HYDROLOGIC MODELING OF SMALL WATERSHEDS

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chapter 13

CURRENTLY AVAILABLE MODELS

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CURRENTLY AVAILABLE MODELS

by K. G. Renard, Director, Southwest Watershed Research Center, USDA, ARS, Tucson, AZ 85705; W. J. Rawls, Hydrologist, USDA, ARS, Beltsville, MD 20705; M. M. Fogel, Hydrologist and Professor, School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721

Users of hydrologic models for small watersheds are generally faced with the problem of selecting from among the many models available in technical literature. Many of the models are site specific (simplifications and assumptions made preclude their use universally), and, therefore, the user is faced with the problem of selecting the model which will most efficiently provide the answers needed. Although we made no comparisons herein of the simulation ease or accuracy of simulation against a common data base, we attempted to pull all of the models of the hydrologic cycle (or subcomponents of the cycle) into one reference. A summary table is presented which references readily available models on the basis of land use, geographic region, and hydrologic cycle portion to be simulated.

In reviewing the literature, we utilized computer literature searches, manual literature searches, and a survey questionnaire widely distributed to people and groups who were felt might have input. The computer data bases searched were those included in the Water Resources Scientific Information System (WRSIS), National Technical Information Service (NTIS), and the Science and Education Administration — Agricultural Research (SEA-AR, formerly Agricultural Research Service) Current Awareness Literature Search.

About 300 survey questionnaires soliciting information on available models were distributed to the following: Federal agencies involved in water, universities (agricultural engineering, civil engineering, and forestry departments), water resources research centers, selected State water agencies, and selected private consultants. We made no effort to include models developed outside of the United States, although some are included because of developments on these models within the U.S. The following information was requested in the questionnaire:

1 Model name.
2 Author's name(s).
3 Address of the senior author.
4 Hydrologic process simulated.
5 Model description.
6 Time scale of simulation.
7 List of major input variables.

8 List of major output variables.
9 Optimization routine.
10 Status of model.
11 Geographic and land use areas where the model has been used.
12 Computer requirements.
13 Pertinent development references.

Within the space and time allowed, it would be impossible to completely list all hydrologic models mentioned by those answering the questionnaire. Also, we felt a listing would serve no useful purpose since many of the models identified in response to the questionnaire were in various preliminary stages of development and were not ready for immediate use. Without a brief model description, the user would not be able to choose between models. Therefore, we decided to include only computer models that were ready for distribution and for simulating the total or a major land phase portion of the

TABLE I SUMMARY OF CURRENTLY AVAILABLE MODELS

	PROCESS SIMULATED									GEOGRAPHIC AREA						LAND USE			
MODEL NUMBER	TOTAL WATERSHED	PRECIPITATION	SNOWMELT	INFILTRATION	EVAPO TRANSPIRATION	SURFACE RUNOFF	SUBSURFACE FLOW	CHEMICAL MOVEMENT	EROSION / YIELD	NORTHEAST	SOUTHEAST	MIDWEST	SOUTHWEST	NORTHWEST	OTHER	FOREST	PASTURE & RANGE	AGRICULTURE	URBAN
1	O			O		O				O									O
2	O	O		O		O	O		O			O				O		O	O
3	O	O			O	O	O	O	O		O					O		O	O
4	O	O		O	O	O				O			O						O
5		O		O	O	O	O								O	O	O		
6									O	O		O				O	O	O	O
7	O	O	O	O	O	O	O							O		O	O	O	O
8						O				O		O		O				O	
9				O								O		O				O	
10				O		O							O				O		
11	O	O		O	O	O	O					O	O			O	O	O	
12	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
13		O		O	O	O				O	O	O	O	O					O
14			O			O									O				
15	O		O	O	O	O	O	O	O		O	O		O				O	O
16	O		O	O	O	O	O	O	O		O	O						O	
17						O				O	O					O			
18		O										O				O	O	O	O
19				O	O	O	O				O	O				O	O		
20	O										O					O		O	
21				O			O				O					O			
22		O								O	O					O			
23	O		O		O	O	O	O					O	O				O	
24	O		O	O	O	O	O			O	O	O	O	O	O	O		O	O
25		O		O	O	O	O				O					O	O	O	
26	O		O	O	O	O	O	O			O				O	O		O	
27	O		O	O	O	O	O	O	O		O	O				O		O	O
28	O	O		O		O	O		O			O						O	
29	O		O	O	O	O	O			O	O	O	O			O		O	O
30	O			O	O	O	O			O	O	O	O			O		O	O
31				O		O		O		O	O	O	O	O					O
32							O						O				O		
33							O	O								O	O	O	
34		O	O										O	O		O			
35	O	O	O		O	O			O				O	O		O			
36	O	O	O		O	O							O	O		O			
37					O										O			O	
38	O				O		O				O					O		O	
39					O						O					O			
40	O		O		O	O				O	O		O	O	O	O	O	O	

hydrologic process. All models meeting these criteria are given in Appendix 13-A. Generally, the following information is included for each model:

1 Name of the model developer(s). (Models are listed alphabetically according to developer's name.)

2 Model name.

3 Address of the senior model developer.

4 Abstract. (Brief description of what the model does, including computer requirements and general geographic and land use for which the model has been used.)

5 Development reference.

Table 1 summarizes the data of each model included in Appendix 13-A, and lists the hydrologic process simulated, and the general geographic location and land use for which the model has been used or should be used. This table should serve to help direct potential users to the model(s) that best fit their requirements.

TABLE I CONT'D

	PROCESS SIMULATED									GEOGRAPHIC AREA						LAND USE			
MODEL NUMBER	TOTAL WATERSHED	PRECIPITATION	SNOWMELT	INFILTRATION	EVAPO TRANSPIRATION	SURFACE RUNOFF	SUBSURFACE FLOW	CHEMICAL MOVEMENT	EROSION / YIELD	NORTHEAST	SOUTHEAST	MIDWEST	SOUTHWEST	NORTHWEST	OTHER	FOREST	PASTURE & RANGE	AGRICULTURE	URBAN
41					O								O					O	
42	O	O	O	O	O	O	O	O	O			O						O	O
43	O	O		O	O	O	O								O	O	O		
44	O					O	O	O				O							O
45	O	O	O	O	O	O	O							O		O	O	O	O
46							O				O	O				O	O	O	O
47	O		O	O	O	O	O					O				O	O	O	
48	O		O	O	O	O	O	O				O				O	O	O	
49		O										O	O			O	O	O	O
50					O							O	O					O	
51					O	O					O	O	O				O	O	
52	O	O	O	O	O	O	O			O	O	O	O	O	O	O	O	O	O
53	O	O			O	O							O			O			
54					O		O	O				O						O	
55				O		O				O	O	O	O	O	O	O	O	O	O
56					O					O								O	
57				O		O			O				O			O			
58						O				O	O	O	O	O	O	O	O	O	O
59				O		O		O	O			O	O				O		O
60	O	O		O	O	O	O					O						O	
61		O	O	O	O			O						O		O			
62						O					O		O			O	O	O	O
63		O		O		O	O			O	O	O	O	O		O	O	O	O
64		O	O	O		O	O			O	O	O	O	O		O	O	O	O
65		O		O		O		O	O	O	O	O	O	O					O
66					O								O					O	
67					O										O			O	
68		O				O									O			O	O
69	O	O		O	O	O		O	O		O								O
70		O	O	O	O	O		O	O	O	O	O	O	O		O	O	O	O
71									O				O				O	O	
72									O		O	O	O	O		O	O	O	
73						O				O	O	O	O	O	O	O	O	O	O
74						O					O	O	O				O	O	O
75		O	O	O		O						O	O						O
76																			
77																			
78																			
79																			
80																			

During the literature search, we found several comprehensive listings of annotated bibliographies on hydrologic models (Table 2). The reader looking for a developed model for his problem should refer to these for additional summaries on hydrologic models. Several references in Table 2 also compared the predicted results using different models on a common watershed data base. Future efforts along this line are needed to assist users in deciding between models. Such efforts will undoubtedly include requirements for data, as well as computer costs which can vary greatly.

