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A Water-Land Use Management Model for the Sevier River Basin

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A WATER-LAND USE MANAGEMENT MODEL
FOR THE SEVIER RIVER BASIN

PHASES I AND II

Prepared by

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Progress Report

to

Utah Division of Water Rights
Department of Natural Resources
State of Utah

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ABSTRACT

A hydrologic model for the Sevier River Basin above Sevier Bridge Reservoir was developed. The model considers large space increments on a monthly time increment. Additional data would improve the reliability of the model developed for some subbasins. A daily hydrologic model was also calibrated to the Circle Valley Subbasin. Data requirements for a daily model using small space increments seem to negate the possibility of the micro-model, for the present at least.

ACKNOWLEDGMENTS

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PHASE I

Introduction

The Utah Division of Water Rights and the Utah Water Research Laboratory have entered into a cooperative agreement to evaluate the effects of installing more efficient irrigation conveyance and application systems on other users in the Sevier River Basin. The objective of the first phase of the project was to calibrate a hydrologic simulation model for the selected subbasins in the Sevier River Basin. The hydrologic model described by Hill et al. (1973) was selected for application to the Sevier River Basin.

The specific objectives of the first phase were to:

1. Inventory and organize monthly hydrologic data for the Sevier River Basin.

2. Calibrate a monthly hydrologic model for the Sevier River Basin.

3. Perform limited management studies in the basin utilizing the monthly model.

Accomplishments

Subbasin Development

The first step in model development is that of spatial resolution of the entire Sevier River Basin. A survey of literature showed that the basin had been divided into six subbasins by the U.S. Department of Agriculture (1969). These subbasins are indicated by letters "A" through "F" in Figure 1. In a study undertaken at the Utah Water Research Laboratory, Duane Jensen (1970) divided the basin into eight subbasins (Figures 2 and 3) on the basis of available field data from stream gaging stations. The present study, however, required modifications in the number of subbasins in order to satisfy the current needs of system definition and the availability of records for calibrating the model. Accordingly, the Sevier River Basin is divided into six subbasins excluding the Delta area. The boundaries of each of the subbasins are discussed below, beginning with the subbasin upstream of the Delta Subbasin.

Sanpitch Subbasin

This subbasin includes the drainage of the Sanpitch River and all the irrigated land in the upper and lower Sanpitch areas. A portion of the area within the lower Sanpitch which includes the acreage of land irrigated by the diversions below Chester was, however, excluded from the present study due to inadequate hydrologic data for modeling purposes.

Salina Subbasin

This subbasin comprises the drainage of the Sevier River between the USGS gaging stations at Sigurd and at the junction of Sanpitch and Sevier Rivers. It essentially considers the drainages of Salina Creek and Willow Creek.

Sevier-Sigurd Subbasin

This subbasin includes the irrigated area between the river gage near Sigurd and the USGS river gage above Clear Creek.

Marysvale-Piute Subbasin

This subbasin includes the drainage areas between the gaging stations above Clear Creek and the USGS gaging station at Circleville.

East Fork River Subbasin

The drainage areas of East Fork River and Otter Creek constitute this subbasin.

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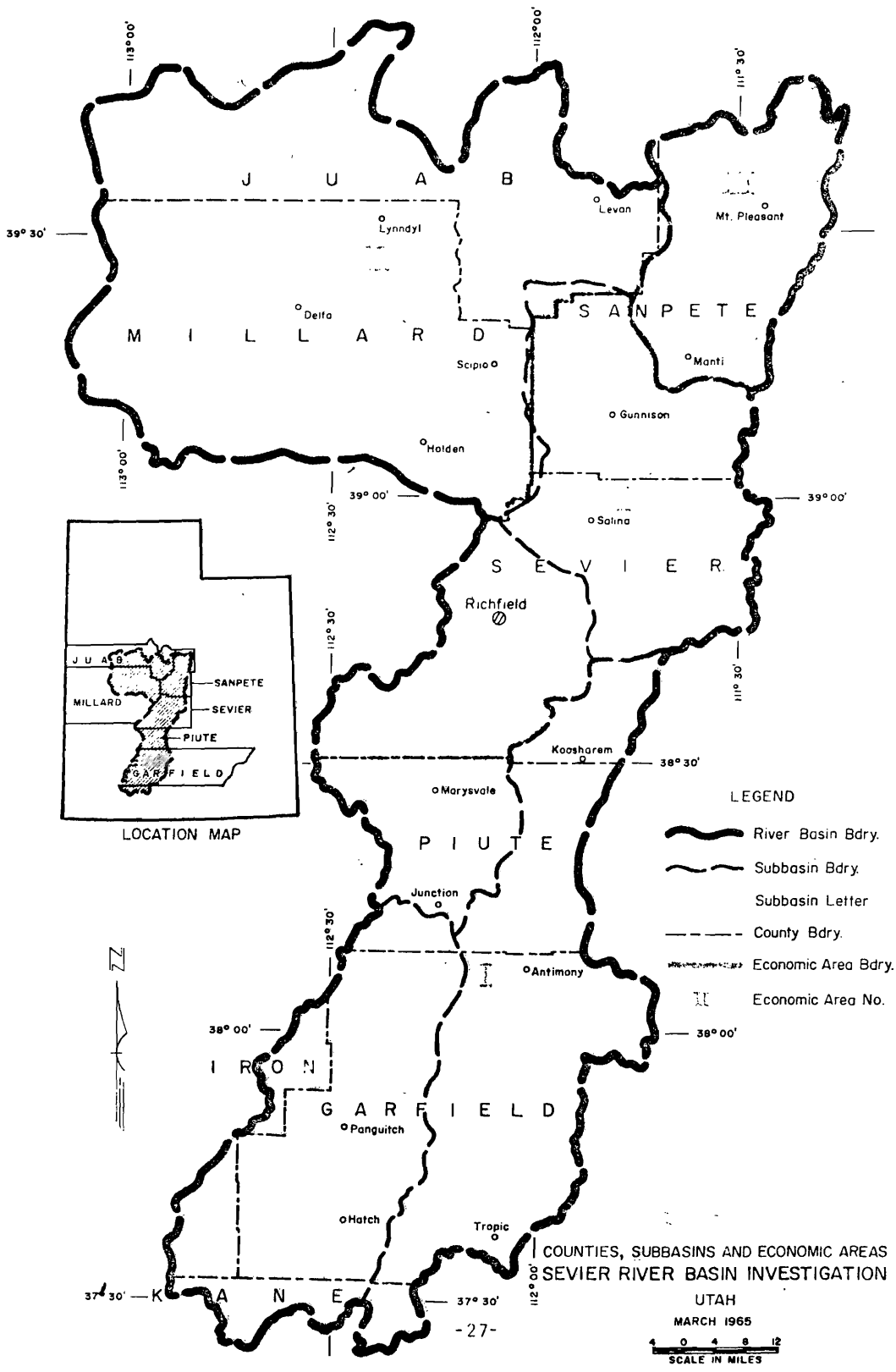
Figure 1. Counties, subbasins, and economic areas, Sevier River Basin investigation.

SEVIER-SIGURD
SUBBASIN

MARYSVALE
SUBBASIN

PIUTE RESERVOIR
SUBBASIN

EAST FORK
SEVIER RIVER
SUBBASIN

SEVIER RIVER
ABOVE CIRCLE-
VILLE SUBBASIN

N

0   5   10   15 MILES

SEVIER LAKE BASIN
UPPER SEVIER RIVER SUBBASINS
Utah Water Research Laboratory
Utah State University
1970

○   Precipitation Only
⊕   Precipitation Temperature
●   Temperature Only
⊕   Precipitation, Temperature, and Evaporation
○   Stream Flow
⊕   Water Quality and Flow
●   Water Quality
▨   Irrigated Land
▨   Water Surface
□   UWRL Quality Monitoring

Figure 2. Divisions of subbasins.

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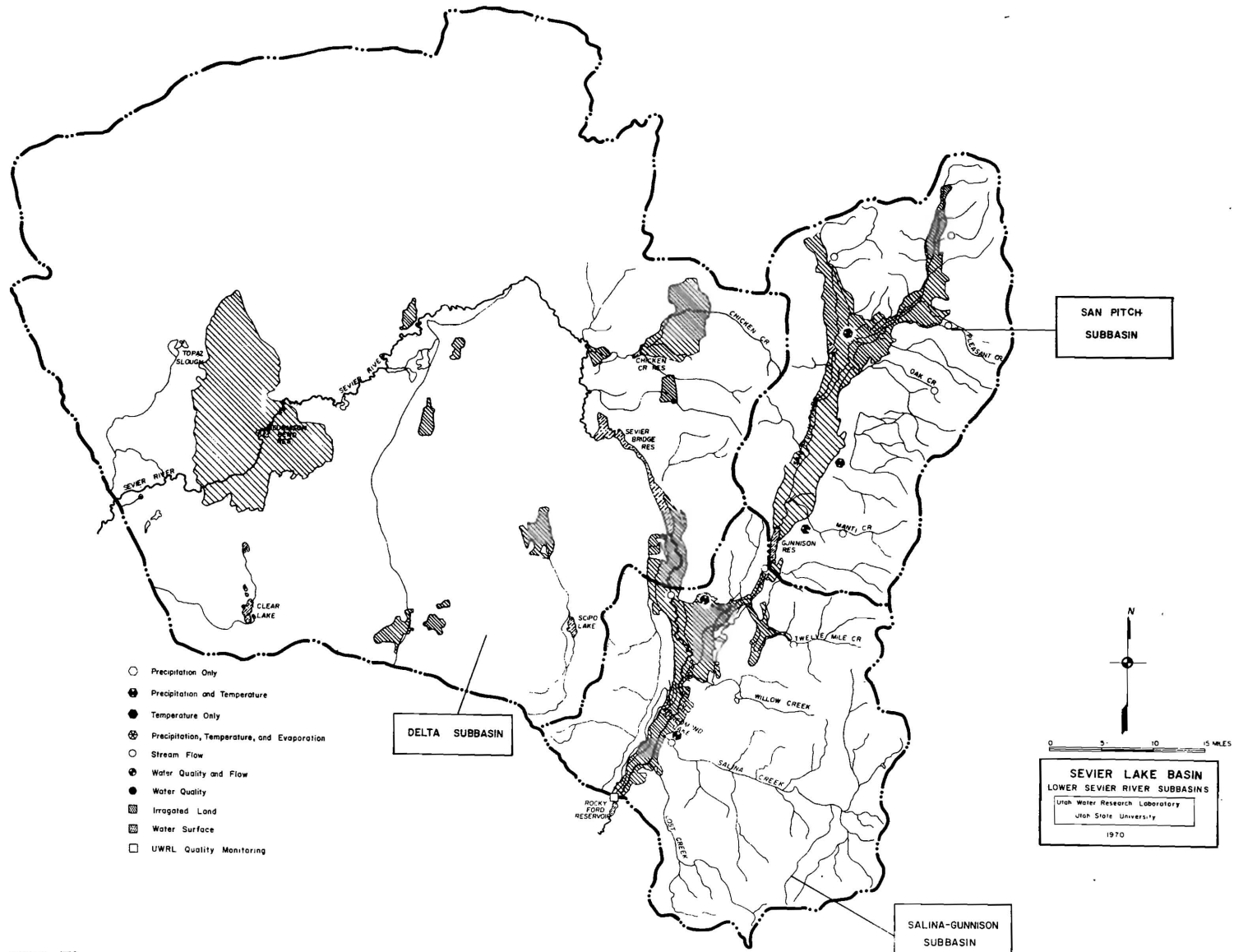
Figure 3. Divisions of subbasins continued.

Circleville Subbasin

This subbasin contains the drainage area of the Sevier River above the USGS gaging station at Circleville.

Data Collection and Processing

In order to calibrate the hydrologic model, efforts were made to collect the hydrologic data for all subbasins for a uniform period of three years. The periods during which hydrologic records are available for the various subbasins are listed in Table 1.

This table shows that streamflow records were available for the water years 1962-64 for all subbasins except the Sanpitch River Subbasin, for which the available records included water years 1971-73.

Data on canal diversions have been obtained from River Commissioner's reports for these years. Vegetation and cropping patterns have been adopted from the published data by the Soil Conservation Service (1973), while annual climatological summaries published by the U.S. Department of Commerce (1961-73) have been used for temperature and precipitation data.

Table 1. Available hydrologic record.

| Subbasin | Stream Flow Measurements | | Canal Diversions | Temperature and Precipitation |
	Gaging Station	Years of Record Available		
Sanpitch	2155		1970→'73	All years
	2100	1954→'73		" "
	2085	1964→'73		" "
	2159	1964→'73		" "
	2162	1965→'73		" "
	2162-1	1964→'73		" "
	2164	1959→'73		" "
Salina	2060	1960→'73	1961→'73	
	2050	1914→'73		
Sigurd	1942	1957→'73		
	1940	1960→'73		
Marysvale -Piute	1910	1914→'73		
	1800	1949→'73		Partly not available during 61-62
Circleville	1763	1961→'73	a	Panguitch
	1745	1939→'73		Circleville
East Fork	1839	1961→'73		
	1850	1957→'73		
	1875	1961-64 1971→'73		
	1880	1934→'73		
	1844-5	1961-1965		
	1873	1964→'73		

[a]Data for some of the canal diversions is not available for period 1967.

Model Calibration

Calibration of a hydrologic model is part of the model verification process. It involves adjustment of model parameters in the various equations used to describe the system (Hill et al., 1973) until a satisfactory fit is achieved between observed and computed stream flow. Once the model is calibrated using the data for a particular period, it can be tested using a second and independent set of data from the same hydrologic unit (the same subbasin) to determine the level of agreement between the observed and predicted output functions.

The model was calibrated using the data for water years 1962-64 for all subbasins except the Sanpitch Subbasin for which the data for the water years 1971-73 were used. The hydrologic inflows, outflows, and canal diversions are indicated by Table 2, while the crop distribution or vegetation patterns is shown by Table 3. The calibration program followed the procedure outlined by Hill et al. (1973). The calibration results are described herein for the various subbasins. Table 4 lists the optimum values of the various parameters obtained during the calibration process.

