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BSAM: Basin Simulation Assessment Model Documentation and User Manual

Utah Water Research Laboratory

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BASIN SIMULATION ASSESSMENT MODEL, BSAM,
DOCUMENTATION AND USER MANUAL

Introduction

The river basin hydrologic simulation model is an evolutionary version of the model orginally developed by the UWRL for simulating the streamflow of the Bear River basin in Utah. Variations of the same basic model have been used to simulate many watersheds and river basins in the Western United States, Mexico, and South American. The underlying concept of the model is that of conservation of mass for a monthly time interval. This is represented by the equation of continuity,

Inflow - Outflow = Change in storage.

A mathematical description of the various hydrologic components of the continuity equation and the routing processes utilized in the model is included in Appendix A. The computer implementation of the model also incorporates a modified pattern search algorithm to aid in the calibration phase of the modeling process. A description of this algorithm as applied to a river basin model is given in the paper, "A Self-Verifying Hybrid Computer Model of River-Basin Hydrology," by R. W. Hill, E. K. Israelsen, A. L. Huber, and J. P. Riley at the Seventh American Water Resources Conference, Washington, D. C., October 24-28, 1971.

Figure 1 shows the structure and interrelationship between the main program, BSAM, and the major subprograms. Detailed instructions for using the program and preparing the input data are given in the following sections. A card listing of the input data for a typical run and the resulting output is given in Appendix B. The FORTRAN computer program is listed in Appendix C.

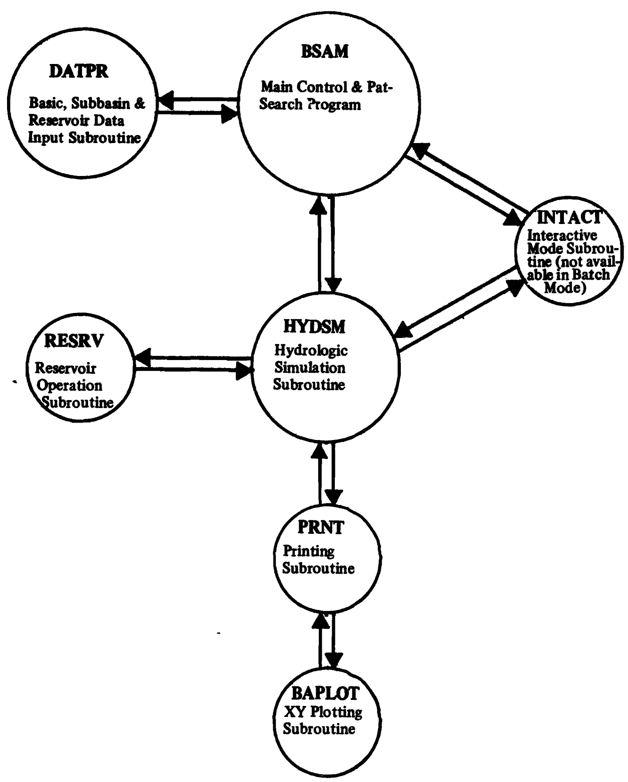

Figure 1. Structure and Interrelationship between BSAM and major subprograms.

General control and I/O structure

After the computer model has been compiled and stored in an executable form, operational control and I/O options are determined by the four variables, ITY, IPL, IPRT, and ICOL punched in the first card of the input data deck. Execution control options are shown schematically in Figure 2 and a deck setup for a typical calibration run is shown in Figure 3. Table 1 gives instructions for preparing the input data. Table 2 describes all of the model parameters and Table 3 identifies each line of the output tables. Figure 4 shows keypunch coding sheets prepared for a typical simulation run.

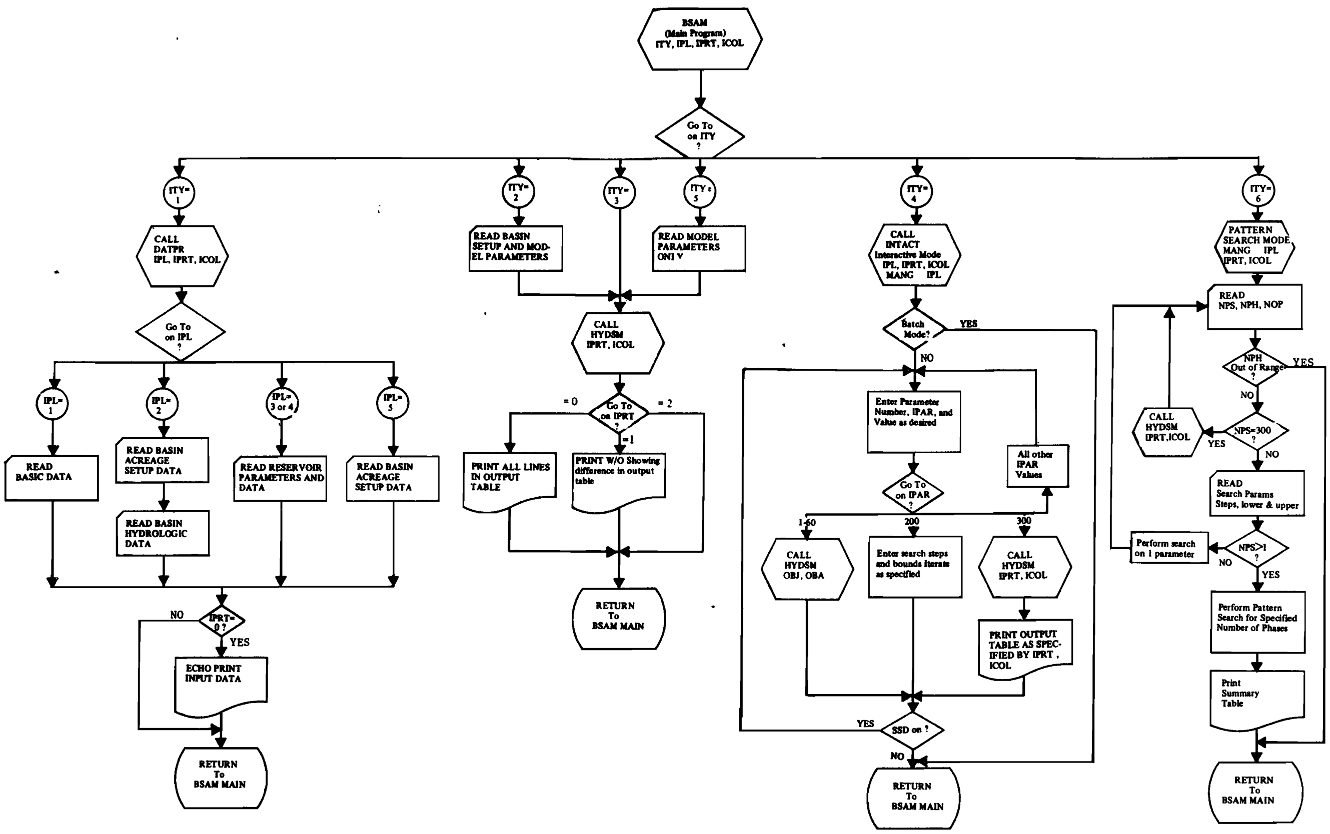

Figure 2. Schematic Diagram of the Execution Control Options for BSAM

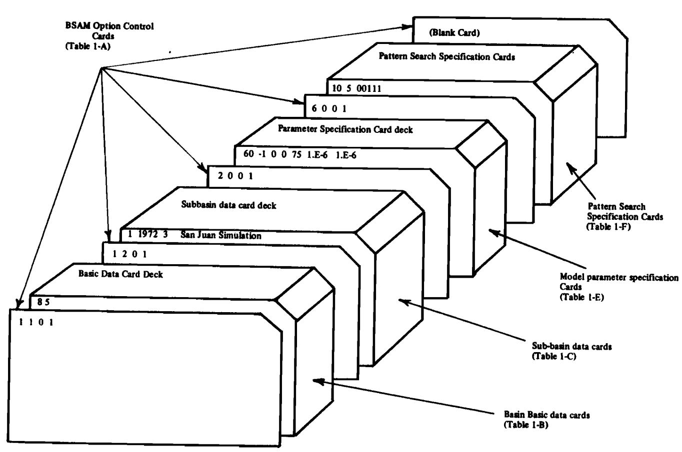

Figure 3. Card Deck Setup for a Typical Simulation Run

Table 1. Input data preparation.

A. Option control card in FORMAT (4I3)

Col.	Name	FORMAT	Description
1-3	ITY	I3	Program control option (1-6)
4-6	IPL	I3	Specification option subordinate to ITY (0-5)
7-9	IPRT	I3	Printing option subordinate to ITY, (0-2)
10-12	ICOL	I3	Line printer column length specification 1 = 80 column printer 2 = 132 column printer

B. Basic data (Called with ITY = 1, IPL = 1)

Card	Column	Name	FORMAT	Description
1	1-3	NCROP	I3	Number of crops
	4-6	NPHRT	I3	Number of phreatophytes
2	1-60	HDG_i	15A4	Headings for the column of the output tables
3-8	1-8	$LABL_i$	10A8	60 element vector of labels, each 8 characters long, for up to 60 lines of output from the model
9	3-10	DLAB	A8	Label for M & I consumptive use coefficients card
	11-15...	$PKCMI_i$	12F5.3	12 element vector of monthly M & I consumptive use coefficients
10	3-10	DLAB	A8	Label for proportion of daylight hours card
	11-15...	PDL_i	12F5.3	12 element vector of monthly proportion of daylight hours for the modified Blaney-Criddle Crop CU method
11	3-10	DLAB	A8	Label for SCS modified B-C crop consumptive use coefficients
	11-15...	$CPKC_{\ell,i}$	12F5.3	12 element vector of BC monthly CU coefficients for crop or phreatophyte ℓ

C. Subbasin data cards (Called with ITY = 1, IPL = 2 or 5)

Card	Column	Name	FORMAT	Description
1	1-2	ISB	I2	Subbasin number (-9, 99)
	3-7	IYRB	I5	Beginning year of simulation
	8-12	NYR	I5	Number of years of simulation
	21-80	BASID	15A4	Descriptive name of basin (≤ 60 columns)
2...	11-13	$I1_i$ DCA_i	(I3,F7.0)	Crop number and area in acre for crop i. Can put up to 7 sets/card and requires a set for each crop and phreatophyte
3	11-20	URLND	F10.0	Urban land area
	21-30	UNDLND	F10.0	Undeveloped land area
	Return if IPL = 5			
4	1-3	N_i	15I3	15 element vector of number of stations for each of 15 types of hydrologic data
5	1-40	FMT_1	10A4	Format for temperature data which follows
6	...	T_1	FMT_1	Monthly temperature data in °F format specified by FMT_1.
7	...	FMT_2	10A4	Format for precipitation data in inches which follows
8		PPT_2	FMT_2	Monthly precipitation data in format specified by FMT_2
9	...	FMT_k	10A4	Format for kth data (k = 3 to 15)
10	...	IX	FMT_k	Power of 10 by which all data on this card are multiplied
	...	DAT_k	FMT_k	Monthly values of kth hydrologic data in acre-feet. Do not include a format and data card if $N_k = 0$

11 Continue with format and data pairs for all data necessary. The data is specified by k as follows: if $N_k = 0$ that format and data pair should not be included.

k = 3 is River inflow, RIV
= 4 is Tributary inflow, TRIB
= 5 is Ungaged correlation inflow, QCOR
= 6 is Canal division, CNL
= 7 is Groundwater inflow, QGI
= 8 is Gaged outflow, GAG
= 9 is Pumped water from the shallow acquifer, QPUM
= 10 is M & I diversion, ΣMIDIV
= 11 is Reservoir inflow, RIN
= 12 is Required minimum reservoir releases to stream, REL
= 13 is Inbasin release, ARD
= 14 is Reservoir exports from the basin, REXP
= 15 is Basin export from the stream channel, BEXP

D. Reservoir parameter cards (Called with ITY = 1, IPL = 3 or 4). These cards are not included if IRES=0, which indicates that there is no reservoir in the subbasin.

Card	Column	Name	FORMAT	Description
1-2	11-20	RES_i	(10X7F10.0)	14 element vector of reservoir parameters

Reservoir parameters are indexed as follows:

i = 1 STI Initial storage in acre-feet
= 2 CSTI not used
= 3 STMN Minimum useable storage
= 4 STMX Maximum allowable storage
= 5 A_1 Reservoir area at zero storage
= 6 C_1 Coefficient in area vs. storage equation
= 7 C_2 Exponent in area vs. storage equation
= 8 BPS Break point storage value between equation defined by A_1, C_1 and C_2 and the one defined by A_2, C_3 and C_4
i = 9 A_2 Reservoir area at zero storage for equation above BPS
=10 C_3 Coefficient in area vs. storage equation
=11 C_4 Exponent in area vs. storage equation
=12 DSPD Change in gaged storage for the calibration period
=13-14 Not used

E. Parameter specification cards (Called when ITY=2*)

Card	Column	Name	FORMAT	Description
1	1-3	NPR	I3	Number of parameters (60)
	4-6	MANG	I3	Management option specification for canal diversions MANG = -1 Calibration mode - use QCNL recorded but limit to water available for diversion, WAD = 0 Calibration mode - Use QCNL as recorded = 1 Management mode - Calculate QCNL and use without limit to satisfy PET = 2 Management mode - Calculate QCNL but limit to WAD = 3 Management mode - Calculate QCNL but put leaching water to zero and limit QCNL to WAD
	7-0	IRES	I3	Reservoir option specification IRES = 0 No reservoir = 1 Tributary or upstream reservoir and requires reservoir inflow, RIN, to be read as input data = 2 Downstream reservoir - sets the reservoir inflow to the computed simulated surface runoff
	10-12	IQGO	I3	Groundwater outflow limiting option: IQGO = 0 Limit routed groundwater outflow, QGO, to be non negative = 1 Allow QGO to take on any value
	13-15	ITMX	I3	Iteration limit for calculating canal seepage
	16-25	TOLF	E10.3	Error criteria for indicating convergence in calculating canal seepage
	26-35	WH	E10.3	Multiplier for weighting the objective function calculations
2	3-10	$DLAB_1$	A8	Label for canal diversion option vector
	11-34	$IDTM_i$	12I2	Vector of diversion option controls - one for each month. If IDTM = 0 Do not allow diversion = 1 Allow diversion
3	3-10	$DLAB_2$	A8	Label for allowable soil moisture storage card
	11-70	CMS_i	12F5.3	Vector of soil moisture level, CMS, that must be maintained in calculating QCNL when in the management mode
* 4-9	1-80	PR_i	(10F8.3)	The 60 element vector of model parameters (see Table 2)

* If ITY = 5, enter here and read only the 6 parameter cards.

F. Pattern Search Specification Cards (Called when ITY = 6)

Card	Column	Name	FORMAT	Description
1	1-3	NPS	I3	Number of parameters to be searched or if NPS = 300 print the entire output table
	4-6	NPH	I3	Number of phases for pattern search (1-5)
	7-21	NOP_i	5I3	Vector of options for resetting the initial parameter vector at the completion of each phase. If NOP_i = 0 Reset to the original initial parameter vector = 1 Reset to the best local minimized objective function parameter vector
2	1-4	L	I4	Parameter number to be searched
(NPS+1)	4-8	NLL	I4	Number of steps in the search
	9-18	PLL	E10.5	Lower boundary for parameter L
	19-28	PHL	E10.5	Upper boundary for parameter L

Note: If NPS = 1 then will only read one type 2 card and return to read another type 1 card. If NPH is outside the range of (1-5) then will return to read a program option control card.

Table 2. Glossary of parameters used in BSAM.

Par	Name	Description	Units
1	SNI	Initial snow storage	Inches
2	SNK	Snow melt rate coefficient	
3	TSM	Threshold temperature above which snow melts	Deg F
4	TPR	Threshold temperature above which precipitation is rain	Deg F
5	COR	Ungaged flow correlation with correlating stream	Ac-ft/ac-ft
6	CSM	Ungaged flow correlation with snow melt	Ac-ft/inch
7	CRN	Ungaged flow correlation with precipitation as rain	Ac-ft/inch
8	RTH	Runoff threshold for ungaged flow from rain	Inches
9	CTP	Ungaged flow correlation with total precipitation	Ac-ft/inch
10	PTH	Runoff threshold for ungaged flow from total precipitation	Inches
11	SMI	Initial soil moisture level	Inches
12	CSM	Critical soil moisture to limit evapotranspiration	Inches
13	SMC	Soil moisture holding capacity	Inches
14	DTA	Delay time for routing DP	Months
15	DPI	Initial DP rate for routing DP	Inches
16	DPK	DP routing rate coefficient	
17	CDP	Proportion of soil moisture above CSM that goes to DP	
18	PSP	Proportion of spills from canal diversions	
19	ECV	Canal conveyance efficiency	
20	EAP	Irrigation application efficiency	
21	CNI	Initial rate for routing canal seepage to GW	Ac-ft/month
22	CNK	Canal seepage rate routing coefficient	
23	CRT	Proportion of canal seepage that returns to stream	
24	C1	Influent flow coefficient for QRIV = 1.	Ac-ft/month
25	C2	Influent flow coefficient	
26	C3	Influent flow limiting value of $C_1 - C_2 \log_{10}$ (QRIV)	
27	GWI	Initial rate of groundwater outflow	Ac-ft/month
28	GWK	Groundwater routing rate coefficient	
29	CGO	Proportion of GW outflow from basin	
30	TAJ	Adjusting coefficient on temperature	
31	PAJ	Adjusting coefficient on precipitation	
32	CNA	Adjusting coefficient on canal diversions	
33	GWA	Adjusting coefficient on groundwater inflow	
34	DMIA	Adjusting coefficient for M & I diversion	
35	CUMIA	Adjusting coefficient for M & I CU	
36	CUA	Adjusting coefficient for irrigated land CU	
37	CGW	Change in GW storage during the calibration period	
38	CUPGW	Proportion of CU for phreatophytes from GW	
39	CUUR	Coefficient for CU on urban land	
40	CUUN	Coefficient for CU on undeveloped land	
41	PURGW	Proportion of urban undeveloped land runoff to GW	
42	SCNR	Ratio of actual inbasin reservoir releases to canals	
43	STH	Snowmelt threshold for ungaged flow from snowmelt	Inches
44	PBST	Proportion of bank storage for reservoir operation	
45-48		Not used currently	
49-60	AGW	Values of delayed DP - one for each month of delay up to 12 (driving function for routed DP (ARF))	Inches/month