TABLE 2: HYDROLOGIC MODELING REFERENCES

1 Agricultural Research Service. 1977. File of agricultural research models. Agricultural Research Service, National Agricultural Library, Beltsville, Maryland.

2 Bowers, C. E., A. F. Pabst, and S. P. Larson. 1972. Computer programs in hydrology. Bulletin 44, Water Resources Research Center, University of Minnesota, Minneapolis, Minn.

3 Brandstetter, A. 1976. Assessment of mathematical models for storm and combined sewers. Environmental Protection Agency, EPA-600/2-76-175a, Washington, DC. 510 pp.

4 Brown, J. W., M. R. Walsh, R. W. McCarley, A. J. Green, Jr., and H. W. West. 1974. Models and methods applicable to Corps of Engineers urban studies. Miscellaneous Paper H-74-8, U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. 300 pp.

5 Chu, Chung Sang, and C. Edward Bowers. 1977. Computer programs in water resources. Bulletin 97, Water Resources Research Center, University of Minnesota, Minneapolis, Minn.

6 Clarke, R. R. 1973. Mathematical models in hydrology, irrigation, and drainage, Paper #19, Food and Agriculture Organization of the United Nations, Rome. 282 pp.

7 Fleming, G. 1975. Computer simulation techniques in hydrology. Elsevier Environmental Series. 333 pp.

8 McCuen, R. H., W. J. Rawls, G. T. Fisher, and R. L. Powell. 1977. Flood frequency for ungaged watersheds: A literature evaluation, ARS-NE-86, Agricultural Research Service, Beltsville, Maryland. 140 pp.

9 U.S. Forest Service. 1976. Non-point water quality modeling in wildland management: A state-of-the-art assessment. EPA-600/3-77-075, Environmental Protection Agency, Washington, DC.

10 World Meteorological Organization. 1975. Intercomparison of conceptual models used in operational hydrological forecasting. WMO Operational Hydrology Report No. 7, Geneva, Switzerland.

APPENDIX 13-A
CURRENTLY AVAILABLE MODELS, AUTHORS, ABSTRACTS, AND REFERENCES

MODEL NUMBER **Authors**

1 Aron, Gert, and David F. Lakatos, Penn State urban runoff model, 212 Sackett Bldg., University Park, PA 16802.

ABSTRACT: The model was constructed specifically for urban watersheds of the Northeast ranging in size from 0.5 to 10 sq mi, with possible application to areas up to 20 sq mi. The model tracks only water quantity for periods from 30 minutes to 2 days. The program is written in Fortran IV, and requires 280-K storage.

REFERENCE: None.

2 Beasley, D. B., E. J. Monke, and L. F. Huggins, (ANSWERS) Areal non-point source watershed environment response simulation, Department of Agricultural Engineering, Univ. of Arkansas, Fayetteville, AK 72701.

ABSTRACT: The model is a distributed parameter event-oriented watershed model applicable to forest, agriculture, and urban areas of the Midwest. It simulates the hydrologic processes of interception, infiltration, surface and subsurface flow, and detachment and transport of sediment on a spatial basis. A variety of input and output options exist to tailor the model to the particular user's needs. The program is written in Fortran IV using GASP Iv and requires 150 K storage.

REFERENCE: Beasley, D. B. 1977. ANSWERS: A mathematical model for simulating the effects of land use and management on water quality. Unpublished PhD Thesis, Purdue University, 266 p.

3 Betson, Roger P., and Harold E. Pratt, TVA Streamflow simulation and analysis model (SSAM), Tennessee Valley Authority, 410 Evans Building, Knoxville, TN 37902.

ABSTRACT: The model package consists of a continuous daily streamflow model and a storm hydrograph model. These two models can be combined in a simulation version which stochastically generates precipitation and simulates evapotranspiration, surface runoff, subsurface flow, sediment and conservative water quality constituent transport for forest, agricultural and urban land use in the Southeast. The package has an optimization routine. The program is written in Fortran IV and requires 170 K storage.

REFERENCE: Betson, R. P. "Storm hydrographs using a double-triangle model," TVA Research Paper No. 8, Feb. 1972, Knoxville, TN 37902.

4 Boning, Charles W., U.S.G.S. Peak flow synthesis rainfall/runoff model, U.S. Geological Survey National Center, Mail Stop 415, Reston, VA 22092.

ABSTRACT: The model was developed for urban areas of the Northeast and Southwest. The model uses daily rainfall and evaporation moisture conditions to compute infiltration and rainfall excess for selected flood events. The rainfall excess is routed through the basin using translation hydrographs and the attenuation of the hydrograph is accomplished using distributed linear storage reservoirs. The time scale of simulation is from 1 to 60 min. An optimization routine is also included. The program is written in PL/1 and requires between 356 to 756 K storage.

REFERENCE: Charles W. Boning. 1974. Users guide for a US Geological Survey rainfall-runoff model: U. S. Geol. Survey open-file report 74-33, 252 p.

5 Boughton, W. C., The Boughton Model, Griffin University, Nathan, Brisbane Queensland, Australia 4111.

ABSTRACT: Several versions exist (McMahon-Mein version is perhaps the best). The model operates on a daily basis, in three cycles, namely, wetting, drying, and drainage, the former cycle operating only on days with recorded rainfall, while the latter two operate each day. The model, written in Fortran IV, consists of three moisture stores (interception store and upper and lower soil stores), and requires 11 parameters and 4 estimated or assumed moisture states for its complete specification. The model has no routing routine.

REFERENCE: Boughton, W. C. 1968. A mathematical catchment model for estimating runoff. J. of Hydrol. (New Zealand), 7:75-100.

6 Boyce, R. C. SEDEL Sediment Delivery, SCS, CTU, 269 Federal Center Building, Hyattsville, MD 20782.

ABSTRACT: The model estimates river basin sediment yield by sub-basins, sheet erosion by Universal Soil Loss Equation, channel types of erosion by unit rates. Routes through existing or proposed impoundments, computes sediment storage requirements for proposed dams. Parallel computations for suspended load and bedload. The model has been used in the Northeast and Midwest for all types of land use. The program is written in Fortran and requires 37-K storage.

REFERENCE: Boyce, R. C. 1975. Sediment routing with sediment delivery ratio, ARS-S-40, pp. 61-66.

7 Boyd, Donald W., and Theodore T. Williams, State Water Planning Model, 318 Roberts Hall, Montana State University, Bozeman, MT 58415.

ABSTRACT: A system of linear simultaneous solution equations with temperature/time varying coefficients; models primary data base with zero prediction error; expands data base via generation of secondary data; is validated via the method of perturbation; proceeds from macro to micro (relative to space and time) in degree of simplicity to complexity; metric format for ease of linking the other models; linearity permits linear programming solution technique when coupled to an objective function. The program is written in Fortran IV and requires 10-K storage.

REFERENCE: Development of a State Water Planning Model, Parts I, II, III (models), Parts IV, V (data preparation of data bank), Montana University Joint Water Resources Research Center, Montana State University, Bozeman, MT 58415.

8 Brakensiek, D. L., Kinematic flood routing, N.W. Watershed Research Center, USDA-SEA-AR, P.O. Box 2700, Boise, ID 83701.

ABSTRACT: This is a flood routing model that routes inflow as overload flow or channel flow with time scales as specified in the program which is written in Fortran IV.

REFERENCE: Brakensiek, D. L. 1966. Storage flood routing without coefficients, ARS-41-122.

9 Brakensiek, D. L., Green and Ampt infiltration into a layered soil, N.W. Watershed Research Center, USDA-SEA-AR, P.O. Box 2700, Boise, ID 83701.

ABSTRACT: The model calculates depth to wetted front, time to reach that depth, total infiltration amount and rate. The program is written in Fortran IV.

REFERENCE: None.

10 Chery, D. L., Jr., WATSHED, Southeast Watershed Research Center, USDA-SEA-AR, P.O. Box 5677, Athens, GA 30604.

ABSTRACT: The model used kinematic solution of overland and channel flow. Distributed lateral inflow from triangular planes to channel flow and uniform lateral inflow to channel flow can be represented. An interactive infiltration model operates on both plane and channel flow. The model has been applied to range conditions in the Southwest. The program is written in Fortran and requires 51-K storage.

