 93 1979

Alfred H. Truesdell and Blair F. Jones, WATEQ, A Computer Program for Calculating Chemical Equilibria of Natural Waters. NTIS PB-220 464
Also, Jour. Res. USGS, 2:2:233

Principal users: USGS, Drinking Water Res. Div., EPA

Assumptions:

The program assumes chemical equilibrium, or a metastable state characterizable by operational "equilibrium" constants. Redox equilibrium is not assumed for the NO_3/NH_4 system. The simultaneous equations are solved by a continuing-fraction iteration technique. Temperature adjustment of equilibrium constants are accomplished by either analytical polynomial functions or by the Van Hoff relation. The program is of limited usefulness if the aqueous or solid species present in a real system are not included in the model. Additionally, the analytical data are presumed to represent dissolved concentrations.

Current implementation:	Mainframe Computer
Current hardware:	Mainframe IBM 370/168, IBM 370/155
Software language(s):	PL/1
Word size(s):	Disc Storage 660K Compile, 400K execution

Input requirements:

Input to the model includes: chemical analytical data (such as pH, Ca, Mg, titration alkalinity, Cl, Pb), temperature, redox potential (or an estimator, such as D.C., options for calculations to be performed and thermochemical data describing the reactions to be considered. Test data sets are given in References 3. Thermochemical data and the ordering of output species are contained in four external files. called by the program if operated as a load module, or to follow the program, if run in-stream.

Output format:

The output consists of the activities of the aqueous species, the molalities of the aqueous species, calculation of ion balance error, derivation of total inorganic carbonate concentration from titration alkalinity (corrected for noncarbonate reactants), saturation indices of solids, several ion ratios, adjustment of equilibrium constants for ionic strength and changes in temperature, calculated TDS, ionic strength and other parameters. Modifications have been made to transfer activities, concentrations and saturation indices to an operating system file for interfacing with a plotting/statistical package such as SAS (Statistical Analysis System, SAS Institute, Raleigh, N.C.).

Date of first version:	1973
Geographic area:	Esturary, Lake, Stream/River, Marine

Analytical Features for Model:	Water Quality	Aeration:	No
Oxygen:	No	Respiration:	No
Water temperature:	Yes	Photosynthesis:	No
DO level:	Yes	Waste treatment plant input:	Yes
Benthal oxygen:	No	Evaporation and precipitation effects:	No
Coliforms:	No	Time-variant pollution:	No
Chlorophyll-A:	No	Point source:	Yes
Radioactivity:	No	Nonpoint source:	No
Salinity:	Yes		
Conservative minerals:	No		
Time-dependent input:	No		
Changes in channel flow:	No		

<u>Steady state:</u>	Yes
<u>Unsteady state:</u>	No
<u>Stream and river:</u>	Yes
<u>Reservoir and lake:</u>	Yes
<u>Estuarine:</u>	Yes
<u>Ocean inlet:</u>	No
<u>Dam computation:</u>	No
<u>Mixing zones:</u>	No

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Model acronym: **WATSPEC2**
Model name: WATSPEC2
Sponsor: EPA
Developer: T.M.L. Wigley and M.R. Shock
Contact: Michael Schock
Contact address: EPA, Muncipal Environmental Research Lab
26 West Saint Clair Street
Cincinnati, Oh 45268
Contact telephone: (513) 684-7236
Availability: Unpublished, through EPA Muncipal Env. Res. Lab
Cincinnati, Oh
Type of model: Water General

Summary:

A chemical model of natural and drinking waters.

Abstract:

WASTSPEC2 is a chemical model for major element speciation of natural and drinking waters, plus several additional constituents such as Sr, Ba. Fe. NO_3 and H_2S. WATSPEC2 is an expanded version of WATSPEC, developed by T.M.L. Wigley (ref. 1). The program takes analytical chemical data and calculates aqueous speciation and solid saturation states, and several indices of water corrosivity toward various kinds of drinking water piping.

Document citation:

Wigley, T.M.L. WATSPEC: A Computer Program for Determining the Equilibrium Speciation of Aqueous Solutions. British Geomorphological Research Group Tech. Bull. No. 20 1977.

Schock, Michael R. WATSPEC2 Program and Documentation. Unpublished, Drinking Water Research Division, US EPA, Cincinnati, OH.

Principal users: U.S. Geological Survey, EPA Drinking Water Res. Div.