Table 3. Information printed in the output array

Line	Variable name used in program	Description	Units
1	T	Temperature	Deg F
2	PPT	Precipitation	Inches
3	SNMT	Snowmelt	Inches
4	SNW1	End of month snow storage	Inches
5	PHET	Phreatophyte evapotranspiration	Inches
6	ETP	Potential crop evapotranspiration	Inches
7	AET	Actual crop evapotranspiration	Inches
8	SM1	End of month soil moisture storage	Inches
9	RIV	River inflow	Acre-feet
10	TRB	Tributary inflow	Acre-feet
11	QUNG	Ungaged inflow	Acre-feet
12	RMPH	Phreatophyte rain plus snow melt	Acre-feet
13	URSF	Urban and undeveloped land surface runoff	Acre-feet
14	QPUM	Pumped water from the shallow acquifier	Acre-feet
15	STGW	Influent water from the stream channels	Acre-feet
16	PHSF	Phreatophyte use from the surface supply	Acre-feet
17	WAD	Surface water available for diversion	Acre-feet
18	EMIDIV	Municipal and industrial diversion	Acre-feet
19	EMIRF	Municipal and industrial return flows	Acre-feet
20	CNL	Canal diversion	Acre-feet
21	GWCNSV	Canal seepage	Acre-feet
22	GWCN	Proportion of the routed canal seepage that goes to groundwater	Acre-feet
23	SEEP	Canal seepage return flow that can be rediverted	Acre-feet
24	SPILL	Canal conveyance and operating spills	Acre-feet
25	QCV	Water delivered to the farm laterals by the canal system	Acre-feet
26	TWTR	Surface runoff from the farms (tailwater return flow)	Acre-feet
27	WAPP	Total water applied to the irrigated area including rain plus snow melt	Acre-feet
28	AETT	Actual crop evapotranspiration	Acre-feet
29	XSM	End of month soil moisture storage	Acre-feet
30	DP	Deep percolation from soil moisture storage	Acre-feet
31	ARF	Routed deep percolation	Acre-feet
32	GWIN	Groundwater inflow	Acre-feet
33	URGW	Groundwater inflow from the urban and undeveloped land area	Acre-feet
34	PHGW	Phreatophyte consumptive use from the groundwater	Acre-feet
35	QGO	Routed groundwater	Acre-feet
36	GEF	Effluent groundwater	Acre-feet
37	CHGW	Change in groundwater storage	Acre-feet
38	GWO	Groundwater outflow	Acre-feet
39	BEXP	Basin surface export	Acre-feet
40	SRF	Surface runoff which is also reservoir inflow if modeling a downstream reservoir (IRES = 2)	Acre-feet
41	QSO or ST	Computed surface outflow or the end of month reservor storage if modeling a downstream reservoir (IRES = 2)	Acre-feet
42	GAG	Gaged or measured surface outflow or measured end of month reservoir storage if modeling a down-stream reservoir (IRES = 2)	Acre-feet
43	DIFF	Difference between computed and gaged values	Acre-feet
----------	(Lines 44-53 are printed only if IRES > 0)		
44	EVP	Reservoir evaporation	Inches
45	RIN	Reservoir surface inflow	Acre-feet
46	AV	Average area of the reservoir water surface during the month	Acres
47	RQRL	Required releases to be met if possible	Acre-feet
48	REL	Actual release to channel	Acre-feet
49	ARD	Canal diversion from reservoir for in basin irrigation	Acre-feet
50	REXP	Reservoir export for trans basin use	Acre-feet
51	RSR	Total reservoir releases	Acre-feet
52	ST	End of month reservoir storage	Acre-feet
53	DS	Monthly change in reservoir storage	Acre-feet

Coding Sheet for Example Run 1 3

```
 1 1 0 1
 8 5
 VAR OCT NOV DEC JAN FEB MAR.   APR MAY JUN JLY AUG SEP ANN
FHR TEMP  PRECIPSNOW MLTSNOW STR  PHR ETCROP PETCROP AET  SM STRRIVER IN TRIB IN
 UNG INPHR RPSM URB SRE PUMP INRIVER GW PHR SUR WTR AVL MRI DIV MRI RET CNL DIV
CNL SEEP  CNL GWSEEP RTN  SPILLFARM DELTAIL WTR TOT APLCROP AET  SM STR     DP
 ROUT DP   GW INURBGW IN  PHR GW ROUT GW EFFL GWCH'GWSTR  GW OUTCHNL EXPSUR RNOF
COMP OUTEAGE OUT   DIFFRES EVAP  RES INRES AREA REQ REL ACT REL CNL RELRES EXPT
 TOT RELEOM STRGCHG STRG
 PKCMI        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
   PDL     .0783.0688.0674.0692.0682.0834.0887.0985.0989.1005.0944.0837
 1ALFALFA  .910 .780 .640 .630  730 .860 .9901.0801.1301.1101.060 .990
 2PAS+OHAY .86  .73  .60  .56  .65  .80  .92  .99 1.03 1.02  .99  .93
 3SPR GRN  .25  .25  .25  .25  .25  .25  .25  .52 1.05 1.28  .57  .25
 4CORN+SOR .58  .25  .25  .25  .25  .25  .25  .36  .58  .92 1.10 1.00
 5DRY BEAN .25  .25  .25  .25  .25  .25  .25  .25  .64 1.06 1.00  .48
 6POTATOES .25  .25  .25  .25  .25  .25  .25   31  .55 1.08 1.36 1.31
 7TR CROPS .25  .25  .25  .25  .25  .25  .25  .31  .64  .81  .80  .59
 8COV ORCH .90  .78  .66  .63  .73  .86  .98 1.09 1.13 1.11 1.06  .99
C1 HWMC  1 1.85 1.85 1.85 1.85 1.85 1.85 1.85 1.85 1.85 1.85 1.85 1.85
C2 HWGW  2 1.25 1.02  .75  .65  .80 1.13 1.36 1.41 1.42 1.42 1.41 1.36
C3 MWGT  3  .81  .76  .96  .56  .53  .53  .55  .61  .68  .77  .82  .83
C4 LWGT  4  .50  .47  .42  .35  .33  .33  .34  .38  .42  .48  .51  .51
B1 OPWT  5 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  1 2 0 1
 7 1972    1          SAN JUAN ABOVE BLUFF
SUB7 CROPS  1 29400.  3 25200.  3  7000.  4  5600.  5   700.  6    0.  7   700.
CROP7 CONT  8  1400.  9     0. 10     0. 11     0. 12     0. 13  2818.
UR-UN LAND        0.        0.
  2 2 1 4 1 1 1 1 0 0 0 0 0 0 0
```

Coding Sheet for Example (Continued) 2 3

```
(20X12F5.0)
72 CORTEZ, COLO.      48.5 35.9 25.9 29.8 35.0 44.7 48.3 56.0 66.8 72.8 69.5 62.8
72 BLUFF, UTAH.       51.4 30.3 25.9 30.8 38.3 49.7 58.6 61.1 72.0 78.0 75.7 67.2
(20X12F5.0)
72 CORTEZ, COLO.      2.12  .84 1.74  .00  .00  .15  .13  .14  .67  .33  .45 1.91
72 BLUFF, UTAH        1.39 1.22 1.66  .00  .00  .00  .00  .00  .35  .50  .09  .60
(6XI2,12F6.0)
723680 3 61.29 44.29 95.51116.30104.70126.10 62.39 83.20 99.63 13.64 26.21 46.08
(6XI2,12F6.0)
723685 0  878.  863.  447.  353.  345. 2160. 1900. 3270. 2820.  670.  390.  570.
723690 0  170.  185.  150.  120.  140. 1200.  490.  720.  390.   98.   53.  105.
723695 0   52.   82.   62.   46.   40.  620.  280.  250.  110.   52.   11.   28.
72 IMP 0 8800. 8800. 5500.    0.    0. 7400.17800.29700.24400.10600. 6400. 5000.
(6XI2,12F6.0)
723710 0  2120  1590  2060  1010  1480  1090    94    79   287     0    76   328
(6XI2,12F6.0)
72 CD7 0 17000   850   810   760   760  8730 35935 77375 65170 44140 24243 20695
(6XI2,12F6.0)
72GW6  0  4311   296   166   136   113    60  1417  5296  3739  3222  3944  4571
(6XI2,12F6.0)
723795 3 99.53 59.20110.20 119.2 109.5 119.5 64.61 81.10 118.1 17.08 30.60 56.33
  2 0 0 1
 60 -1 0 0 75          1.    1.E-06
 IDTM      1 1 1 1 1 1 1 1 1 1 1 1
 CMS         0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
     0.     .40     28.     30.    5.00   9000.  15000.    1.2     0.      0.
    4.0     3.0      6.      1.     0.      0.     .05     0.     .6      .8
     .5     1.9      1.      0.     0.      0.      0.     0.     0.      1.
     1.      1.      1.      1.     1.      1.      0.     .3     0.      0.
     0.      0.      0.      0.     0.      0.      0.     0.     1.      0.
```

Coding Sheet for Example (Continued) 3 3

```
     0.      0.      0.      0.     0.      0.      0.     0.     0.      0.
 6 -1 0 1
 3 2 0 0
  5 10      0.0    5.0
  6 20    0000.  10000.
  7 20   15000.  25000.0
      (blank card)
```

Figure 4. Keypunch Coding Sheets Prepared for a Typical Simulation Run

Model Requirements

The fundamental requirements of a computer model of a hydrologic system are:

1. It simulates on a continuous basis all important processes and relationships within the system it represents.

2. It is non-unique with respect to space. This implies that it can be easily applied to different geographic areas with existing hydrologic data.

3. It is capable of answering questions concerning perturbations in the system or of accurately predicting outputs resulting from varying input and process parameters.

The Conceptual Model

The basis of the hydrologic model is a fundamental and logical mathematical representation of the various hydrologic processes and routing functions. These physical processes are not specific to any particular geography, but rather are applicable to any hydrologic unit. Experimental and analytical results can be used to assist in testing and establishing some of the mathematical relationships included within the model. Under a model verification procedure, equation constants are established which calibrate or fit the model for a particular drainage area. Average values of hydrologic quantities needed for model verification were estimated in onè of three ways: (1) From available data, (2) by statistical correlation techniques, and (3) through verification of the model.

A flow diagram of the hydrologic system is shown by Figure A-1. As this flow chart indicates, the total input to a subbasin is the combination of surface and subsurface inflows of water obtained by summing river and tributary inflows, precipitation, groundwater inflows, and imports from other basins. Depletions from the subbasins occur through evapotranspiration, municipal and industrial consumption, and exports. The residual quantity is a combination of surface and subsurface outflow of water from the area. Subsurface flows may undergo various time delays as they move through the system.

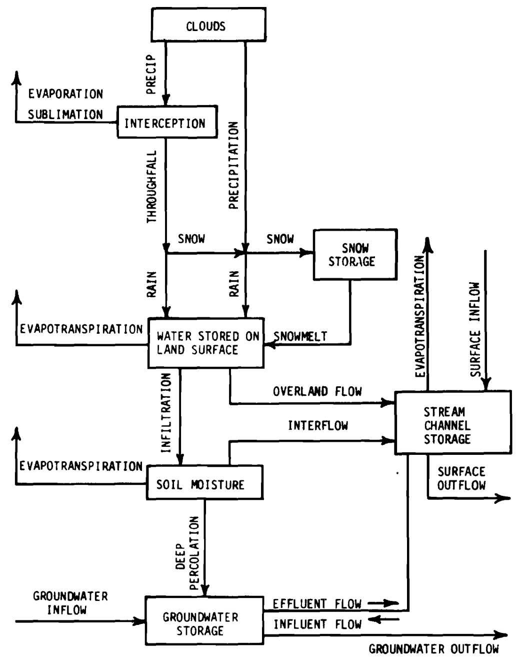

Figure A-1. Flow Diagram of the Hydrologic System

The Hydrologic Balance

A dynamic system consists of three basic components, namely the medium or media acted upon, a set of constraints, and an energy supply or driving force. In a hydrologic system, water in any one of its physical states is the medium of interest. The constraints are applied by the physical nature of the hydrologic basin, and the driving forces are supplied by direct solar energy, gravity, and capillary potential fields. The various functions and operations of the different parts of the system are interrelated by the concepts of continuity of mass and momentum. Unless relatively high velocities are encountered, such as in channel flow, the effects of momentum are negligible, and the continuity of mass becomes the only link between the various processes within the system.

Continuity of mass is expressed by the general equation:

Input - Output = Change in Storage

A hydrologic balance is the application of this equation to achieve an accounting of physical, hydrologic measurements within a particular unit. Through this means and the application of appropriate translation or routing functions, it is possible to predict the movement of water within a system in terms of its occurrence in space and time.

The concept of the hydrologic balance is pictured by the block diagram in Figure A-1. The inputs to the system are precipitation and surface and groundwater inflow, while the output quantity is divided among surface outflow, groundwater outflow and evapotranspiration. As water passes through this system, storage changes occur on the land surface, in the soil moisture zone, in the groundwater zone, and in the stream channels. These changes occur rapidly in surface locations and more slowly in the subsurface zones.

In the course of model development, each of the system processes must be described mathematically as completely as possible. The flow chart of Figure A-1 is a schematic representation of the system processes and storage locations and their relationship to each other. In the model each box and connecting line is represented by a mathematical expression.

Time and Space Increments

Practical data limitations and problem constraints require that increments of time and space be considered during model design. Data, such as temperature and precipitation readings, are usually available as point measurements in terms of time and space; and integration in both dimensions is usually accomplished by the method of finite increments.

The complexity of a model designed to represent a hydrologic system largely depends upon the magnitude of the time and spatial increments utilized in the model. In particular, when large increments are applied, the scale magnitude is such that the effect of phenomena which change over relatively small increments of space and time is insignificant. For instance, on a monthly time increment, interception rates and changing snowpack temperatures are neglected. In addition, the time increment chosen might coincide with the period of cyclic changes in certain hydrologic phenomena. In this event net changes in these phenomena during the time interval are usually negligible. For example, on an annual basis, storage changes within a hydrologic system are often insignificant, whereas on a monthly basis, the magnitude of these changes are frequently appreciable and need to be considered. As time and spatial increments decrease, improved definition of the hydrologic processes is required. No longer can short-term transient effects or appreciable variations in space be neglected, and the mathematical model, therefore, becomes increasingly more complex with an accompanying increase in the requirements of data, computer capacity, and computer capability.

For this report, a monthly time increment and large space units (subbasins) were adopted. Selection of the subbasins was based on hydrologic boundaries and points of data collection. It was felt that the selection of the subbasins and the monthly time increment would satisfy the requirements of a general planning-management model for the basin.

System Processes

Surface Inflows

The basic inflow or input of water into any hydrologic system originates as a form of precipitation. However, for simulation models of valley floor areas, direct precipitation input to the system is greatly overshadowed by river and tributary inflows.

Streamflow is defined as that portion of the precipitation which appears in streams and rivers as the net or residual flow collected from all or a portion of a watershed. When unaffected by the activities of man, such runoff is referred to as "natural or virgin" flow. Artificial diversions and regulatory action in lakes and reservoirs affect the regimes of nearly every stream within the basin.

The surface water inflow component consists of flow traveling over the ground surface and through channels to enter a stream. At the stream surface runoff usually combines with other flow components to form the total surface runoff hydrograph. Within the runoff cycle surface runoff begins to occur when the capacities of vegetative interception, infiltration, and surface retention are reached. Continued precipitation beyond this point serves as a source for surface runoff. Small basins have different runoff characteristics than do large watersheds, and the characteristics peculiar to each basin must be evaluated on an individual basis.

For each subbasin a limiting rate of surface runoff exists for any particular time period. Surface runoff is assumed to occur when the threshold or limiting rate of surface water supply, consisting of snowmelt, rainfall, canal diversions, or any combination of these, is exceeded.

This concept of surface runoff is particularly important when precipitation is considered as the initial water input to the watershed. Riley and Chadwick (1966) indicate that for particular conditions there exists a limiting or threshold rate of surface supply, R_{tr}, at which surface runoff, S_r, begins to occur. This relationship can be written:

$$S_{wr} = W_{gr} - R_{tr}, \quad (S_{wr} \geq 0) \quad . \quad . \quad . \quad . \quad (1)$$

in which

S_{wr} = rate of surface runoff during a particular time

W_{gr} = rate at which water is available at the soil surface

R_{tr} = limiting or threshold rate of surface water supply at which surface runoff begins to occur

When considered for a model time increment of one month, an average value of the threshold surface runoff rate, R_{tr}, is probabilistic in nature, depending essentially upon soil surface conditions, soil moisture, storm characteristics, and rate of available water, W_{gr}.

In this study only the valley bottom lands are considered in the model, and it is assumed that no surface runoff from precipitation occurs from these relatively flat areas. Under this assumption, the rate at which precipitation is available at the soil surface at no time exceeds the threshold rate for surface runoff to occur. Thus,

$$S_{wr} = 0, \ (W_{gr} \leq R_{tr}) \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The model does provide for surface runoff from agricultural lands due to irrigation application rates which exceed soil infiltration rates. The runoff quantity constitutes a portion of the irrigation return flow.

Surface runoff from the surrounding watershed areas is concentrated in stream channels, and therefore, enters the model (valley bottom) as tributary flow. That part of the inflow rate which is measured or gaged is designated as $Q_{is}(m)$.

Unmeasured surface inflows to the model are estimated by a correlation technique which considers three hydrologic parameters, namely a gaged tributary inflow rate, precipitation rate, and snowmelt rate. Thus, in functional form:

$$Q_{is}(u) = \int \{q_{is}(m), P_r, W_{sr}\} \quad . \quad . \quad . \quad (3)$$

in which

$Q_{is}(u)$ = estimated rate of unmeasured surface inflow

$q_{is}(m)$ = measured rate of surface inflow from a particular tributary area

P_r = gaged precipitation rate in the form of rain on the valley floor

W_{sr} = estimated snowmelt rate in terms of water equivalent

If empirical correlation factors are included in the preceding equation, the expression becomes:

$$Q_{is}(u) = k_u q_{is}(m) + k_a P_r + k_b W_{sr} \quad . \quad . \quad (4)$$

in which k_u, k_a, and k_b are correlation factors relating ungaged surface inflow rate to, respectively, a gaged surface inflow rate, precipitation rate, and snowmelt rate. Each of these factors is established through the model verification process for a particular subbasin.

With reference to the measured tributary inflow rate, $q_{is}(m)$, used in Equation 4, this quantity might refer to either the total measured tributary inflow or a specific stream within the area. The main criterion for selecting the gaged area is that the watershed exhibit the same general runoff characteristics as that of the ungaged area.

The second independent term in Equation 4 refers to the rates of precipitation occurring on the valley floor in the form of rain. Because it is assumed that the influence of snow upon the surface runoff is restricted to the melt period, only rainfall is considered by the equation. Generally, a direct plot of rainfall against runoff for individual storms yields a low correlation because of the variable nature of the factors affecting runoff (Chow, 1964). However, when mean monthly values of precipitation and runoff are considered, many of the transient processes are smoothed and reasonably good correlation of runoff with precipitation is achieved.

The third independent term of Equation 4 considers the influence of snowmelt upon surface runoff. Snowmelt rates on the valley floor are predicted in the model by Equation 8. This process is discussed in further deatil later in this chapter.

The total surface inflow rate to the model (valley floor) is estimated by summing the measured rate and estimated ungaged rate from Equation 4. Thus,

$$Q_{is} = Q_{is}(m) + Q_{is}(u) \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

in which Q_{is} refers to the total surface inflow rate, and the two independent quantities are as previously defined.

Interflow

Interflow is defined as the lateral movement of moisture through the plant root zone. The process is discussed in further detail at a later point in this chapter. Interflow rate, N_r, is not treated as a separate identity in the hydrologic model of the valley bottoms, but is considered as being a part of the surface runoff from irrigation. In most cases, small interflow rates are encountered in flat lands. Furthermore, for a model time increment of one month, interflow usually produces an insufficient delay time to enable this quantity to be distinguished from surface runoff.

Groundwater Inflow

Groundwater or subsurface inflow refers to those waters which enter the model area or valley floor beneath the ground surface. Much of this water is subsequently discharged as effluent flow into the main channel of the valley, and thus provides a "base flow" for the stream. Discharge from the groundwater basin of the valley floor also occurs by way of spring flows, pumped waters, and consumptive use by phreatophytes.