Circleville Subbasin

Represented by Figure 4 are the computed and observed outflows from this subbasin, with a correlation coefficient (R) of 0.97 for the three years of calibration period (36 months; n = 36). Calibration studies indicated that the conveyance and irrigation efficiencies are approximately 55 percent, while the contribution of groundwater to surface runoff is about 50 percent. The large contribution of groundwater to the surface flow may indicate a larger than normal salinity contribution from this subbasin since the groundwater system normally has a higher concentration of dissolved solids than does the surface system.

East Fork Subbasin

Reservoir storage significantly affected the calibration of this subbasin. Of the three major reservoirs, namely the Tropic, Otter Creek, and Koosharem, records of changes in storage are available only for the Otter Creek Reservoir. This resulted in limiting the subbasin to the irrigated area south of Otter Creek Reservoir for calibration purposes. Significant quantities of ungaged inflow are contributed by the various creeks joining the main stream between the gaging stations on the East Fork River at Ruby's Inn and on the Otter Creek Reservoir. The ungaged inflows have, therefore, been apportioned between the increases in storage of the Otter Creek Reservoir in the winter months and the observed streamflow in the main stem of East Fork River in the summer months.

Figure 5 represents the observed and computed outflows and indicates that the high flows have a closer correlation than the low flows, with an overall R = 0.975, n = 36. Some of the variations in the predicted and observed outflows may be attributed to the transmountain diversions from the Tropic Canal into the Colorado River drainage, for which adequate data are not available. The results of calibration indicated that there is an insignificant groundwater contribution to surface runoff from this subbasin.

Marysvale-Piute Subbasin

Represented by Figure 6 are the computed and observed outflows from this subbasin, with an R value of 0.973, n = 36. Calibration studies indicated that the conveyance and irrigation efficiencies are approximately 40 percent, while the contribution of effluent groundwater is about 20 percent of the surface runoff .

Sigurd Subbasin

Of all the subbasins within the Sevier River system, the Sigurd Subbasin has the most irrigation. Figure 7 represents the computed and observed runoff from this subbasin. The simulated outflows are significantly low in summer months, while in the winter months the predicted outflows are higher than the corresponding observed values. The variation is probably due to the increase in storage of Rocky Ford Reservoir in the winter months and the corresponding reservoir releases in the summer months. This feature could not be represented in the calibration of the model because adequate records showing these storage changes were not available. The computed and observed outflows have, however, a correlation of R = 0.946, n = 33. The calibration results indicate an irrigation efficiency of 80 percent. The proportion of effluent groundwater contribution to surface runoff is approximately 75 percent. It is likely that the applied irrigation water has undergone recycling within the irrigated areas. The substantial amounts of effluent groundwater contributing to the surface outflow is also indicative of the potential water quality degradation in this subbasin.

Salina Subbasin

The Salina and Sanpitch Subbasins are interconnected in terms of the land use, diversion channels, and the individual runoff contributions to the Sevier River. However, the Salina Subbasin can be separated from the Sanpitch Subbasin with the assumption that

Table 2. Inflows, outflows, and canal diversions.

	Circleville	East Fork	Piute-Marysvale	Sigurd	Salina	Sanpitch
Stream inflows (Main stem) Tributary	Sevier River at Hatch Panguitch	East Fork Sevier River at Ruby's Inn Antimony Creek Otter Creek above Reservoir	Sevier River at Kingston East Fork River at Kingston	Sevier River above Clear Creek Clear Creek above diversions	Sevier River near Sigurd 1. Salina Creek near Salina 2. Rocky Ford Canal 3. Westview Canal	Oak Creek near Fairview Pleasant Creek near Mount Pleasant
Stream outflow	Sevier River at Circleville	East Fork River Near Kingston	Sevier River above Clear Creek	1. Sevier River near Sigurd 2. Rocky Ford Canal	Sevier River below Sanpitch River	1. West Point drainage 2. Make of the river 3. Ephraim Olsen ditch 4. West drainage canal
Canal diversions	West Hatch East Hatch Upper Wilson ditch Long & East Bench East Panguitch Barton Lefevre Tebbs Ditch McEvan Canal Bear Creek Canal Marshall ditch Whittakar ditches	Tropic Canal Allen ditch	Cannon ditch Parker ditch Loss Creek Canal West Canal Old Kingston Canal Dalton-Thompson Canal Junction Canal Junction middle ditch Kingston main canal Nielson-Howes ditch	Joseph Cove high line Clear Creek Canal Monroe South bend Canal Sevier Valley & Piute Canal Joseph Canal Wells Canal Monroe Canal Elsinore Canal Brooklin Canal Richfield Canal Annabella Canal Vermillion Canal	Rocky Ford Canal Westview Canal Gunnison Fayette Canal Dover Canal	1. Diversions in upper Sanpitch -
Precipitation & Temperature gaging stations	Circleville Panguitch	Bryce Canyon	Piute dam Marysvale	Richfield	Salina	Moroni
Major Reservoir storage considered		Otter Creek Reservoir	Piute Reservoir			
Exports						
Imports						Transmountain diversions

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Table 3. Crop distribution and vegetation patterns by subbasin.[a]

Description		Circleville	East Fork	Piute-Marysvale	Sigurd	Salina	Sanpitch
Cropping pattern	Alfalfa	6470	4270	5860	19900	16435	24530
	Pasture	4900	3330	5470	7900	6514	
	Meadow Hay	1870	1140	1645			
	Barley	1150	760	1045			
	Corn			40	1900	1550	660
	Sugar Beets				1140	930	
	Grain				6750	5581	7520
Vegetation	Wet Meadow	2810	360	2970	5460	3170	
							15508
	Phreatophytes	860	960	1570	2150	6640	
	Water surfaces	430	2660	200	840	1200	--

[a]Figures are in acres.

Table 4. Optimum value of parameters obtained after calibration.

Param-eter	Description (Mnemonic)	OPTIMUM VALUES					
		Circleville	East Fork	Piute-Marysvale	Sigurd	Salina	Sanpitch
1	Snowmelt rate	0.225	0.15	0.5	0.15	0.15	0.15
2	Temperature above which snow melts, ^{o}F	30	15	20.	18 .	21.0	24.
3	Temperature below which snow falls, ^{o}F	40	34	30.5	29.	28.	44.
4	Initial snow water content inches	0.	0.	0.	0.	0.	0.
5	Stream correlation	.1	0.60	0.5	0.	.45	1.24
6	Snow correlation (acre-feet/inch)	2500	0.	3200	2700	2400	4500
7	Precipitation correlation (acre-feet/inch)	400	0.	3000	0.	1500	0.
8	Precipitation threshold above which surface runoff occurs (inches)	0.	0.	1.5	0.	0.5	0.
9	Coefficient for influent flow from stream	0.3	0.	0.1	0.08	0.45	0.1
10	Coefficient for influent flow from stream	0.	0.	0.	0.	0.	0.
11	Smoothing coefficient in groundwater function	10.	10.	10.	10.	10.	10.
12	Initial groundwater flow rate (acre-feet/month)	3000.	1000.	2800.	3000.	2000.	2500.
13	Proportion of groundwater outflow that does not return to stream surface as effluent groundwater in the basin	0.	1.0	0.4	0.	0.	0.

Table 4. Continued.

| Param-eter	Description (Mnemonic)	OPTIMUM VALUES					
		Circleville	East Fork	Piute-Marysvale	Sigurd	Salina	Sanpitch
14	Efficiency of delivery and application	0.55	0.4	0.4	0.8	0.3	0.6
15	Soil moisture capacity (inches)	7.5	8.5	6.0	6.0	8.0	6.0
16	Critical soil moisture level below which ET becomes limited because of moisture stress (inches)	3.0	2.0	2.0	3.0	2.5	2.5
17	Initial soil moisture level (inches)	6.0	8.5	4.5	3.5	4.0	4.0
18	Agricultural groundwater return flow delay time (months)	3.0	0.5	0.5	3.0	5.0	0.5
19	Initial agricultural return flow rate (inches/month)	4.0	2.0	4.0	2.0	5.5	4.0
20-27							0.
28	IC for spring flow						1000.
29	Canal conveyance efficiency						0.8
30	Adjusting coefficient for PPT on phreatophyte land						0.8
31	Proportion of phreatophyte use from groundwater						0.6
32	Spring flow adjusting coefficient						1.0
33	Consumptive use on urban land						1.0
34	Consumptive use on undeveloped land						1.0
35	Coefficient for GW recharge and surface runoff						1.0
36	K for calculating spring flow						15.0
37	GWIN used in calculating spring flow						0.
38	Groundwater inflow adjusting coefficient						1.0
39	Municipal and industrial adjusting coefficient						1.0
40	M & I consumptive use adjusting coefficient						0.35
41	Proportion of surface runoff gaged						0.40