REFERENCE: Chery, D. L. 1976. An approach to simplification of watershed models for application purposes. PhD dissertation, Utah State University, Logan UT 84321.

11 Claborn, B. J., and W. L. Moore, University of Texas Watershed Model/Texas Watershed Model, Department of Civil Engineering, Texas Tech. University, Lubbock, TX 79409.

ABSTRACT: This is a general, continuous, accounting-type of watershed model in which an attempt is made to simulate, as realistically as possible, physical processes occurring in the watershed. Most of the parameters have a physical meaning, and some of them are independently measurable. It emphasizes the importance of soil moisture movement and simulates runoff at a time interval appropriate to the conditions. The model uses many of the same algorithms as the Stanford Model. Major difference is in infiltration (Holtan's equation is used), evaporation, and time scale. The model has been applied to areas in the Midwest and Southwest under all types of land use. The program is written in Fortran and requires 160-K storage.

REFERENCE: Claborn, B. J., and W. L. Moore. 1970. Numerical simulation of watershed hydrology, Tech. Rept. HYD 14-7001, University of Texas, Austin, TX 78712.

12 Crawford, N. H., R. K. Linsley, D. D. Franz, et al., Hydrocomp Simulation Programming (HSP), HYDROCOMP INC., 1502 Page Mill Road, Palo Alto, CA 94304.

ABSTRACT: The HSP system simulates hydrologic processes (including snow accumulation and melt) and water quality processes for as many as 20 water quality variables. Channel processes and reservoirs are also simulated. HSP is a continuous simulation model, and has been used in all sections of the U.S. for all types of land use. The time scale of simulation varies from 5 min to hourly, depending on the process. Statistical analysis of continuous output time series is used to produce data for economic analysis of alternate water management plans. The program is written in PL/I and requires about 250-K storage.

REFERENCES: 1. Hydrocomp 1976. Hydrocomp Simulation Programming Operations Manual, Hydrocomp Inc., Palo Alto, California. 2. Hydrocomp 1977. Hydrocomp Water Quality Operations Manual, Hydrocomp Inc., Palo Alto, CA.

13 Dawdy, David, John Schaake, and William Alley, Dawdy-Schaake Urban Stormwater Model, Dames and Moore, Suite 700, 7101 Wisconsin Ave., Washington, DC 20014.

ABSTRACT: The model computes intermediate and outfall hydrographs for urban or partially urban basins of variable land-use type. The model uses a kinematic method of land surface and has a conduit routing provided for detention reservoir routing. The model uses USGS-type infiltration model with optimization of parameters. The program is written in Fortran IV and requires 250-K storage.

REFERENCE: D. R. Dawdy, John Schaake, and William Allen. 1977. Distributed routing rainfall-runoff model for urban planning, U.S. Geological Survey Computer Contribution (In press).

14 Dingman, S. Lawrence, Snowmelt-runoff model for the U.S. Tundra biome (SNOR03), Institute of Natural and Environmental Resources, University of New Hampshire, Durham, NH 03824.

ABSTRACT: The model simulates a small tundra watershed of low slope as a linear reservoir. In present revision, snowmelt due to solar radiation only is simulated. Distribution of water equivalent on watershed is important to results, and is accounted for in model. Can be modified to nonlinear reservoir, if appropriate. The program is written in Basic language.

REFERENCE: "Development of a Snowmelt-Runoff Model for the U.S. Tundra Biome — Progress Report," by S. Lawrence Dingman, U.S. IBP Tundra Biome Report 73-3, 1973. Available from author or from Dr. Jerry Brown, Director, U.S. Tundra Biome Program, USA CRREL, P.O. Box 282, Hanover, NH 03755.

15 Donigian, A. S., Jr., and N. H. Crawford, Nonpoint Source Pollutant Loading (NPS) Model, HYDROCOMP INC., 1502 Page Mill Road, Palo Alto, CA 94304

ABSTRACT: The NPS Model simulates hydrologic processes (including snow accumulation and melt), erosion processes, and surface nonpoint source pollutants. The hydrologic model is based on the Stanford Watershed Model. The model can simulate up to five different user-specified pollutants from up to five different land uses in a single operation. All pollutants are simulated as a function of the eroded sediment. Pervious and impervious land surfaces within each land use are simulated separately. Channel processes are not simulated. The program is written in Fortran IV and requires 150-K storage.

REFERENCES: 1. Donigian, A. S., Jr., and N. H. Crawford. Modeling nonpoint pollution from the land surface. Office of Research and Development, U.S. Environmental Protection Agency, EPA-600/3-76-083, July, 1976. 2. Donigian, A. S., Jr., and N. H. Crawford. Simulation of nutrient loadings in surface runoff with the NPS model. Office of Research and Development, U.S. Environmental Protection Agency, November, 1976. 109 p. (In press)

16 Donigian, A. S., Jr., and N. H. Crawford, Agricultural Runoff Management (ARM) Model, HYDROCOMP INC, 1502 Page Mill Road, Palo Alto, CA 94304.

ABSTRACT: The ARM Model simulates hydrologic processes (including snow accumulation and melt), erosion processes, pesticide-soil interactions, and soil nutrient transformations to model runoff, sediment loss, and pesticide and nutrient content of runoff from small agricultural watersheds. The hydrologic model is based on the Stanford Watershed Model. No channel processes are simulated. The ARM Model is a continuous simulation model. The program is written in Fortran IV and requires 360-K storage.

REFERENCES: 1. 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. EPA-660/2-74-013. December, 1973. 211 p.

2. Donigian, A. S., Jr., and N. H. Crawford. Modeling Pesticides and Nutrients on Agricultural Lands. Office of Research and Development, U.S. Environmental Protection Agency. EPA-600/2-76-043, February, 1976. 263 p.

3. Donigian, A. S., Jr., D. C. Beyerlein, H. H.Davis, Jr., and N. H. Crawford. The Agricultural Runoff Management (ARM) Model Version II: Testing and Refinement. U.S. Environmental Protection Agency, June, 1977. (In preparation.)

17 Douglass, James E., Streamflow modification, U.S. Forest Service, Coweeta Hydrologic Lab., Box 601, Franklin, NC 28734.

ABSTRACT: Curves or equations are used to predict magnitude and duration of streamflow change after cutting of hardwood forests in Appalachian highlands of eastern U.S. The time scale of simulation is annual and the simulation uses an algebraic expression for changes in basal area, land slope, and aspect.

REFERENCE: Douglass, J. E., and W. T. Swank. 1975. Effects of Management Practices. In *Municipal Watershed Management Symposium Proceedings*, USDA For. Serv. Gen. Tech. Rept. NE-13:1-13.

18 Eli, Robert N., II, and Thomas E. Croley, II, IIHR Hourly Precipitation Model, Department of Civil Engineering, West Virginia Univ., Morgantown, WV 26506.

ABSTRACT: A stochastic data generation model for producing a time series of hourly precipitation accumulations at a point. Related wet time intervals, corresponding to an independent storm event, are scheduled by an inter-arrival time model using a fitted exponential distribution. Intra-storm structure is described in terms of "storm segments," correponding to the passage of a storm rainfall cell or group of cells. The location in time and the duration of storm segments can be entirely specified by independent random variables. The intensity and distribution of precipitation within storm segments are modeled by fitted log-normal intensity probability distributions and by cataloguing sample storm segment shapes. The program is written in Fortran and requires 120-K storage.

REFERENCE: Eli, R. N., and T. E. Croley. 1976. "An hourly precipitation model for Ralston Creek," IIHR Report No. 192, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, IA.

19 Goldstein, R. A., and J. B. Mankin, PROSPER, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94304.

ABSTRACT: Daily evapotranspiration, calculated by combination equation, is in steady state with liquid water flow through vegetation and soil. Liquid water flow is simulated by network equations (potentials, resistances). Darcy flow equation used for water flow between soil layers. Roots occur in the upper two (A and B horizons) of up to five soil layers. The model has been used in the Southeast and Midwest for forest and range conditions. The program is written in Fortran IV.