Assumptions:

The program assumes chemical equilibrium or a metastable state characterizable by operational "equilibrium" constants. Redox equilibrium is not assumed for NO_3/NH_4 system. The simultaneous equations are solved by a continuing-fraction iteration technique. Temperature adjustment of equilibrium constants are accomplished by either analytical polynomials or the Van Hoff relation. The analytical data are assumed to represent dissolved concentrations.

Current implementation: Mainframe Computer
Current hardware: Mainframe IBM 370/168
Software language(s): FORTRAN, GI Compiler
Operating system(s): Disc Storage or tape-5 tracks
Magnetic tape storage or disc

Input requirements:

WATSPEC2 accepts analytical chemical input as mg/L (mg/L $CaCo_3$ for alkalinity), rather than meq/L as in WATSPEC. Program input also includes some calculation options if some output is unnecesary, optional calculation of ionic strength from IDS or SPC, temperature and a redox potential (or D.O.). The program can be set to default to a particular pE.

Output format:

The output includes aqueous speciation, saturation indices for 43 solids, ion balance error, an approximation of the buffer capacity of the water, the (chloride - sulfate)/alkalinity ratio, the Aggressiveness Index, the calculated pH of saturation for calcite and a fresh calcium carbonate precipitate, the total inorganic carbonate concentration. equilibrium CO_2 partial pressure, the calculated TDS, plus some others.

User manual:	Unpublished
Geographic area:	Estuary, Lake, Stream/river, Marine
Analytical Features for Model:	Water Quality
Oxygen:	No
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	No.
Coliforms:	No
Chlorophyll-A:	No
Radioactivity:	No
Salinity:	Yes
Conservative minerals:	No
Time-dependent input:	No
Changes in channel flow:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	No
Evaporation and precipitation effects:	No
Time-variant pollution:	No
Point source:	Yes
Nonpoint source:	No
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No

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Model acronym: **WHTM**

Model name: Wisconsin Hydrologic Transport Model

Sponsor: National Science Foundation TRANN
Environmental Aspects of Trace Contaminants Program

Developer: Oak Ridge National Laboratory

Contact: Enviromental Science Divsion

Contact address: Oak Ridge National Laboratory
Oak Ridge, Tenn. 37830

Availability: Public

Type of model: Water General

Summary: Simulate hydrologic transport of a trace contaminant.

Abstract:

This hydrologic transport model is based on the Stanford Watershed Model and forms a major component of the Unified Transport Model being developed at ORNL. WHTM included the hydrologic transport of a trace contaminant by entrainment in overland flow, infiltration, impervious area runoff, and base flow. Chemical exchange reactions are simulated with a simple ion-exchange submodel for interaction with the soil and a sheet erosion submodel for transport of the trace contaminant that is sorbed on the surface of eroded soil particles. Detailed instructions for the application of the WHTM are given, and lists of the FORTRAN IV source decks and sample input data are provided. Simulation of the hourly flow in seven reaches of a stream channel system for a period of 1 year can be done on the IBM System 360/91 computer in about 4 minutes.

Document citation:

Patterson, M.R.; Munro, J.K.; Fields, D.E., Ellison, R.D., Brooks, A.A., and Huff, D.D. A User's Manual for the FORTRAN IV Version of the Wisconsin Hydrologic Transport Model. ORNL-NSF-EATC-7, Oak Ridge National Laboratory, Oct. 1974.

Principal users: Environmental Science Division
Oak Ridge National Laboratory

Current implementation: Mini Computer, Mainframe Computer

Current hardware:

Software language(s): FORTRAN IV

Output complexity: Medium

User manual: Yes

Systems documentation: Yes

Date of first version: 1974

Learning difficulty: High

Analytical Features for Model: Water Quality

DO level: No

Benthal oxygen: No

Coliforms: No

Chlorophyll-A: No

Salinity: No

Conservative minerals: Yes

Time-dependent input:	Yes
Aeration:	No
Respiration:	No
Photosynthesis:	No
Waste treatment plant input:	No
Evaporation and precipitation effects:	Yes
Time-variant pollution:	Yes
Point source:	No
Nonpoint source:	Yes
Unsteady state:	
Stream and river:	Yes
Reservoir and lake:	No
Estuarine:	No
Ocean inlet:	No
Dam computation:	No
Mixing zones:	No
Analytical Features for Model:	Surface Water Hydrology
Large watershed areas:	Yes
Rural land areas:	Yes
Flood routing:	No
Continuous simulation in real time:	Yes
Sedimentation and scour:	Yes
Infiltration rates:	Yes

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Model acronym: WQAM
Model name: Water Quality Assessment Methodology
Sponsor: EPA
Developer: Midwest Research Institute; Tetra Tech, Inc.
Contact: Robert B. Ambrose, Jr.
Contact address: EPA Athens Environmental Research Lab
Center for Water Quality Modeling
College Station Road, Athens, GA 30613
Contact telephone: (404)546-3546
Availability: Public
Type of Model: Surface Water Quality

Summary: Performing a screening assessment of surface water quality.