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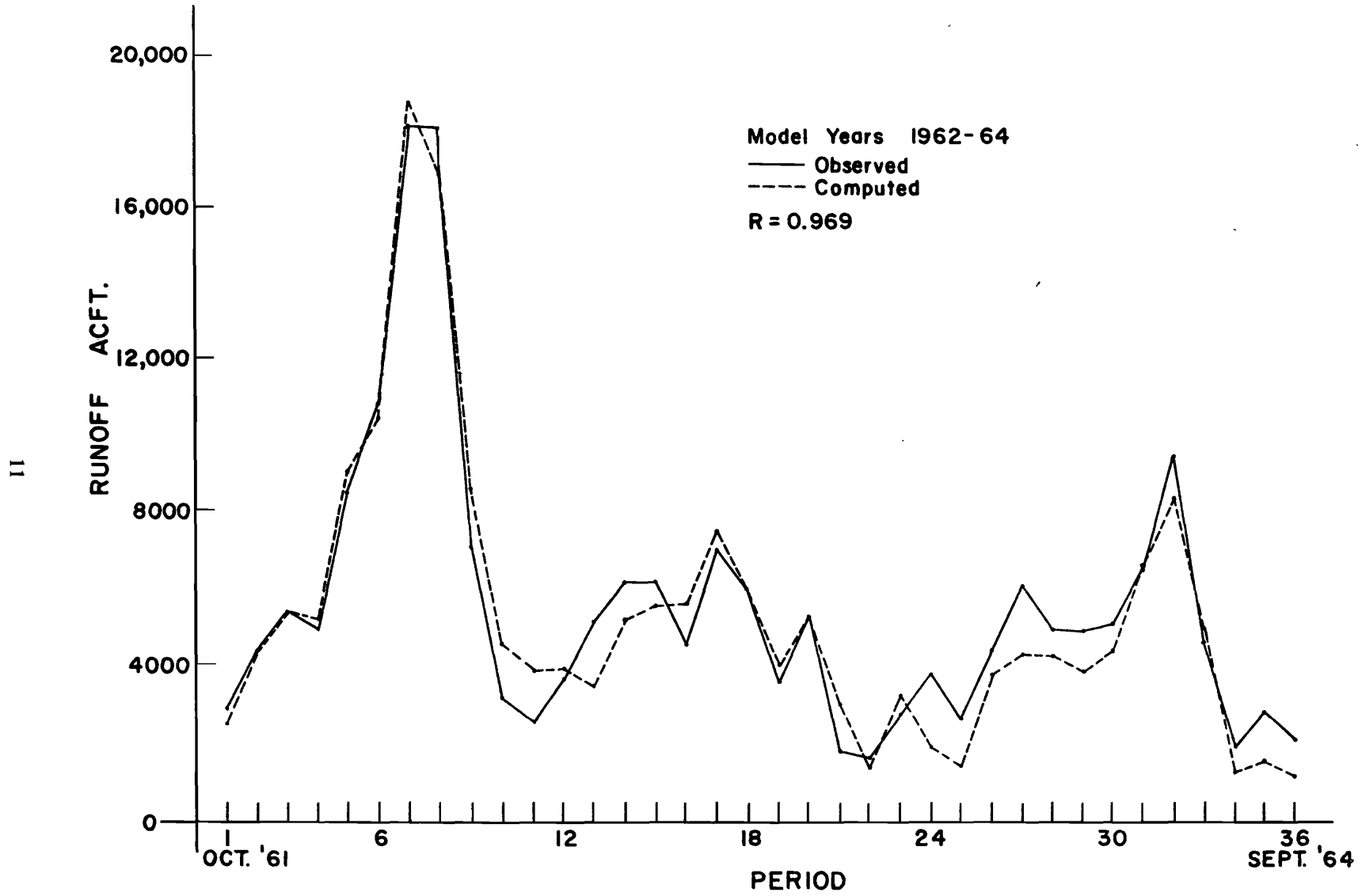
Figure 4. Circleville Subbasins observed vs. computed runoff.
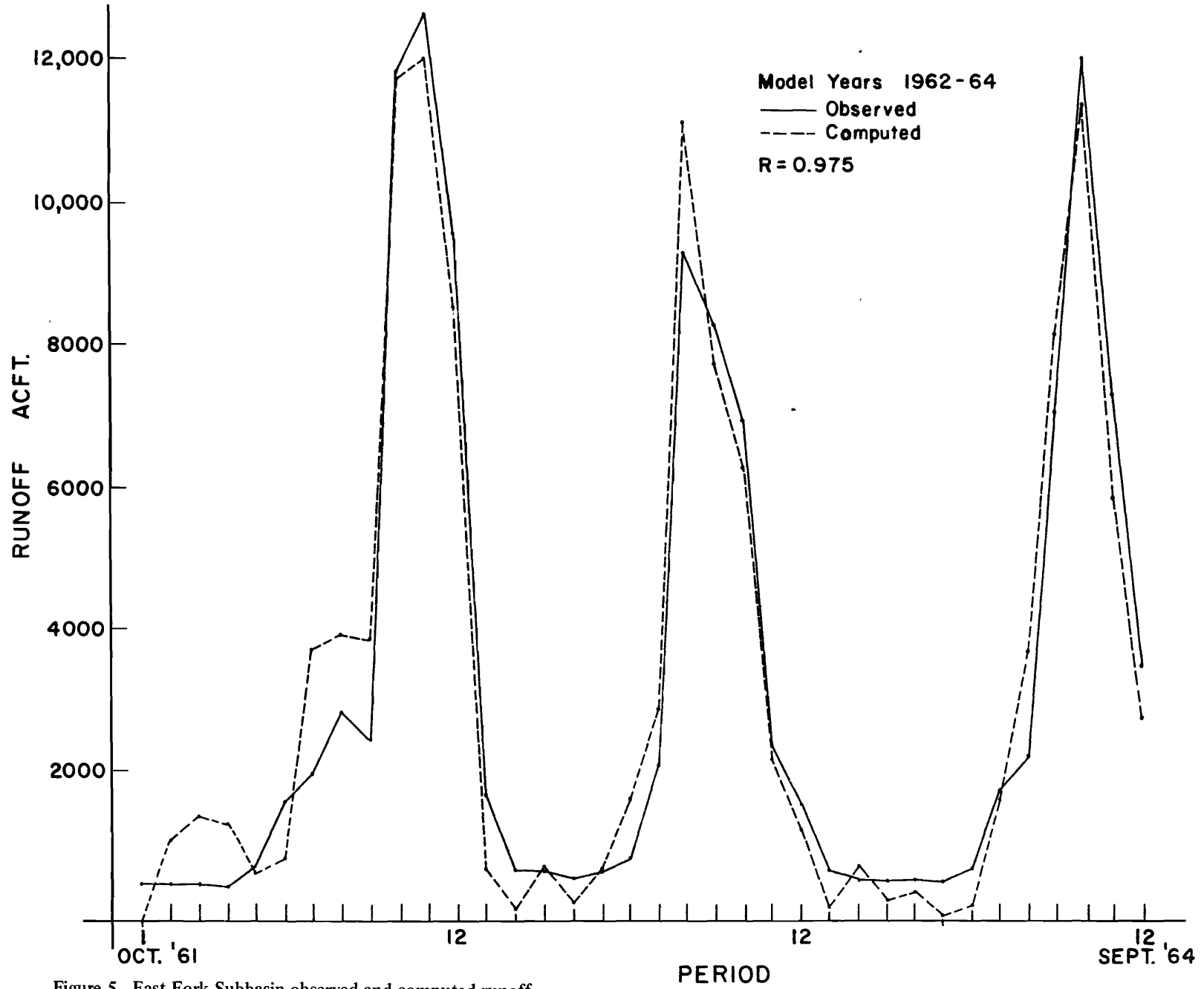
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Figure 5. East Fork Subbasin observed and computed runoff.
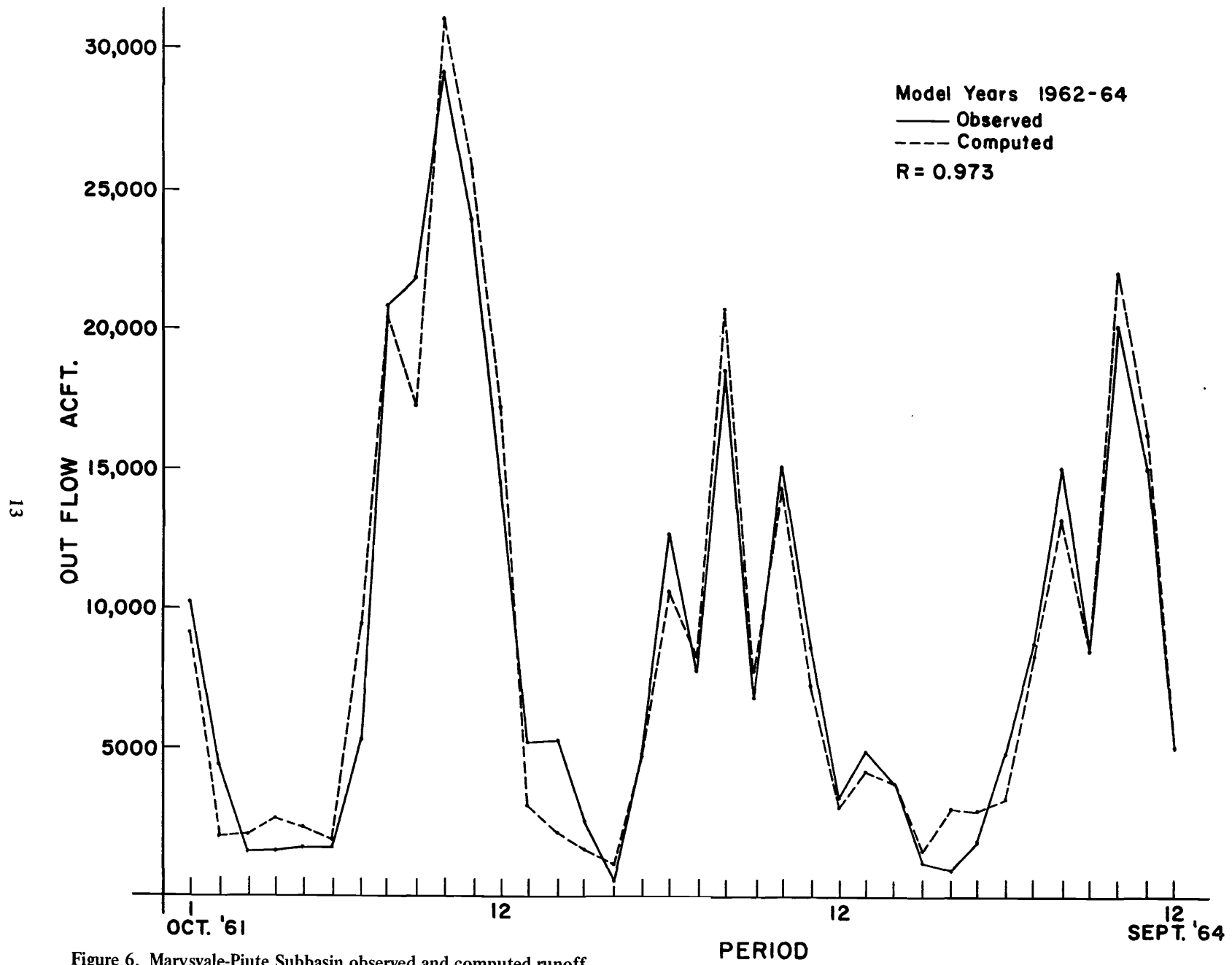
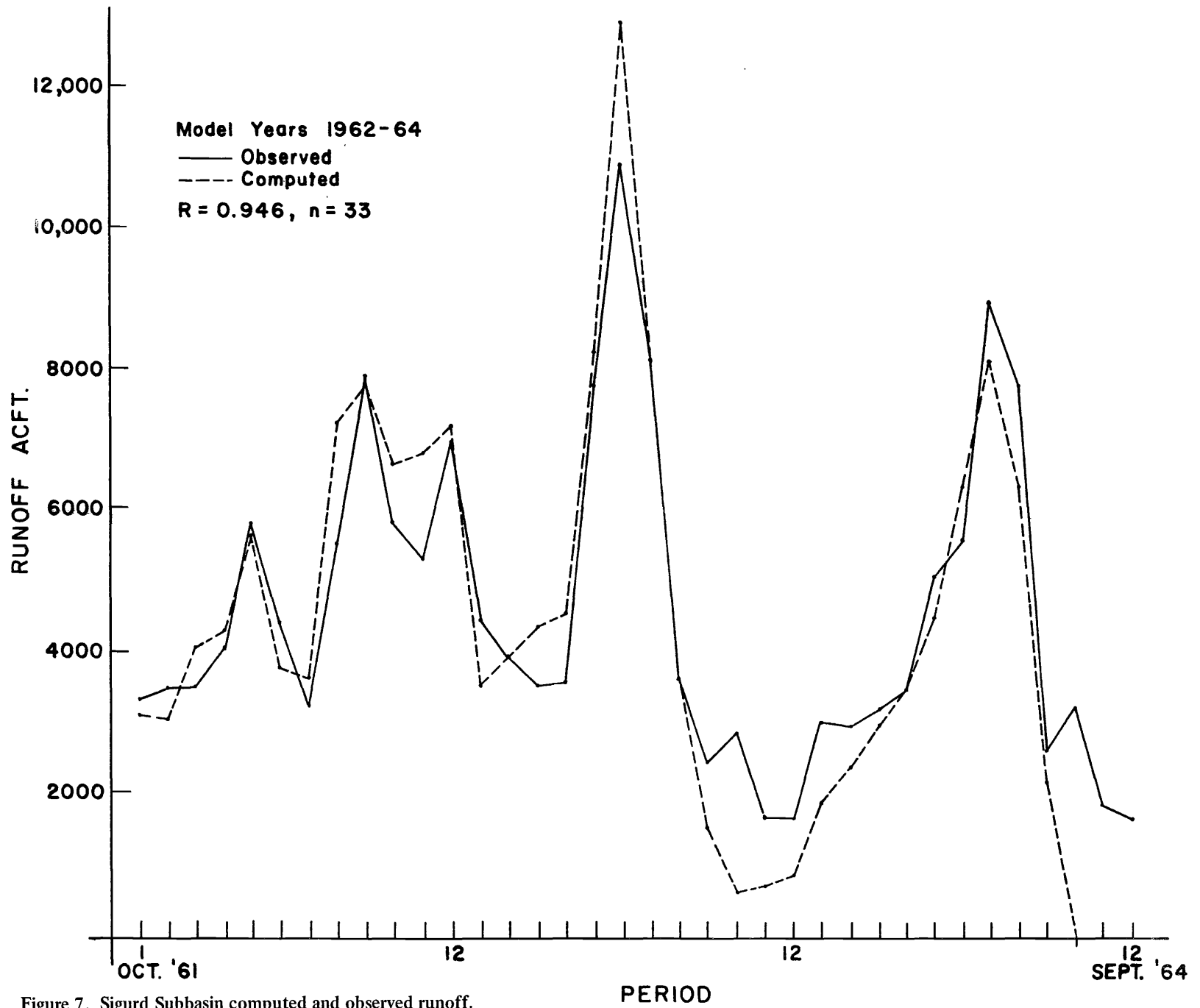Figure 6. Marysvale-Piute Subbasin observed and computed runoff.

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Figure 7. Sigurd Subbasin computed and observed runoff.

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the flow of Sanpitch River is negligible in most parts of the year. The corresponding land use patterns have been suitably estimated for calibration purposes. Records of the storage reservoirs and diversions above the stream gage at Salina Creek, and the details of flow from the Redmond Lake are, however, not available. Data deficiencies cause a less accurate estimate of the ungaged inflows to the subbasin. The computed and observed outflows from this subbasin are shown by Figure 8. The predicted outflows in summer months are lower, and those in the winter months are higher than the corresponding observed values because of the lack of reservoir storage data.

The results of calibration show that the irrigation efficiency is only 30 percent. The proportion of effluent groundwater entering the surface runoff is about 70 percent, again indicating the potential degradation of water quality for use in the downstream reaches.

Sanpitch Subbasin

Monitoring the groundwater system, transmountain diversions and the reservoir-pond storage significantly affected the calibration of this subbasin. It was therefore necessary to modify the hydrologic model to incorporate the effects of spring flow on the system as a whole. There are 13 transmountain diversions to the drainage area of this subbasin, of which flow data are available for only three. Data are also lacking for the discharge of the flowing and pumped wells, and the quantity of spring flows within the subbasin. Changes in storage of Wales Reservoir and other surface ponds in the valley were not available. Groundwater inflow through the bedrock, and the discharges of the pumped and flowing wells were estimated from published data (Robinson, 1971).

Subject to the above restrictions, the computed and observed outflows at Chester are shown by Figure 9, with R = 0.67, n = 33. The Sanpitch Subbasin was the most difficult to calibrate and provides less accuracy in prediction than do the other subbasins. The difficulty encountered in calibrating this subbasin is mirrored in the low R value. The calibration results indicated that only a portion of the surface

runoff is represented by the observed gages. The disagreement between the observed and computed outflows is most likely due to lack of data regarding the reservoir/pond storage. However, the calibration studies indicate the extent of recycling of water within the basin. More data on the groundwater system will result in better definition of the system and improved calibration of the model.

Conclusions

A study of the water management alternatives in the Sevier River Basin can be accomplished through the application of a hydrologic simulation model to each of the subbasins. The hydrologic model has been verified for all of the subbasins of interest. The model predicts groundwater and overland flow contributions to surface runoff and thereby gives an indication of water recycling in the system.

The models resulting from the first phase of study provide a functional tool that can be utilized in making future management decisions in the Sevier River Basin. The models can be easily altered to represent new cropping patterns, irrigation efficiencies, and distribution practices and thus provide data for future decisions and directives.

Consistent with the improvements made during Phase II of this research, the model can be used in a variety of management alternatives. Some of the more important ones are:

1. Estimating water available for downstream users resulting from changes in upstream irrigated acres, irrigation deliveries, or storage capacities.