REFERENCE: Goldstein, R. A., J. B. Mankin, and R. J. Luxmore. 1974. "Documentation of PROSPER: A model of atmosphere-soil-plant-water flow," EDFB-IBP-73-9, Oak Ridge National Laboratory, Oak Ridge, TN.

20 Haan, C. T., Monthly Water Yield Model, Agricultural Engineering Department, University of Kentucky, Lexington, KY 40506.

ABSTRACT: The model simulates monthly water yield based on daily precipitation and average daily potential evapotranspiration. Three types of runs can be made: (1) parameter optimization runs (there are four parameters), (2) simulation runs with four parameters known and with observed monthly runoff, and (3) simulation runs without observed runoff. The model has been primarily used in forest and agricultural areas of the Southeast. The program is written in Fortran IV and requires 115-K storage.

REFERENCE: Haan, C. T. 1975. A monthly water yield model computer program documentation. Agr. Eng. Tech. Rept. 6, Agr. Eng. Dept., University of Kentucky, Lexington, KY.

21 Helvey, J. D., Soil Moisture, U.S. Forest Service, 1133 N. Western Ave., Wenatchee, WA 98801.

ABSTRACT: The model consists of a series of equations which predict soil moisture content in Southern Applachian mountains. The model can be solved easily on any computer by solving some algebraic equations.

REFERENCE: Helvey, J. D., J. D. Hewlett, and J. E. Douglass. 1972. Predicting Soil Moisture in the Southern Appalachians, Soil Science Society of America Proceedings 36(6):954-959.

22 Helvey, J. D., Canopy and litter interception — Hardwoods and pines, U.S. Forest Service, 1133 N. Western Ave., Wenatchee, WA 98801.

ABSTRACT: The model is a series of predictive equations for canopy, streamflow, and litter interception for mixed hardwood forests throughout the eastern U.S. Eastern White Pine in the southern Appalachian Mountains, and Loblolly Pine in the South Carolina Piedmont. The model, consisting of some algebraic equations, simulates on either a storm, season, or annual basis.

REFERENCE: Helvey, J. D. 1967. Interception by Eastern White Pine. Water Resources Res. 3(3):723-729.

23 Hill, Robert W., A. L. Huber, E. K. Israelsen, and J. P. Riley, HYDSM, Utah State University, Department of Agriculture and Irrigation Engineering, Logan, UT 84322

ABSTRACT: River basin hydrology-salinity flow simulation model related to agricultural crop use. The model has been used in the agricultural areas of the Southwest and Northwest. The program is written in Fortran IV and requires 32-K storage.

REFERENCE: None furnished.

24 Holtan, H. N., University of Maryland version of USDAHL Model, Shriver Lab., University of Maryland, College Park, MD 20742.

ABSTRACT: The model uses linear dimensions available from soil survey to compute storage volumes on the soil surface and in layers of soil profiles. Watersheds are zoned by soils, by land use, by slope or whatever feature is important to the problem. Water balances are computed for each layer of each zone to produce watershed outflow. This model has been applied to all types of land use in all geographic parts of the U.S. The program is written in Fortran IV and requires 99-K storage.

REFERENCE: Holtan, H. N., G. J. Stiltner, W. H. Henson, and N. C. Lopez. 1975. USDAHL-74 model of watershed hydrology, USDA Tech. Bull. No. 1518, ARS, Beltsville, MD.

25 Huber, W. C., J. P. Heaney, and P. B. Bedient, HLAND, Department of Environmental Engineering Sciences, Univ. of Florida, Gainesville, FL 32611.

ABSTRACT: The model combines Thornthwaite and Mather soil moisture accounting procedure with SCS runoff method for obtaining soil moisture storage. T-M procedure compiles change in soil storage, areal ET, and surface runoff. A base flow relationship is included. Surface overland flow is routed in a manner equivalent to use of a linear reservoir. Streamflow is routed via the Muskingum method. The model has been used for all types of land use in the Southeast. The program is written in Fortran IV and requires 37-K storage.

REFERENCE: Huber, W. C., J. P. Heaney, P. B. Bodient, and J. P. Bender. "Environmental resources management studies in the Kissimmee River Basin," Final Report No. ENV-05-76-3 to Central and Southern Fla. Flood Control Dist., West Palm Beach, Fla., Dept. of Env. Engr. Sciences, Univ. of Florida, Gainesville, May 1976. 379 p.

26 Huff, D. D., R. J. Luxmoore, J. B. Mankin, and C. L. Begovich, TEHM: A terrestrial ecosystem hydrology model, Bldg. 3017, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, TN 37830.

ABSTRACT: The TEHM is a process oriented, mechanistic model for watershed hydrology and the role of water in transport of nutrients and contaminants. It is designed to interface with an atmospheric transport model, a soil chemistry model, a primary productivity model, and models for the uptake and cycling of materials by basin vegetation. Its core is a soil-plant-atmosphere water dynamics model. Snowmelt is included, but not tested. The model has been used for forest and agricultural areas of the Southeast. The program is written in Fortran IV and requires 540-K storage.

REFERENCE: Huff, D. D., R. J. Luxmoore, J.B. Mankin, and C. L. Begovich. 1977. TEHM: A terrestrial ecosystem hydrology model, ORNL/NSF/EATC-27, EDFB/IBP 76-8, Oak Ridge National Laboratory.

27 Huff, D D., Wisconsin hydrologic transport model, Bldg. 3017, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, TN 37830.

ABSTRACT: This hydrologic transport model is based on the Stanford Watershed Model and forms a major component of the Unified Transport Model developed at ORNL. It includes the hydrologic transport of a trace contaminant by entrainment in overland flow, infiltration, impervious area runoff and subsurface flow. Chemical exchange is designed to interface with atmospheric transport and sediment transport modules. The model has been used for all types of land use for the Southeast and Midwest. Optimization is included. The program is written in Fortran IV and requires 540-K storage.

REFERENCE: Patterson, M. R. et al. 1974. A user's manual for the FORTRAN IV version of the Wisconsin hydrologic transport model. ORNL/NSF/EATC-7, EDFB/IBP/74-9, Oak Ridge National Laboratory.

28 Huggins, L. F., D. B. Beasley, E. J. Monke, and J. R. Burney, ANSWERS, Agricultural Engineering Department, Purdue University, W. Lafayette, IN 47907.

ABSTRACT: The model uses a distributed parameter approach to characterize behavior of all points throughout the catchment. Watershed is subdivided into a grid of elements for simulation. Model generally applicable to areas less than 20 sq mi. Time scale of simulation is variable, but usually resolution to 1 min. The model has been used for agricultural areas of the Midwest. The program is written in Fortran and storage depends on number of watershed elements.

REFERENCES: 1. Beasley, D. B. 1977. ANSWERS: A mathematical model for simulating the effects of land use management on water quality. PhD Thesis, Purdue University. 2. Huggins, L. F., and E. J. Monke. 1968. A mathematical model for simulating the hydrologic response of a watershed. Water Resour. Res. 4(3):529-539.

29 James, L. Douglas, Kentucky Watershed Model, Utah Water Research Laboratory, Utah State University, Logan, UT 84322.

ABSTRACT: This is Fortran translation and modification of the Stanford Watershed Model providing continuous simulation of streamflow and other hydraulic responses. The model has been used for all types of land use and in all geographic areas of the U.S., except the Northwest. The program includes an optimization routine and requires 150-K storage.

REFERENCE: James L. Douglas. 1972. Hydrologic modeling, parameter estimation, and watershed characteristics. J. of Hydrol. 17:283-307.

30 James, L. Douglas, OPSET, Utah Water Research Laboratory, Utah State Univsity, Logan, UT 84322.

ABSTRACT: This is a self-calibrating version of the Stanford Watershed Model. The model will proceed from default initial values to estimate values for each parameter that best matches simulated to recorded flows. Time scale of simulation is 15 min. The model has been used for all types of land use and in all geographic parts of the country, except the Northwest. The program is written in Fortran IV and requires 90-K storage.

REFERENCE: Liou, E. Y. 1970. OPSET: Program for computerized selection of watershed parameter values for the Stanford Watershed Model. Research Report 34, Water Resources Institute, University of Kentucky, Lexington, KY.