Essentially, all groundwater is constantly in motion though velocities may range from several feet per day to only a few inches per year. This groundwater movement is basically confined to permeable geologic formations called aquifers which serve as transmission conduits. Movement and volume of groundwater runoff may be calculated through application of Darcy's Law, providing adequate data are available. However, if subsurface flow data are sparse, time and spatial distribution of groundwater flows can be estimated by an empirical approach through the model verification procedure. For the steep watersheds near the headwaters of major drainage divisions, groundwater inflows to the valley floors were usually sufficiently small to be neglected. At downstream subbasins it may become apparent through the time distribution of the water inputs to the model in relation to the recorded outflow that groundwater inflow rates are appreciable. Correlation procedures and transport delays can be used to estimate and simulate groundwater movement into the subbasin. This water is then distributed with time through use of long transport delay networks on the computer. The required delay setting of these networks is established during the model verification process. Hence, the rate of groundwater inflow is described as follows:

$$Q_{ig}(u) = k_c q_{is} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (6)$$

in which

$Q_{ig}(u)$ = rate of total unmeasured inflow to the groundwater system

k_c = coefficient relating the rate of unmeasured groundwater inflow to a measured surface runoff rate

q_{is} = rate of surface runoff (either total measured tributary inflow or measured inflow from a representative tributary)

For some subbasins a subsurface groundwater movement under the outflow gage in the streambed alluvium occurs. The time and spatial distribution of this outflow forms a component of the groundwater inflow or input to the adjacent downstream subbasin.

Total Inflow

Total inflow rate to the valley bottoms consists of the summation of the surface and groundwater inflow rates. The surface inflows for the most part have already been summed and are concentrated in stream channels as they enter the valley floor or agricultural areas. Gaged surface inflow rates are available from surface water records published by the U. S. Geological Survey.

The remaining two components of total inflow, namely ungaged surface inflow and groundwater inflow, are estimated from Equation 4 and 6, respectively. Therefore, the total inflow, Q_i, to a given subbasin is given by the following expression:

$$Q_i = Q_{is} + Q_{ig} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

in which the terms Q_{is} and Q_{ig} are given by Equations 5 and 6, respectively.

Precipitation

The ultimate source of water input to any hydrologic unit is precipitation in one form or another. Precipitation is considered to be any moisture which emanates from the atmosphere and falls to the earth.

Precipitation input to the hydrologic system varies with respect to both time and space and it is therefore, necessary to convert point measurements from climatological stations into an integrated or averaged monthly value over a finite area. Some precipitation data are available for all subbasins used in this study.

Two forms of precipitation, rain and snow, are considered in this study. Air temperature is used as the criterion for establishing the occurrence of these two forms. This criterion is not an ideal index for determining the form of precipitation since no one temperature exists below which it always snows and above which it always rains. However, the surface air temperature appears to be the most suitable single index of precipitation form now available.

Based on investigations by the U. S. Army (1956) at a surface air temperature of 35°F, there is a 50 percent chance that precipitation will be as snow, whereas at 32°F the probability is 95 percent of precipitation falling as snow. In this study a double standard was used because average monthly temperatures provided the criteria. Snow was assumed to fall below a threshold temperature, and snowmelt was assumed to occur above another threshold temperature. This assumption provided for the occurrence of snowfall and snowmelt during the same month. These threshold temperatures varied in the different subbasins.

Temperature

Air temperature is an important parameter in a hydrologic system because it can be utilized as a criterion for establishing the form of precipitation, and as an index of the energy available for the snowmelt and evapotranspiration processes. Temperature varies according to both time and space. To obtain average temperature values for the valley floor, or a portion thereof, within a particular subbasin, requires that point measurements be utilized for estimating an effective or average temperature value for an area. In this study average temperatures for a particular area and a given time period (one month) are estimated by an arithmetic average of temperature measurements taken in the subbasin.

Snowmelt

Although rational formulas which include the various factors involved in the snowmelt process have been developed, data limitations often prohibit a strictly analytical approach to the process. Rational models include fundamental processes, such as those which relate to energy transfer, and requirements for input data are high. An additional restriction to the analytical approach for snowmelt computation is a large modeling time increment such as a month. Many of the short-term, transient phenomeon which occur within a snowpack cannot be represented in a macroscopic model of this scale. An empirical relationship was, therefore, adopted for this study model. Riley et al. (1966) proposed a relationship which states that the rate of melt is proportional to the available energy and the quantity of precipitation stored as snow. As a differential equation the relationship is written:

$$\frac{d\, W_s(t)}{dt} = - k_s (T_a - T_b) \frac{RI_s}{RI_h} W_s(t) \quad . \quad . \quad (8)$$

in which the undefined terms are:

- k_s = a constant
- T_a = surface air temperature in degrees F
- RI_s = the radiation index on a surface possessing a known degree and aspect of slope
- RI_h = the radiation index for a horizontal surface at the same latitude as the particular watershed under study
- W_s = snow storage in terms of water equivalent
- T_b = assumed base temperature in degrees F at which melt begins to occur.

Riley et al. (1966) report reasonable agreement between predicted snowmelt rates from Equation 8 and observed values. They used a value of k_s equal to 0.10 based on studies using data from several snow courses in the Rocky Mountain area where average snow depths are high. It has been found, however, that the value of k_s is somewhat inversely dependent upon snowpack depth. In other words, as the snow depth decreases pack melt rates increase for a given energy input. Thus, k_s is relatively larger for areas of shallow snowpack depth and relatively smaller for areas where depths tend to be large. The radiation index paramater allows adjustment to be made for variation of the total insolation with land surface slope and aspect. However, since only the valley floors are included in the modeling area, it is assumed that the topographic surface of the area is essentially horizontal. This assumption simplifie Equation 8 in that RI_s becomes equal to RI_h and their ratio goes to unity.

The independent variables on the right side of Equation 8 can be expressed as either continuous functions of time or as step functions consisting of mean constant values for a given time increment. For this study a time increment was utilized and integration was performed in steps over each successive time period. Hence, the final values of $W_s(t)$ at the end of a particular time period became the initial value for the integration process over the following period. On this basis, and setting the ratio RI_s/RI_h equal to unity (assuming the agricultural area is flat), the differential form of Equation 8 becomes:

$$\int_{W_s(0)}^{W_s(1)} \frac{dW_s}{W_s} = - k_s (T_a - T_b) \int_0^1 dt \quad . \quad . \quad (9)$$

$$W_s(1) = W_s(0) \exp\{-k_s (T_a - T_b)\}. \quad . \quad . \quad . \quad (10)$$

Canal Diversions

Canal diversions profoundly affect the time and spatial distribution of water within an irrigated area. A portion of this diverted water is returned directly to the stream as spill and portion is evaporated directly to the atmosphere. Another portion enters the soil profile through canal seepage and the infiltration on the irrigated lands, and the remainder returns to the source as overland flow or evaporates. Some of the water which enters the soil profile is lost through plant consumptive use. The remainder either percolates downward to the groundwater basin or is intercepted by drainage systems. Irrigation practices, therefore, alter the distribution characteristics of a hydrologic system. The irrigation efficiency factors used in this study include both the conveyance and application efficiencies. A composite irrigation efficiency factor is given by the following expression:

$$\text{Eff} = (W_{tr} - W_{sp})\, E_c E_a \quad \ldots\ldots\ldots \quad (11)$$

in which

Eff = water conveyance and application efficiency in percent

W_{sp} = the spills

E_c = the conveyance efficiency

E_a = application efficiency

W_{tr} = total rate at which water is diverted from the stream or reservoir

Records of water diversion to the agriculture lands within each subbasin were found to be lacking. Adjustment of these records was necessary in many cases to get a realistic application rate for the irrigated acreage.

As already indicated, a portion of the water diverted for irrigation returns to the streams as overland flow and interflow. Although the large time increment allows this water to be treated in the model as a single identity, it is important to distinguish between the two components. Overland flow (often termed tailwater) is surface return flow or runoff from the end of the field resulting from the application of water to the irrigated land at rates exceeding the infiltration capacity of the soil. Interflow is defined as that part of the soil water which does not enter the groundwater basin, but rather which moves largely in a lateral direction through the upper and more porous portion of the soil profile until it enters a surface or subsurface drainage channel. Both the overland flow and the interflow return to the stream channels in short distances and times consisting of usually only a few days.

Available Soil Moisture

The usual definition of available soil moisture capacity is the difference between the field capacity and the wilting point of the soil. Water within this range is available for plant use, and is termed available soil moisture. The field capacity is defined as the soil moisture content after gravity drainage has occurred. Most of the gravity water drains rapidly from the soil thus affording plants little opportunity for its use. The wilting point represents the soil moisture content when plants are no longer able to abstract water in sufficient quantities to meet their needs, and permanent wilting occurs. Available soil moisture can be expressed in several units but in this report it carries the unit of depth in inches.

Sources of available water. Basically, moisture in the soil is derived from infiltration, which is the passage of water through the soil surface into the soil profile. The water available for infiltration at the soil surface is derived from three sources, namely, precipitation in the form of rain, P_r, snowmelt, W_{sr}, and irrigation water, W_{dr}. As springtime temperatures rise to the point at which melting occurs, all snow cover on the land is assumed to melt and enter the soil mantle through the infiltration process. In the case of irrigated crops, the most important source of available soil moisture is water which is diverted to the agriculture lands. Thus, the total water available for infiltration into the soil, W_{gr}, can be written as:

$$W_{gr} = W_{dr} + P_r + W_{sr} \quad \ldots\ldots\ldots \quad (12)$$

in which all quantities are as previously defined.

Available soil moisture quantities. The maximum quantity of water in a soil available for use by plants is a function of the moisture holding capcity of the soil and the average rooting depth or extraction pattern of the plant.

The basic forces involved in the absorption of water by plants are osmotic, imbibitional, metabolic, and transpiration pull (Thorne and Peterson, 1954). These forces basically define the soil moisture tension or "pull" that must be exerted by the plant to remove water from the soil. Of these forces the principal one is the osmotic pressure created within plant root cells. Opposing these forces are those exerted on the moisture by the soil particles. The forces exerted by the plants vary with different plants, soils, and climates, but the average maximum force which plants can exert in obtaining sufficient water for growth is approximately 15 atmospheres of pressure. At field capacity where water is readily available for plant use, the average soil moisture tension is only about 0.1 atmosphere. However, the soil moisture tension or "pull" plants exert in their quest for water is in itself no indication of the amount of available water contained by the soil. The actual amount of water held by the soil at any given tension value is a function of the soil type.

Determination of the soil depth effectively utilized by a plant is based on the average rooting depth or the average moisture extraction pattern. The soil moisture available for extraction depends on the moisture holding capacity of the soil and the extraction pattern. The typical agricultural crop extracts 70 percent of its moisture from the upper 50 percent of the soil penetrated by the plant roots. Average or typical rooting depths for various plants are reported by McCullock et al. (1967). Illustrative depths include 4 to 6 feet for alfalfa, 4 feet for grains and corn, and 2 to 3 feet for pasture. The average available soil moisture capacity of the irrigated lands was estimated for each subbasin.

Under normal circumstances, additions to available soil moisture storage occur through the infiltration process, F_r. Abstractions or depletions from available soil moisture storage occur through evapotranspirational losses, ET_r, and deep percolation, G_r. Thus, the soil moisture storage existing at any time, t, can be stated:

$$M_s(t) = (F_r - ET_r - G_r)\ dt \quad . . . . \quad (13)$$

Each of the three terms on the right side of this equation is discussed in the following sections.

Infiltration

As already indicated, additions to available soil moisture occur through the process of infiltration, F_r. Factors which influence the infiltration rate include various soil properties and surface characteristics. A moisture gradient induced by the adhesive properties of the soil particles also influence infiltration rate.

In this study, the rate of infiltration into the soil is given by the following equations

$$F_r = W_{gr},\ (W_{gr} \leq R_{tr}) \quad . . . . (14)$$

and

$$F_r = R_{tr},\ (W_{gr} > R_{tr}) \quad . . . . (15)$$

for which all terms were previously defined. The quantity W_{gr} in Equation 14 is given by Equation 12.

Evapotranspiration

The second term on the right side of Equation 13 represents depletion from the soil moisture storage through the evapotranspiration process, ET_r. Comsumptive use, or evapotranspiration is the sum of all water used and lost by growing vegetation due to transpiration through plant foliage and evaporation from the plant and surrounding environment such as adjacent soil surfaces. Potential evapotranspiration is defined as that rate of consumptive use by actively growing plants which occurs under conditions of complete crop cover and non-limiting soil moisture supply.

The evapotranspiration process depends upon many interrelated factors whose individual effects are difficult to determine. Included among these factors are type and density of crop, soil moisture supply, fertilizer, soil salinity, and climate. Climatological parameters usually considered to influence evapotranspiration rates are precipitation, temperature, daylight hours, solar radiation, humidity, wind velocity, cloud cover, and length of growing season. Numerous relationships have been developed for estimating the potential evapotranspiration rate.

Perhaps one of the most universally applied evapotranspiration equations is that proposed by Blaney and Criddle (1950). This equation is written as follows:

$$U = kf \quad . . . . \quad (16)$$

in which

U = monthly crop potential consumptive use in inches

k = monthly coefficient which varies with type of crop and

F = monthly consumptive use factor and is given by the following equation:

$$f = \frac{tp}{100} \quad . . . . \quad (17)$$

in which

t = mean monthly temperature in degrees F

p = monthly percentage of daylight hours of the year

A modification of the Blaney-Criddle formula was proposed by Phelan et al. (1962), wherein the monthly coefficient, k, is subdivided into two parts, a crop coefficient, k_c, and a temperature coefficient, k_t. The relationship describing k_t is an empirical one, depending upon only temperature, and is expressed as:

$$k_t = (0.0173T_a - 0.314) \quad . . . . . . \quad (18)$$

where T_a is the mean monthly temperature in degrees F. The crop coefficient, k_c, is basically a function of the physiology and stage of growth of the crop. Curves of k_c are available for many agriculture crops (Soil Conservation Service, 1964).

Thus, the modified Blaney-Criddle equation for estimating potential evapotranspiration rates is written as follows:

$$ET_{cr} = k_c k_t \frac{T_a p}{100} \quad . . . . \quad (19)$$

Because of its simplicity, low data requirements (only surface air temperature is needed), and applicability to the irrigated areas of the Western United States, Equation 19 was adopted for this study model. Since the time increment selected for use was one month, the variables on the right of Equation 19 represent mean monthly values although these parameters could be expressed as continuous functions instead of the indicated step functions. Thus, Equation 19 estimates the mean potential evapotranspiration rate during each month.

Evapotranspiration losses from the agriculture area during the non-cropping season were estimated from Equation 19. For many crops it was necessary to extend the k_c curves to include the non-growing season (West, 1959). Because the k_c curve for grass pasture seems to represent a reasonable set of values for native vegetation (Riley et al., 1967), this curve was used as a guide in the development of a similar k_c curve for phreatophytes.

Effects of soil moisture on evapotranspiration. As was discussed earlier, as the moisture content of a soil is reduced by evapotranspiration, the moisture tension which plants must overcome to obtain sufficient water for growth is increased. It is generally conceded that some reduction in the evapotranspiration rate occurs as the available quantity of water decreases in the plant root zone. Studies by the U. S. Salinity Laboratory in California (Gardner and Ehlig, 1963) indicate that transpiration occurs at the full potential rate through approximately the first one-third of the available soil moisture range, and that thereafter the actual evapotranspiration rate lags the potential rate. When this critical point in the available moisture range is reached, the plants begin to wilt because soil moisture becomes a limiting factor.

The actual evapotranspiration rate is approximated by the two following equations which take the above phenomenon into account:

$$ET_r = ET_{cr}, \{M_{es} < M_s(t)\} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

and

$$ET_r = ET_{cr} \left(\frac{M_{cs} - M_{es}}{M_{cs}}\right), \{0 \leq M_s(t) \leq M_{es}\} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

in which

ET_r = actual evapotranspiration rate

ET_{cr} = potential evapotranspiration rate

M_{es} = limiting or threshold content of available water within the root zone below which the actual becomes less than the potential evapotranspiration rate

$M_s(t)$ = quantity of water available for plant consumption which is stored in the root zone at any instant of time

M_{cs} = root zone storage capacity of water available to plants

Deep Percolation

The final independent term, G_r, of Equation 13 represents the rate of deep percolation. Percolation is simply the movement of water through the soil. Deep percolation is defined as water movement through the soil from the plant root zone to the underlying groundwater basin. The dominant potential forces causing water to percolate downward from the plant root zone are gravity and capillary forces. Water is removed quickly by gravity from a saturated soil under normal drainage conditions. Thus, the rate of deep percolation, G_r, is most rapid immediately after irrigation when the gravity force dominates, and decreases constantly, continuing at slower rates through the unsaturated conditions. Because the capillary potential applies through all moisture regimes, deep percolation continues, though at low rates, even when the moisture content of the soil is less than field capacity (Willardson and Pope, 1963).

Because of a lack of data in the study area regarding deep percolation rates in the unsaturated state, and in order to simplify the model, the assumption was made that deep percolation occurs at a continual small percent, k_p, of soil moisture storage between saturation and the limiting threshold storage. Thus, for this model, the deep percolation rate is expressed as:

$$G_r = F_r - ET_{cr}, \{M_s(t) = M_{cs}\} \quad . \quad . \quad . \quad (22)$$

$$G_r = k_p M_{sg} \{M_{es} < M_s(t) < M_{cs}\} \quad . \quad . \quad (23)$$

$$G_r = 0, \{M_s(t) < M_{cs}\}. \quad . \quad . \quad . \quad . \quad (24)$$

in which all terms are as previously defined.

River Outflow

Using the continuity of mass principle the hydrologic balance is maintained by properly accounting for the quantities of flow at various points within the system. The appropriate translation or routing of inflow water through the system in relationship to the chronological abstraction and additions occurring in space and time concentrates the water at the outlet point as both surface and subsurface outflow. As mentioned earlier, active network delays on the computer simulate the long transport time necessary for groundwater inflows and deep percolating waters to be routed to the outflow gaging station.

Thus, the total rate of water outflow from a subbasin is obtained through the summation of various quantities as follows:

$$Q_o = Q_{is} - W_{tr} + OF_r + Q_{ob} - Q_e \quad . \quad . \quad . \quad (25)$$

in which

Q_o = total rate of outflow from the system

Q_{is} = rate of total surface inflow to the subbasin including both measured and unmeasured flows

W_{tr} = total rate at which water is diverted from the stream or reservoir

OF_r = total of overland flow and interflow rates

Q_{ob} = rate of outflow from the groundwater basin of routed deep percolating waters and subsurface inflows to the subbasin

Q_e = rate of water diversions from surface sources for use outside the boundaries of the subbasin. Exports to other drainage basins fall within this category

If subbasins are selected such that there exists no flow of subsurface water past the gaged outflow point, the hydrograph of surface outflow, Q_{so}, is given by Equation 25. This situation is assumed to exist at reservoir sites within the basin because of construction measures taken to eliminate subsurface flows under the dams which create the reservoir. For this reason, whenever possible, subbasins were terminated at the outfall of a reservoir. These sites thus enabled a check to be made on groundwater inflow rates to the subbasin as predicted from verification studies involving models for one or more upstream subbasins.

For many subbasins the termination or outlet point was taken at a Geological Survey gaging station, and in several of these cases groundwater flow occurs in the streambed alluvium beneath the surface channel. For these basins, the total system outflow can be written as:

$$Q_{to} = Q_{so} + Q_{go} \quad \ldots \ldots \ldots \quad (26)$$

in which

Q_{so} = rate of surface outflow from the subbasin

Q_{go} = rate of subsurface or groundwater outflow from the subbasin

Surface outflow rates, Q_{so}, can be compared to the recorded values, but subsurface outflow rates, Q_{go}, are unmeasured and must be predicted or estimated.