2. Estimating return flow quantities which may indicate some degree of salinity control from irrigated agriculture.

3. Estimating water availability changes resulting from management scheduling alternatives or physical changes in the delivery system.
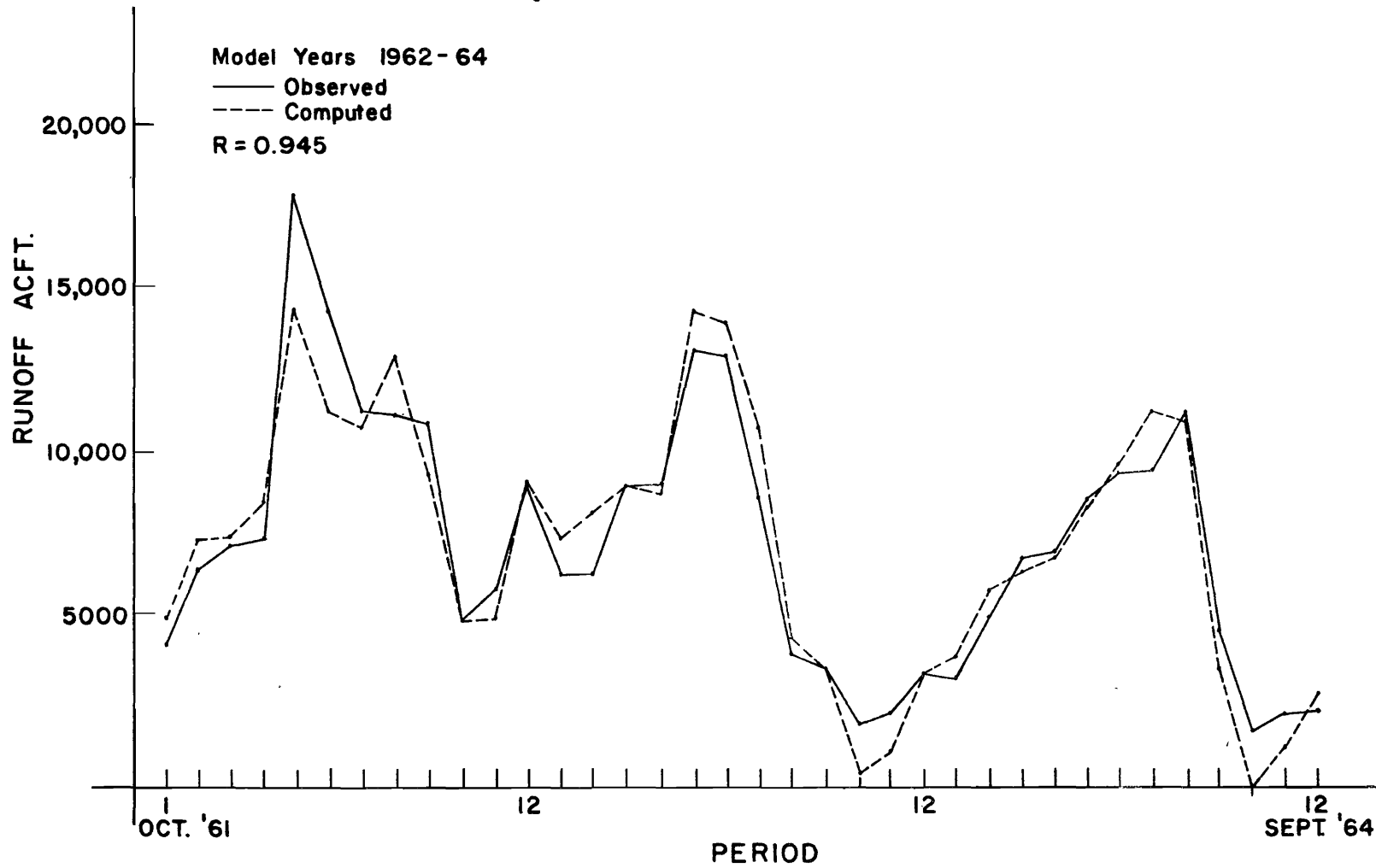
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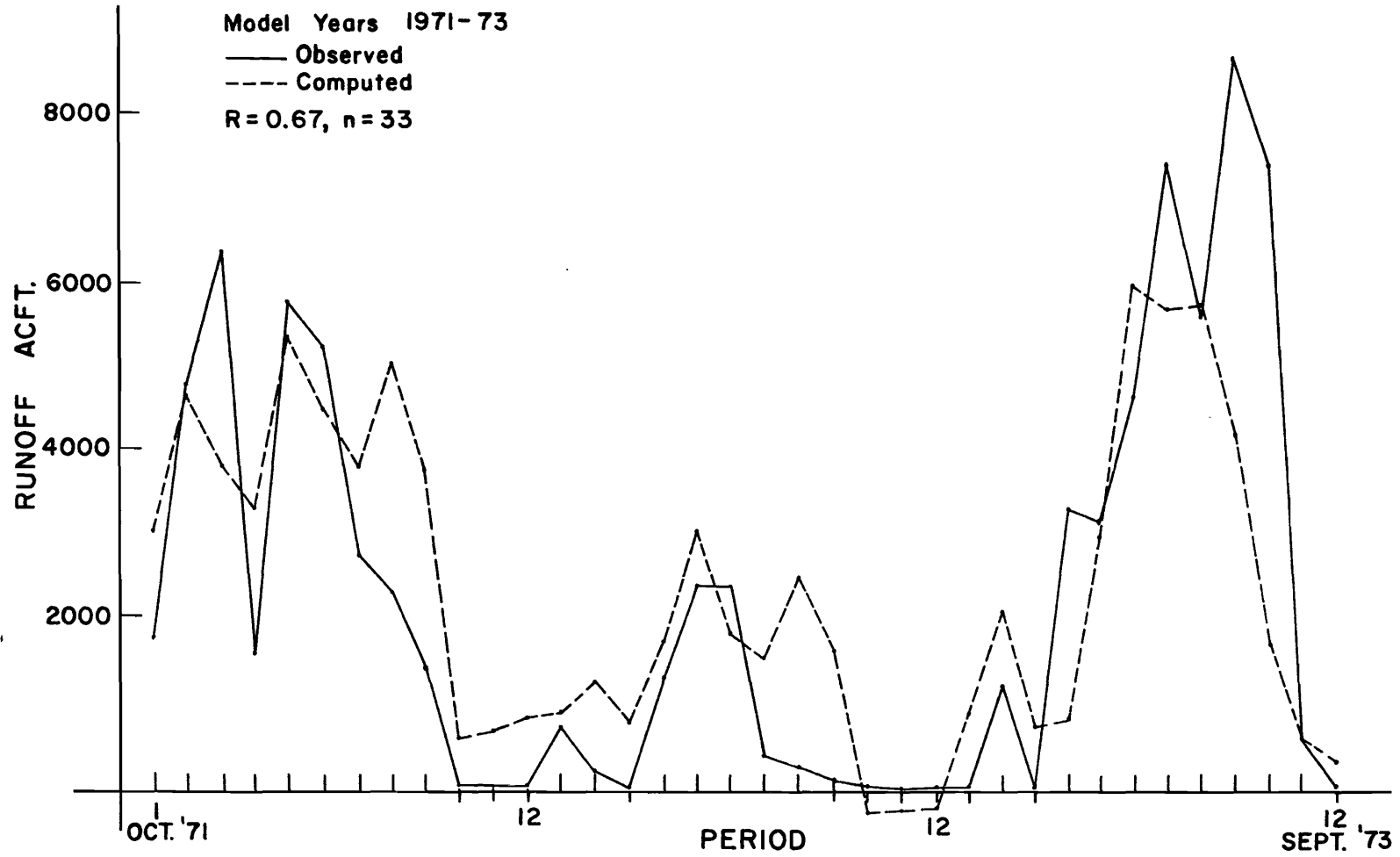
Figure 8. Salina Subbasin observed and computed runoff.

Figure 9. Sanpitch Subbasin observed and computed runoff.

PHASE II

Introduction

Phase II of the study of the water-land use management model involved the following activities pertaining to both the monthly model and a short time and space increment model.

1. The existing monthly model was improved to adequately represent some of the hydrologic processes such as seepage from canals, spring flows, and seepage returns to canals as water available for further diversions. However, the conclusions indicated in the report submitted for Phase I study with respect to the Sanpitch Subbasin are still maintained. This subbasin needed more definition of the in-basin processes.

2. The feasibility of development and operation of a short time and space water management model for a select agricultural area was investigated.

3. Conceptual development of a short time increment model was accomplished.

4. Existing data and required additional data were identified, and recommendations for a required data collection system for the additional data were made.

Feasibility of a Short Time and Small Space Increment Model

The resolution of a mathematical model of the hydrologic system depends upon the size of the space and time increments. Consideration of model resolution must be made with respect to the problems to be solved and the available data or the physical and financial ability to collect the required data.

Inspection of the available data for the Circle Valley Subbasin disclosed that most of the data were measured on a daily time increment. Since a weekly time increment would have been formed by summing the daily increments, the decision was made to investigate the feasibility of short term modeling on a daily time increment. The combination of measured data plus possible synthesized data gave credence to the assumption that a daily model for Circle Valley was feasible (Figure 10).

However, it seemed much easier to collect the temporal data for small time increments than to obtain the data required for small space increments. This was so because the small time increment data for a large subbasin can be collected from the same number of stations required to collect data on a large time increment for the large subbasin. Conversely, it is so desirable to have (at least) inflow and outflow from each subbasin division plus measures of the division characteristics in small space increments. This requires additional stations for each subbasin division.

In spite of additional difficulties, it appeared feasible to operate a short term (either daily or weekly) model on a selected subbasin of the Sevier River Basin. With this in mind, the conceptual development of a short term model was approached.

Modeling Concepts

For many hydrologic models, continuity of mass is the only link between the various processes within the system. Continuity of mass is expressed by the general equation:

$$\text{Input} = \text{Output} \pm \text{Change in Storage} \ldots . (1)$$

A hydrologic balance is the application of this equation in order to achieve an accounting of physical hydrologic quantities within a particular unit. Typical hydrologic quantities which might be applied to a particular unit are listed as follows:

Inflows	Outflows	Storages
Precipitation	Overland	Snow
Surface inflow (river	runoff	Soil moisture
main stem, tribu-	Subsurface	Surface reser-
taries, snowmelt,	interflow	voirs
imports, spring	Groundwater	Groundwater
flows, pumped	outflow	storage
groundwater)	Exports	
Subsurface inflows		

By means of the continuity equation 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. These same basic concepts apply to the operation of any dynamic system, and are, therefore, applied to the short time and space increment model. Only the valley floor is used for modeling purposes, and no attempt is made to describe the processes of the ad-
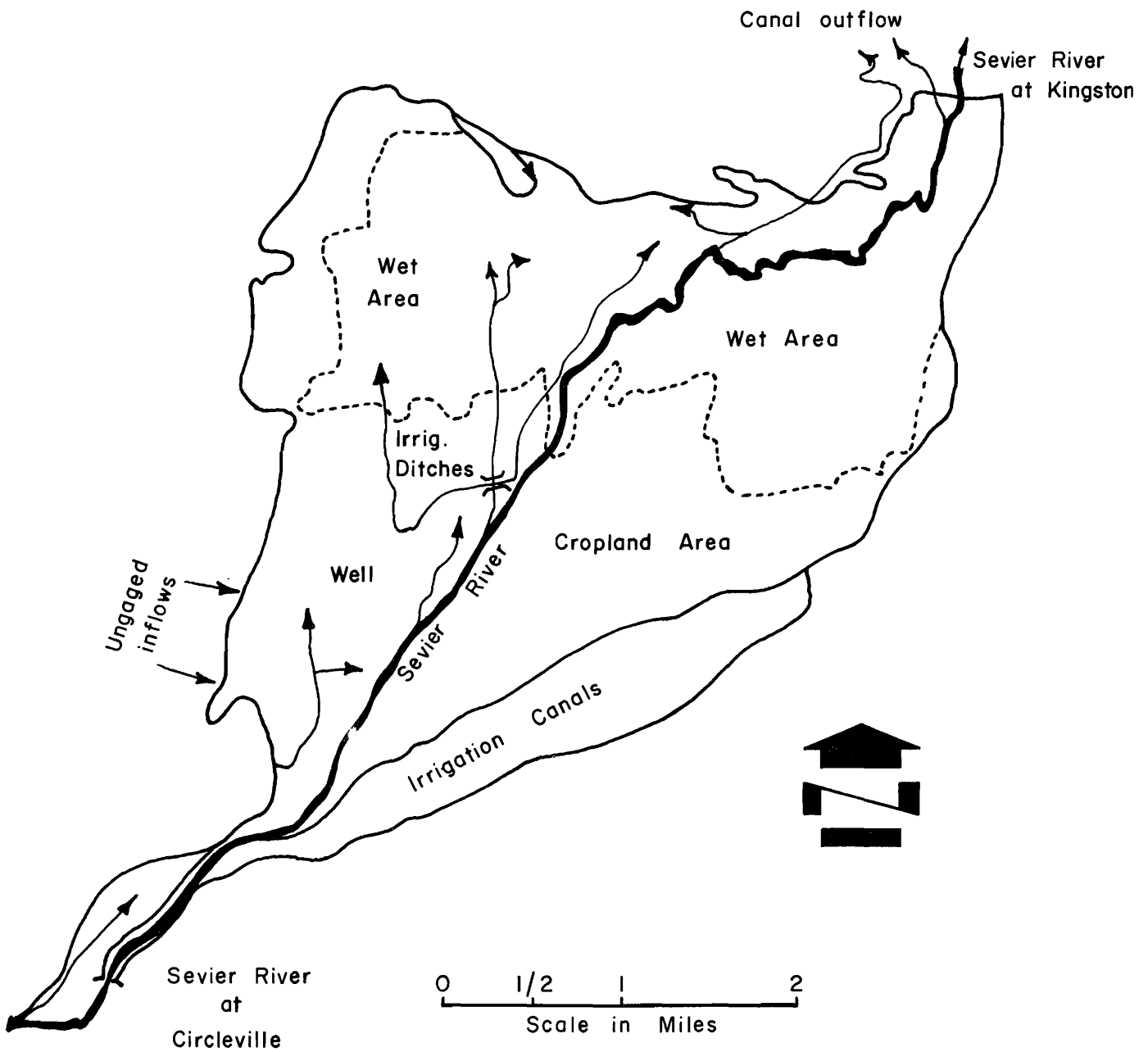
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Figure 10. Agricultural areas of Circle Valley.

joining watersheds which change the inputs to the model area.

Some of the specific processes which are considered in the development of a short time and small space increment model are discussed briefly as follows.

Inbasin use processes

The inbasin use process is primarily the cropland evapotranspiration, and the model should identify this process accurately. Cropland consumptive use consists of two parts:

1. Consumptive use of the growing crops, and

2. Evapotranspiration by the vegetative phreatophytes. This could be apportioned to the available water from the surface and the contribution from the groundwater separately.

The hydrologic processes which are associated with the inbasin uses are canal diversions, groundwater pumping, spring flows, and effluent groundwater movement. The quantities of pumped water and spring flow signify the extent of recycling of water within the basin.

Canal diversions

Quantities of water diverted through the canals consist of surface and subsurface inflows from developed and undeveloped lands, streamflows (gaged and ungaged), reservoir releases, pumped groundwater, and spring flows. Accuracy of estimation or measurement of these quantities will, therefore, have direct effect on the model predicted results.