31 Jennings, Marshall E., QWILLUDAS, U.S. Geological Survey, Gulf Coast Hydro Science Center, Bay St. Louis, MS 39529.

ABSTRACT: The model is basically the urban stormwater model ILLUDAS, developed by the Illinois State Water Survey with additions for detention reservoir flow and QW routing of land-use pollutants. The model has been used in all geographic sections of the U.S. The program is written in Fortran IV and requires 280-K storage.

REFERENCE: Tenstreip, Michael L., and John B. Stall. 1974. The Illinois urban drainage area simulator, ILLUDAS. Illinois State Water Survey, Bull. 58, 90 p., Urbana, IL.

32 Lane, L. J., Southwest Watershed Research Center, USDA-SEA-AR, 442 East Seventh Street, Tucson, AZ 85705.

ABSTRACT: A stochastic runoff model was developed for describing intermittent and independent runoff events in arid/semiarid areas of the Southwest. A probability distribution is used to describe variables for the start of the runoff season, number of events per season, time interval between events, beginning time of the runoff event, and runoff volume and peak discharge. The mean and standard deviation used to describe each distribution are expressed as functions of the watershed area. The program is written in Fortran and requires 50-K storage.

REFERENCES: 1. Diskin, M. H., and L. J. Lane. 1972. A basinwide stochastic model for ephemeral stream runoff in southeastern Arizona. Bulletin IAHS 17(1):61-76. 2. Lane, L. J. and K. G. Renard. 1972. Evaluation of a basinwide stochastic model for ephemeral runoff from semiarid watersheds. TRANSACTIONS of the ASAE 15(1):280-283.

33 Larson, N. M., and M. Reeves, No model name. Oak Ridge National Laboratory, Oak Ridge, TN 37830.

ABSTRACT: This model predicts coupled movement of water and trace contaminants through a layered and unsaturated soil-moisture zone. Rapid computation speed is achieved via approximation of moisture properties as exponential functions of pressure head, allowing analytical solution of the resulting equations. The model depends on site-specific parameters. The program is written in Fortran IV and requires 270-K storage.

REFERENCE: Larson, N. M., and Reeves, M. Analytical analysis of soil-moisture and trace-contaminant transport, Oak Ridge National Laboratory Report, Oak Ridge, TN ORNL/NSF/EATC-12.

34 Leaf, Charles F., and Glen E. Brink, Snow melt model (MELTMOD), 4412 E. Mulberry #113, Fort Collins, CO 80521.

ABSTRACT: The model simulates daily snowmelt in Colorado subalpine watersheds for all combinations of aspect, slope, elevation, and forest cover composition and density. The model simulates winter snow accumulation, the energy balance, snowpack condition, and resultant melt in time and space. The model has been used in the Southwest and Northwest. The program is written in Fortran IV and requires 50-K storage.

REFERENCE: Leaf, Charles F., and Glen E. Brink. 1973. Computer simulation of snowmelt within a Colorado subalpine watershed. USDA For. Serv. Res. Pap. RM-99, 22 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, CO.

35 Leaf, Charles F., and Glen E. Brink, Land use model (LUMOD), 4412 E. Mulberry #113, Fort Collins, CO 80521.

ABSTRACT: This model simulates the short- and long-term hydrologic impacts of combinations of timber harvesting and weather modification to develop management strategies for planning intervals which can vary from a few years to the rotation age of subalpine forests (120 yr and longer). The model contains time trend functions which compute changes in evapotranspiration, soil water, forest cover density, reflectivity, interception, snow redistribution, and sediment yield as the forest stands respond to timber harvesting. The program is written in Fortran IV and requires 60-K storage.

REFERENCE: Leaf, Charles F., and Glen E. Brink. 1975. Land use simulation of the subalpine coniferous forest zone. USDA For. Serv. Res. Pap. RM-135, 42 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, CO.

36 Leaf, Charles F., and Glen E. Brink, Water Balance Model (WBMODEL), 4412 E. Mulberry #113, Fort Collins, CO 80521.

ABSTRACT: This model is specifically designed to determine the probable hydrologic changes resulting from watershed management in the Colorado subalpine zone. It simulates the total water balance on a continuous year-round basis and compiles the results from individual hydrologic response units into a "composite overview" of an entire drainage basin. The program is written in Fortran IV and requires 100-K storage.

REFERENCE: Leaf, Charles F., and Glen E. Brink. 1973. Hydrologic simulation model of Colorado subalpine forest. USDA For. Serv. Res. Pap. RM-107. 23 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, CO 80521.

37 Makkink, G. F., and H. D. J. van Heemst. ROTTEGAT. Agricultural University, Wageningen, Netherlands.

ABSTRACT: ROTTEGAT is a computer program which simulates the water balance of the soil and the depth of the shallow water table. The model which operates continuously is based on macrometeorological data, the physical properties of the soil, the hydrological situation of the field, and some pertinent data on the crop cover throughout the year. The program is written in CSMP language and has been used in the Netherlands.

REFERENCE: Makkink, G. F., and H. D. J. van Heemst. 1974. Simulation of the water balance of arable land and pastures. Simulation Monographs, Centre for Agricultural Publishing and Documentation, Wageningen, Netherlands.

38 Molz, Fred J. Practical simulation models for the subsurface hydrologic system, Civil Engineering Department, Auburn University, Auburn, AL 36830.

ABSTRACT: The model consists of the groundwater flow equation with a source term to allow for groundwater recharge. The model has national application under all types of land use. The program is written in Fortran with variable storage provisions.

REFERENCE: Molz, F. J. Practical simulation models of the subsurface hydrologic system. W.R.R.I. Bulletin 19, Water Resources Research Inst., Auburn University.

39 Moore, Allen, LEM: Litter evaporation model, Biology Department, Western Carolina University, Cullowhee, NC 28723.

ABSTRACT: The model predicts daily water content and evaporative losses in the litter of a mixed deciduous forest. Model incorporates throughfall and litter delay functions. The model has been used for forested areas of the Southeast. The program is written in Fortran.

REFERENCE: Moore, A., and Swank, W. T. 1974. A model of water content and evaporation for hardwood leaf litter. In *Mineral cycling in Southwestern ecosystems*, F. G. Howell, J. B. Gentry, and M. H. Smith eds., ERDA Symposium Series CONF-740513, pg. 58-69,

40 National Weather Service Hydrologic Research Laboratory, National Weather Service River Forecast System, National Weather Service, W23, NOAA, Silver Spring, MD 20910.

ABSTRACT: This is an operational model for real time simulation for river forecasting. It contains many models including catchment (Sacramento) snow accumulation and ablation, dynamic wave routing, reservoir operation and extended streamflow prediction. Also contains procedures for data processing and analyses for calibration and forecast models. The model has been used in all sections of the country for all types of land use. The program is written in Fortran and contains an optimization routine.

REFERENCE: Staff, Hydrologic Research Laboratory, "National Weather Service river forecast system, forecast procedures," *NOAA Tech Memo NWS HYDRO-14 and HYDRO-17*, U.S. Dept. of Commerce, Silver Spring, MD December 1972.

41 Nimah, M. N. and R. J. Hanks. No model name. Utah State University, Department of Soil Science and Biometeorology, Logan, UT 84321.

ABSTRACT: A model to predict soil water content profiles, evapotranspiration, water flow from or to the water table, root extraction, and root water potential under transient field conditions.

REFERENCE: Nimah, M. N., and R. J. Hanks. 1973. Model for estimating soil water, plant and atmospheric interrelations: I. Description and sensitivity. Soil Sci. Soc. of Am. Proc. 37(4):522-527.

42 Novotny, Vladmir, LANDRUN, Department of Civil Engineering, Marquette University, 1515 W. Wisconsin Place, Milwaukee, WI 53233.

ABSTRACT: This program models the total hydrologic cycle. The kinematic wave theory is used for the flow routing. Erosion modeling is based on the Universal Soil Loss Equation and chemical pollution is based on absorption theory. The model has been used for agricultural and urban areas of the Midwest. The program is written in Fortran IV and requires 30-K storage.