In the model described in this report, the groundwater outflow is estimated as a proportion of the total groundwater flux. The groundwater flux is computed by keeping track of all inflows and effluent flows that interface with the shallow groundwater acquifer. These include influent river channel flow, canal seepage, deep percolation, pumped water and groundwater inflow. The net effect of these variables provides the driving function for a linear reservoir routing subroutine. Flow routing through a linear reservoir is derived as follows from the continuity and linear storage equations:

$$\frac{dS}{dt} = I - O \quad \ldots \ldots \ldots \quad (27)$$

and

$$S = k_s O \quad \ldots \ldots \ldots \quad (28)$$

where

$\frac{dS}{dt}$ = change in storage

I = inflow

O = outflow

S = storage

k_s = the linear routing rate coefficient

By substituting equation 28 into 27 and assuming I is constant $\frac{dO}{I-O} = \frac{1}{k_s}\,dt$ is obtained which may then be integrated to give

$$\int_{O_o}^{O_1} \frac{dO}{I-O} = \frac{1}{k_s} \int_0^1 dt$$

or

$$\ln (I-O) \Big|_{O_o}^{O_1} = -\frac{1}{k_s}\, t \Big|_o^1 \quad \ldots \ldots \quad (29)$$

By evaluating at the limits of integration, exponentiating both sides and solving for O_1 the final routing equation is obtained:

$$O_1 = I + (O_o - I)\, e^{-\frac{1}{k_s}} \quad \ldots \ldots \quad (30)$$

The routed value of groundwater flux Q_{ob}, is then separated into an effluent portion, Q_{ef}, which makes up part of the surface outflow and the groundwater outflow, Q_{go}, by the equation:

$$Q_{go} = k_{gw} Q_{ob} \quad \ldots \ldots \ldots \quad (31)$$

and

$$Q_{ef} = Q_{ob} - Q_{go} \quad \ldots \ldots \ldots \quad (32)$$

where k_{gw} is the proportion of groundwater flux that remains as groundwater flow.

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Appendix B. Input to and Output from a Typical Simulation Run

Listing of Input Data Cards

```
  1   1   0   1
  8   5
 VAR OCT NOV DEC JAN FEB MAR      APR MAY JUN JUL AUG SEP ANN
FHR TEMP  PRECIPSNOW MLTSNOW STR  PHR ETCROP PETCROP AET  SM STRRIVER IN TRIB IN
  UNG INPHR RPSM URB SRF PUMP INRIVER GW PHR SUR WTR AVL M&I DIV M&I RET CNL DIV
CNL SEEP  CNL GWSEEP RTN   SPILLFARM DELTAIL WTR TOT APLCROP AET  SM STR      DP
 ROUT DP   GW INURBGW IN  PHR GW ROUT GW EFFL GWCH GWSTR  GW OUTCHNL EXPSUR RNOF
COMP OUTGAGE OUT    DIFFRES EVAP  RES INRES AREA REQ REL ACT REL CNL RELRES EXPT
 TOT RELEOM STRGCHG STRG
 PKCMI    0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
    PDL   .0783.0688.0674.0692.0682.0834.0887.0985.0989.1005.0944.0837
 1ALFALFA   91    78    64    63    73    86    99   108   113   111   106    99
 2PAS+OHAY  85    73    60    56    65    80    92    99   103   102    99    93
 3SPR GRN   25    25    25    25    25    25    25    52   105   128    57    25
 4CORN+SOR  58    25    25    25    25    25    25    36    58    92   110   100
 5DRY BEAN  25    25    25    25    25    25    25    25    64   106   100    48
 6POTATOES  25    25    25    25    25    25    25    31    55   108   136   131
 7TR CROPS  25    25    25    25    25    25    25    31    64    81    80    59
 8COV ORCH  90    78    66    63    73    86    98   109   113   111   106    99
C1  HWMC 1 185   185   185   185   185   185   185   185   185   185   185   185
C2  HWGW 2 125   102    75    65    80   113   136   141   142   142   141   136
C3  MWGT 3  81    76    96    56    53    53    55    61    68    77    82    83
C4  LWGT 4  50    47    42    35    33    33    34    38    42    48    51    51
B1  OPWT 5 100   100   100   100   100   100   100   100   100   100   100   100
  1   2   0   1
 7 1972     1          SAN JUAN ABOVE BLUFF
SUB7 CROPS  1 29400.  2 25200.  3  7000.  4  5600.  5   700.  6     0.  7   700.
CROP7 CONT  8  1400.  9     0. 10     0. 11     0. 12     0. 13  2818.
UR-UN LAND        0.          0.
  2  2  1  4  1  1  1  1  0  0  0  0  0  0  0
(20X,12F5.0)
72 CORTEZ, COLO.     48.5 35.9 25.9 29.8 35.0 44.7 48.3 56.0 66.8 72.8 69.5 62.8
72 BLUFF, UTAH       51.4 38.3 25.9 30.8 38.3 49.7 54.6 61.1 72.0 78.0 75.7 67.2
(20X12F5.0)
72 CORTEZ            2.12 0.84 1.74 0.00 0.00 0.15 0.13 0.14 0.67 0.33 0.45 1.91
72 BLUFF, UTAH       1.39 1.22 1.66 0.00 0.00 0.00 0.00 0.00 0.35 0.50 0.09 0.60
(6X,I2,12F6.0)
723680 3 61.29 44.29 95.51116.30104.70126.10 62.39 83.20 99.63 13.64 26.21 46.08
(6X,I2,12F6.0)
723685 0  878.  863.  447.  353.  345. 2160. 1800. 3270. 2820.  670.  390.  570.
723690 0  170.  185.  150.  120.  140. 1200.  490.  720.  390.   98.   53.  105.
723695 0   52.   82.   62.   46.   40.  620.  280.  250.  110.   52.   11.   28.
72 IMP   8800. 8800. 5500.                   7400.17800.29700.24400.10600. 6400. 5000.
(6X,I2,12F6.0)
723710    2120  1590  2060  1010  1480  1090    94    79   287     0    76   328
(6X,I2,12F6.0)
72 CD7 0 17000   850   810   760   760  8730 35935 77375 65170 44140 24253 20695
(6X,I2,12F6.0)
72GW6    4311.  296.  166.  136.  113.   60. 1417. 5296. 3739. 3222. 3944. 4571.
(6X,I2,12F6.0)
723795 3 99.53 59.2 110.2 119.2 109.5 119.5  64.61 81.10118.1  17.08 30.60 56.33
  2   0   0   1
 60 -1   0   0 75          1.     1.E-06
  IDTM       1 1 1 1 1 1 1 1 1 1 1 1
  CMS          0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.
     0.       .40      28.       30.       3.    5000.   20000.      1.2       0.       0.
    4.0       3.0       6.        1.       0.       0.     .05       0.       .6       .8
     .5       1.9       1.        0.       0.       0.      0.       0.       0.       1.
     1.        1.       1.        1.       1.       1.      0.       .3       0.       0.
     0.        0.       0.        0.       0.       0.      0.       0.       1.       0.
     0.        0.       0.        0.       0.       0.      0.       0.       0.       0.
  6 -1   0   1
  3   2   0   0
   5  10        0.0        5.0
   6  20        0.0      10000.
   7  20     15000.      25000.

                          BLANK CARD
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```
 VAR OCT NOV DEC JAN FEB MAR      APR MAY JUN JUL AUG SEP ANN
   1 FHR TEMP   2    PRECIP    3 SNOW MLT    4 SNOW STR    5    PHR ET    6 CROP PET
   7 CROP AET   8    SM STR    9 RIVER IN   10   TRIB IN   11    UNG IN   12 PHR RPSM
  13  URB SRF  14   PUMP IN   15 RIVER GW   16   PHR SUR   17   WTR AVL   18   M&I DIV
  19  M&I RET  20   CNL DIV   21 CNL SEEP   22    CNL GW   23 SEEP RTN   24     SPILL
  25 FARM DEL  26 TAIL WTR   27   TOT APL   28 CROP AET   29    SM STR   30        DP
  31  ROUT DP  32     GW IN   33 URBGW IN   34    PHR GW   35   ROUT GW   36   EFFL GW
  37 CH GWSTR  38    GW OUT   39 CHNL EXP   40 SUR RNOF   41  COMP OUT   42 GAGE OUT
  43     DIFF  44 RES EVAP   45    RES IN   46 RES AREA   47   REQ REL   48   ACT REL
  49  CNL REL  50 RES EXPT   51   TOT REL   52 EOM STRG   53 CHG STRG   54
  55           56            57            58            59            60
KCMI       .100  .100  .100  .100  .100  .100  .100  .100  .100  .100  .100  .100
  PDL      .078  .068  .067  .069  .068  .083  .088  .098  .098  .100  .094  .083
 1ALFALF   .910  .780  .640  .630  .730  .860  .990 1.080 1.130 1.110 1.060  .990
 2PAS+OH   .850  .730  .600  .560  .650  .800  .920  .990 1.030 1.020  .990  .930
 3SPR GR   .250  .250  .250  .250  .250  .250  .250  .520 1.050 1.280  .570  .250
 4CORN+S   .580  .250  .250  .250  .250  .250  .250  .360  .580  .920 1.100 1.000
 5DRY BE   .250  .250  .250  .250  .250  .250  .250  .250  .640 1.060 1.000  .480
 6POTATO   .250  .250  .250  .250  .250  .250  .250  .310  .550 1.080 1.360 1.310
 7TR CRO   .250  .250  .250  .250  .250  .250  .250  .310  .640  .810  .800  .590
 8COV OR   .900  .780  .660  .630  .730  .860  .980 1.090 1.130 1.110 1.060  .990
 9  HWMC  1.850 1.850 1.850 1.850 1.850 1.850 1.850 1.850 1.850 1.850 1.850 1.850
10  HWGW  1.250 1.020  .750  .650  .800 1.130 1.360 1.410 1.420 1.420 1.410 1.360
11  MWGT   .810  .760  .960  .560  .530  .530  .550  .610  .680  .770  .820  .830
12  LWGT   .500  .470  .420  .350  .330  .330  .340  .380  .420  .480  .510  .510
13  OPWT  1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000

SUB 7 1972 TO 1972  SAN JUAN ABOVE BLUFF
LAND AREAS
       CROP LAND         PHR LAND           URB LAND          UND LAND         TOTAL LAND
         70000.              2818.                0.                0.             72818.
INCH TO AC-FT CONVERSION FACTORS
     5833.333007      234.833312          .000000           .000000        6068.166015
CROP AND PHREATOPHYTE ACRES
    1  29400.    2  25200.    3   7000.    4   5600.    5    700.    6      0.
    7    700.    8   1400.    9      0.   10      0.   11      0.   12      0.
   13   2818.
PROP CROP AND PHR
  1    .419999  2    .359999  3    .099999  4    .079999  5    .010000  6    .000000
  7    .010000  8    .020000
  9    .000000 10    .000000 11    .000000 12    .000000 13   1.000000
WEIGHTED CROP AND PHR COEFFICIENTS
  .782  .656  .548  .528  .605  .716  .816  .918 1.032 1.075  .985  .886
 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
HYDROLOGIC DATA
  1 1972         49.95        37.10        25.90        30.30        36.65        47.20
                 51.45        58.55        69.40        75.40        72.60        65.00
                619.49
  2 1972          1.75         1.03         1.70          .00          .00          .07
                   .06          .07          .51          .41          .27         1.25
                  7.14
  3 1972      61289.99     44289.99     95509.98    116299.98    104699.98    126099.98
              62389.99     83199.98     99629.98     13639.99     26209.99     46079.99
             879339.00
  4 1972       9900.00      9930.00      6159.00       519.00       525.00     11380.00
              20370.00     33940.00     27720.00     11420.00      6854.00      5703.00
             144420.00
  5 1972       2120.00      1590.00      2060.00      1010.00      1480.00      1090.00
                 94.00        79.00       287.00          .00        76.00       328.00
              10214.00
  6 1972      17000.00       850.00       810.00       760.00       760.00      8730.00
              35935.00     77375.00     65170.00     44140.00     24253.00     20695.00
             296478.00


  7 1972       4311.00       296.00       166.00       136.00       113.00        60.00
               1417.00      5296.00      3739.00      3222.00      3944.00      4571.00
              27271.00
  8 1972      99529.98     59199.99    110199.98    119199.98    109500.00    119500.00
              64609.98     81099.98    118099.98     17079.99     30599.99     56329.99
             984949.12
```

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SAN JUAN ABOVE BLUFF
60 -1  0   0 75  .100E+01  .100E-05
PAR   1        2        3        4        5        6        7        8        9        10
     .000     .400   28.000   30.000   3.0005000.000$20000.0   1.200     .000     .000
    4.000    3.000    6.000    1.000     .000     .000     .050     .000     .600     .800
     .500    1.900    1.000     .000     .000     .000     .000     .000     .000    1.000
    1.000    1.000    1.000    1.000    1.000    1.000     .000     .300     .000     .000
     .000     .000     .000     .000     .000     .000     .000     .000    1.000     .000
     .000     .000     .000     .000     .000     .000     .000     .000     .000     .000
 IDTM      1 1 1 1 1 1 1 1 1 1 1 1
 CMS       .000 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000
```

SAN JUAN ABOVE BLUFF
WATER

YEAR 1972

VAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1 PHR TEMP	49.949	37.899	25.899	30.300	36.649	47.199	51.449	58.549	69.399	75.399	72.599	64.999	51.624
2 PRECIP	1.765	1.030	1.700	.000	.000	.070	.060	.070	.510	.415	.270	1.255	7.144
3 SNOW MLT	.000	.000	.000	1.022	.656	.021	.000	.000	.000	.000	.000	.000	1.700
4 SNOW STR	.000	.000	1.700	.677	.021	.000	.000	.000	.000	.000	.000	.000	.000
5 PHR ET	2.151	.836	.523	.629	.799	1.070	2.620	4.030	6.005	7.505	6.455	4.409	38.035
6 CROP PET	1.683	.546	.206	.332	.484	1.417	2.140	3.781	6.281	8.074	6.364	3.987	35.229
7 CROP AET	1.683	.546	.206	.332	.484	1.417	2.146	3.781	6.281	6.939	3.718	2.102	29.643
8 SM STR	5.262	5.045	5.209	5.072	5.027	5.130	5.755	6.000	5.147	1.864	.354	1.194	4.454
9 RIVER IN	61209.	44209.	95509.	116299.	104699.	126899.	62389.	83199.	99629.	13639.	26209.	46079.	879339.
10 TRIB IN	9900.	9930.	6159.	519.	525.	11300.	20370.	33940.	27720.	11420.	6654.	5703.	144420.
11 UNG IN	17466.	4770.	6160.	8142.	7728.	3376.	282.	237.	861.	.	228.	2084.	51341.
12 PHR RPSM	412.	241.	0.	240.	154.	22.	15.	18.	119.	97.	63.	294.	1677.
13 URB SRF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14 PUMP IN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15 RIVER GW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16 PHR SUR	65.	0.	86.	0.	23.	309.	421.	651.	916.	1165.	1016.	518.	5174.
17 WTR AVL	91367.	60818.	108948.	125879.	113534.	142337.	89566.	133491.	147866.	43184.	47593.	65785.	1170287.
18 M&I DIV	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19 M&I RET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20 CNL DIV	17000.	850.	816.	760.	760.	8730.	35935.	77375.	65170.	43184.	24253.	20695.	295442.
21 CNL SEEP	6800.	340.	324.	304.	304.	3492.	14374.	30958.	26068.	17241.	9701.	8278.	118176.
22 CNL GW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23 SEEP RTN	2763.	1703.	1106.	825.	611.	1790.	6939.	16765.	20572.	19209.	15318.	12437.	100222.
24 SPILL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25 FARM DEL	10199.	510.	486.	456.	456.	5238.	21566.	46424.	39101.	25862.	14551.	12416.	177265.
26 TAIL WTR	2040.	102.	97.	91.	91.	1047.	4312.	9285.	7820.	5172.	2910.	2483.	35453.
27 TOT APL	18397.	6416.	388.	6329.	4192.	4752.	17628.	37546.	34256.	23110.	13216.	17254.	183491.
28 CROP AET	9822.	3282.	1674.	1940.	2824.	8267.	12523.	21589.	36641.	40479.	21693.	12262.	172920.
29 SM STR	30696.	32938.	30854.	34259.	34579.	29972.	33572.	34999.	30827.	10876.	2069.	6970.	6970.
30 DP	1211.	988.	798.	984.	1047.	1091.	1505.	14531.	2587.	1781.	329.	91.	26933.
31 ROUT DP	5833.	1211.	988.	798.	984.	1047.	1091.	1505.	14531.	2587.	1781.	329.	32675.
32 GW IN	4311.	296.	166.	136.	113.	68.	1417.	5296.	3739.	3222.	3944.	4571.	27271.
33 URBGW IN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34 PHR GW	27.	0.	36.	0.	10.	132.	180.	279.	392.	499.	435.	222.	2217.
35 ROUT GW	10116.	1507.	1109.	926.	1087.	974.	2327.	6522.	17877.	5310.	5298.	4678.	57729.
36 EFFL GW	10116.	1507.	1109.	926.	1087.	974.	2327.	6522.	17877.	5310.	5298.	4678.	57729.
37 CH GWSTR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38 GW OUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
39 CHNL EXP	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40 SUR RNOF	86524.	61578.	109345.	126137.	113952.	135638.	60265.	71923.	108394.	10482.	31541.	52252.	968027.
41 COMP OUT	86524.	61578.	109345.	126137.	113952.	135638.	60265.	71923.	108394.	10482.	31541.	52252.	968027.
42 BASE OUT	99529.	59199.	110199.	119199.	109500.	119508.	64609.	81099.	118099.	17079.	30599.	56329.	984949.
43 DIFF	-13005.	2378.	-854.	6937.	4452.	16130.	-4344.	-9176.	-9705.	-6597.	941.	-4077.	-16921.

OBJ = 761.97   OAH = -16921.8

PAR	NL	PL	PH	DF
5	10	.00000	5.00000	.50000
6	20	.00000	10000.00000	500.00000
7	20	15000.00000	25000.00000	500.00000