Irrigation efficiency

The overall irrigation efficiency consists of the conveyance or canal efficiency and the application efficiency, plus the losses due to spills and tailwater runoff. All the quantities except the application efficiency are continuous with respect to time. Water application periods vary with crop growth and season consistent with the consumptive use requirements of the crops. The components of irrigation efficiency are, therefore, variant within the time increment of the model, and their dynamic effects will be attenuated in a monthly time increment model.

Runoff components

The total surface runoff is represented by an overland flow component and a subsurface component.

The effluent groundwater flow must also be apportioned between groundwater outflow from the model area and its contribution to surface channels within the farm area. The relative proportions of each of these processes will, however, change with time and spatial resolution of a model.

Inbasin use processes considered in the model

1. _Potential daily consumptive use._ Representation of the various inbasin hydrologic processes in a short time and space increment model depends on availability of adequate field data, and the particular questions to be answered by the model. The consumptive use process, however, needs careful consideration in any short time increment model. Choice of a method to computer the potential daily or weekly consumptive use again depends on available data. Dutt et al. (1972) utilized the modified Blaney Criddle method based on average daily temperatures to predict daily consumptive use of growing crops and achieved satisfactory results. As an initial approach to represent the potential evapotranspiration of growing crops, with minimum data requirements, modified Blaney Criddle method based on average daily temperatures is, therefore, adapted in this model.

2. _Irrigation efficiency._ The model considers the conveyance efficiency, spills, and tailwater runoff. Application efficiency, however, is not required to be considered for model calibration, but would be necessary for management studies after a complete model is developed. A listing of the computer model developed based on the above concepts is shown in Appendix A.

Data collection and processing

In an attempt to calibrate the daily time increment model, efforts were made to collect the requisite hydrologic data for the agricultural area of Circle Valley of the Circleville Subbasin. The reasons for choosing this area are:

1. Riley et al. (1966) attempted to model the Circle Valley area on a monthly time increment using an electronic analog computer for the year 1962 and achieved reasonable agreement between the observed and computed outflows from the area.

2. Streamflow diversion data are available on a daily basis from the River Commissioner's report.

3. Climatological data are taken from the published records of the U.S. Department of Commerce (1962) for daily temperature and precipitation records.

4. Estimates of groundwater pumping rates for the Water Year 1962 and vegetation and cropping patterns are taken from the report published by Riley et al. (1966).

Model calibration

Calibration of a daily model of an agricultural area using the historic record differs significantly from the calibration of a monthly model for the same area. Some of the important considerations are:

1. The return flow delay time. A zero delay in a monthly model could still mean a delay up to 30 days in a daily model, depending upon the spatial extent of the area represented by the model, in addition to other factors.

2. Exports. Canal diversions often run beyond individual farms, thus accounting for a significant quantity of export water often ungaged to downstream farmers. In a large space and time increment model the effect would be dampened.

3. Effluent groundwater. Local variations of groundwater conditions have significant impact on the effluent water from a small spatial unit, compared to a larger spatial resolution model in which this effect may be much less.

4. Model parameters might show variation over a period of time from season to season. These are affected by irrigation scheduling, snow storage, and cropping pattern (double cropping, as an example). Parameter optimization procedure, therefore, needs additional considerations for a small space and time increment model.

In view of the above considerations, model calibration was approached. Typical calibration results showing the observed and computed runoff from the area is shown by Figure 11 for the month of December 1962. The computed runoff has a close agreement with the observed values on a daily basis.

Development of a Data Collection System

As outlined in the above discussion, it is feasible to develop a short time and space increment model. However, representation of the dynamic nature of the hydrologic system over a shorter space and time increment will require more precise measurements and dense network of measuring stations at the boundaries of the individual farms in order to identify the various inbasin use processes. The nature of measurements, and the costs involved with them, will depend primarily on the questions to be answered by the model. The model developed herein is preliminary with a specific purpose of examining the feasibility of such a model. Consistent with the requirements of the Utah Division of Water Rights, the model, however, needs improvement in many respects.

The preliminary model outlined has identified the necessity of a detailed data collection network. The purpose of any data collection network is to be able to identify the inflows and outflows while defining the various inbasin use processes. Described below is a check list of daily data collection program required for a small time and space increment model.

1. Measured or estimated values of inflows to and outflows from the farm area, both surface and subsurface.

2. Identify the inbasin use processes such as groundwater pumping, and seepage returns.

3. Climatological data such as panevaporation records, solar radiation index, estimates of weekly or daily crop growth coefficients to be able to compute the consumptive use of crops.

Costs

The major cost of extending a small space and time increment model to the entire Sevier River system would be that of data collection. Each space unit should have a measurement of input and output for proper characterization. Precipitation gages should also be increased. Perhaps not one for each space unit, but more than one or two for each present subbasin.

To extend the data collection system to the entire subbasin, the following assumptions are made:

1. The present subbasins will be divided into ten smaller units for a total of 60 units.

2. The surface outflows from each unit can be measured at one point.

3. Twelve additional weather stations would be sufficient.

4. The average cost of each surface outflow measurement structure would be $1,500.

The cost of equipment would be:

Surface inflow	1500 x 20	$ 30,000
Surface outflow measuring	1500 x 60	90,000
Precipitation equipment	1000 x 12	12,000
Radiation equipment	1000 x 6	6,000
Deep percolation measuring	1000 x 6	6,000
		$144,000
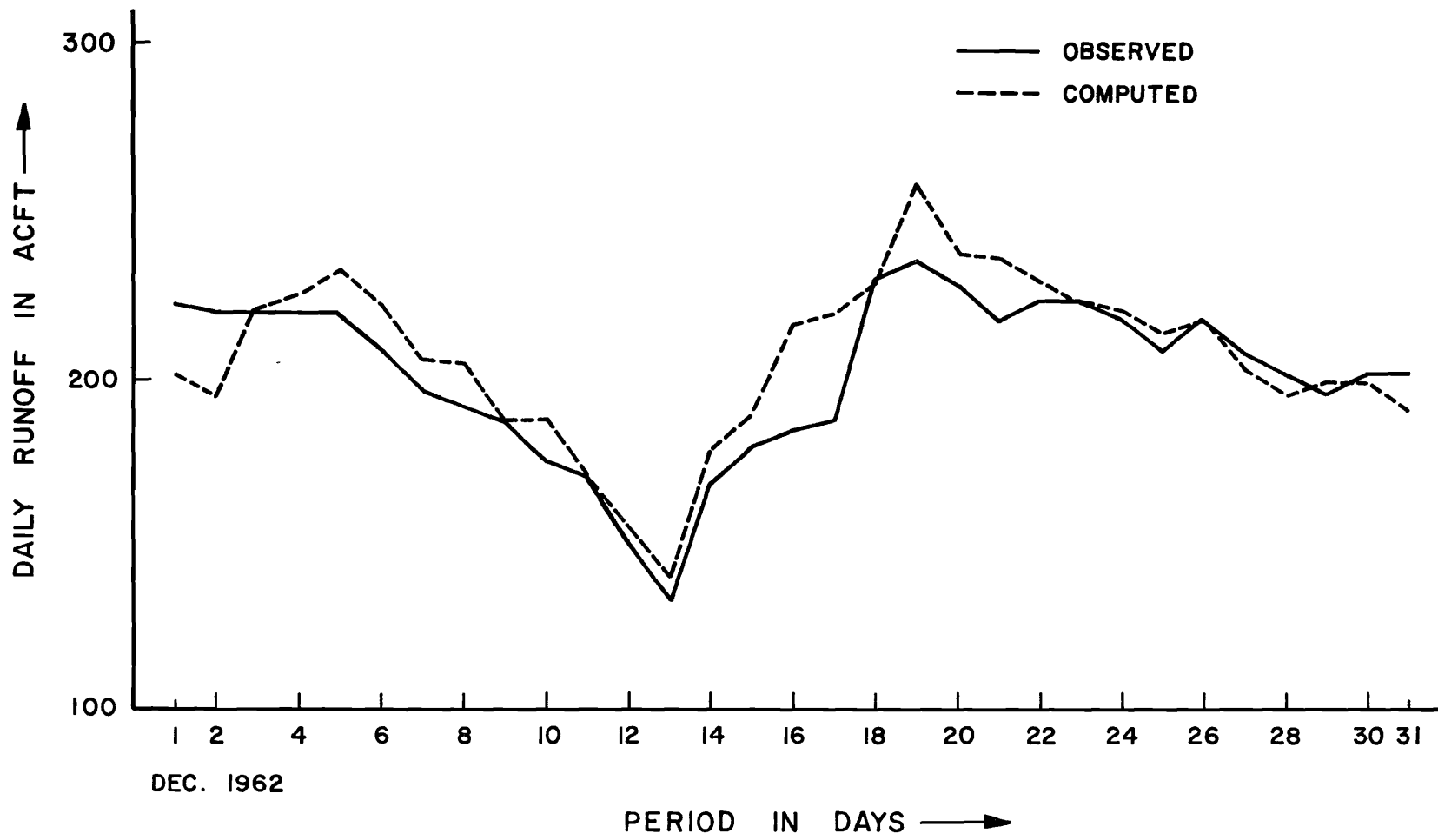
Figure 11. A typical calibration of Circle Valley area for December 1972 showing observed and computed runoff.

Labor Costs

Equipment installation	20 x 1000	$ 20,000
	60 x 1000	60,000
	12 x 500	6,000
	6 x 500	3,000
	6 x 1000	6,000
		$ 95,000

Data Collection/2 Years

Labor	$ 20,000
Travel	10,000
	$ 30,000

Model Application

	60 x 1000	$ 60,000
		$329,000

To extend the small space and time increment to the presently modeled area for a two-year period would cost an estimated $330,000. Overhead costs have not been included. Changes in the assumptions would cause increment cost increases. For example, if a unit outflow must be measured at two places instead of one, the estimated cost would be $3,000 instead of $1,500 for that unit. Characterization of groundwater outflows could easily require additional money. Smaller or larger space increments would force the estimate up or down depending on the scale. Any conceived shortcuts for measuring could reduce the costs. The $330,000 estimate should be considered as conservative in performing the desired measurements in a conventional manner.

Conclusions and Recommendations

The daily model for Circle Valley did prove successful, but because of the lack of data on other sub-basins, it is doubtful that this type of model could be extended without a great deal of data gathering. The following recommendations should be followed and answered before a daily model is prepared for the total drainage.

1. Development of a hydrosalinity model for the Sevier River system. Modifications will have to be made in the model outlined in Phase I of this study, as discussed in this report.

2. An extensive listing of questions concerning the Sevier system which need to be answered in order to determine the degree of resolution required in future model development studies.

3. A plan for the solution of current and unexpected future problems.

4. Data collection to help resolve the anticipated problems.

5. A priority listing of problems requiring solution with an expected requirement of resources to solve the problem.

6. Use of current models by the Division of Water Rights personnel which may require adaptation to another system and instruction of use.

7. Development and use of models consistent with problems, available data, and resources.

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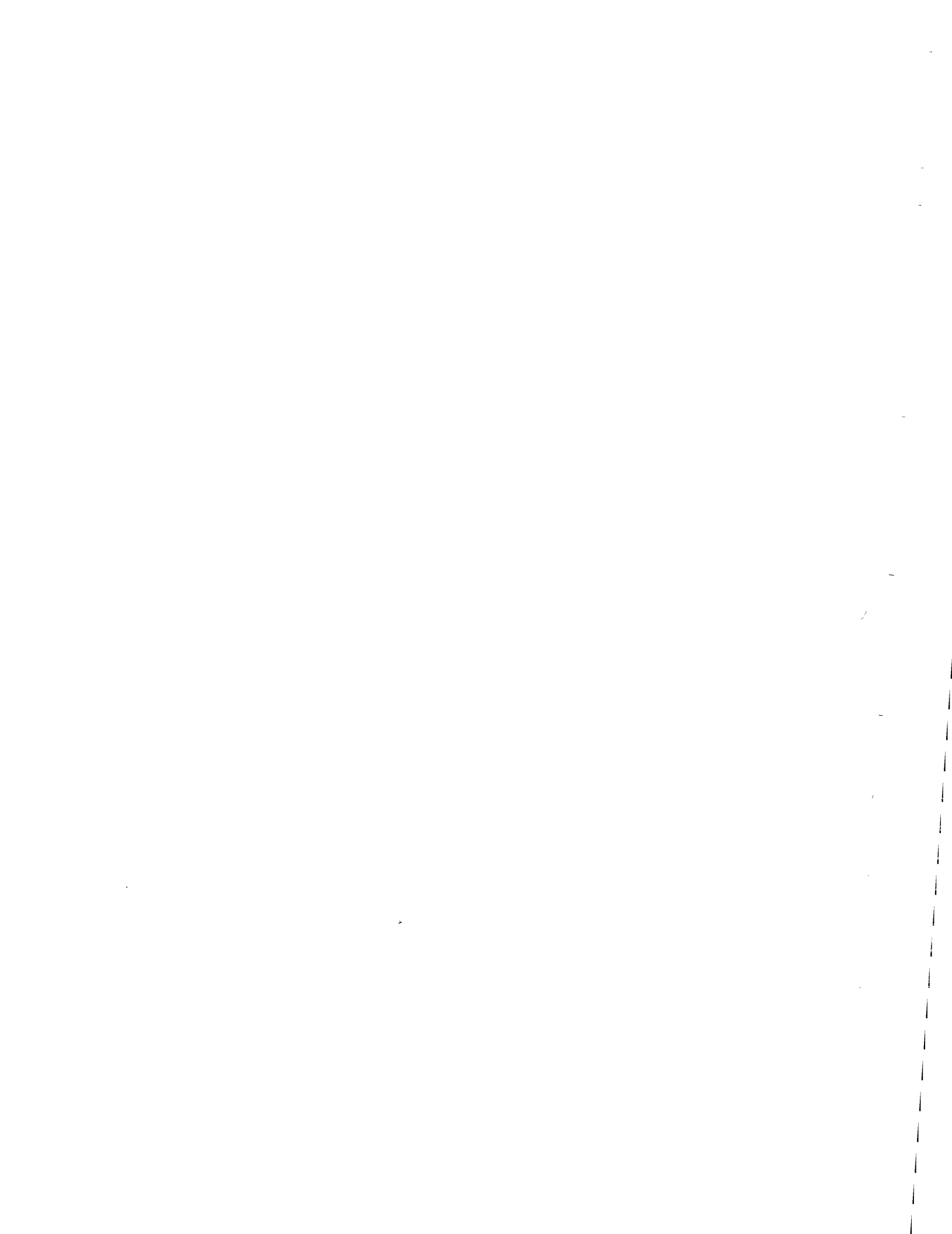
APPENDIX