REFERENCE: Novotny, V., J. G. Mahoney, and J. Konrad. 1976. Land use effect on water quality. An overload non-point continuous model. Nat. Conf. on Env. Eng., ASCE, Seattle, WA.

43 Porter, J. W., and T. A. McMahon, The monash model, Melbourne and Metropolitan Board of Works, Melbourne, Victoria, Australia.

ABSTRACT: This model is applicable to any catchment to synthesize daily (or hourly) discharges on a continuous basis using rainfall and evaporation data. Infiltration is based upon an adaptation of a simplified equation derived from diffusion theory by Philip, and nonlinear routing techniques were used in both the daily and hourly versions of the model. Spatial and temporal variations in rainfall can be considered by dividing the catchment into sub-areas, and up to four hydrologic regimes may be specified to model spatial variations in physical characteristics. The model is written in Fortran IV.

REFERENCE: Porter, J. W., and T. A. McMahon. 1975. Application of a catchment model in southeastern Australia. J. Hydrol. 24:121-134.

44 Preul, H. C., and C. Papadakis, Storm water management. Division of Water Resources, Civil Engineering Dept., University of Cincinnati, Cincinnati, OH 45221.

ABSTRACT: Two mathematical models of urban runoff are presented: One simulates the rate of runoff, and the other simulates the rate of pollution transport. The reference also reviews urban runoff models. The model has been tested using watershed characteristics and runoff quantity and quality data for a combined sewer watershed in Cincinnati.

REFERENCE: Pruel, H. C., and C. Papadakis. 1970. Urban runoff characteristics. EPA Water Pollution Control Research Series 11024 DQU 10/70. 339 p.

45 Quick, M. C., and A. Pipes, UBC Watershed Model, Department of Civil Engineering, University of British Columbia, Vancouver, B.C., Canada.

ABSTRACT: The model is designed for forecasting runoff from mountain catchments and for this reason the model is divided into area-elevation bands. The model estimates snowpack accumulation and depletion, and operates entirely from meteorological inputs of daily maximum and minimum temperatures and precipitation. Soil moisture and groundwater characteristics are used to control the sub-division into fast, medium, and slow components of runoff. These various components of runoff are routed to the stream system by using unit hydrograph and storage routing techniques. Additional facilities are available in the model to describe lake storage and lake routing. The model has been used for all types of land use in the Northwest. The program is written in fortran IV and requires 300-K storage.

REFERENCE: Quick, M. C., and Pipes, A. "Daily and seasonal forecasting with a water budget model," Proceedings of the International Symposium on the Role of Snow and Ice in Hydrology, UNESCO, WMO, and NRC, Banff, Canada, September 1972, pp. 1017-1034.

46 Reeves, M., and J. O. Duguid, Model name - none, Oak Ridge National Laboratory, Oak Ridge, TN 37830.

ABSTRACT: The model provides solution to the nonlinear saturated-unsaturated flow equations for two-dimensional flow under transient conditions. The model depends on site specific parameters. The program is written in Fortran IV.

REFERENCE: Reeves, M., and Duguid, J. O. Water movement through saturated-unsaturated porous media: A finite-element Galerkin model, Oak Ridge National Laboratory Report, Oak Ridge, TN ORNL-4927, 1975.

47 Ricca, Vincent T., The Ohio State University version of the Stanford streamflow simulation model, The Ohio State University, 1790 Neil Avenue, Columbus, OH 43210.

ABSTRACT: This is a deterministic model which generates continuous watershed hydrographs in response to precipitation data. The program is written in Fortran IV and requires 300-K of storage.

REFERENCES: 1. Ricca, V. T. 1972. "The Ohio State University version of the Stanford streamflow simulation model," Office of Water Resources Research, USDI, Projects #B-005-OHIO, and B-019-OHIO. 2. Warns, J. C. 1971. "User's Manual for The Ohio State University version of the Stanford Streamflow Simulation Model IV." M.S. Thesis, The Ohio State University.

48 Ricca, Vincent T., The deep mine source model and the refuse pile and strip mine pollutant source model, The Ohio State University, 1790 Neil Avenue, Columbus, OH 43210.

ABSTRACT: These models produce a time trace of acid load and flow rate from acid drainage sources as a function of climatic conditions, watershed status, and mine situations. The model, written in Fortran IV, requires 300-K and has been used on Midwestern watersheds.

REFERENCES: 1. North, A. H. 1971. "Acid mine drainage: A mathematical model." PhD Dissertation, The Ohio State University. 2. Blemel, G. D. 1975. "Watershed evaluation and data needs for hydrologic and acid mine drainage modeling." M.S. Thesis, The Ohio State University.

49 Richardson, C. W., Time-area rainfall generation, USDA-SEA-AR, Box 748, Temple, TX 76501.

ABSTRACT: This model generates daily rainfall amounts at multiple points in an area or watershed with the same statistical properties as observed rainfall. The model has been used in the Midwest and Southwest. The program is written in Fortran IV and requires 32-K storage.

REFERENCE: Richardson, C. W. "A model of stochastic structure of daily precipitation over an area," PhD dissertation, Dept. of Civil Engineering, Colorado State University, 1976.

50 Richardson, C. W., and J. T. Ritchie, Water balance model, USDA-SEA-AR, P.O. Box 748, Temple, TX 76501.

ABSTRACT: The model predicts daily components of the water balance of an agricultural watershed. The model has been used for range and agricultural conditions in the Southeast, Midwest, and Southwest. The program is written in Fortran and requires 40-K storage.

REFERENCE: Richardson, C. W., and J. T. Ritchie. Soil water balance for small watersheds, TRANSACTIONS of the ASAE 16(1):72-77. 1973.

51 Ritchie, Joe T. No model name. Grassland-Forage Research Center, USDA-SEA-AR, Box 748, Temple, TX 76501.

ABSTRACT: Models the daily evaporation rate from a row crop canopy situation in which the soil water supply to the plant roots is not limited. The crop evaporation rate is calculated by adding the soil surface and surface components (based on a leaf area index), the potential evaporation, the rainfall, and the net radiation above the canopy.

REFERENCE: Ritchie, J. T. 1972. Model for predicting evaporation from a row crop with incomplete cover. Water Resources Research 8(5):1204-1213.

52 Rockwood, David M., Streamflow synthesis and reservoir regulation (SSARR), Army Corps of Engineers, North Pacific Division, 220 N.W. 8th Avenue, Portland, OR 97209.

ABSTRACT: This model simulates the runoff process in complex river basins. The three major components of the model are: a generalized watershed model which translates rainfall/snowmelt into runoff according to continuous soil moisture accounting indices; a river routing model; and a reservoir regulation model. It can be operated in a forecasting mode to predict future streamflows. The model has been used in all sections of the country for all types of land use. The model is written in Fortran and requires 32-K of storage.

REFERENCE: Rockwood, D. M. 1975. SSARR, Streamflow synthesis and reservoir regulation model, U.S. Army Corps of Engineers, North Pacific Division, Portland, OR.

53 Rogerson, Thomas L., Ouachita HYDROSIM, Southern Forest Experiment Station, 830 Fairview Street, Fayetteville, AR 72701.

ABSTRACT: This is a simple simulation model to predict the water balance and hydrologic changes resulting from thinning small pine-hardwood drainages in central Arkansas. The program is written in GPSS and requires 100-K storage.

REFERENCE: Rogerson, T. L. Simulating hydrologic behavior on Ouachita Mountain Drainages. USDA, FS Research Paper SO-119.

54 Saxton, Keith E., AET2-NUT, USDA-SEA-AR, Smith Agricultural Engineering Building, Washington State University, Pullman, WA 99164.

ABSTRACT: Part one, AET2, is a detailed daily budget of evapotranspiration and soil moisture considering atmospheric, plant, and soil characteristics. Daily relationships of plant canopy, phenological development, rooting, and moisture stress are used. Soil water movement in a 6-ft profile is calculated by tension and conductivity relationships. Part two, NUT, calculates daily nitrate budgets in the soil profile by considering fertilizer addition, plant uptake, and water movement. The model has been used in agricultural areas of the Midwest. The program is written in Fortran and requires 140-K storage.