Abstract:

The Water Quality Assessment Methodology is a collection of formulas, tables and graphs which planners can use to perform a preliminary (screening) assessment of surface water quality in large basins. Analyses require little data and, in most cases, can be accomplished with the assistance of a desk-top calculator. Desk-top calculation procedures are provided for the following subject categories:1)Wasteload estimation, including point and nonpoint source pollutants;2)Stream analyses for water temperature, biochemical oxygen demand, dissolved oxygen, total suspended solids, coliform bacteria, plant nutrients and conservative constituents;3)Lake analyses for thermal stratification, sediment accumulation, phosphorus budget, eutrophication potential and hypolimnion DO;4)Estuarine analyses for estaurine classification, temperature, BOD, DO, turbidity, sediment accumulation and conservative constituents.

Document citation:

Water Quality Assessment: A Screening Method for Nondesignated 208 Area. EPA 600/9-77-023, Available from NTIS (PB277161/AS for $29). August 1977.

Principal users: EPA and consulting firms

Assumptions:

The nonpoint source loading section is based on the modified Universal Soil Loss Equation. The stream section is based on steady-state, plug-flow solutions to the conservation-of-mass equation. The lake section is based on empirical stratification relationships and mass balance. The estuary section is based on the modified tidal prism and/or fraction of freshwater formulas.

Current implementation: Handbook, programmable calculator
Current hardware: Calculator
Operating system: Use hand calculator

Input requirement:

The methodology is designed to operate with minimum data, recognizing that the more data available, the more accurate the analysis. Basic information needed includes land use, stream lengths and net flow, reservoir depths and volumes, and estuary salinity distributions. Point source loading data is also needed.

Output format:

Output from the model includes: 1) predicted stream concentrations of BOD, DO total N, total P, Temperature and conservative pollutants by reach; 2) total lake nutrient concentrations, eutrophic status and hypolimnion DO-deficient. Estuary concentrations are done by hand calculator and can be arranged to the user's convenience.

User manual:	Yes
Learning difficulty:	Low
Geographic area:	Estuary, lake, stream/river, urban, rural
Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	Yes
Radioactivity:	No
Salinity:	No
Conservative minerals:	Yes
Time-dependent input:	No
Changes in channel flow:	No
Aeration:	Yes
Waste treatment plant input:	Yes
Time variant pollution:	No
Point source:	Yes
Nonpoint source:	Yes
Steady state:	Yes
Unsteady state:	No
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	Yes
Ocean inlet:	Yes
Mixing zones:	Yes
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	Yes
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Water flow from a simulation:	No
Automatic time interval generation:	No
Infiltration rates:	No

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Model acronym: **WQRRS**
Model name: Water Quality for River Reservoir Systems
Sponsor: HEC, US Army Corps of Engineers
Developer: Hydrologic Engineering Center (HEC)
US Army Corps of Engineers
Contact: R.G. Willey
Contact address: Hydrologic Engineering Center (HEC)
609 Second Street
Davis, CA 95616
Contact telephone: (916)440-3292
Availability: Public
Type of model: Surface water general
Summary: Simulation of hydraulics and water quality in a river-reservoir system.

Abstract:

WQRRS was developed and is supported by the U.S. Army Corps of Engineers' Hydrologic Engineering Center. The WQRRS model (HEC, 1978) consists of three separate but integral modules: the reservoir module, the stream hydraulic module, and the stream quality module. The three computer programs may be integrated for complete river basin water quality analysis through automatic storage of results. An output tape can be made for input to a separate plotting and statistical program called the Statistical and Graphical Analysis of Stream Water Quality Data (HEC, 1978).