SMALL SPACE AND TIME
INCREMENT MODEL

```
C *** MANAGEMENT   **MNGMNT**
C ***   DAILY MODEL- HYDROLOGY
      REAL LABL,MIC,MES,KS,MS,MCS
      COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
     1WH,XKG,IDTA,SMAV,PR(45),NPR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
     2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
     3ITX,MDAY(31),VAD(12),TM(31)
      COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
     1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
     3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMI(12),IDTM(12),REL
      COMMON/BLK3/ HD(12,31,1)
C *** KR= READ FROM CARDS
C *** MR= READ FROM MAG TAPE
      READ(6,100) KR,MR
    1     CONTINUE
  100 FORMAT(16I5)
      READ(KR,100)ITY,IPL
      IF(ITY)99,1,3
    3 GOTO(4,5, 9,11),ITY
C     ITY=1 READ DATA WITH DATPR   IPL=1 BASIC ONLY  =2 SUBBASIN ONLY
C                                        =3 MANAGEMENT  =4 RESERVOIR DATA
C                                        =5 ACREAGE DATA AND PAR
C         =2 SET-UP PARAMETERS
C            AND OPERATE AND PRINT
C         =3 OPERATE AND PRINT WITH DATA IN
C         =4  CALIBRATION CALL CALBRT ETC.
    4 CALL DATPR(IPL,KR,MR)
      GOTO 1
C     OPERATE SIMULATION MODELS AND PRINT RESULTS
    5 IENT=1
      IRET=1
      GOTO 10
    9 IENT=2
      IRET=1
   10 CALL HYDSM(IENT,IRET)
      GOTO 1
   11 CALL CALBRT(KR,MR)
      GO TO 1
   99 STOP
      END
C      CALIBRATION   **CALBRT**
      SUBROUTINE CALBRT(KR,MR)
      REAL LABL,MIC,MES,KS,MS,MCS
      COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
     1WH, KG,IDTA,SMAV,PR(45),NPR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
     2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
     3ITX,MDAY(31),VAD(12),TM(31)
      COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
     1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
     3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMI(12),IDTM(12),REL
      COMMON/BLK3/ HD(12,31,1)
      DIMENSION XIN(5,45),XMN(45),XPM(45),DF(45),OBI(5),NOP(4)
     1,PL(45),PH(45),NL(45)
    1 CONTINUE
  100 FORMAT(16I5)
      READ(KR,100)ITY,IPL
      IF(ITY.LE.0) GO TO 99
    3 GOTO(4,5, 9,11),ITY
C     ITY=1 READ DATA WITH DATPR   IPL=1 BASIC ONLY  =2 SUBBASIN ONLY
C         =2 READ INITIAL VECTO
```

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```
C           AND OPERATE AND PR
C         =3 OPERATE AND PRINT WITH DATA IN
C          =4  CALIBRATION READ BOUNDS AND LEVELS,ETC.
    4 CALL DATPR(IPL,KR,MR)
      GO TO 1
    5 READ(KR,101)(XIN(1,L),L=1,NPR)
  101 FORMAT(10F8.3)
    7 DO8 L=1,NPR
    8 PR(L)=XIN(1,L)
C     OPERATE SIMULATION MODELS AND PRINT RESULTS
      IENT=1
      IRET=1
      IP=0
      GO TO 10
    9 IENT=2
      IRET=1
      IP=2
   10 CALL HYDSM(IENT,IRET)
      GO TO 1
C     INPUT PATTERN SEARCH BOUNDS AND LEVELS
   11 READ(KR,100)NPH,(NOP(L),L=1,4)
      READ(KR,101)(PL(L),L= 1,NPR)
      READ(KR,101)(PH(L),L= 1,NPR)
      READ(KR,100)(NL(L),L= 1,NPR)
   13 CONTINUE
      OBI(1)=OBJ
      OH = OBH
      AH = OAH
C     INITIALIZE MINIMUM CONDITIONS
      PHMN=OBJ
      PRMN=OBJ
      DO14 L=1,NPR
      XMN(L)=XIN(1,L)
      XPM(L)=XIN(1,L)
   14 DF(L)=PH(L)-PL(L)
C     TAKE NEW PAGE WRITE PH,PL, NL
      WRITE(6,102)
  102 FORMAT(1H1///19X,3HPAR,8X,2HPH,8X,2HPL,8X,2HDF,8X,2HNL///)
      DO15 L=1,NPR
   15 WRITE(6,103)L,PH(L),PL(L),DF(L),NL(L)
  103 FORMAT(15X,I7,3X,3F10.3,I7)
  104 FORMAT(1H1//20X,5HPHASE,I3,2X,5HPMIN=,F10.1)
  105 FORMAT(5X,10F7.3)
  106 FORMAT(///6X,13HIP  LV    PAR,10X,3HOBJ,8X,3HOBH,8X,3HOAH//)
  107 FORMAT(5X,I3,2X,I3,F11.3,5F11.1)
  108 FORMAT(5X,I3,2H *,I3,F11.3,5F11.1)
C     BEGIN PHASE LOOP
      DO90 K=1,NPH
C     TAKE NEW PAGE WRITE PHASE ONE INITIAL VECTOR
      WRITE(6,104)K,PHMN
      WRITE(6,105)(XIN(K,L),L=1,NPR)
      WRITE(6,106)
C     BEGIN PAR LOOP
      DO80 J=1,NPR
      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
      DO70I=1,NLO
      IF(I.GT.1) GO TO 40
      XNL=NL(J)
      DS=DF(J)/XNL
```

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```
   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))49,64,49
C     OPERATE MODELS AND DETERMINE OBJECTIVE FUNCTION
   49 CALL HYDSM(3,3)
      WRITE(6,107)J,I,PR(J),OBJ,OBH,OAH
      GO TO 65
   64 WRITE(6,108)J,I,XIN(K,J),OBI(K),OH,AH
      OBJ=OBI(K)
C     IF NEW PAR. INITIALIZE LOCAL MIN
   65 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)52,70,70
   52 PHMN=OBJ
      DO53L=1,NPR
   53 XPM(L)=PR(L)
   70 CONTINUE
C     RESET PR(J) TO FIXED LEVEL FOR NEXT PAR.
      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(1,3)
      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(1,1)
      OBI(K+1)=OBJ
      OH=OBH
      AH=OAH
   90 CONTINUE
C     WRITE OUT INITIAL VECTOR TABLE
      NHP=NPH+1
      WRITE(6,109)(OBI(L),L=1,NHP)
  109 FORMAT(1H1//27X,15HINITIAL VECTORS//10X,5HPHASE,7X,1H1,9X,1H2,9X,
     11H3,9X,1H4,9X,1H5//12X,3HOBJ,5F10.0/)
      WRITE(6,110)
  110 FORMAT(12X,3HPAR/)
      NPT=NPH+1
      DO91 L=1,NPR
   91 WRITE(6,111)L,(XIN(M,L),M=1,NPT)
  111 FORMAT(12X,I3,5F10.3)
```
30

```
   99 RETURN
      END
C    ****SUBROUTINE DATPR ****
      SUBROUTINE DATPR(IPL,KR,MR)
      REAL LABL,MIC,MES,KS,MS,MCS
      COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
     1WH,KG,IOTA,SMAV,PR(45),NPR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
     2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
     3ITX,MDAY(31),VAD(12),TM(31)
      COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
     1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
     3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMI(12),IDTM(12),REL
      COMMON/BLK3/ HD(12,31,1)
      DIMENSION N(12),CAC(16),I1(16),DCA(16),PCAP(16),FMT(10),DD(12,32),
     1IX(12)
C    ** IPL=1 BASIC DATA ONLY
C    ** IPL=2 SUBBASIN DATA ONLY
C    ** IPL=3 MANAGEMENT DATA ONLY
C    ** IPL=4 RESERVOIR DATA ONLY
C    ** IPL=5 ACREAGE AND PARAMETERS ONLY
C    *** ITX= 0  ** PRINT DAILY DATA
    1 GOTO(10,20,300,400,20),IPL
   10 READ(KR,100)NSB,NMO,ITX
      MMDAY=0
      READ(KR,100) (MDAY(M),M=1,NMO)
      DO 5 I=1,NMO
    5 MMDAY=MMDAY+MDAY(I)
  100 FORMAT(16I5)
  101 FORMAT(20A4)
      READ(MR,101)(HDG(I),I=1,15)
      READ(MR,101)(VAD(I),I=1,12)
      READ(MR,101)(LABL(I),I=1,48)
      READ(MR,102)(PKCMI(I),I=1,12)
      READ(MR,102)(CMS(I),I=1,12)
C*****READ IN PROPORTION DAYLIGHT HOURS AND USE COEFFICIENTS
      READ(MR,102)(PDL(I),I=1,12)
  102 FORMAT(10X,12F5.3)
      DO 11 L=1,16
   11 READ(MR,102)(CPKC(L,I),I=1,12)
C    *** WRITE INITIAL DATA
      WRITE(6,103)
  103 FORMAT(1H1,5A4,12I5)
      WRITE(6,100)NSB,NMO,ITX,MMDAY
      WRITE(6,100) (MDAY(I),I=1,NMO)
      WRITE(6,110)(HDG(I),I=1,15)
      WRITE(6,110)(VAD(I),I=1,12)
      WRITE(6,110)(LABL(I),I=1,48)
  110 FORMAT(1X,20A4)
      WRITE(6,102)(PDL(I),I=1,12)
      WRITE(6,102) (CMS(I),I=1,12)
      WRITE(6,102)(PKCMI(I),I=1,12)
      DO 12 L=1,16
   12 WRITE(6,102)(CPKC(L,I),I=1,12)
   19 RETURN
C    *** READ SUB-BASIN DATA
   20 READ(KR,104)(BASID(I),I=1,5),NPR,MANG,IQGO,IQSPR,IRES,IB
      READ(KR,102)WH,TOLAF
      READ(KR,205)(PR(I),I=1,NPR)
  104 FORMAT(5A4,12I5)
C    *** READ CROP ACREAGES
      DO21 I=1,16
   21 CAC(I)=0.0
  106 FORMAT(10X,I3,F7.0,I3,F7.0,I3,F7.0,I3,F7.0,I3,F7.0,I3,F7.0,I3,F7.0
```

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```
      1)
      SPAC=0.0
      SCAC=0.0
      READ(KR,106)(I1(I),DCA(I),I=1,11)
      READ(KR,106)(I1(I),DCA(I),I=12,16)
      DO 25 I=1,16
      L=I1(I)
      IF(L)25,25,22
   22 CAC(L)=DCA(I)
      IF(I-12)23,24,24
   23 SCAC=SCAC+CAC(L)
      GOTO 25
   24 SPAC=SPAC+CAC(L)
   25 CONTINUE
C     READ URBAN LAND AREA AND UNDEVELOPED LAND AREA
      READ(KR,350) URLND,UNDLND
      TOTA=URLND+UNDLND+SCAC+SPAC
      CONVV=TOTA/12.
      CONV1=(TOTA-SPAC)/12.
  350 FORMAT(10F8.0)
C *** COMPUTE PROPORTIONS
      DO 28 I=1,16
      IF(I-12)26,27,27
   26 PCAP(I)=CAC(I)/SCAC
      GOTO 28
   27 PCAP(I)=CAC(I)/SPAC
   28 CONTINUE
C *** COMPUTE SCALE FACTORS
      CSV=1.0/SCAC
      CONV=SCAC/12.0
      CONPV=SPAC/12.0
      CNV=12.0/SCAC
      CONUR=URLND/12.
      CONUN=UNDLND/12.
C **  COMPUTE WEIGHTED USE COEF.
      DO 35 I=1,12
      SPKC=0.0
      SCKC=0.0
      DO 34 L=1,16
      SCP=CPKC(L,I)*PCAP(L)
      IF(L-12)32,33,33
   32 SCKC=SCKC+SCP
      GOTO 34
   33 SPKC=SPKC+SCP
   34 CONTINUE
      CKC(I)=SCKC
   35 PKC(I)=SPKC
C *** WRITE OUT DATA UP TO THIS POINT
      WRITE(6,103)(BASID(I),I=1,5),NPR,MANG,IQGO,IQSPR,IRES,IB
      WRITE(6,108)WH,TOLAF
      IF(ITX) 502,502,503
  502 WRITE(6,207)(PR(I),I=1,NPR)
  207 FORMAT(1X,10F8.3)
  205 FORMAT(10F8.3)
      WRITE(6,107)
      WRITE(6,107) CSV,CONV,CONPV,CNV
  107 FORMAT(//10X,4F15.7//)
      WRITE(6,206)(CAC(I),I=1,11),SCAC
      WRITE(6,206)(CAC(I),I=12,16),SPAC
  206 FORMAT(10F8.0)
      WRITE(6,108) (PCAP(I),I=1,16)
  108 FORMAT(/10X,7F10.5/)
      WRITE(6,107)
```