REFERENCE: Saxton, K. E., H. P. Johnson, and R. H. Shaw. 1974. Modeling evapotranspiration and soil moisture. TRANSACTIONS of the ASAE 17(4):673-677.

55 Schaake, John C. Jr., Deterministic urban runoff model, Hydrologic Research Laboratory, W23, National Weather Service, NOAA, Silver Spring, MD 20910.

ABSTRACT: The model uses kinematic wave equations and a selection of infiltration equations to route surface runoff overland and through a channel system. Model allows distributed precipitation inputs and distributed parameters. Model is similar to MIT Catch-Model. The model has been used for all types of land use in all areas of the country. The program is written in Fortran IV and requires 8-K words of storage.

REFERENCE: 1. Schaake, J. C. 1971. Deterministic urban runoff model, Chapter VIC, in Treatise on Urban Water Systems. Ed. by M. L. Albertson et al., Colorado State University, pp. 357-383. 2. Leclere, G., and J. C. Schaake. 1973. Methodology for assessing the potential impact of urban development on urban runoff and the relative efficiency of runoff control alternatives, MIT Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Report 167.

56 Showcroft, R. W. and E. R. Lemon. The soil-plant-atmosphere model, USDA-SEA, Cornell University, Bradfield Hall, Ithaca, NY 14853.

ABSTRACT: The model sequence is: (1) to define the response of leaf and soil surfaces to a given microclimate; (2) to calculate the immediate microclimate of the leaf and soil surface from the gross meteorological boundary conditions; (3) to calculate the specific response of leaf and soil surfaces to this immediate microclimate; and (4) to sum this response from the soil surface to the top of the crop by layers. The program is written in Fortran and simulates on a 1/2- or 1-hr interval.

REFERENCE: Showcroft, R. W., E. R. Lemon, L. H. Allen, D. W. Stewart, and S. E. Jensen. 1974. The soil-plant-atmosphere model and some of its predictions. Agr. Meteor. 14:287-307.

57 Simons, D. B., R. M. Li, and M. A. Stevens, WASED, Civil Engineering Department, Engineering Research Center, Colorado State University, Fort Collins, Co 80523.

ABSTRACT: The model allows user to stratify watershed into homogeneous land and channel units. It is an individual storm model which includes water balance, loose soil detachment by raindrop impact and by moving water, and water and sediment routing for both overland and channel flow systems. Flow routing is by nonlinear kinematic wave approximation. The model has been used for forested areas of the Southwest. The program is written in Fortran with the storage requirement proportional to the watershed size and number of simulation units.

REFERENCES: 1. Simons, D. B., R. M. Li, and M. A. Stevens. 1975. Development of a model for predicting water and sediment routing and yield from storms on small watersheds. USDA Forest Service, Rocky Mountain Forest and Range Expt. Station, Flagstaff, AZ. 2. Li, R. M., R. K. Simons, and L. Y. Shiao. 1977. Mathematical modeling of on-site soil erosion. Proc. Int. Symp. on Urban Hydrology, Hydraulics and Sediment Control, University of Kentucky, Lexington, KY. p. 87-94.

58 Soil Conservation Service, U.S. Department of Agriculture, Computer program for project formulation hydrology (TR), Central Technical Unit, Room 269, Federal Building, Hyattsville, MD 20782.

ABSTRACT: This model computes surface runoff resulting from any synthetic or natural rain storm; develops flood hydrographs; routes through stream channels and reservoirs; combines hydrographs with those from tributaries and provides peaks and/or flood hydrographs, their time of occurrence and water surface elevations at any desired cross-section or structure. Up to nine storm rainfall distributions can be used for continuous analyses of a watershed under present conditions and with combinations of land cover/use, structural

and/or channel modifications. The model has been used for all types of land use all over the country. The program is written in Fortran IV and requires 256-K storage.

REFERENCE: Soil Conservation Service — Technical release-20 (TR-20) computer program for project formulation hydrology, May 1965, Supplement 1, March 1969.

59 Smith, R.E., and D. A. Woolhiser, KINEROS, USDA-SEA-AR, Engineering Research Center, CSU Foothills Campus, Fort Collins, CO 80521.

ABSTRACT: The model uses kinematic approximation and mass balance for runoff from infiltrating planes. Watershed topography is approximated by sequences of cascading planes and branching channels. Water quality and quantity simulated on storm runoff using transfer function assumptions. Erosion quantities totaled and erosion sedimentation depths calculated (optional). The model has been used in the Midwest and Southwest on range and urban conditions. The program is written in Fortran and requires 70-K storage.

REFERENCE: Smith, R. E. 1977. Field test of a distributed watershed erosion/sedimentation model. In *Soil erosion: Prediction and control*, Proc. Nat'l Conf. on Soil Erosion. SCSA Special Publ. #21, pp. 201-209, Ankeny, IA.

60 Smith, R. L., and Ernest C. Pogge, Kansas water budget model, University of Kansas, Civil Engineering Department, Lawrence, KS 66044.

ABSTRACT: The KWBM takes as input hourly and daily precipitation, and maximum and minimum daily temperatures. Simulation of the land phase of the hydrologic cycle is performed. Moisture accounting on various zones of soil profile is performed. Surface runoff, interflow and baseflow are outputted on a daily basis. The program has been used in agricultural areas of the Midwest. The program is written in Fortran.

REFERENCE: Smith, R. L., and A. M. Lumb. 1966. Derivation of basin hydrographs. Kansas Water Resources Research Institute Contribution No. 19, Lawrence, KS.

61 Sollins, Phillip, G. Swartzman, and Al Brown, CONIFER, USFS Forest Sci. Laboratory, 3200 Jefferson Way, Corvallis, OR 97331.

ABSTRACT: CONIFER consists of about 40 nonlinear difference equations, and is designed to predict effects of perturbations (e.g., thinning, defoliation, fertilization, climatic change) on productivity, water yield, and rates of N circulation. Water and N flux in through fall, litter, and soil drainage are considered as are evaporation from canopy surfaces, transpiration, and evaporation from litter. Many hydrologic processes are keyed to leaf area index and percent canopy cover, both of which are calculated from carbon state variables (foliage and stem carbon mass) of the model. Decomposition processes are also modeled. The model has been used in the Northwest. The program is written in Fortran.

REFERENCE: CF Modeling Group 1977. CONIFER: A model of carbon and water flow through a coniferous forest (Documentation). Bulletin No. 8, Coniferous Forest Biome, Univ. of Washington, Seattle.

62 U.S. Army Corps of Engineers, HYDPAR — Hydrologic parameters, The Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

ABSTRACT: This model computes SCS and Snyder unit hydrograph and precipitation loss rate parameters from a grid cell data bank of spatial geographic characteristics. The model has been used for all types of land use in the Southeast and Southwest. The program is written in Fortran IV and requires 27-K storage.

REFERENCE: U.S. Army Corps of Engineers. 1977. HYDPAR user's manual, The Hydrologic Engineering Center, Davis, CA.

63 U.S. Army Corps of Engineers, Unit hydrograph and loss rate optimization, The Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

ABSTRACT: The model computes optimal unit graph and loss rate coefficients for a watershed from historical rainfall and runoff data. Several storms may be used to determine overall optimal parameters. The model has been used for all types of land use in all geographic areas of the U.S. The program is written in Fortran IV and requires 20 K-storage.

REFERENCE: U.S. Army Corps of Engineers. 1966. Unit hydrograph and loss rate optimization, The Hydrologic Engineering Center, Davis, CA.

64 U.S. Army Corps of Engineers, HEC-1 Flood hydrograph package, The Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

ABSTRACT: Simulates single event rainfall/snowmelt runoff processes in complex watersheds. Automatic optimization may be made for loss rate and unit graph or routing parameters. Sophisticated hydrologic analysis of basin wide flow-frequencies and analysis of expected annual flood damages may also be accomplished. The model has been used for all types of land use and in all geographic areas of the U.S. The program is written in Fortran IV and requires 35-K storage with four input-output units.

REFERENCE: U.S. Army Corps of Engineers. 1973. HEC-1 flood hydrograph package user's manual, The Hydrologic Engineering Center, Davis, CA.