```
                        PHASE  1  PMIN=         761.972
PAR 1         2         3         4         5         6         7         8         9        10
     .000      .400    28.000    30.000    3.0005000.000$20000.0    1.200      .000      .000
    4.000     3.000     6.000     1.000      .000      .000      .050      .000      .600      .800
     .500     1.900     1.000      .000      .000      .000      .000      .000      .000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000      .000      .300      .000      .000
     .000      .000      .000      .000      .000      .000      .000      .000     1.000      .000
     .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
```

IP		LV	PAR	OBJ	OAH	GRAD
5		1	.000	902.194	-47563.882	.000
5		2	.500	858.979	-42456.882	-86.429
5		3	1.000	823.702	-37349.882	-70.554
5		4	1.500	796.363	-32242.878	-54.677
5		5	2.000	776.962	-27135.878	-38.802
5		6	2.500	765.498	-22028.886	-22.927
5	*	7	3.000	761.972	-16921.886	-7.052
5		8	3.500	766.384	-11814.886	8.823
5		9	4.000	778.733	-6707.886	24.698
5		10	4.500	799.020	-1600.886	40.574
6		1	.000	695.304	-25421.855	.000
6		2	500.000	698.649	-24571.855	.006
6		3	1000.000	702.731	-23721.855	.008
6		4	1500.000	707.552	-22871.855	.009
7		1	15000.000	844.173	-19971.878	.000
7		2	15500.000	835.253	-19666.886	-.017
7		3	16000.000	826.489	-19361.886	-.017
7		4	16500.000	817.880	-19056.886	-.017
7		5	17000.000	809.426	-18751.886	-.016

7		6	17500.000	801.128	-18446.886	-.016
7		7	18000.000	792.986	-18141.886	-.016
7		8	18500.000	784.999	-17836.886	-.015
7		9	19000.000	777.168	-17531.886	-.015
7		10	19500.000	769.492	-17226.886	-.015
7	*	11	20000.000	761.972	-16921.886	-.015
7		12	20500.000	754.607	-16616.886	-.014
7		13	21000.000	747.398	-16311.886	-.014
7		14	21500.000	740.344	-16006.886	-.014
7		15	22000.000	733.446	-15701.886	-.013
7		16	22500.000	726.704	-15396.886	-.013
7		17	23000.000	720.116	-15091.886	-.013
7		18	23500.000	713.685	-14786.886	-.012
7		19	24000.000	707.409	-14481.886	-.012
7		20	24500.000	701.288	-14176.886	-.012
7		21	25000.000	695.323	-13871.886	-.011

SAN JUAN ABOVE BLUFF
WATER

YEAR 1972

VAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1 FHR TEMP	49.949	37.899	25.899	30.300	36.649	47.199	51.449	58.549	69.399	75.399	72.599	64.999	51.624
2 PRECIP	1.755	1.030	1.700	.000	.000	.075	.065	.070	.510	.415	.270	1.255	7.144
3 SNOW MLT	.000	.000	.000	1.022	.656	.021	.000	.000	.000	.000	.000	.000	1.700
4 SNOW STR	.000	.000	1.700	.677	.021	.000	.000	.000	.000	.000	.000	.000	.000
5 PHR ET	2.151	.836	.523	.629	.799	1.078	2.629	4.038	6.085	7.565	6.455	4.409	38.835
6 CROP PET	1.683	.548	.286	.332	.484	1.417	2.146	3.781	6.281	8.074	6.364	3.987	35.229
7 CROP AET	1.683	.548	.286	.332	.484	1.417	2.146	3.781	6.281	6.939	3.718	2.102	29.643
8 SM STR	5.262	5.645	5.289	5.872	5.927	5.138	5.755	6.008	5.147	1.864	.354	1.194	4.454
9 RIVER IN	61289.	44289.	95589.	116299.	104699.	120899.	62389.	83199.	99620.	13639.	26289.	46879.	879339.
10 TRIB IN	9908.	9938.	6159.	519.	525.	11380.	20370.	33940.	27720.	11420.	6854.	5783.	144420.
11 UNG IN	20235.	4770.	6180.	3830.	4440.	3270.	282.	237.	861.	0.	220.	2359.	45892.
12 PHR RPSM	412.	241.	0.	240.	154.	22.	15.	16.	119.	97.	63.	294.	1677.
13 URB SRF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14 PUMP IN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15 RIVER GW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16 PHR SUR	65.	0.	86.	0.	23.	309.	421.	651.	916.	1165.	1816.	518.	5174.
17 WTR AVL	94142.	60818.	108948.	120766.	110253.	142231.	89560.	133491.	147866.	43104.	47593.	66060.	1164837.
18 M&I DIV	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19 M&I RET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20 CNL DIV	17000.	850.	810.	760.	760.	8730.	35935.	77375.	65170.	43104.	24253.	20695.	295442.
21 CNL SEEP	6800.	340.	324.	304.	304.	3492.	14374.	30958.	26068.	17241.	9701.	8278.	118176.
22 CNL GW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23 SEEP RTN	2763.	1783.	1186.	825.	611.	1790.	6939.	16765.	20572.	19209.	15318.	12437.	100222.
24 SPILL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25 FARM DEL	10199.	510.	486.	456.	456.	5238.	21560.	46424.	39101.	25862.	14551.	12416.	177265.
26 TAIL WTR	2040.	102.	97.	91.	91.	1047.	4312.	9285.	7820.	5172.	2910.	2483.	35453.
27 TOT APL	18397.	6416.	388.	6329.	4192.	4752.	17628.	37548.	34256.	23110.	13216.	17254.	183491.
28 CROP AET	9822.	3282.	1674.	1940.	2824.	8267.	12523.	21589.	36641.	40479.	21693.	12262.	172920.
29 SM STR	30696.	32930.	30854.	34259.	34579.	29972.	33572.	34999.	30027.	10876.	2069.	6970.	6970.
30 DP	1211.	988.	790.	984.	1047.	1091.	1505.	14531.	2587.	1781.	329.	91.	26933.
31 ROUT DP	5833.	1211.	988.	790.	984.	1047.	1091.	1505.	14531.	2587.	1781.	329.	32675.
32 GW IN	4311.	296.	166.	136.	113.	60.	1417.	5296.	3739.	3222.	3944.	4571.	27271.
33 URBGW IN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34 PHR GW	27.	0.	36.	0.	10.	132.	180.	279.	392.	499.	435.	222.	2217.
35 ROUT GW	10116.	1507.	1109.	926.	1007.	974.	2327.	6522.	17877.	5310.	5298.	4678.	57729.
36 EFFL GW	10116.	1507.	1109.	926.	1007.	974.	2327.	6522.	17877.	5310.	5298.	4678.	57729.
37 CH GWSTR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38 GW OUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
39 CHNL EXP	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40 SUR RNOF	89299.	61578.	109345.	121824.	110671.	135523.	60265.	71923.	108394.	10482.	31541.	52527.	962577.
41 COMP OUT	89299.	61578.	109345.	121824.	110671.	135523.	60265.	71923.	108394.	10482.	31541.	52527.	962577.
42 GAGE OUT	99529.	59199.	110199.	119199.	109500.	119500.	64609.	81099.	118099.	17079.	30599.	56329.	984949.
43 DIFF	-10230.	2378.	-854.	1824.	1171.	16023.	-4344.	-9176.	-9705.	-6597.	941.	-3802.	-22371.

PHASE 2 PMIN= 695.304

PAR 1	2	3	4	5	6	7	8	9	10
.000	.400	28.000	30.000	3.000	.000	25000.0	1.200	.000	.000
4.000	3.000	6.000	1.000	.000	.000	.050	.000	.600	.800
.500	1.900	1.000	.000	.000	.000	.000	.000	.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	.000	.300	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	1.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

IP		LV	PAR	OBJ	OAH	GRAD
5		1	.000	793.851	-53013.851	.000
5		2	.500	746.474	-47906.851	-94.753
5		3	1.000	707.035	-42799.851	-78.878
5		4	1.500	675.533	-37692.859	-63.002
5		5	2.000	651.970	-32585.855	-47.127
5		6	2.500	636.344	-27478.855	-31.251
5	*	7	3.000	628.655	-22371.855	-15.376
5		8	3.500	628.905	-17264.855	.498
5		9	4.000	637.092	-12157.855	16.374
5		10	4.500	653.217	-7050.855	32.250
6	*	1	.000	628.655	-22371.855	.000
6		2	500.000	632.000	-21521.855	.006
6		3	1000.000	636.083	-20671.855	.008
6		4	1500.000	640.904	-19821.855	.009
7		1	15000.000	777.505	-28471.847	.000
7		2	15500.000	768.585	-28166.855	-.017
7		3	16000.000	759.821	-27861.855	-.017
7		4	16500.000	751.212	-27556.855	-.017
7		5	17000.000	742.758	-27251.855	-.016

7	6	17500.000	734.460	-26946.855	-.016
7	7	18000.000	726.318	-26641.855	-.016
7	8	18500.000	718.331	-26336.855	-.015
7	9	19000.000	710.500	-26031.855	-.015
7	10	19500.000	702.824	-25726.855	-.015
7	11	20000.000	695.304	-25421.855	-.015
7	12	20500.000	687.939	-25116.855	-.014
7	13	21000.000	680.730	-24811.855	-.014
7	14	21500.000	673.676	-24506.855	-.014
7	15	22000.000	666.778	-24201.855	-.013
7	16	22500.000	660.036	-23896.855	-.013
7	17	23000.000	653.448	-23591.855	-.013
7	18	23500.000	647.017	-23286.855	-.012
7	19	24000.000	640.741	-22981.855	-.012
7	20	24500.000	634.620	-22676.855	-.012
7	* 21	25000.000	628.655	-22371.855	-.011

SAN JUAN ABOVE BLUFF YEAR 1972
WATER

VAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1 PHR TEMP	49.949	37.099	25.899	30.380	36.640	47.199	51.449	58.549	69.399	75.399	72.599	64.999	51.624
2 PRECIP	1.755	1.030	1.700	.000	.000	.075	.065	.070	.510	.415	.278	1.255	7.144
3 SNOW MLT	.000	.000	.000	1.022	.656	.021	.000	.000	.000	.000	.000	.000	1.700
4 SNOW STR	.000	.000	1.700	.677	.021	.000	.000	.000	.000	.000	.000	.000	.000
5 PHR ET	2.151	.036	.523	.029	.799	1.978	2.629	4.030	6.085	7.505	6.455	4.409	38.035
6 CROP PET	1.683	.548	.286	.332	.484	1.417	2.146	3.781	6.281	8.074	6.364	3.907	35.229
7 CROP AET	1.683	.548	.286	.332	.484	1.417	2.146	3.781	6.281	6.939	3.718	2.102	29.643
8 SM STR	5.262	5.645	5.289	5.872	5.927	5.138	5.755	6.000	5.147	1.864	.354	1.194	4.454
9 RIVER IN	61289.	44289.	95500.	116299.	104699.	126899.	62389.	83199.	99629.	13639.	26209.	46079.	879339.
10 TRIB IN	9900.	9930.	6159.	519.	525.	11380.	20370.	33940.	27720.	11420.	6854.	5703.	144420.
11 UNG IN	26235.	4770.	6180.	3030.	4440.	3270.	282.	237.	861.	0.	228.	2359.	45892.
12 PHR RPSM	412.	241.	0.	240.	154.	22.	15.	16.	119.	97.	63.	294.	1677.
13 URB SRF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14 PUMP IN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15 RIVER GW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16 PHR SUR	65.	0.	86.	0.	23.	389.	421.	651.	916.	1165.	1016.	518.	5174.
17 WTR AVL	94142.	60810.	108948.	120766.	110253.	142231.	89560.	133491.	147866.	43184.	47593.	66060.	1164837.
18 M&I DIV	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19 M&I RET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20 CNL DIV	17000.	850.	810.	760.	760.	8730.	35935.	77375.	65170.	43184.	24253.	20695.	295442.
21 CNL SEEP	6800.	340.	324.	304.	304.	3492.	14374.	30950.	26868.	17241.	9701.	8278.	118176.
22 CNL GW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23 SEEP RTN	2783.	1783.	1186.	825.	611.	1790.	6939.	16765.	20572.	19289.	15318.	12437.	100222.
24 SPILL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25 FARM DEL	10199.	510.	486.	456.	456.	5230.	21560.	46424.	39101.	25862.	14551.	12416.	177265.
26 TAIL WTR	2048.	102.	97.	91.	91.	1047.	4312.	9285.	7820.	5172.	2910.	2483.	35453.
27 TOT APL	18397.	6416.	388.	6329.	4192.	4752.	17628.	37548.	34256.	23110.	13216.	17254.	183491.
28 CROP AET	9822.	3202.	1674.	1940.	2824.	8267.	12523.	21509.	36641.	40479.	21693.	12262.	172920.
29 SM STR	38696.	32930.	38854.	34259.	34579.	29972.	33572.	34999.	38027.	10876.	2069.	6970.	6970.
30 DP	1211.	988.	790.	984.	1047.	1891.	1505.	14531.	2587.	1781.	329.	91.	26933.
31 ROUT DP	5833.	1211.	988.	790.	984.	1047.	1891.	1505.	14531.	2587.	1781.	329.	32675.
32 GW IN	4311.	296.	166.	136.	113.	60.	1417.	5296.	3739.	3222.	3944.	4571.	27271.
33 URBGW IN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34 PHR GW	27.	0.	36.	0.	18.	132.	180.	279.	392.	499.	435.	222.	2217.
35 ROUT GW	10116.	1507.	1189.	926.	1087.	974.	2327.	6522.	17877.	5310.	5298.	4678.	57729.
36 EFFL GW	10116.	1507.	1189.	926.	1087.	974.	2327.	6522.	17877.	5310.	5298.	4678.	57729.
37 CH GWSTR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38 GW OUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
39 CHNL EXP	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40 SUR RNOF	89299.	61578.	109345.	121024.	110671.	135523.	60265.	71023.	108394.	10482.	31541.	52527.	962577.
41 COMP OUT	89299.	61578.	109345.	121024.	110671.	135523.	60265.	71023.	108394.	10482.	31541.	52527.	962577.
42 GAGE OUT	99529.	59199.	110199.	119199.	109500.	119500.	64609.	81099.	118099.	17879.	30599.	56329.	984949.
43 DIFF	-10230.	2378.	-854.	1824.	1171.	16023.	-4344.	-9176.	-9785.	-6597.	941.	-3802.	-22371.

INITIAL VECTORS

PHASE	1	2	3	4	5	6
OBJ	761.972	628.655	628.655			
PAR						
1	.000	.000	.000			
2	.400	.400	.400			
3	28.000	28.000	28.000			
4	30.000	30.000	30.000			
5	3.000	3.000	3.000			
6	5000.000	.000	.000			
7	20000.000	25000.000	25000.000			
8	1.200	1.200	1.200			
9	.000	.000	.000			
10	.000	.000	.000			
11	4.000	4.000	4.000			
12	3.000	3.000	3.000			
13	6.000	6.000	6.000			
14	1.000	1.000	1.000			
15	.000	.000	.000			
16	.000	.000	.000			
17	.050	.050	.050			
18	.000	.000	.000			
19	.600	.600	.600			
20	.800	.800	.800			

21	.500	.500	.500
22	1.900	1.900	1.900
23	1.000	1.000	1.000
24	.000	.000	.000
25	.000	.000	.000
26	.000	.000	.000
27	.000	.000	.000
28	.000	.000	.000
29	.000	.000	.000
30	1.000	1.000	1.000
31	1.000	1.000	1.000
32	1.000	1.000	1.000
33	1.000	1.000	1.000
34	1.000	1.000	1.000
35	1.000	1.000	1.000
36	1.000	1.000	1.000
37	.000	.000	.000
38	.300	.300	.300
39	.000	.000	.000
40	.000	.000	.000
41	.000	.000	.000
42	.000	.000	.000
43	.000	.000	.000
44	.000	.000	.000
45	.000	.000	.000
46	.000	.000	.000
47	.000	.000	.000
48	.000	.000	.000
49	1.000	1.000	1.000
50	.000	.000	.000
51	.000	.000	.000
52	.000	.000	.000
53	.000	.000	.000
54	.000	.000	.000
55	.000	.000	.000
56	.000	.000	.000
57	.000	.000	.000
58	.000	.000	.000
59	.000	.000	.000
60	.000	.000	.000

Appendix C. FORTRAN Listing of the Computer Program BSAM

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C     GENERAL HYDROLOGY MODEL *BSAM* 7/16/76
      COMMON/BLK1/LABL(60),AGW(24),CMS(12),PKCMI(12),IDTM(12),BASID(15),
     1RES(14),PR(120),PDL(12),CKC(12),PKC(12),CPKC(25,12),HDG(20),
     2OUT(60,13)/BLK2/MANG,NCRPH,ISB,NSB,IYRB,NYR,IYRN,KR,IRES,IQGO,WH,
     3KMN,KMX,JMN,JMX,SMAX,SMIN,CONV,CONPV,CONUR,CONUN,TOLF,DUM(13),ITMX
     5/BLK3/HD(15,12,1)
      DOUBLE PRECISION LABL,DLAB1,DLAB2
      DIMENSION XIN(6,100),XMN(100),XPM(100),DF(100),OBI(6),NOP(6),
     1PL(100),PH(100),NL(100),NP(100)
      KR=6
    1 READ(KR,200)ITY,IPL,IPRT,ICOL
  200 FORMAT(5I3,2E10.3)
      IF(ITY.LE.0.OR.ITY.GT.6)GO TO 99
    3 GOTO(4,5,8,15,6,25),ITY
C     EXPLANATION OF OPTIONS
C     ITY=1READ DATA WITH DATPR
C          IPL=1 BASIC ONLY               IPRT=0 ECHO PRINT INPUT
C             =2 SUBASIN ONLY             IPRT=1 SUPPRESS PRINT
C             =3-4 RESERVOIR DATA               ICOL=1 80 COL PRINTER
C             =5 SUBASIN WO HYDROLOGY           ICOL=2 132 COL PRINTER
C     ITY=2 READ INITIAL SET UP-OPERATE AND PRINT
C          IPL NOT USED
C          IPRT=0 PRINT WATER SHOWING DIFF   ICOL=1 80 COL PRINTER
C              =1 SUPPRESS DIFF PRINTING           =2 132 COL PRINTER
C              =2 SUPPRESS ALL PRINT
C     ITY=3 REPEAT WITH SAME DATA
C            IPRT AND ICOL SAME AS UNDER ITY=2
C     ITY=4 INTERACTIVE SEARCH MODE
C            IPL = MANG OPTION
C            IPRT AND ICOL SAME AS ITY =2
C     ITY=5 READ PARAMETERS ONLY-OPERATE AND PRINT
C            IPL NOT USED
C            IPRT AND ICOL SAME AS ITY=2
C     ITY=6 PATTERN SEARCH MODE
C            IPL=MANG OPTION
C            IPRT AND ICOL SAME AS ITY=2
C     READ DATA WITH DATPR
    4 CALL DATPR(IPL,IPRT,ICOL)
      GO TO 1
C     READ SUBASIN DATA-PARAMETERS--OPERATE AND PRINT
    5 READ(KR,200)NPR,MANG,IRES,IQGO,ITMX,TOLF,WH
      WRITE(6,227) (BASID(I),I=1,15)
  227 FORMAT(1H120A4)
      WRITE(6,200) NPR,MANG,IRES,IQGO,ITMX,TOLF,WH
      READ(KR,201)DLAB1,(IDTM(I),I=1,12)
  201 FORMAT(2XA8,12I2)
      READ(KR,202)DLAB2,(CMS(I),I=1,12)
  202 FORMAT(2XA8,12F5.3)
C     READ PARAMETERS ONLY OPTION ITY=3
    6 READ(KR,203)(PR(L),L=1,NPR)
  203 FORMAT(10F8.3)
      WRITE(6,226)(I,I=1,10)
  226 FORMAT(1X3HPARI4,9I8)
      WRITE(6,204)(PR(I),I=1,NPR)
  204 FORMAT(1X10F8.3)
      WRITE(6,201)DLAB1,(IDTM(I),I=1,12)
      WRITE(6,202)DLAB2,(CMS(I),I=1,12)
    8 DO 10 I=1,NPR
      XIN(1,I)=PR(I)
   10 CONTINUE
      CALL HYDSM(IPRT,ICOL,OBJ,OAH)
      IF (MANG.LE.0)WRITE(6,206)OBJ,OAH
      GO TO 1
C      INTERACTIVE SEARCH MODE
   15 MANG=IPL
   16 CALL INTACT(NPR,NL,IPRT,ICOL,PR)
      GO TO 1
C     PATTERN SEARCH MODE
   25 MANG=IPL
      CALL HYDSM(4,1,OBJ,OAH)
      OBJ1=OBJ
      NLM=0
C     INITIALIZE PH, PL, AND NL
      DO 26 I=1,NPR
      PL(I)=0.
      PH(I)=0.
      NL(I)=1
   26 CONTINUE
   27 READ(KR,100)NPS,NPH,(NOP(L),L=1,NPH)
  100 FORMAT(25I3)
      IF(NPH.LE.0.OR.NPH.GT.5) GO TO 1
C      NPS IS NO OF PARAMETERS TO BE SEARCHED
C      NPH IS NO OF PHASES - NOP IS RESETTING OPTION FOR EACH PHASE
C          IF NOP = 0 RESET TO INITIAL, IF = 1 RESET TO BEST LOCAL
      IF(NPS.NE.300) GO TO 277
      CALL HYDSM(IPRT,ICOL,OBJ,OAH)
      WRITE(6,206) OBJ,OAH
  206 FORMAT(6H0OBJ =F15.2,5X5HOAH =F15.1)
      GO TO 27
  277 DO 28 I=1,NPS
      READ(KR,101) L,NLL,PLL,PHL
  101 FORMAT(2I4,2E10.5)
      IF(L.LE.0.OR.L.GT.60) GO TO 27
      NP(I)=L
      NL(L)=NLL
      PL(L)=PLL
      PH(L)=PHL
   28 CONTINUE
      OBI(1)=OBJ
      AH = OAH
C     INITIALIZE MINIMUM CONDITIONS
      PHMN=OBJ
      PRMN=OBJ
      DO 30 L=1,NPR
      RL=NL(L)
      XMN(L)=XIN(1,L)
      XPM(L)=XIN(1,L)
      DF(L)=(PH(L)-PL(L))/RL
   30 CONTINUE
C     WRITE OUT HEADINGS FOR PAR NL PL PH AND DF
      WRITE(6,102)
  102 FORMAT(1H0 4X,3HPAR,3X2HNL10X2HPL13X2HPH13X2HDF)
      DO 35 LL=1,NPS
      L=NP(LL)
      WRITE(6,103) L,NL(L),PL(L),PH(L),DF(L)
  103 FORMAT( 1XI7,I5,3F15.5)
   35 CONTINUE
      IF(NPS.GT.1) GO TO 39
      J=NP(1)
      NLO=NL(J)+1
      IF(NLO.LE.1) GO TO 27
      WRITE(6,106)
  106 FORMAT(3X2HIP3X2HLV4X3HPAR12X3HOBJ12X3HOAH11X4HGRAD)
      DO 38 I=1,NLO
      XI=I-1
      IF(DF(J).EQ.0.)GO TO 27
      PR(J)=PL(J)+DF(J)*XI
      OBJ1=OBJ
      CALL HYDSM(4,1,OBJ,OAH)
      GRAD=0.
      IF(I.EQ.1)GO TO 37
      IF(DF(J).EQ.0.) GO TO 37
      GRAD=(OBJ-OBJ1)/DF(J)
C     CHECK FOR CONSECUTIVE IMPROVEMENT AND IF NOT IMPROVED FOR 3 TIMES
C     THEN TERMINATE SEARCH
      IF(GRAD.LT.0.)GO TO 36
      NLM=NLM+1
      GO TO 37
   36 IF(NLM.GT.0)NLM=0
   37 WRITE(6,107) J,I,PR(J),OBJ,OAH,GRAD
  107 FORMAT(2XI3,2XI3,F10.3,3F15.3)
      IF(NLO.EQ.2) GO TO 27
      IF(NLM.GT.3)GO TO 27
   38 CONTINUE
      GO TO 27
C     BEGIN PHASE LOOP
   39 DO90 K=1,NPH
C     TAKE NEW PAGE WRITE PHASE ONE INITIAL VECTOR
      WRITE(6,104)K,PHMN,(I,I=1,10)
  104 FORMAT(1H120X5HPHASEI3,2X5HPMIN=F15.3/1X3HPARI2,9I8)
      WRITE(6,105)(XIN(K,L),L=1,NPR)
  105 FORMAT(1X10F8.3)
      WRITE(6,106)
C     BEGIN PAR LOOP
      DO 80 JJ=1,NPS
      J=NP(JJ)
      NLO=NL(J)+1
      IF(NLO.LE.2) GO TO 80
      D1=XIN(K,J)+.0005
      D2=XIN(K,J)-.0005
C     BEGIN INCR LOOP
      NLM=0
      DO 70 I=1,NLO
      IF(I.GT.1) GO TO 40
      OBJ1=OBJ
      GRAD=0.
      DS=DF(J)
      IF(DS.EQ.0.)GO TO 68
   40 XI=(I-1)
      PR(J)=PL(J)+DS*XI
      D3=PR(J)
      IF(D3-D2)49,41,41
   41 IF(D3-D1)42,42,49
   42 IF(NOP(K))49,60,49
C      OPERATE MODELS AND DETERMINE OBJECTIVE FUNCTION
   49 CALL HYDSM(4,1,OBJ,OAH)
      GRAD=0.
      IF(I.EQ.1)GO TO 47
      GRAD=(OBJ-OBJ1)/DS
      IF(GRAD.LT.0.)GO TO 46
      NLM=NLM+1
      GO TO 47
   46 IF(NLM.GT.0)NLM=0
   47 WRITE(6,107)J,I,PR(J),OBJ,OAH,GRAD
      GO TO 65
   60 OBJ=OBI(K)
      GRAD=0.
      IF(I.EQ.1)GO TO 64
      GRAD=(OBJ-OBJ1)/DS
      IF(GRAD.LT.0.)GO TO 63
      NLM=NLM+1
      GO TO 64
   63 IF(NLM.GT.0)NLM=0
   64 WRITE(6,108)J,I,XIN(K,J),OBJ,AH,GRAD
  108 FORMAT(2XI3,2H *I3,F10.3,3F15.3)
   65 OBJ1=OBJ
C     IF NEW PAR, INITIALIZE LOCAL MIN
      IF(I.GT.1) GO TO 67
      PRMN=OBJ
      XMN(J)=PR(J)
C     CK LOCAL AND PHASE MINS
      GO TO 51
   67 IF(OBJ-PRMN)50,51,51
   50 PRMN=OBJ
      XMN(J)=PR(J)
   51 IF(OBJ-PHMN)52,55,55
   52 PHMN=OBJ
      DO53L=1,NPR
   53 XPM(L)=PR(L)
C     IF NO IMPROVEMENT IN OBJ FOR 3 CONSECUTIVE TIMES, GO TO NEXT
```

```
C       PARAMETER
   55 IF(NLM.GE.3)GO TO 68
   70 CONTINUE
C       RESET PR(J) TO FIXED LEVEL FOR NEXT PAR.
   68 IF(NOP(K)-1)71,72,72
   71 PR(J)=XIN(K,J)
      GO TO 80
   72 PR(J)=XMN(J)
   80 CONTINUE
      NOOP=NOP(K)
       IF(NOOP.EQ.1) GO TO 83
   81 DO82L=1,NPR
   82 PR(L)=XMN(L)
      CALL HYDSM(4,1,OBJ,OAH)
      PRMN=OBJ
C       SELECT BEST VECTOR FOR NEXT PHASE
   83 IF(PRMN-PHMN)84,86,86
   84 DO85L=1,NPR
      XIN(K+1,L)=XMN(L)
   85 PR(L)=XMN(L)
      GO TO 88
   86 DO87L=1,NPR
      XIN(K+1,L)=XPM(L)
   87 PR(L)=XPM(L)
   88 CALL HYDSM(IPRT,ICOL,OBJ,OAH)
      OBI(K+1)=OBJ
      AH=OAH
   90 CONTINUE
C       WRITE OUT INITIAL VECTOR TABLE
      NHP=NPH+1
      WRITE(6,109)(L,L=1,6),(OBI(L),L=1,NHP)
  109 FORMAT(1H127X15HINITIAL VECTORS/1X5HPHASEI8,5I13/1X3HOBJ5F13.3,
     1F12.3)
      WRITE(6,110)
  110 FORMAT(12X3HPAR/)
      DO91 L=1,NPR
   91 WRITE(6,111)L,(XIN(M,L),M=1,NHP)
  111 FORMAT(1XI3,6F12.3)
      GO TO 1
   99 STOP
      END
```

```
C       INTERACTIVE CALIBRATION SUBROUTINE
      SUBROUTINE INTACT(NPR,NL,IPRT,ICOL,PR)
      DIMENSION NL(1),PR(1)
      CALL HYDSM(4,1,OBJ,OAH)
    3 NPR1=NPR
      IL=0
C       SSW OPTIONS
C       D ON STAY IN INTERACTIVE MODE
C       IF SSW E ON SUPPRESS PRINT
      OCT 23410
      J    .2
      J    .1
    2 WRITE(6,111)(I,I=1,10),(PR(I),I=1,NPR)
  111 FORMAT(/1X3HPARI4,9I8/(1X10F8.3))
      WRITE(6,112)OBJ,OAH
  112 FORMAT(5H OBJ=F15.5,10X4HOAH=F15.1)
    1 TYPE 100
  100 FORMAT(28HENTER PARAMETER NO AND VALUE/)
      ACCEPT 101,L,D
  101 FORMAT(I5,F15.5)
      IF(L.LE.0.OR.L.GT.NPR1)GO TO 15
C       IF SSW E ON SUPPRESS PRINT
      OCT 23440
      J    .5
      J    .10
    5 WRITE(6,107)L,PR(L),D
  107 FORMAT(11H CHANGE PARI3,5H FROMF15.5,3H TOF15.5)
   10 TYPE 102,L,PR(L),D
  102 FORMAT(10HCHANGE PARI3,5H FROMF15.5,3H TOF15.5)
      PR(L)=D
      IL=IL+1
      NL(IL)=L
      GO TO 1
   15 IF(L.EQ.200) GO TO 60
      IF(L.NE.300)GO TO 20
      CALL HYDSM(IPRT,ICOL,OBJ,OAH)
C       IF L = 300 PRINT ALL TABLES WHEN RUNNING HYDSM
      GO TO 90
   20 IF(IL.LE.0) GO TO 1
C       IF SSW E ON SUPPRESS PRINT
      OCT 23410
      J    .25
      J    .35
   25 WRITE(6,110)(NL(I),I=1,IL)
  110 FORMAT(1X8HPAR CHNG24I3)
   35 TYPE 112,OBJ,OAH
   45 CALL HYDSM(4,1,OBJ,OAH)
      IL=0
   46 TYPE 112,OBJ,OAH
C       IF SSW E ON SUPRESS PRINTING
      OCT 23410
      J    .50
      J    .1
   50 WRITE(6,112) OBJ,OAH
      GO TO 1
C**     ITERATION MODE
   60 TYPE 103
  103 FORMAT(47HENTER PAR, NO STEPS, INIT VALUE AND FINAL VALUE/)
      ACCEPT 104,L,N,P1,P2
  104 FORMAT(2I5,2F15.5)
      IF(L.LE.0.OR.L.GT.NPR1) GO TO 60
      IF(N.LE.0) GO TO 1
      EN=N
      NF=N+1
      DX=(P2-P1)/EN
C       IF SSW E ON SUPPRESS PRINT
      OCT 23410
      J    .65
      J    .70
   65 WRITE(6,105)
  105 FORMAT(9H PAR STEP5X3HVAL14X3HOBJ17X3HOAH)
   70 TYPE 105
      DO 80 I=1,NF
      EI1=I-1
      PR(L)=P1+EI1*DX
      CALL HYDSM(4,1,OBJ,OAH)
C       IF SSW E ON SUPPRESS PRINT
      OCT 23410
      J    .74
      J    .75
   74 WRITE(6,106)L,I,PR(L),OBJ,OAH
   75 TYPE 106,L,I,PR(L),OBJ,OAH
  106 FORMAT(2I4,F9.3,2F20.3)
      IF(N.LE.1) GO TO 1
   80 CONTINUE
      GO TO 1
C       IF SSW D ON CONTINUE IN INTERACTIVE MODE
   90 OCT 23420
      J    .99
      J    .3
   99 RETURN
      END
```

```
C       INPUT OF BASIC DATA **DATPR**
      SUBROUTINE DATPR(IPL,IPRT,ICOL)
      COMMON/BLK1/LABL(60),AGW(24),CMS(12),PKCMI(12),IDTM(12),BASID(15),
     1RES(14),PR(120),PDL(12),CKC(12),PKC(12),CPKC(25,12),HDG(15),
     2OUT(60,13)/BLK2/MANG,NCRPH,ISB,NSB,IYRB,NYR,IYRN,KR,IRES,IQGO,WH,
     3KMN,KMX,JMN,JMX,SMAX,SMIN,CONV,CONPV,CONUR,CONUN,TOLF,DUM(13),ITMX
     5/BLK3/HD(15,12,1)
      DOUBLE PRECISION LABL, DLAB
      DIMENSION N(15),CAC(25),I1(25),DCA(25),PCAP(25),FMT(10),DD(12)
C   ** IPL=1 BASIC DATA ONLY
C   ** IPL=2 SUBBASIN DATA ONLY
C   ** IPL=3 OR 4 RESERVOIR DATA ONLY
C   ** IPL=5 ACREAGE AND PARAMETERS ONLY
      IF(ICOL.LE.0.OR.ICOL.GT.2) ICOL=1
    1 GOTO(10,30,200,200,30),IPL
   10 READ(KR,500)NCROP,NPHRT
  500 FORMAT(25I3)
      NCRPH=NCROP+NPHRT
   15 READ(KR,501)(HDG(I),I=1,15)
  501 FORMAT(20A4)
      IF(IPRT.EQ.0) WRITE(6,502)(HDG(I),I=1,15)
  502 FORMAT(1H120A4)
      READ(KR,503)(LABL(I),I=1,60)
  503 FORMAT(10A8)
      IF(IPRT.EQ.0)WRITE(6,504)(I,LABL(I),I=1,60)
  504 FORMAT((1X6(I4,1XA8)))
      READ(KR,505)DLAB,(PKCMI(I),I=1,12)
  505 FORMAT(2XA8,12F5.3)
      IF(IPRT.EQ.0)WRITE(6,506)DLAB,(PKCMI(I),I=1,12)
  506 FORMAT(1XA8,12F6.3)
C*****READ IN PROPORTION DAYLIGHT HOURS AND USE COEFFICIENTS
      READ(KR,505) DLAB,(PDL(I),I=1,12)
      IF(IPRT.EQ.0)WRITE(6,506)DLAB,(PDL(I),I=1,12)
      DO 20 L=1,NCRPH
      READ(KR,505)DLAB,(CPKC(L,I),I=1,12)
      IF(IPRT.EQ.0)WRITE(6,507)L,DLAB,(CPKC(L,I),I=1,12)
  507 FORMAT(1XI2,A6,12F6.3)
   20 CONTINUE
C ***   WRITE INITIAL DATA
      GO TO 300
C ***   READ SUB-BASIN DATA
   30 READ(KR,508)ISB,IYRB,NYR,(BASID(I),I=1,15)
  508 FORMAT(I2,2I5,8X15A4)
      IYRN=IYRB+NYR-1
      IF(IPRT.EQ.1) GO TO 35
      WRITE(6,507)
      WRITE(6,509)ISB,IYRB,IYRN,(BASID(I),I=1,15)
  509 FORMAT(1X3HSUBI2,I5,3H TOI5,2X15A4)
C**     READ CROP AND PHREATOPHYTE ACREAGES
   35 DO 40 I=1,25
      CAC(I)=0.0
   40 CONTINUE
      SPAC=0.0
      SCAC=0.0
      READ(KR,106)(I1(I),DCA(I),I=1,NCRPH)
  106 FORMAT((10X7(I3,F7.0)))
      DO 50 I=1,NCRPH
      L=I1(I)
      IF(L.LE.0) GO TO 50
      CAC(L)=DCA(I)
      IF(L.GT.NCROP) GO TO 45
      SCAC=SCAC+CAC(L)
      GO TO 50
   45 SPAC=SPAC+CAC(L)
   50 CONTINUE
```

```
C       READ URBAN LAND AREA AND UNDEVELOPED LAND AREA
        READ(KR,510) URLND,UNDLND
  510 FORMAT(10X2F12.0)
        TOTA=URLND+UNDLND+SCAC+SPAC
C *** COMPUTE PROPORTIONS
        DO 60 I=1,NCRPH
        IF(I.GT.NCROP) GO TO 55
        PCAP(I)=CAC(I)/SCAC
        GO TO 60
   55 PCAP(I)=CAC(I)/SPAC
   60 CONTINUE
C *** COMPUTE SCALE FACTORS
        CONV=SCAC/12.0
        CONPV=SPAC/12.0
        CONUR=URLND/12.
        CONUN=UNDLND/12.
        CONTOT=TOTA/12.
C **  COMPUTE WEIGHTED USE COEF.
        DO 80 I=1,12
        SPKC=0.0
        SCKC=0.0
        DO 75 L=1,NCRPH
        SCP=CPKC(L,I)*PCAP(L)
        IF(L.GT.NCROP) GO TO 70
        SCKC=SCKC+SCP
        GO TO 75
   70 SPKC=SPKC+SCP
   75 CONTINUE
        CKC(I)=SCKC
        PKC(I)=SPKC
   80 CONTINUE
C *** WRITE OUT DATA UP TO THIS POINT
        IYRN =IYRB +NYR-1
        IF(IPRT.EQ.1) GO TO 100
        WRITE(6,511)
  511 FORMAT(1X10HLAND AREAS)
        WRITE(6,512)
  512 FORMAT(8X9HCROP LAND8X8HPHR LAND8X8HURB LAND8X8HUND LAND
      18X10HTOTAL LAND)
        WRITE(6,513)SCAC,SPAC,URLND,UNDLND,TOTA
  513 FORMAT(1X5F16.0)
        WRITE(6,514)
  514 FORMAT(1X32HINCH TO AC-FT CONVERSION FACTORS)
        WRITE(6,515)CONV,CONPV,CONUR,CONUN,CONTOT
  515 FORMAT(1X5F16.6)
        WRITE(6,517)
  517 FORMAT(1X27HCROP AND PHREATOPHYTE ACRES)
        WRITE(6,518)(I,CAC(I),I=1,NCRPH)
  518 FORMAT((1X6(I5,F8.0)))
        WRITE(6,519)
  519 FORMAT(1X17HPROP CROP AND PHR)
        WRITE(6,520)(I,PCAP(I),I=1,NCROP)
  520 FORMAT((1X6(I3,F10.6)))
        K=NCROP+1
        WRITE(6,520)(I,PCAP(I),I=K,NCRPH)
        WRITE(6,521)
  521 FORMAT(1X34HWEIGHTED CROP AND PHR COEFFICIENTS)
        WRITE(6,522)(CKC(I),I=1,12)
  522 FORMAT(1X12F6.3)
        WRITE(6,522)(PKC(I),I=1,12)
  100 IF(IPL.EQ.5)RETURN
C *** INPUT HYDROLOGIC DATA
C       DATA IS READ IN THE FOLLOWING ORDER AND STORED IN HD(I,K,J)
C       I = 1 IS TEMP, T
C           2 IS PRECIP, PPT
C           3 IS RIVER INFLOW, RIV
C           4 IS TRIBUTARY INFLOW, TRIB
C           5 IS UNGAGED CORRELATION INFLOW, QCOR
C           6 IS CANAL DIVERSIONS, CNL
C           7 IS GROUNDWATER INFLOW, QGI
C           8 IS GAGED OUTFLOW, GAG
C           9 IS PUMPED WATER FROM THE SHALLOW ACQUIFER, QPUM
C          10 IS M AND I DIVERSION, EMIDIV
C          11 IS RESERVOIR INFLOW, RIN
C          12 IS REQUIRED MINIMUM-RESERVOIR RELEASES TO STREAM, REL
C          13 IS RESERVOIR IN BASIN RELEASE FOR CANAL, ARD
C          14 IS RESERVOIR EXPORTS FROM THE BASIN, REXP
C          15 IS BASIN EXPORTS FROM THE STREAM CHANNEL, BEXP
        READ(KR,500)(N(I),I=1,15)
        DO 120 I=1,15
        DO 120 K=1,12
        DO 120 J=1,NYR
        HD(I,K,J)=0.
  120 CONTINUE
        DO 170 I=1,15
        NN=N(I)
        IF(NN.LE.0)GOTO170
        IF(I.GT.2)GOTO 140
C  ** INPUT TEMP AND PPT
        XC=NN
        CDL=1.0/XC
        READ(KR,501)(FMT(L),L=1,10)
        DO 130 L=1,NN
        DO 125 J=1,NYR
        READ(KR,FMT)(DD(  K),K=1,12)
        DO125 K=1,12
        HD(I,K,J)=HD(I,K,J)+DD(K)*CDL
  125 CONTINUE
  130 CONTINUE
        GO TO 170
C **  INPUT STREAMFLOW DATA
  140 READ(KR,501)(FMT(L),L=1,10)
        DO 150 L=1,NN
        DO145 J=1,NYR
        READ(KR,FMT)IX,(DD(K),K=1,12)
        DO 145 K=1,12
        HD(I,K,J)=HD(I,K,J)+DD(K)*10.**IX
  145 CONTINUE
  150 CONTINUE
  170 CONTINUE
C *** WRITE DATA BY TYPE AND YEAR
C **  HYDROLOGIC **
        IF(IPRT.EQ.1) GO TO 300
        WRITE(6,523)
  523 FORMAT(1X15HHYDROLOGIC DATA)
        DO 190 I=1,15
        NN=N(I)
        IF(NN.LE.0)GO TO 190
        DO 185 J=1,NYR
        SS=0.
        DO 180 K=1,12
        SS=SS+HD(I,K,J)
  180 CONTINUE
        LYRP=IYRB+J-1
        IF(ICOL.GE.2) GO TO 183
        WRITE(6,524)I,LYRP,(HD(I,K,J),K=1,12),SS
  524 FORMAT(1XI3,I5,6F12.2/(9X6F12.2))
        GO TO 185
  183 IF(I.GT.2) GO TO 184
        WRITE(6,529)I,LYRP,(HD(I,K,J),K=1,12),SS
  529 FORMAT(1XI3,I5,12F9.3,F12.3)
        GO TO 185
  184 WRITE(6,528)I,LYRP,(HD(I,K,J),K=1,12),SS
  528 FORMAT(1XI3,I5,12F9.0,F12.0)
  185 CONTINUE
  190 CONTINUE
        GO TO 300
C        READ RESERVOIR PARAMETERS
  200 READ(KR,525) (RES(I),I=1,14)
  525 FORMAT(10X,7F10.0)
        IF(IPRT.EQ.1) GO TO 300
        WRITE(6,526)
  526 FORMAT(1X20HRESERVOIR PARAMETERS)
        WRITE(6,527)(I,RES(I),I=1,14)
  527 FORMAT((1X5(I5,F10.2)))
  300 RETURN
        END
```

```
C       PRINT SUBROUTINE
        SUBROUTINE PRNT(J,IDF,ICOL)
        COMMON/BLK1/LABL(60),AGW(24),CMS(12),PKCMI(12),IDTM(12),BASID(15),
      1RES(14),PR(120),PDL(12),CKC(12),PKC(12),CPKC(25,12),HDG(15),
      2OUT(60,13)/BLK2/MANG,NCRPH,ISB,NSB,IYRB,NYR,IYRN,KR,IRES,IQGO,WH,
      3KMN,KMX,JMN,JMX,SMAX,SMIN,CONV,CONPV,CONUR,CONUN,TOLF,DUM(13),ITMX
      5/BLK3/HD(15,12,1)
        DOUBLE PRECISION LABL
        LYRP=IYRB+J-1
C       IF IDF=0 PRINT GAGED + DIFF
C             =1 SUPPRESS PRINTING GAGED + DIFF
C             =2 OR GREATER SUPPRESS PRINTING - GO TO BAPLOT
C       IF ICOL =1 80 COLUMN PRINTER
C               =2 132 COLUMN PRINTER
C       SET UP FOR WATER OR WATER + RESERVOIR
        IF(IDF.GE.2) GOTO 199
C        INITIALIZE ON FIRST CALL
        IF(J.GT.1) GOTO 5
        NT=1
        NT1=8
        NT2=9
        NT3=43
        NT4=44
        NT5=45
        NT6=53
        NDF=NT3-1
        IF(ICOL.LT.1.OR.ICOL.GT.2) ICOL=1
    5 WRITE(6,100)(BASID(I),I=1,15),LYRP
        WRITE(6,101)
  100 FORMAT(1H115A4,5X4HYEARI5)
  101 FORMAT(1X5HWATER/)
        GO TO (10,150), ICOL
C       80 COL PRINT LINE
C       IPG=0 FOR FIRST PAGE AND 1 FOR 2ND PAGE
   10 IPG=0
        WRITE(6,115)(HDG(I),I=1,7)
  115 FORMAT(6XA4,8XA4,5(7XA4)/)
        GO TO 21
   20 WRITE(6,116)(HDG(I),I=8,15)
  116 FORMAT(//1XA4,4XA4,6(7XA4)/)
   21 DO 25 I=NT,NT1
        IF(IPG.EQ.1) GO TO 23
        WRITE(6,118)I,LABL(I),(OUT(I,L),L=1,6)
  118 FORMAT(1XI3,1XA8,6F11.3)
        GO TO 25
   23 WRITE(6,119)I,(OUT(I,L),L=7,13)
  119 FORMAT(1XI3,7F11.3)
   25 CONTINUE
        DO 30 I=NT2,NT3
        IF(I.GE.NDF.AND.IDF.GT.0) GOTO 35
        IF(IPG.EQ.1) GOTO 33
        WRITE(6,120)I,LABL(I),(OUT(I,L),L=1,6)
  120 FORMAT(1XI3,1XA8,6F11.0)
        GOTO 30
   33 WRITE(6,121)I,(OUT(I,L),L=7,13)
  121 FORMAT(1XI3,7F11.0)
```

```
   30 CONTINUE
   35 IF(IRES.GE.1) GOTO 38
      IF(IPG.GE.1) GOTO 199
      GOTO 65
C     OUTPUT RESERVOIR DATA
   38 WRITE(6,108)
  108 FORMAT(/1X9HRESERVOIR)
      I=NT4
      IF(IPG.EQ.1) GOTO 40
      WRITE(6,118)I,LABL(I),(OUT(I,L),L=1,6)
      GOTO 45
   40 WRITE(6,119)I,(OUT(I,L),L=7,13)
   45 DO 50 I=NT5,NT6
      IF(IPG.EQ.1) GOTO 48
      WRITE(6,120)I,LABL(I),(OUT(I,L),L=1,6)
      GOTO 50
   48 WRITE(6,121)I,(OUT(I,L),L=7,13)
   50 CONTINUE
   60 IF(IPG.GE.1) GOTO 165
   65 IPG=1
      WRITE(6,122) LYRP
  122 FORMAT(1H1I4)
      GOTO 20
C     132 COLUMN PRINTER
  150 WRITE(6,105)(HDG(I),I=1,7),(HDG(I),I=9,15)
  105 FORMAT(6XA4,6XA4,11(5XA4),7XA4/)
      DO 155 I=NT,NT1
      WRITE(6,106)I,LABL(I),(OUT(I,L),L=1,13)
  106 FORMAT(1XI3,1XA8,12F9.3,F11.3)
  155 CONTINUE
      DO 156 I=NT2,NT3
      IF(I.GE.NDF.AND.IDF.GT.0) GOTO 157
      WRITE(6,107)I,LABL(I),(OUT(I,L),L=1,13)
  107 FORMAT(1XI3,1XA8,12F9.0,F11.0)
  156 CONTINUE
  157 IF(IRES.EQ.0) GOTO 199
C     OUTPUT RESERVOIR DATA
      WRITE(6,108)
      I=NT4
      WRITE(6,106)I,LABL(I),(OUT(I,L),L=1,13)
      DO 160 I=NT5,NT6
      WRITE(6,107)I,LABL(I),(OUT(I,L),L=1,13)
  160 CONTINUE
  165 IF(J.NE.NYR) GOTO 199
C     WRITE RESERVOIR EXTREMES
      IKMN=1
      IKMX=1
      IF(KMN.GT.6) IKMN=2
      IF(KMX.GT.6) IKMX=2
      WRITE(6,109)
  109 FORMAT(/1X18HRESERVOIR EXTREMES)
      KI=KMX+IKMX
      WRITE(6,110) SMAX,HDG(KI),JMX
  110 FORMAT(1XF15.0,7H AC-FT A4,I6)
      KI=KMN+IKMN
      WRITE(6,110)SMIN,HDG(KI),JMN
  199 CALL BAPLOT(J,NYR,OUT)
      RETURN
      END
C *** SUBROUTINE DOUT ***
      SUBROUTINE DOUT(K,L,XD,KTYPE)
      COMMON/BLK1/LABL(60),AGW(24),CMS(12),PKCMI(12),IDTM(12),BASID(15),
     1RES(14),PR(120),PDL(12),CKC(12),PKC(12),CPKC(25,12),HDG(15),
     2OUT(60,13)/BLK2/MANG,NCRPH,ISB,NSB,IYRB,NYR,IYRN,KR,IRES,IQGO,WH,
     3KMN,KMX,JMN,JMX,SMAX,SMIN,CONV,CONPV,CONUR,CONUN,TOLF,DUM(13),ITMX
     5/BLK3/HD(15,12,1)
      DOUBLE PRECISION LABL
C     KTYPE =0 RETURN
C            1 SUM
C            2 AVERAGE
C            3 LAST MONTH
      IF(KTYPE.LE.0.OR.KTYPE.GT.3) GOTO 99
      OUT(L,K)=XD
      GOTO (80,85,90) ,KTYPE
   80 OUT(L,13)=OUT(L,13)+XD
      GOTO 99
   85 OUT(L,13)=OUT(L,13)+XD/12.
      GOTO 99
   90 OUT(L,13)=OUT(L,K)
   99 RETURN
      END


C**** HYDROLOGIC SIMULATION ***HYDSM***
      SUBROUTINE HYDSM(IPRT,ICOL,OBJ,OAH)
      COMMON/BLK1/LABL(60),AGW(24),CMS(12),PKCMI(12),IDTM(12),BASID(15),
     1RES(14),PR(120),PDL(12),CKC(12),PKC(12),CPKC(25,12),HDG(15),
     2OUT(60,13)/BLK2/MANG,NCRPH,ISB,NSB,IYRB,NYR,IYRN,KR,IRES,IQGO,WH,
     3KMN,KMX,JMN,JMX,SMAX,SMIN,CONV,CONPV,CONUR,CONUN,TOLF,DUM(13),ITMX
     5/BLK3/HD(15,12,1)
      DOUBLE PRECISION LABL
      EQUIVALENCE (PR(1),SNI),(PR(2),SNK),(PR(3),TSM),(PR(4),TPR),
     1(PR(5),COR),(PR(6),CSN),(PR(7),CRN),(PR(8),RTH),(PR(9),CTP),
     2(PR(10),PTH),(PR(11),SMI),(PR(12),CSM),(PR(13),SMC),(PR(14),DTA),
     3(PR(15),DPI),(PR(16),DPK),(PR(17),CDP),(PR(18),PSP),(PR(19),ECV),
     4(PR(20),EAP),(PR(21),CNI),(PR(22),CNK),(PR(23),CRT),(PR(24),C1),
     5(PR(25),C2),(PR(26), C3),(PR(27),GWI),(PR(28),GWK),(PR(29),CGO),
     6(PR(30),TAJ),(PR(31),PAJ),(PR(32),CNA),(PR(33),GWA),(PR(34),DMIA),
     7(PR(35),CUMIA),(PR(36),CUA),(PR(37),CGW),(PR(38),CUPGW),(PR(39),
     8CUUR),(PR(40),CUUN),(PR(41),PURGW),(PR(43),STH),(PR(44),PBST)
C     IF IPRT = 0 PRINT ALL LINES
C               1 SUPPRESS PRINTING OF GAGED AND DIFF
C               2 OR GT SUPPRESS ALL PRINT
C     IF ICOL = 1 80 COLUMN LINE PRINTER
C               2 132 COLUMN LINE PRINTER
C     INITIALIZE  OBJECTIVE FUNCTIONS
      CHGWS=0.
      OBH=0.0
      OAH=0.0
      SCHGW=0.
      SMSTRC=(SMC-CSM)/SMC
C     INITIALIZE SNOW, GROUND WATER, SALT IC'S
      SNW1=SNI
      GW1=GWI
      SM1=SMI
      ARF1=DPI
      PTW=1.-EAP
      GWCNIC=CNI
      DO 10 L=1,12
      K1=L+48
      K=L+12
      AGW(K)=PR(K1)
   10 CONTINUE
      IF(DTA.GE.12.) DTA=11.99999
      IDTA=DTA
      RIDTA=IDTA
      IF(IDTA.LE.0) GO TO 15
      P1=AMOD(DTA,RIDTA)
      GO TO 20
   15 P1=DTA
   20 PO=1.-P1
C    DO FOR EACH YEAR
      DO 200 J=1,NYR
C      INITIALIZE ANNUAL VALUES
      DO 25 L=1, 60
      OUT(L,13)=0.
   25 CONTINUE
      DO 30 L=1,12
      AGW(L)=AGW(L+12)
      AGW(L+12)=0.0
   30 CONTINUE
C      DO FOR EACH MONTH
      DO 190 K=1,12
      KC1=0
   40 CALL HSP(T   ,J,K,1)
      CALL HSP(PPT,J,K,2)
      CALL HSP(RIV,J,K,3)
      CALL HSP(TRB,J,K,4)
      CALL HSP(QCOR,J,K,5)
      CALL HSP(CNL,J,K,6)
      CALL HSP(QGI,J,K,7)
      CALL HSP(GAG,J, K,8)
      CALL HSP(QPUM,J,K,9)
      CALL HSP(EMIDIV,J,K,10)
      CALL HSP(BEXP,J,K,15)
      ARD=0.
      RIN=0.
      PPT=PPT*PAJ
      REL=0.0
      IF(IRES.EQ.0) GO TO 45
      CALL HSP(ARD,J,K,13)
      SCNR=0.
      IF(CNL.LE.0.) GO TO 44
      SCNR=ARD/CNL
   44 IF(SCNR.LE.0.) SCNR=PR(42)
   45 TEMP=T+TAJ
      GWIN=QGI*GWA
      CNL=CNL*CNA
      EMIDIV=EMIDIV*DMIA
      CFEMI=PKCMI(K)*CUMIA
C      COMPUTE POTENTIAL EVAPTRANS
      CALL BCCU(TEMP,PDL(K),CKC(K),EKT,ETF,PET)
      ETP=PET*CUA
      PHET=PKC(K)*ETF
C     CALCULATE EVP FOR OPEN WATER FOR USE IN RESRV
      EVP=CPKC(NCRPH,K)*ETF
C     DETERMINE RAIN,SNOW AND SNOWMELT
   50 RAIN=0.
      SNMT=0.0
      IF(TEMP.GE.TPR) GO TO 55
      SNW1=SNW1+PPT
      GOTO 60
   55 RAIN=PPT
   60 DTM=TEMP-TSM
      IF(DTM.LE.0.) GO TO 75
      IF(SNW1.LE.0.) GO TO 75
      XMTK=SNK*DTM
C     INITIALIZE SNOW, GROUND WATER, SALT IC'S
      IF(XMTK.GE.85.) GO TO 65
      SNW2=SNW1*EXP(-XMTK)
      GOTO 70
   65 SNW2=0.
   70 SNMT=SNW1-SNW2
        IF(SNW1.LT.SNMT)SNMT=SNW1
   75 RPSM=RAIN+SNMT
      SNW1=SNW1-SNMT
      RMPH=RPSM*CONPV
C     CALCULATE PHREATOPHYTE ET NEEDED FROM INFLOWS
      PNET=(PHET-RPSM)*CONPV
      IF(PNET.LT.0.0)PNET=0.0
C     CALCULATE UNGAGED FLOWS
      UNSM=CSN*(SNMT-STH)
      IF(UNSM.LT.0.) UNSM=0.
      UNRN=CRN*(RAIN-RTH)
      IF(UNRN.LT.0.) UNRN=0.
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      UNTP=CTP*(PPT-PTH)
      IF(UNTP.LT.0.) UNTP=0.
      QUNG=COR*QCOR+UNSM+UNRN+UNTP
C***  CALCULATE INFLUENT GW
      QRIV=RIV+TRB+QUNG
      IF(QRIV.GT.1.) GO TO 80
      STGW=0.
      GO TO 85
   80 CINF=C1-C2*ALOG10(QRIV)
      IF(CINF.LT.C3) CINF=C3
      STGW=CINF*QRIV
C***  CALCULATE RUNOFF AND CONSUMPTIVE USE FROM LAND AREA OF URBAN AND
C     UNDEVELOPED LAND AND PROPORTION TO GW
   85 PCPURU=RPSM*(CONUR+CONUN)
      URUNCU=RPSM*(CONUR*CUUR+CONUN*CUUN)
      URSF=PCPURU-URUNCU
      URGW=URSF*PURGW
      URSF=URSF-URGW
      QIN=QRIV+QPUM+URSF-STGW
C     CALCULATE PHREATOPHYTE USE
      PHSF=PHET*CONPV-RMPH
      IF(PHSF.GT.0.) GO TO 90
      QIN=QIN-PHSF
      PHSF=0.
      PHGW=0.
      GOTO 100
   90 PHGW=PHSF*CUPGW
      PHSF=PHSF-PHGW
      IF(QIN.GE.PHSF) GO TO 100
      PHSF=QIN
      IF(PHSF.LT.0.) PHSF=0.
  100 QIN=QIN-PHSF
C     CALCULATE CANAL DIVERSIONS FOR MANAGEMENT MODE
      IF(MANG.LE.0) GO TO 110
      CALL CANAL(CNL,MANG,IDTM(K),ETP,EAP,ECV,PSP,SM1,CMS(K),RPSM,CONV)
  110 KC2=0
      SEEP1=GWCNIC*CRT
      SEEP=SEEP1
      CNL1=CNL
C      RESERVOIR OPERATION
      IF(IRES.NE.1) GO TO 120
C     IF IRES = 0 NO RESERVOIR
C             = 1 THEN TRIBUTARY OR UPSTREAM RESERVOIR
C             = 2 THEN DOWNSTREAM RESERVOIR
      ARD=CNL*SCNR
      CNL=CNL-ARD
      CALL RESRV(J,K,IRES,OUT,HD,RES,PR,EVP,PPT,RIN,ARD,REL,ST,KMN,
     1KMX,JMN,JMX,SMIN,SMAX,IYRB)
      CNL=CNL+ARD
C     ITERATE HERE TO ABOUT 130 FOR SEEPAGE IN MANAGEMENT MODE
  120 WAD=QIN+SEEP+REL+ARD-RIN
      IF(WAD.LT.0.) WAD=0.
      CALL URBEMI(WAD,EMIDIV,CFEMI,EMICU,EMIRF)
C     IF MANG=-1 LIMIT CNL TO WAD
C     IF MANG= 0 OR 1 USE AS RECORDED
C      IF MANG = 2 OR 3 LIMIT TO WAD
      IF(MANG.EQ.0.OR.MANG.EQ.1) GO TO 125
      IF(CNL.GT.WAD) CNL=WAD
  125 GWCN=CNL*(1.-ECV)
      GWCNSV=GWCN
C     ROUTE SEEPAGE WATER FROM CANALS
      CALL GWROUT(GWCN,GWCNIC,CNK,GWCN)
      SEEP=GWCN*CRT
      IF(ABS(SEEP-SEEP1).LE.TOLF) GOTO 130
      CNL=CNL1
      KC2=KC2+1
      SEEP1=SEEP
      IF(KC2.LE.ITMX) GOTO 120
      WRITE(6,500) J,K,SEEP1,SEEP
  500 FORMAT(1X19HSEEP ITMAX FOR YEARI3,2X5HMONTHI3,2F10.1)
  130 SPILL=CNL*PSP
      QCV= CNL-GWCNSV-SPILL
      GWCN=GWCN-SEEP
      TWTR=QCV*PTW
      WAGS=QCV-TWTR
      QIGS=RPSM+WAGS/CONV
      STR=WAD-CNL+TWTR+SPILL
      WAPP=QIGS*CONV
C     WAGS IS DELIVERED WATER BY IRRIGATION CANALS IN ACRE-FT
C     QIGS IS TOTAL WATER APPLIED TO SOIL IN INCHES
C     WAPP IS TOTAL WATER THROUGH THE SOIL IN ACRE-FT
C    COMPUTE SOIL MOISTURE LEVEL
      DPO=0.
      SM1W=SM1+QIGS
      IF(SM1W.GT.CSM) DPO=(SM1W-CSM)*CDP
      SM1WDP=SM1W-DPO
      SM2=SM1WDP-ETP
      IF(SM2.LT.0.) SM2=0.
      DP=SM2-SMC
      IF(DP.LT.0.) GO TO 140
      SM2=SMC
      GOTO 145
  140 DP=0.
      IF(SM2.GE.CSM) GO TO 145
C     ET IS LESS THAN POTENTIAL
      ETT=SM1WDP-CSM
      IF(ETT.LT.0.) ETT=0.
      ETB=ETP-ETT
C     ETB IS AMT OF ETP THAT MUST COME FROM BELOW CRITICAL
      AET=ETT+ETB*SMSTRC
      SM2=SM1WDP-AET
      IF(SM2.GT.0.) GO TO 150
      SM2=0.
      AET=SM1WDP
      GOTO 150
  145 AET=ETP
  150 DP=DP+DPO
C***  CROPLAND DP ROUTED TO GW
      KIDTA=K+IDTA
      AGW(KIDTA)=DP*PO+AGW(KIDTA)
      AGW(KIDTA+1)=AGW(KIDTA+1)+DP*P1
      CALL GWROUT(ARF2,ARF1,DPK,AGW(K))
      ARF=ARF2*CONV
C***  CALCULATION OF SPRING FLOW AND  RETURN FLOW DIVERTED TO CANALS  *
      DUMSP=GWCN+ ARF+STGW+URGW
      ARF1=ARF2
      SMAV=(SM1+SM2)*0.5
      SM1=SM2
      GWCNIC=GWCN+SEEP
C***  ROUTING OF GW THROUGH BASIN
      GGW=GWIN+DUMSP-QPUM-PHGW
      CALL GWROUT(QO2,GW1,GWK,GGW)
C***  LIMIT QO2 TO BE GE 0
      IF(IQGO.NE.0) GO TO 160
      IF(QO2.LT.0.)QO2=0.
  160 QGO=QO2
      GW1=QO2
      CHGW=GGW-QGO
      GWO=QGO*CGO
      GEF=QGO-GWO
C     PROPORTION OF GAGED SURFACE RUNOFF  SRF
      SRF=STR+GEF-BEXP
C     IF DOWNSTREAM RESERVOIR THEN SRF BECOMES INFLOW TO RESERVOIR
C     AND OBH AND OAH ARE BASED ON DS, THE CHANGE IN RESERVOIR STORAGE
      IF(IRES.LE.1) GOTO 165
      CALL RESRV(J,K,IRES,OUT,HD,RES,PR,EVP,PPT,SRF,ARD,REL,ST,KMN,
     1KMX,JMN,JMX,SMIN,SMAX,IYRB)
      QSO=ST
      GOTO 170
  165 QSO=SRF
  170 DIFF= QSO-GAG
      OBH=OBH+DIFF*DIFF
      AETT=AET*CONV
      XSM=SM1*CONV
      DP=DP*CONV
C     CALL DOUT
   21 CALL DOUT( K, 1,     T,2)
      CALL DOUT( K, 2,   PPT,1)
      CALL DOUT( K, 3,  SNMT,1)
      CALL DOUT( K, 4,  SNW1,3)
      CALL DOUT( K, 5,  PHET,1)
      CALL DOUT( K, 6,   ETP,1)
  536 CALL DOUT( K, 7,   AET,1)
      CALL DOUT( K, 8,   SM1,2)
      CALL DOUT( K, 9,RIV,1)
      CALL DOUT( K,10,TRB,1)
      CALL DOUT( K,11,QUNG,1)
      CALL DOUT( K,12,  RMPH,1)
      CALL DOUT( K,13,  URSF,1)
      CALL DOUT( K,14,  QPUM,1)
      CALL DOUT( K,15,  STGW,1)
      CALL DOUT( K,16,  PHSF,1)
      CALL DOUT( K,17,   WAD,1)
      CALL DOUT( K,18,EMIDIV,1)
      CALL DOUT( K,19, EMIRF,1)
      CALL DOUT( K,20,   CNL,1)
      CALL DOUT( K,21,GWCNSV,1)
      CALL DOUT( K,22,  GWCN,1)
      CALL DOUT( K,23,  SEEP,1)
      CALL DOUT( K,24, SPILL,1)
      CALL DOUT( K,25,   QCV,1)
      CALL DOUT( K,26,  TWTR,1)
      CALL DOUT( K,27,  WAPP,1)
      CALL DOUT( K,28,  AETT,1)
      CALL DOUT( K,29,   XSM,3)
      CALL DOUT( K,30,    DP,1)
      CALL DOUT( K,31,   ARF,1)
      CALL DOUT( K,32,  GWIN,1)
      CALL DOUT( K,33,  URGW,1)
      CALL DOUT( K,34,  PHGW,1)
      CALL DOUT( K,35,   QGO,1)
      CALL DOUT( K,36,   GEF,1)
      CALL DOUT( K,37,  CHGW,1)
      CALL DOUT( K,38,   GWO,1)
      CALL DOUT( K,39,  BEXP,1)
      CALL DOUT( K,40,   SRF,1)
      IF(IRES.LT.2) GOTO 180
      CALL DOUT(K,41, ST,3)
      CALL DOUT(K,42, GAG,3)
      GOTO 185
  180 CALL DOUT( K,41,   QSO,1)
      CALL DOUT( K,42,   GAG,1)
  185 CALL DOUT( K,43,  DIFF,1)
  190 CONTINUE
C    COMPUTE OBJECTIVE FUNCTION
      OAH=OAH+OUT(43,13)
      CHGWS=CHGWS+OUT(37,13)
  195 CALL PRNT(J,IPRT,ICOL)
  200 CONTINUE
      DX=CHGWS-CGW
      OBH=(OBH+DX*DX)*WH
      OBJ=OBH
      RETURN
      END
```