The system is based on a comprehensive lake ecological simulation program originally developed by Chen and Orlob (1972) and a river simulation model developed by Norton(1972). The original river routines only simulated steady hydraulic conditions, so the capability to dynamically route streamflow using either the St. Venant equations, Kinematic Wave, Muskingum or Modified Pulse method was added. Subsequent updating of the system added the capability to analyze branched/looped stream systems and added additional water quality/biological constituents (King, 1976; Smith, 1978). A separate program for statistical and graphical analyses of stream water quality data is available (HEC, 1978).

Document citations:

Chen, C.W. and Orlob, G.T. Ecologic Simulation of Aquatic Environments, Office of Water Resources Research, U.S. Dept. of Interior, Washington, D.C.,1972.

King, I.P. Flow Routing for Branched River Systems, prepared for Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, CA 95616, 1976.

Norton, W.R. An Assessment of Water Quality in the Lower American River: Past, Present and Future, County of Sacramento, Dept. of Public Works, Sacramento, CA 95616, 1972.

HEC, Water Quality for River Reservoir Systems, Hydrologic Engineering Center, US Army Corps of Engineers, Davis, CA 95616, 1978a.

HEC, Statistical and Graphical Analyses of Stream Water Quality Data. Hydrologic Engineering Center, US Army Corps of Engineers, Davis CA, 1978b.

Smith, D.J. Revised Water Quality for River Reservoir Systems Model, prepared for Hydrologic Engineering Center, US Army Corps of Engineers, Davis, CA 95616, 1978.

Willey, R.G. and Huff, D. Chattahoochee River Water Quality Analysis, Hydrologic Engineering Center, US Army Corps of Engineers, Davis, CA 95616, 1978.

Willey, R.G., Abbot, J. and Gee, M. Oconee River Water Quality and Sediment Analysis, Hydrologic Engineering Center, US Army Corps of Engineers, Davis, CA 95616, 1977.

Assumptions: WQRRS simulates reservoirs as a one-dimensional vertical plane and stream segments as a one-dimensional horizontal plane.

Current implementation: Mainframe computer

Current Hardware: Univac 1108, IBM 360/50, CDC 7600, Honeywell 600

Software language(s): FORTRAN

Word size(s): 50,000 words on Univac 1108

Operating system(s): Magnetic tape storage, printer any model

Input requirements:

(1) Initial setup/calibration needs are: (a) flow rates for all lake/stream inflows, (b) lake and stream hydrogeometric data, (c) lake outflow elevations and locations, (d) latitude and longitude of prototype systems, (e) Secchi disc depth for light extinction, (f) concentrations of quality constituents, biological parameters and temperatures in all lake inflows and river sediments throughout the simulation period, (g) initial conditions of quality constituents, biological parameters and temperatures in each lake layer and river segment, (h) all kinetic parameters, including growth rates, decay rates, respiration rates, settling velocities, mortality rates and other chemical-ecologic reaction rates, (i) temperature stability coefficients, and (j) meteorological data-air temperature (wet and dry bulb), atmospheric pressure, wind speed, sky cover, (2) verification needs are: (a) conditions of quality constituents, biological parameters and temperatures during the simulation period (vertical profile for lakes, horizontal profile for river segments), (b) constituent concentrations, biological parameters, and temperatures at the lake outflow for specified time periods, and (c) time history of lake water surface elevations during simulation.

Output format:

(1) Information Output consists of: (a) time history of quality constituents, temperatures and biological parameters in each lake layer and river segment, (b) time history of quality constituents, temperatures and biological parameters in lake outflows, and (c) all input values specified (2) output formats are: (a) tabular printout and (b) reservoir outflows to river system recorded on cards or magnetic tape.

User manual: Yes

Date of first version: 1972

Date of latest version: Sept. 1980

Date of latest documents: 1978

Learning difficulty: Medium

User support: Yes, (916)440-2105 or (FTS) 448-2105 Jerry Willey

Debugging maintenance: Yes

Continued enhancement: No

Geographic area: Lake, stream/river

AD-A133 454 FEASIBILITY STUDY FOR AN AIR FORCE ENVIRONMENTAL MODEL AND DATA EXCHANGE..(U) GENERAL SOFTWARE CORP LANDOVER MD S MCKENZIE ET AL. JUL 83 AFESC/ESL-TR-82-13-VOL-3 3/3

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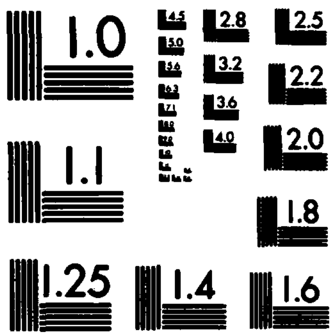