65 U.S. Environmental Protection Agency, Storm Water Management Model (SWMM), Municipal Pollution Control Division OR&D, Environmental Protection Agency, Waterside Mall, Room 3828, Washington, D.C. 20460.

ABSTRACT: The model gives detailed analysis of urban storm runoff, combined sewer systems, diversions, storage, treatment and receiving waters. Time scale for simulation is single events using short time steps. The program is written in Fortran IV and requires 325-K storage.

REFERENCE: Metcalf & Eddy, Inc., University of Florida, and Water Resources Engineers, Inc., Storm water management model. U.S. Environmental Protection Agency, Report No. 11024DOC07/71, October 1971.

66 van Bavel, C. H. M., and J. Ahmed. No model name. Texas A&M Univ., Dept. of Soil and Crop Sciences, College Station, TX 77843.

ABSTRACT: The joint effect of the distribution of soil water potential and root mass upon the water uptake by the crop is represented by a single equation. The expression is used to join a layered crop canopy model for finding the evapotranspiration, as controlled by stomatal action and weather, with a hydraulic flow model for the root zone and the underlying soil. The program is written in CSMP language.

REFERENCE: van Bavel, C. H. M., and J. Ahmed. 1976. Dynamic simulation of water depletion in the root zone. Ecological Modeling 2:189-212.

67 van Kenlen, H. ARID CROP. Department of Theoretical Production-Ecology, Agricultural University, Wageningen, Netherlands.

ABSTRACT: ARID CROP calculates the course of dry matter production for a crop and the distribution of soil water below that crop from basic or derived physical and physiological properties of plant and soil as well as from meteorological observations from standard weather stations. The model assumes that adequate nutrients are available and that growth is determined mainly by the availabililty of water. The program is written in CSMP and was developed in the Netherlands.

REFERENCE: van Kenlen, H. 1975. Simulation of water use and herbage growth in arid regions. Simulation Monographs, Centre for Agricultural Publishing and Documentation, Wageningen, Netherlands.

68 Wang, Ru-Yih, I-Pai Wu, and L. Stephen Lau, Instantaneous unit hydrograph model. Department of Agricultural Engineering, National Taiwan University, Taipei, Taiwan, Republic of China.

ABSTRACT: A short duration unit hydrograph has been used to develop an instantaneous unit hydrograph by using Nash's method and the method of moment for the Hawaiian small watershed. The instantaneous unit hydrographs have been developed for 29 small watersheds on Oahu using a computer program. The two instantaneous unit hydrograph parameters, Gamma function arguments, N, and reservoir constant, K, were found to correlate with the drainage area with assumed triangular shape for hydrographs. Program is written in Fortran IV.

REFERENCE: Wang, R., I. Wu, and L. S. Lau. Instantaneous unit hydrograph analysis of Hawaiian small watersheds, Technical Report No. 42, pp. 54, Water Resources Research Center, University of Hawaii, Honolulu, Hawaii 96822, USA.

69 Wanielista, Martin, Diversion Storage, Florida Tech University, Box 25000, Orlando, FL 32816.

ABSTRACT: The model determines BOD, SS, N, and P efficiencies for a diversion basin where percolation rates, inventories on soil moisture, routing using Muskingum pollutant transport by exponential function, and impervious and pervious load areas are considered. The program, written in Fortran, requires 120-K storage and was developed for nonpoint pollution work in Florida.

REFERENCE: None provided.

70 Water Resources Engineers/Hydrologic Engineering Center, USCE, Storage, Treatment, Overflow Runoff Model (STORM), Water Resources Engineers, 710 South Broadway, Walnut Creek, CA 94596.

ABSTRACT: The model provides continuous analysis of quantity and quality of storm runoff from urban and non-urban watersheds. Two main uses are:

1. Prediction of wet-weather pollutographs for use in receiving water assessment models.
2. Preliminary sizing of detention reservoirs and treatment plant capacities. The model has been used for all types of land use all over the country. The model is written in Fortran and requires 50-K storage.

REFERENCE: Storage, treatment, overflow runoff model, generalized. Computer Program, User's Manual, July 1976, The Hydrologic Engineering Center, Davis, CA.

71 Williams, J. R. Sediment routing, USDA-SEA-AR, Blackland Research Center, Box 748, Temple, TX 76501.

ABSTRACT: The model routes sediment yield from small watersheds through streams and valleys to the outlet of large watersheds. The technique is based on MUSLE and a first-

amounts of floodplain scour and deposition can be predicted. The model has been used for agricultural and range areas of the Southwest. The program is written in Fortran IV and requires 50-K storage.

REFERENCE: Williams, J. R. Sediment routing for agricultural watersheds. AWRA Water Resources Bulletin, Vol. 11, No. 5, Oct. 1975, pp. 965-974.

72 Williams, J. R., Modified Universal Soil Loss Equation (MUSLE), USDA-SEA-AR, Blackland Research Center, Box 748, Temple, TX 76501.

ABSTRACT: The USLE was modified by replacing the rainfall energy factor with a runoff factor. MUSLE does not require a delivery ratio and is applicable to individual storms. Daily sediment yield is predicted for ungaged watersheds by attaching MUSLE to the SCS curve number water yield model and HYMO. The model has been used in forest, range, and agricultural lands in all parts of the country, except the Northeast. The program is written in Fortran and requires 100-K storage.

REFERENCE: Williams, J. R. Sediment yield prediction with universal equation using runoff energy factor. Proceedings of the Sediment Yield Workshop, Oxford, MS Nov. 28-30, 1972, ARS-S-40, June 1975, pp. 244-252.

73 Williams, J. R., and R. W. Hann, HYMO, USDA-SEA-AR, Blackland Research Center, Box 748, Temple, TX 76501.

ABSTRACT: HYMO is a problem-oriented computer language that is useful in flood control planning, flood forecasting, and water quality modeling. It was designed to transform rainfall into runoff hydrographs and to route these hydrographs through streams and valleys or reservoirs. HYMO will also predict sediment yield for an individual storm at any point on a watershed. The model has been used under all types of land use in all sections of the country. The program is written in Fortran IV and requires 73-K storage.

REFERENCE: Williams, J. R., and R. W. Hann. HYMO: Problem-oriented computer language for hydrologic modeling, User's Manual, USDA ARS-S-9, May 1973, 76 p.

74 Williams, J. R., and W. V. LaSeur, SCS curve number water yield model, USDA-SEA-AR, Blackland Research Center, Box 748, Temple, TX 76501.

ABSTRACT: The model is based on the SCS runoff curve number technique and a soil moisture accounting procedure. It predicts daily runoff from agricultural watersheds with areas up to about 2500 km^2. The model is calibrated on a gaged watershed, and can be used to extend short periods (3-5 yr) of record into long-term periods for the calibrated watershed or to predict water yield for nearby ungaged watersheds. The model has been used in most areas of the country under all types of land use, except forest. The program is written in Fortran and requires 90-K storage.

REFERENCE: Williams, J. R., and W. V. LaSeur. 1976. Water yield model using SCS curve numbers. ASCE J. Hyd. Div. 102(HY9):1241-1253.

75 Yen, Ben Chie, and Ven Te Chow, IUSR: Illinois Urban Storm Runoff Model, Department of Civil Engineering, University of Illinois, Urbana, IL 61801.

ABSTRACT: The model consists of three submodels: a surface runoff quantity and quality model, a channel-sewer system quantity (ISS) model, and a channel-sewer system quality model. They can be run separately. The surface routing is by nonlinear kinematic wave method. The channel-sewer routing is by solving numerically the complete St. Venant equation accounting for backwater effects and reversal flow in networks. The model has been used for urban areas of the Midwest and Southwest. The program is written in Fortran and PL-1 and requires 300-K storage.

REFERENCE: Yen, B.C., A. O. Akan, V. T. Chow, and A. S. Sevuk. 1976. "Prediction model for urban storm runoff." *Utility of urban runoff modeling*, Proceedings of a special symposium of the Am. Geophys. Union 1976 Spring Annual Meeting, ASCE Urban Water Resour. Res. Prog. Tech. Memo. No. 31, pp. 108-117.