```
      WRITE(6,102)(CKC(I),I=1,12)
      WRITE(6,108)
      WRITE(6,102)(PKC(I),I=1,12)
      WRITE(6,107) CONUR,CONUN,TOTA
      WRITE(6,108)
  503 CONTINUE
      IF(IPL.EQ.5)RETURN
C *** INPUT HYDROLOGIC DATA
      READ(KR,100) (N(I),I=1,12)
      DO 36I=1,NMO
      TM(I)=0.
      JJ=MDAY(I)
      DO 37L=1,JJ
      DO 38K=1,12
   38 HD(I,L,K)=0.0
   37 CONTINUE
   36 CONTINUE
      DO 70 I=1,12
      NN=N(I)
      IF(NN.LE.0)GOTO 70
      IF(I.GT.2)GOTO 50
C  ** INPUT TEMP AND PPT
      XC=NN
      CDL=1.0/XC
      READ(MR,101)(FMT(L),L=1,10)
      DO 49 L=1,NN
      DO 48 J=1,NMO
      JJ=MDAY(J)
      READ(MR,FMT)(DD(J,K),K=1,JJ)
      DO 47 K=1,JJ
   47 HD(J,K,I)=HD(J,K,I)+DD(J,K)*CDL
   48 CONTINUE
   49 CONTINUE
C     COMPUTE AVERAGE MONTHLY TEMPERATURE
      IF(I.EQ.1) GO TO 52
      GO TO 54
   52 DO 53 II=1,NMO
      JJ=MDAY(II)
      XD=JJ
      CDM=1./XD
      DO 53 K=1,JJ
   53 TM(II)=TM(II)+HD(II,K,I)*CDM
   54 CONTINUE
      GOTO 70
C  ** INPUT STREAMFLOW DATA
   50 M=I-2
      READ(MR,101)(FMT(L),L=1,10)
      DO 59 L=1,NN
      DO 51 J=1,NMO
      JJ=MDAY(J)
   51 READ(MR,FMT)IX(J),(DD(J,K),K=1,JJ)
   55 DO 57 J=1,NMO
      JJ=MDAY(J)
      DO 56 K=1,JJ
      IXP=IX(J)
   56 HD(J,K,I)=HD(J,K,I)+DD(J,K)*10.**IXP
   57 CONTINUE
   59 CONTINUE
   70 CONTINUE
C *** WRITE DATA BY TYPE AND MONTH
C  ** HYDROLOGIC **
      IF(ITX) 504,504,81
  504 CONTINUE
```

```
      DO 80 I=1,12
      DO 79 J=1,NMO
      JJ=MDAY(J)
   79 WRITE(6,109)I,J,(HD(J,K,I),K=1,JJ)
  109 FORMAT(2X,I3,I5,6F11.2/12X,6F11.2/12X,6F11.2/12X,6F11.2/12X,
     16F11.2/12X,6F11.2/)
   80 CONTINUE
   81 WRITE(6,102) (TM(II),II=1,NMO)
   99 RETURN
C *** READ CARDS FOR CANAL MANAGEMENT
  300 READ(KR,100) (IDTM(I),I=1,12)
  301 FORMAT(10X,7F10.0)
      WRITE(6,302)
  302 FORMAT(1H0,10X,10HMANAGEMENT //)
      WRITE(KR,100) (IDTM(I),I=1,12)
C *** READ CARDS FOR RESERVOIR MANAGEMENT
      READ(KR,303) (SMLV(I),I=1,12)
      WRITE(6,303) (SMLV(I),I=1,12)
  303 FORMAT(10X,12F5.2)
      RETURN
  400 READ(KR,301) (RES(I),I=1,14)
      WRITE(6,304)
  304 FORMAT(1H0,10X,9HRESERVOIR //)
      WRITE(6,107) (RES(I),I=1,14)
      RETURN
      END
C**** HYDROLOGIC SIMULATION ***HYDSM***
      SUBROUTINE HYDSM(IENT,IRET)
      REAL LABL,MIC,MES,KS,MS,MCS
      COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
     1WH, KG,IDTA,SMAV,PR(45),NPR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
     2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
     3ITX,MDAY(31),VAD(12),TM(31)
      COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
     1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
     3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMI(12),IDTM(12),RFL
      COMMON/BLK3/ HD(12,31,1)
      DIMENSION DDP(732)
      IPRT=0
      IF(IENT+IRET.LE.3)IPRT=1
C     INITIALIZE  OBJECTIVE FUNCTIONS
      OBH=0.0
      OBJ=0.0
      OAH=0.0
      EMS2=MIC
      NAS=0
      SNW1=PR(4)
      C1=PR(9)
      CKG=PR(10)
      C2=PR(10)
      CKG1=PR(11)
      GW1=PR(12)
      QG2IC=GW1
      MCS=PR(15)
      MES=PR(16)
      MIC=PR(17)
      MS=MIC
      SM1=PR(17)
      ARF1=PR(19)
      QGTIC=ARF1
      SPRIC=PR(20)
      ECV=PR(21)
      EAP=PR(14)
```

```
          XKG=PR(34)
          PTW=PR(35)
          PSP=PR(36)
          SKG=PR(37)
          GWCNIC=PR(38)
          JJJ=MDAY(1)
          DO 9L=1,JJJ
          XJ=JJJ
        9 AGW(L)=SKG/XJ
C *** PR(18)= AG  GW  RETURN FLOW DELAY TIME (DAYS)
          IDTA=PR(18)
C       INITTALIZE ANNUAL VALUES
          DO 10 L=1,48
       10 OUT(L,13)=0.0
          DO 11 I=1,MMDAY
          LLL=L+MMDAY
       11 AGW(L)=AGW(LLL)
C    DO FOR EACH MONTH
          DO 200 J=1,NMO
          JJ=MDAY(J)
          DO 7 I=1,48
        7 OUTD(I,JJ+1)=0.
C    DO FOR EACH DAY
          DO 190 KK=1,JJ
          KC1=0
          K=KK
C INSERT A *********
       20 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(COR,J,K,5)
          CALL HSP(CNL,J,K,6)
          CALL HSP(QGI,J,K,7)
          CALL HSP(QPUM,J,K,9)
          CALL HSP(EMIDIV,J,K,10)
          ARD=0.0
          RSR=0.0
          RAV=0.0
          QRIV=RIV+TRB
          TEMP=T
          GWIN=QGI*PR(30)
          EMIDIV=EMIDIV*PR(31)
          CFEMI=PKCMI(K)*PR(32)
          CALL EPOT(T,MDAY,PDL,CKC,PET,ETP,ETPH,TM,J,PKC,JJ,PHET)
        2 CONTINUE
          IF(IRES.EQ.0)GOTO 14
          CALL RESRV(K,1,ETF,IPRT,J,JJ)
C       DETERMINE RAIN,SNOW AND SNOWMELT
       14 RAIN=0.0
          SNMT=0.0
          IF(T-PR(3))15,16,16
       15 SNW1=SNW1+PPT
          GOTO 17
       16 RAIN=PPT
       17 IF(T-PR(2))19,19,18
       18   IF(SNW1.LE.0.0)GOTO 19
          SNW2=SNW1*EXP(-PR(1)*(T-PR(2)))
          SNMT=SNW1-SNW2
          IF(SNW1.LT.SNMT)SNMT=SNW1
          SNW1=SNW1-SNMT
       19 RPSM=RAIN+SNMT
          RPMT=RPSM
```

```
        RMPH=RPMT*PR(22)*CONPV
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 PET
C                2 CALC QCNL BUT LIMIT TO WAD
        IF(MANG) 5,5,4
      5 QCNL=CNL
        GO TO 6
C       MANAGEMENT STUDY CANAL DIVERSIONS
C       PUT LEACHING WATER REQD IN (HD(J,K,6))
      4 ETP1=ETP
     31 IF(IDTM(J)) 35,35,36
     35 ETN=0.
        GO TO 38
C ***   ASSUME THRESHOLD  SM  TO BE UNIFORM OVER THE MONTH
     36 ETN=ETP1-RPMT-(MS-CMS(J))
     37 IF(ETN.LT.0.) ETN=0.
C       APPLICATION EFFICIENCY IS PR(14)
C       CANAL CONVEYANCE EFFICIENCY IS PR(21)=ECV
     38 QCNL=CNL+(ETN*CONV)/(EAP*(1.-PTW)*(ECV-PSP))
        CNL=QCNL
C       CALCULATE UNGAGED FLOWS
      6 PNET=(PHET-RPSM)*CONPV
        IF(PNET.LT.0.0)PNET=0.0
        PWNG=PR(7)*(PPT-PR(8))
        IF(IB.GT.0)PWNG=PR(7)*(RAIN-PR(8))
        IF(PWNG.LT.0.0)PWNG=0.0
        PSUNG=PR(6)*SNMT+PWNG
        UNG=COR*PR(5)+PSUNG
        QUNG=UNG
C       MANAGEMENT STUDY RESERVOIR OPERATION
        IF(IRES.EQ.0)GOTO 113
        CALL RESRV(K,2,ETF,IPRT,J,JJ)
    113 CONTINUE
C***    CALCULATE INFLUENT GW
        IF(QRIV) 116,116,117
    116 STGW=0.
        GO TO 118
    117 STGW=(C1-C2*ALOG10(QRIV))*QRIV
        GIF=STGW
C***    CALCULATE RUNOFF AND CONSUMPTIVE USE FROM LAND AREA OF URBAN AND
C       UNDEVELOPED LAND AND PROPORTION TO GW
    118 PCPURU=RPMT*(CONUR+CONUN)
        URUNCU=RPMT*(CONUR*PR(25)+CONUN*PR(26))
        URSF=PCPURU-URUNCU
        URGW=URSF*PR(27)
        QIN=RIV+QUNG+QPUM+TRB+RSR+URSF-STGW-URGW
C       CALCULATE PHREATOPHYTE USE
        PHSF=ETPH*CONPV-RMPH
        IF(PHSF.GT.0.) GO TO 186
        QIN=QIN-PHSF
    185 PHSF=0.
        PHGW=0.
        GO TO 290
    186 IF(QIN.GE.PHSF) GO TO 187
        PHGW=QIN*PR(23)
        DIF=PHSF-PHGW
        IF(QIN.GE.DIF) GO TO 189
        PHSF=QIN
        GO TO 290
    187 PHGW=PR(23)*PHSF
    189 PHSF=PHSF-PHGW
    290 QIN=QIN-PHSF
```

36

```
      QSI=QIN
      QSPR=SPRIC*PR(24)
      EMSPR=MS
C     SAVE INITIAL DP FOR ROUTING IN DDP
      DO 85 I=1,MMDAY
      DDP(I)=AGW(I)
   85 CONTINUE
C***  CALCULATE SPRING FLOW BY ITERATING HERE TO 301
  119 QSPR1=QSPR
      MS=EMSPR
      WAD=QIN+QSPR
      IF(WAD.LT.0.) WAD=0.
      CALL URBEMI(WAD,EMIDIV,CFEMI,EMICU,EMIRF)
C***  IF MANG =0 OR 1 DO NOT LIMIT QCNL TO WAD
      IF(MANG.EQ.0.OR.MANG.EQ.1) GO TO 87
      IF(CNL.LE.WAD) GO TO 87
      CNL=WAD
   87 CONTINUE
      GWCN=CNL*(1.-ECV)
      SPILL=CNL*PSP
      QCV=CNL-GWCN-SPILL
      TWTR=QCV*PTW
      QDIV=QCV-TWTR
      QIGS=RPMT+QDIV/CONV
      QAPS=QDIV
      STR=WAD-CNL+TWTR+SPILL
C     COMPUTE SOIL MOISTURE LEVEL
      WAGS=QIGS
      SM2=SM1+WAGS-PET
      DP=SM2-PR(15)
      IF(DP)41,43,49
   41 IF(SM2 -PR(16))42,43,43
   42 ETT=SM1+WAGS-PR(16)
      IF(ETT.LT.0.0) ETT=0.0
      ETB=PET-ETT
      IF(SM2.LT.0.)SM2=0.0
      SMG=(SM2+PR(16))*0.5
      IF(ETT.LE.0.0001) SMG=(SM2+SM1+WAGS)*0.5
      DO 45 NSM=1,10
      ETC=ETB*SMG/PR(16)
      SMH=PR(16)-ETC
      IF(ETT.LE.0.0001) SMH=SM1+WAGS-ETC
      SM2=(SMH+SMG)*0.5
      IF(ABS(SM2-SMG).LT.0.005) GO TO 44
      IF(SM2.LT.0.0) SM2=0.0
      SMG=SM2
   45 CONTINUE
   44 AET=ETT+PR(16)-SM2
      IF(ETT.LE.0.0001) AET=SM1+WAGS-SM2
      GOTO 48
   43 AET=PET
   48 DP=0.0
      GOTO 55
   49 AET=PET
      SM2=PR(15)
C***  CROPLAND DP ROUTED TO GW
   55 KIDTA=K+IDTA
   60 AGW(KIDTA)=DP
   62 CALL GWROUT(ARF2,ARF1,XKG,AGW(K))
      ARF=ARF2*CONV
      GWIR=ARF
C     ROUT SEEPAGE WATER FROM CANALS
      CALL GWROUT (GWCN,GWCNIC,PR(39),GWCN)
```

```
C***   CALCULATION OF SPRING FLOW
       DUMSP=GWCN+GWIR+STGW+URGW
C      OPTION TO ALLOW QSPR TO BE 0
       IF(IQSPR)303,302,303
  303  SPIN=PR(29)*GWIN+DUMSP
       CALL GWROUT(SPROUT,SPRIC,PR(28),SPIN)
       QSPR=PR(24)*SPROUT
       KC1=KC1+1
       IF(KC1.GT.75) TYPE 505
  505  FORMAT(//8HKC1 = 75//)
       IF(ABS(QSPR-QSPR1)-TOLAF) 301,301,119
C      RESTORE AGW TO NEXT ITERATION
   83  DO 84 I=1,MMDAY
       AGW(I)=DDP(I)
   84  CONTINUE
       GO TO 119
  301  SPRIC=SPROUT
       GO TO 304
  302  QSPR=0.
  304  ARF1=ARF2
       SMAV=(SM1+SM2)*0.5
       SM1=SM2
       SM=SM1
       GWCNTC=GWCN
   23  CALL HSP(GAG,J,KK,8)
C***   ROUTING OF GW THROUGH BASIN
       GGW=GWIN+DUMSP-QPUM-QSPR-PHGW
       CALL GWROUT(Q02,QG2IC,CKG1,GGW)
C***   LIMIT Q02 TO BE GE 0
       IF(IQG0)380,365,380
  365  IF(Q02) 370,380,380
  370  Q02=0.
  380  QG0=Q02
       QG2IC=Q02
       CHGW=GGW-QG0
       GWO=PR(13)*QG0
       GEF=QG0-GWO
C      PROPORTION OF GAGED SURFACE RUNOFF  SRF
       SRF=STR+GEF
       WEXP=SRF*PR(33)
       QSO=SRF-WEXP
       DIFF= QSO-GAG
       OAH=OAH+DIFF
C      SCALE DIFF AND OBH TO INCHES OVER CROP AREA
       ADIFF=DIFF*CNV
       OBH=OBH+ADIFF*ADIFF
C     CALL DOUT( ) IF TPRT >0
       EMID=EMIDIV
       URUC=URUNCU
       RF=EMIRF
       EMIC=EMICU
       WAGS=WAGS*CONV
       AETT=AET*CONV
       XSM=SM*CONV
C      CALL DOUT
       IF(IPRT)535,535,21
   21  CALL DOUT( K, 1,    T,J,JJ)
       CALL DOUT( K, 2,  PPT,J,JJ)
       CALL DOUT( K, 3, SNW1,J,JJ)
       CALL DOUT( K, 4, PHET,J,JJ)
       CALL DOUT( K, 5,  PET,J,JJ)
  536  CALL DOUT(KK, 6,  AET,J,JJ)
       CALL DOUT(KK, 7,   SM,J,JJ)
```

38