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C*****SUBROUTINE HSP ****
      SUBROUTINE HSP(D,J,K,I)
      COMMON/BLK1/LABL(60),AGW(24),CMS(12),PKCMI(12),IDTM(12),BASID(15),
     1RES(14),PR(120),PDL(12),CKC(12),PKC(12),CPKC(25,12),HDG(15),
     2OUT(60,13)/BLK2/MANG,NCRPH,ISB,NSB,IYRB,NYR,IYRN,KR,IRES,IQGO,WH,
     3KMN,KMX,JMN,JMX,SMAX,SMIN,CONV,CONPV,CONUR,CONUN,TOLF,DUM(13),ITMX
     5/BLK3/HD(15,12,1)
      DOUBLE PRECISION LABL
      D=HD(I,K,J)
      RETURN
      END
C      BLANEY CRIDDLE CU CALCULATION
      SUBROUTINE BCCU(T,PDL,CKC,EKT,ETF,PET)
      EKT=0.0173*T-0.314
      IF(EKT.LT.0.3)EKT=0.3
      ETF=EKT*T*PDL
      PET=CKC*ETF
      RETURN
      END
C     CANAL DIVERSIONS FOR MANAGEMENT
      SUBROUTINE CANAL(CNL,MANG,IDTM,ETP,EAP,ECV,PSP,EMS,CMS,RPSM,CONV)
C***  IF MANG=-1 LIMIT QCNL TO WAD BUT UES GAGED RECORDS
C                0 USE QCNL AS RECORDED
C                1 CALC QCNL AND USE WITHOUT LIMIT TO SATISFY 7ET
C                2 CALC QCNL BUT LIMIT TO WAD
C                3 PUT LEACHING WATER TO ZERO AND LIMIT TO WAD
      IF(MANG.GE.3) CNL=0.
      IF(IDTM.GT.0) GO TO 10
      CNL=0.
      GO TO 50
   10 ETN=ETP-(RPSM+(EMS-CMS))
      IF(ETN.LT.0.) ETN=0.
      CNL=CNL+(ETN*CONV)/(EAP*(ECV-PSP))
   50 RETURN
      END
C     SUBROUTINE FOR M&I CU
      SUBROUTINE URBEMI(WAD,DIV,CF,CU,RF)
      IF(DIV.GT.WAD) DIV=WAD
      CU=DIV*CF
      RF=DIV-CU
      WAD=WAD-CU
   20 RETURN
      END
C     GROUND WATER ROUTING SUBROUTINE
      SUBROUTINE GWROUT(QO2,QO1,XKG,QI)
      IF(XKG.LE..012) GO TO 1
      QO2=QI+(QO1-QI)*EXP(-1./XKG)
      GO TO 2
    1 QO2=QI
    2 RETURN
      END