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Analytical Features for Model:	Water Quality
Oxygen:	Yes
Water temperature:	Yes
DO level:	Yes
Benthal oxygen:	Yes
Phosphorous:	Yes
Coliforms:	Yes
Chlorophyll-A:	Yes
Radioactivity:	No
Salinity:	No
Conservative minerals:	No
Time-dependent input:	Yes
Changes in channel flow:	Yes
Aeration:	Yes
Respiration:	Yes
Photosynthesis:	
Waste treatment plant input:	Yes
Evaporation and precipitation effects:	Yes
Time-variant pollution:	Yes
Point source:	Yes
Nonpoint source:	Yes
Steady state:	
Unsteady state:	Yes
Stream and river:	Yes
Reservoir and lake:	Yes
Estuarine:	No
Ocean inlet:	No
Dam computation:	
Mixing zones:	No

Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	No
Large watershed areas:	No
Rural land areas:	Yes
Urban land areas:	Yes
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	Yes
Water flow from a simulation:	Yes
Infiltration rates:	No

(99)

Model acronym: **WSP2**
Model name: Water Surface Profile 2
Sponsor: U.S. Department of Agriculture
Developer: Soil Conservation Service
Contact: National Technical Information Service
Magnetic Tape: PB 260 750
Contact address: Soil Conservation Service
Washington, D.C.
Contact telephone: (202) 447-5157 (Distributions Branch)
Availability: Public
Type of model: Surface Water Quantity
Summary: Determine flow characteristics for streams and flood plains

Abstract:

This program was developed by the Soil Conservation Service to aid in the determination of flow characteristics for a given set of stream and flood plain conditions. It can compute water surface profiles in open channels and estimate head losses at restrictive sections including roadways with either bridge or culvert openings. It is not a general system in that many features have not been considerd (e.g., supercritical flow, multiple bridge openings). The system requires much experience to interpret and validate results but is readily available and convertible to various computers.

Document citations:

U.S. Department of Agriculture, WSP2 Computer Program. Soil Conservation Service, Technical Release 61, Hyattsville, MD, May 1976, (NTIS, PB-260 751).

Schelling, D.R. and Sternberg, Y.M. Highway Stormwater Management Models; Final Report. Department of Natural Resources, Silver Spring, MD, December 1976.

Principal users: Soil Conservation Service

Assumptions:

The program cannot handle supercritical flow and critical depth computations are limited to irregular single-segment cross sections. Important limitations to the BPR bridge analysis procedure are: (1) the channel in the vicinity of the bridge must be nearly straight; (2) cross-sectional area of the stream must be fairly uniform; (3) stream gradient between the exit and approach sections must be approximately constant; (4) flow must be free to contract and expand; (5) no appreciable scour can be present at the bridge; (6) flow must be subcritical.

WSP2 culvert analysis is limited to rectangular, circular and standard arch shapes. A culvert that is deformed by sediments , partially filled with sediment or of a different shape must be represented by one of the three standard shapes. Of all parameters estimated, a close similarity should be maintained between the actual area of the culvert chosen as most representative.

Current implementation:	Mainframe computer
Feasible implementation:	Mini computer
Current hardware:	IBM 360/65 IBM 370/168 (also, CDC & UNIVAC)
Software language(s):	FORTRAN IV, IBM Assembler
Word size(s):	32 bit
Operating system(s):	The program requires about 220 kilobytes of core storage and three temporary data files.
Input requirements:	Computer cards-char. and numerical formatted
Output format:	Printed tables and printer plots, punched card output is available.
Load module storage:	215K bytes
User manual:	Yes
Systems documentation:	Yes
Date of latest version:	1976
Date of latest documents:	1976
Machine interface:	Batch
Learning difficulty:	Medium
Output interpretation difficulty:	Medium
Analytical Features for Model:	Surface Water Hydrology
Small watershed areas:	Yes
Large watershed areas:	Yes
Rural land areas:	No
Urban land areas:	No
Entire hydrographs:	No
Flood routing:	No
Snowmelt considerations:	No
Continuous simulation of a storm event:	No
Continuous simulation in real time:	No
Sedimentation and scour:	No
Water flow from a simulation:	Yes
Automatic time interval generation:	No
Infiltration rates:	No


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