```
            CALL DOUT(KK,  8,RIV,J,JJ)
            CALL DOUT(KK,  9,TRB,J,JJ)
            CALL DOUT(KK,10,UNG,J,JJ)
            CALL DOUT(KK,11,QPUM,J,JJ)
            CALL DOUT(KK,12,QSPF,J,JJ)
            CALL DOUT(KK,13,RSR,J,JJ)
            CALL DOUT(KK,14,URSF,J,JJ)
            CALL DOUT(KK,15,URGW,J,JJ)
            CALL DOUT(KK,16,QSI,J,JJ)
            CALL DOUT(KK,17,WAD,J,JJ)
            CALL DOUT(KK,18,QGI,J,JJ)
            CALL DOUT(KK,19,STGW,J,JJ)
            CALL DOUT(KK,20,CHGW,J,JJ)
            CALL DOUT(KK,21,GEF,J,JJ)
            CALL DOUT(KK,22,EMID,J,JJ)
            CALL DOUT(KK,23,RF,J,JJ)
            CALL DOUT(KK,24,CNL,J,JJ)
            CALL DOUT(KK,25,QCV,J,JJ)
            CALL DOUT(KK,26,GWCN,J,JJ)
            CALL DOUT(KK,27,QAPS,J,JJ)
            CALL DOUT(KK,28,QIRF,J,JJ)
            CALL DOUT(KK,29,WAGS,J,JJ)
            CALL DOUT(KK,30,AETT,J,JJ)
            CALL DOUT(KK,31,XSM,J,JJ)
            CALL DOUT(KK,32,DP,J,JJ)
            CALL DOUT(KK,33,PHGW,J,JJ)
            CALL DOUT(KK,34,PHSF,J,JJ)
            CALL DOUT(KK,35,ARF,J,JJ)
            CALL DOUT(KK,36,STP,J,JJ)
            CALL DOUT(KK,37,SRF,J,JJ)
            CALL DOUT(KK,38,WEXP,J,JJ)
            CALL DOUT(KK,39,GWO,J,JJ)
            CALL DOUT(KK,40,QSO,J,JJ)
            CALL DOUT(KK,41,GAG,J,JJ)
            CALL DOUT(KK,42,DIFF,J,JJ)
C     COMPUTE OBJECTIVE FUNCTION
  535 OBJ=WH*OBH
      IF(ITX.EQ.0.AND.IPRT.GT.0) GO TO 196
      GO TO 190
  196 CALL PRNT(K,J,JJ)
  190 CONTINUE
  200 CONTINUE
      ITX=1
      IF(IPRT)197,197,195
  195 CALL PRNT(K,J,JJ)
  197 RETURN
      END
C **  SUBROUTINE TO CALCULATE DAILY ET BY MODIFIED BLANEY-CRIDLE
      SUBROUTINE EPOT(T,MDAY,PDL,CKC,PET,ETP,ETPH,TM,J,PKC,JJ,PHET)
      DIMENSION MDAY(12),PDL(12),TM(12),PKC(12),CKC(12)
C     PDL,CKC ARE MONTHLY VALUES
      TT=T
C     COMPUTE POTENTIAL EVAPTRANSPIRATION
      EKT=0.0173*TT-0.314
      IF(EKT.LT.0.3)EKT=0.3
      XJJ=JJ
      FTF=EKT*TT*PDL(J)/XJJ
      PET=CKC(J)*ETF
      ETP=PET
      PHET=PKC(J)*ETF
      ETPH=PHET
      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(Q02,Q01,XKG,QI)
        IF(XKG.LE..012) GO TO 1
        Q02=QI+(Q01-QI)*EXP(-1./XKG)
        GO TO 2
      1 Q02=QI
      2 RETURN
        END
C*****SUBROUTINE HSP ****
        SUBROUTINE HSP(D,J,K,I)
        COMMON/BLK3/ HD(12,31,1)
        D=HD(J,K,I)
        RETURN
        END
C*****SUBROUTINE DOUT *****
        SUBROUTINE DOUT(K,L,XD,J,JJ)
        COMMON/BLK1/CONV,CNV,COMPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
       1WH, KG,IDTA,SMAV,PR(45),NPR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
       2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
       3ITX,MDAY(31),VAD(12),TM(31)
        COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
       1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
       3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMI(12),IDTM(12),REL
        OUTD(L,K)=XD
        XMO=NMO
        XJ=JJ
        IF(L-7) 1,1,2
      1 CONTINUE
        GO TO (3,2,5,2,2,2,5),L
      2 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD
        GO TO 4
      3 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
        GO TO 4
      5 OUTD(L,JJ+1)=XD
      4 CONTINUE
        IF(K.EQ.JJ) GO TO 100
        GO TO 90
    100 OUT(L,J)=OUTD(L,JJ+1)
        XDJ=OUT(L,J)
        IF(L-7) 81,81,80
     81 CONTINUE
        GO TO (85,80,90,80,80,80,90),L
     80 OUT(L,13)=OUT(L,13)+XDJ
        GO TO 90
     85 OUT(L,13)=OUT(L,13)+XDJ/XMO
     90 RETURN
        END
C*****SUBROUTINE PRNT ******
C   ** SUBROUTINE FOR WRITING OUT DATA ***PRNT***
        SUBROUTINE PRNT(K,J,JJ)
        REAL LABL,MIC,MES,KS,MS,MCS
        COMMON/BLK1/CONV,CNV,COMPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
       1WH, KG,IDTA,SMAV,PR(45),NPR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
       2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
       3ITX,MDAY(31),VAD(12),TM(31)
```

```
      COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
     1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
     3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMI(12),IDTM(12),REL
      COMMON/BLK3/ HD(12,31,1)
      IPRTF=1
      NT=1
      NTT=42
      NT1=7
      NT2=8
      NT4=8
C     ITX=0 PPINT DAILY VALUES
C     ITX=1 PRINT MONTHLY VALUES
    1 IF(K.EQ.1) WPITE(6,100) (BASID(I),I=1,5),J
  100 FORMAT(1H1//20X,5A4,10X,I5)
  101 FORMAT(  //5X,A4,7(6X,A4))
      IF(ITX) 200,200,201
  201 IF(IPRTF-2)2,2,4
    2 WRITE(6,301)
      GOTO 5
    4 WRITE(6,303)
    5 L1=1
  301 FORMAT(/40X,5HWATER )
  303 FORMAT(/40X,9HRESERVOIR )
      L2=6
      L3=1
      L4=7
      DO 12 LL=1,2
      WRITE(6,101)(HDG(I),I=L3,L4)
      DO 10 I=NT,NT1
   10 WRITE(6,102)LABL(I),(OUT(I,L),L=L1,L2)
  102 FORMAT(6X,A4,7(F10.3))
      IF(IPRTF.EQ.3) GO TO 502
      DO 9 I=NT4,NTT
    9 WRITE(6,103) LABL(I),(OUT(I,L),L=L1,L2)
      IF(IPRTF.EQ.1) GO TO 105
      GO TO 502
  502 DO 11 I=NT2,NT3
   11 WRITE(6,103)LABL(I),(OUT(I,L),L=L1,L2)
  103 FORMAT(6X,A4,7(F10.0))
  105 CONTINUE
      L1=7
      L2=13
      L3=8
      L4=15
      IF(LL.EQ.2) GO TO 501
      WRITE(6,500)
  500 FORMAT(1H1)
   12 CONTINUE
  501 CONTINUE
   99 IF(IRES.LE.0)GOTO 81
C    SET UP TO OUTPUT RESERVOIR
      IF(NT.GE.42)GOTO 81
      IPRTF=3
      NT=43
      NTT=42
      NT1=43
      NT2=44
      NT3=50
      GOTO 1
   81 IF(J.NE.NMO)GOTO85
      IF(IRES.LE.0)GOTO 84
C    WRITE RESERVOIR EXTREMES
      IKMN=1
```
41

```
      IKMX=1
      IF(KMN.GT.6)IKMN=2
      IF(KMX.GT.6)IKMX=2
      WRITE(6,400)
  400 FORMAT(//30X,18HRESERVOIR EXTREMES )
      KI=KMX+IKMX
      WRITE(6,401) SMAX,HDG(KI),JMX
      KI=KMN+IKMN
      WRITE(6,401) SMIN,HDG(KI),JMN
  401 FORMAT(//35X,F10.0,6H ACFT ,A4,I6)
   84 WRITE(6,402)OAH
  402 FORMAT(/30X,4HOAH=,F10.0)
   85 RETURN
C     PRINT DAILY OUTPUT
  200 CONTINUE
      IF(K.EQ.1) WRITE(6,202) (VAD(I),I=1,12)
  202 FORMAT(6X,12A6/)
  203 FORMAT(2I3,3F6.3,9F6.0)
      WRITE(6,203) J,K,OUTD(2,K),OUTD(3,K),OUTD(6,K),OUTD(10,K),
     1OUTD(16,K),OUTD(24,K),OUTD(35,K),OUTD(37,K),OUTD(21,K),OUTD(40,K),
     2OUTD(41,K),OUTD(42,K)
      RETURN
      END
C** RESERVOIR SIMULATION ** RESRV****
      SUBROUTINE RESRV(K,IOP,ETF,IPRT,J,JJ)
      REAL LABL,MIC,MES,KS,MS,MCS
      COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBH,OBJ,OAH,BASID(5),IB,CSV,
     1WH, KG,IDTA,SMAV,PR(45),NFR,PDL(12),CKC(12),PKC(12),CPKC(16,12),
     2NSB,HDG(15),OUTD(48,32),LABL(48),IRES,MMDAY,NMO,
     3ITX,MDAY(31),VAD(12),TM(31)
      COMMON/BLK2/AGW(732),DP,PES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
     1RAV,ARD,RSR,CNL,MANG,TOLAF,CONVV,CONV1,OUT(48,13),SMLV(12),
     3CONUR,CONUN,CMS(12),IQGO,IQSPR,PKCMT(12),IDTM(12),REL
      COMMON/BLK3/ HO(12,31,1)
C     J=MO.,K= DAY,ETF=MOD BC TEMP FACTOR
C     RAV=RES WATER AVAL. FOR CANAL DIV.
C     ARD=ACTUAL CANAL RELEASE (WATER)
C     RSR=TOTAL RELEASES (WATER)
      IF(IOP-2)10,30,30
   10 JK=J+K
      IF(JK.NE.2)GOTO 13
C     INITIALIZE FIRST  DAY, FIRST MONTH
      STI=RES(1)
      CSTI=RES(2)
      SMAX=STI
      SMIN=STI
      JMN=IYRR-1
      JMX=JMN
      KMN=12
      KMX=12
C     SET UP DAILY  DATA
   13 CALL HSP(RIN,J,K,11)
      CALL HSP(PPT,J,K,2)
      RAV=0.0
      ARD=0.0
      EVP=CPKC(16,K)*ETF
      DSEP=PPT-EVP
      CALL AREA(STI,AI,RES)
C     OPERATE RESERVOIR
   30 CALL HSP(REL,J,K,12)
      EXRS=0.0
      RSR=REL+ARD
      ST=STI+DST
```

42

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      CALL AREA(ST,AE,RES)
      AV=(AI+AE)/2.0
      DST=RIN-RSR+DSEP*AV/12.0
      ST=STI+DST
      IF(IOP.NE.1)GOTO 32
C     COMPUTE WATER AVAILABLE FOR IRRIGATION
      PAV=ST-RES(3)
      IF(RAV.LE.0.0)RAV=0.0
      RETURN
C     CHECK EOM STORAGE AGAINST MAX AND MIN
   32 IF(ST.GT.RES(4))GO TO 33
      IF(ST.LT.RES(3)) GO TO 34
      GOTO 40
   33 EXRS=ST-RES(4)
      RSR=RSR+EXRS
      ST=RES(4)
      GOTO 40
   34 STCK=ST+RSR-RES(3)
      IF(STCK)35,35,37
   35 ST=ST+RSR
      RSR=0.0
      APD=0.0
      IF(ST.LT.0.0)ST=0.0
      GOTO 40
   37 RSR=STCK
      ST=RES(3)
      RSRX=RSR-REL
      IF(RSRX)40,40,38
   38 IF(ARD)60,60,59
   59 IF(ARD-RSRX)40,40,62
   62 DARD=ARD
      ARD=RSRX
      CNL=CNL-DAPD+ARD
      GOTO 40
   60 ARD=0.0
C     INITIALIZE NEXT    DAYS STORAGE
   40 DS=ST-STI
      STT=STI
      STI=ST
C     SET UP OUT IF IPRT GT 0
      IF(IPRT)50,50,41
   41 CALL DOUT(K,43, EVP)
      CALL DOUT(K,44,  DS)
      CALL DOUT(K,45,  ST)
      CALL DOUT(K,46, REL)
      CALL DOUT(K,47, RSR)
      CALL DOUT(K,48, ARD)
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
      SUBROUTINE AREA(S,A,RES)
      DIMENSION RES(14)
```
43

```
      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
```