C** RESERVOIR SIMULATION ** RESRV****
      SUBROUTINE RESRV(J,K,IOP,OUT,HD,RES,PR,EVP,PPT,RIN,ARD,REL,ST,KMN,
     1KMX,JMN,JMX,SMIN,SMAX,IYRB)
      DIMENSION OUT(60,1),HD(15,12,1),RES(1),PR(1)
C     IOP=IRES= 1 IS FOR TRIBUTARY OR UPSTREAM RESERVOIR AND
C                 RIN AND ARD ARE READ INTO HD BY DATPR
C               2 IS FOR DOWNSTREAM RESERVOIR AND RIN IS
C                 PASSED FROM HYDSM
C     J=YR.,K=MNTH,ETF=MOD BC TEMP FACTOR
C     ARD=ACTUAL CANAL RELEASE (WATER OR SALT)
C     RSR=TOTAL RELEASES (WATER OR SALT)
C     REXP=RES EXPORT
C     RESERVOIR PARAMETERS, RES, ARE AS FOLLOWS
C     RES(1) = INITIAL STORAGE (AC-FT)
C         2  = NOT USED (WAS INITIAL SALT CONCENTRATION (PPM))
C         3  = MINIMUM USEABLE STORAGE (AC-FT)
C         4  = MAXIMUM ALLOWABLE STORAGE (AC-FT)
C         5  = RESERVOIR AREA AT ZERO STORAGE INTERCEPT (ACRES)
C         6  = C1 COEFFICIENT IN AREA VS STORAGE EQUATION
C         7  = C2 EXPONENT  IN AREA VS STORAGE EQUATION
C         8  = STORAGE LEVEL SEPARATING TWO AREA VS STORAGE EQUATIONS
C         9  = RESERVOIR AREA AT ZERO STORAGE - INTERCEPT FOR UPPER EQ
C        10  = C3 COEFFICIENT FOR UPPER EQUATION
C        11  = C4 EXPONENT FOR UPPER EQUATION
C     12-14  = NOT USED
   10 JK=J+K
      IF(JK.NE.2)GOTO 13
C     INITIALIZE FIRST MNTH, FIRST YEAR
      CBST=1.-PR(44)
      STI=RES(1)
      CSTI=RES(2)
      SMAX=STI
      SMIN=STI
      JMN=IYRB-1
      JMX=JMN
      KMN=12
      KMX=12
C     SET UP MONTHLY DATA
   13 CALL HSP(REL,J,K,12)
      CALL HSP(REXP,J,K,14)
      IF(IOP.GE.2) GOTO 14
      CALL HSP(RIN,J,K,11)
      CALL HSP(ARD,J,K,13)
C **  BEFORE OPERATIONS
C      RIN IS RESERVOIR INFLOW
C      REL IS MINIMUM REQUIRED RESERVOIR RELEASE TO THE STREAM SHANNEL
C      ARD IS IN BASIN CANAL RELEASE
C      REXP IS RESERVOIR EXPORT DESIRED
C **  AFTER OPERATIONS
C      RQRL IS REQUIRED MINIMUM RELFASE
C      REL IS ACTUAL RELEASE
C      REXP IS ACTUAL EXPORT
C      ARD IS ACTUAL CANAL RELEASE
C      DS IS CHANGE IN STORAGE
C      ST IS EOM STORAGE
   14 RQRL=REL
      DSEP=PPT-EVP
      CALL AREA(STI,AI,RES)
C     OPERATE RESERVOIR
      DSPOS=(RES(4)-STI)/CBST
      DSNEG=(RES(3)-STI)/CBST
      EXRS=0.
      RSR=REL+ARD+REXP
      DST=RIN-RSR+DSEP*AI/12.
   16 IF(DST.GT.0.) GOTO 20
C     CASE WHEN DST IS NEGATIVE
      IF(DST.GT.DSNEG) GOTO 17
      IF(DSNEG.GT.0.) GOTO 30
      DST=DSNEG*CBST
      GOTO 30
   17 DST=DST*CBST
      GOTO 30
C     CASE WHEN DST IS POSITIVE
   20 IF(DST.LT.DSPOS) GOTO 17
      DST=DSPOS*CBST
   30 ST=STI+DST
      IF(ST.LT.1.)ST=1.
      CALL AREA(ST,AE,RES)
      AV=(AI+AE)*.5
      DST=RIN-RSR+DSEP*AV/12.
C     CHECK EOM STORAGE AGAINST MAX AND MIN
   32 IF(DST.GT.DSPOS) GOTO 33
      ST=STI+DST*CBST
      IF(ST.LT.RES(3)) GOTO 34
      GOTO 40
C     CASE OF EXCESS WATER - SPILLS FROM RES
   33 EXRS=DST-DSPOS
      RSR=RSR+EXRS
      REL=REL+EXRS
      ST=RES(4)
      GOTO 40
   34 STCK=ST+RSR-RES(3)
      IF(STCK)35,35,37
   35 ST=ST+RSR
      RSR=0.0
      REL=0.0
      ARD=0.0
      REXP=0.0
      IF(ST.LT.0.0)ST=0.0
      GOTO 40
   37 RSR=STCK
      ST=RES(3)
      IF(STCK.GT.REL)GO TO 38
      REL=STCK
      ARD=0.0
      REXP=0.0
      GO TO 40
   38 RSRX=STCK-REL
      IF(RSRX.GT.ARD)GO TO 39
      ARD=RSRX
      REXP=0.0
      GO TO 40
   39 REXP=RSRX-ARD
C     INITIALIZE NEXT MONTHS STORAGE
   40 DS=ST-STI
      STT=STI
      STI=ST
   41 CALL DOUT(K,44, EVP,1)
      CALL DOUT(K,45, RIN,1)
      CALL DOUT(K,46,  AV,2)
      CALL DOUT(K,47,RQRL,1)
      CALL DOUT(K,48, REL,1)
      CALL DOUT(K,49, ARD,1)
      CALL DOUT(K,50,REXP,1)
      CALL DOUT(K,51, RSR,1)
      CALL DOUT(K,52,  ST,3)
      CALL DOUT(K,53,  DS,1)
C     CHECK EXTREMES
   50 EMX=ST-SMAX
      IF(EMX.LE.0.0)GOTO 51
      SMAX=ST
      JMX=IYRB+J-1
      KMX=K
      GOTO 52
   51 EMN=SMIN-ST
      IF(EMN.LE.0.0)GO TO 52
      SMIN=ST
      JMN=IYRB+J-1
      KMN=K
   52 RETURN
      END
C     RESERVOIR AREA SUB **AREA**
      SUBROUTINE AREA(S,A,RES)
      DIMENSION RES(14)
      IF(S.LT.0.0) GO TO 10
      IF(S.LT.RES(8)) GO TO 1
      C4=RES(11)
      A=RES(9)+RES(10)*S**C4
      GOTO 12
    1 C2=RES(7)
      A=RES(5)+RES(6)*S**C2
      GOTO 12
   10 A=RES(5)
   12 RETURN
      END
```

```
C **  BASIN PLOT SUBROUTINE **  BAPLOT
      SUBROUTINE BAPLOT(J,NYR,OUT)
      DIMENSION OUT(60,1)
      DATA IPX/0/
C***  PLOT INSERT
C****SSW A ON PLOT DATA *****
  999 OCT 023600
      J   .81
      IF(IPX.EQ.1) GO TO 21
  998 CALL QSHYIN(IERR,580)
      CALL QSC(1,IERR)
C**   SET ALL DAC'S TO ZERO AND RAISE PEN
      CALL QWLBB('30000,IE)
      DO 20 I=1,8
      KK=I-1
      CALL QWJDAR(0.,KK,IE)
   20 CONTINUE
      IPX=1
   21 TYPE 201
  201 FORMAT(32HSET B ON TO READ PLOT PARAMETERS/29HTURN B OFF TO GO TO
     1NEXT YEAR/)
C    ** IF SSW B IS  ON READ PLOT PARMETERS **
C    ** IF SSW B IS  OFF GO TO NEXT YEAR **
      OCT 025000
      OCT 023500
      J   .80
C     RAISE PEN
      CALL QWLBB('030000,IE)
      READ(6,203) IPLT,IDASH,SC,NXPYR,ID,LD,ILF,ILW,KX,KY'
C**   KX AND KY ARE THE DAC CHANNELS FOR PLOTTING
  203 FORMAT(I2,I3,F10.0,10I5)
C**   IPLT IS VAR NO TO BE PLOTTED, IDASH IS NO OF DASHES TO BE DRAWN
C**   PER TIME PERIOD, SC IS SCALE FACTOR IN UNITS/VOLT, NXPYR IS NO.
C**   OF TIME PERIODS PER YEAR, ID AND LD ARE DELAY TIMES TO ALLOW FOR
C**   USING DIFFERENT ANALOG PLOTTERS, ILF IS DELAY TIME FOR RAISING
C**   THE PEN AND ILW IS DELAY TIME FOR LOWERING THE PEN.
      TYPE 202, IPLT
  202 FORMAT(12HPLOT VAR NO.I3/)
      SC=SC*10.
      XXC=NYR
      XXD=J-1
      XDI=-(XXD/XXC)
      XNYR=NXPYR
      XD=1./(XXC*XNYR)
      XD=-XD
      PDX1=0.0
      XP=XDI
      CALL QWJDAR(XP,KX,IE)
      CALL QWJDAR(PDX1,KY,IE)
      LAD=ID+LD
      CALL QSDLY(LAD)
C      LOWER PEN
      CALL QWLBB('020000,IE)
      CALL QSDLY(ILW)
      IF(IDASH.LE.1) GOTO23
      ISPAC=IDASH-1
      IDS=ISPAC+IDASH
      LDD=LD/IDS
      XDASH=3*IDASH-1
      XDASH=XDASH/2.0
      XL=XD/XDASH
      XS=XL/2.0
   23 DO 30 I=1,NXPYR
      PDX=OUT(IPLT,I)/SC
      PDX=-PDX
      CALL QWJDAR(PDX,KY,IE)
      CALL QSDLY(ID)
      IF(IDASH.LE.1) GO TO 26
   24 XP=XP+XL
      CALL QWJDAR(XP,KX,IE)
      CALL QSDLY(LDD)
C     DASH LINE LOOP
      DO 25 L=1,ISPAC
      CALL QWLBB(!030000,IE)
      CALL QSDLY(ILF)
      XP=XP+XS
      CALL QWJDAR(XP,KX,IE)
      CALL QSDLY(LDD)
      CALL QWLBB('020000,IE)
      CALL QSDLY(ILW)
      XP=XP+XL
      IF(XP.LE.-1.) XP=-.999999
      CALL QWJDAR(XP,KX,IE)
      CALL QSDLY(LDD)
   25 CONTINUE
      J   .28
   26 XP=XP+XD
      IF(XP.LE.-1.) XP=-.999999
      CALL QWJDAR(XP,KX,IE)
      CALL QSDLY(LD)
   28 CONTINUE
   30 CONTINUE
C     RETURN PEN TO INITIAL LOCATION
      CALL QWJDAR(PDX1,KY,IE)
      CALL QSDLY(ID)
      CALL QWLBB('030000,IE)
      CALL QSDLY(ILF)
      CALL QWJDAR(XDI,KX,IE)
      CALL QSDLY(ID)
      J   .21
   80 IF(J.NE.NYR) GOTO81
      CALL QWJDAR(PDX1,KX,IE)
C**   END OF PLOT INSERT
   81 RETURN
      END
```