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

V. A. Narasimhan

Eugene K. Israelsen

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

PHASES I AND II

Prepared by
V. A. Narasimhan
Eugene K. Israelsen

Progress Report
to
Utah Division of Water Rights
Department of Natural Resources
State of Utah

Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84322

September 1975
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

Sincere appreciation is expressed to the Four Corners Regional Commission, the Utah Division of Water Resources, and the Utah Water Research Laboratory for making the funds available to conduct the study leading to this report, and to the Utah Division of Water Rights for assistance in obtaining data and coordinating the project. Appreciation also is expressed to those who assisted in preparing the report for publication.
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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.
Figure 1. Counties, subbasins, and economic areas, Sevier River Basin investigation.
Figure 2. Divisions of subbasins.
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>
<thead>
<tr>
<th>Subbasin</th>
<th>Stream Flow Measurements</th>
<th>Canal Diversions</th>
<th>Temperature and Precipitation</th>
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<tbody>
<tr>
<td></td>
<td>Gaging Station</td>
<td>Years of Record Available</td>
<td></td>
</tr>
<tr>
<td>Sanpitch</td>
<td>2155</td>
<td>1964-73</td>
<td>1970-73</td>
</tr>
<tr>
<td></td>
<td>2100</td>
<td>1964-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>2085</td>
<td>1965-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>2159</td>
<td>1965-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>2162</td>
<td>1965-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>2162-1</td>
<td>1964-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>2164</td>
<td>1959-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td>Salina</td>
<td>2060</td>
<td>1960-73</td>
<td>1961-73</td>
</tr>
<tr>
<td></td>
<td>2050</td>
<td>1914-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td>Sigurd</td>
<td>1942</td>
<td>1957-73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1940</td>
<td>1960-73</td>
<td></td>
</tr>
<tr>
<td>Marysvale -Piute</td>
<td>1910</td>
<td>1914-73</td>
<td>Partly not available during 61-62</td>
</tr>
<tr>
<td></td>
<td>1800</td>
<td>1949-73</td>
<td></td>
</tr>
<tr>
<td>Circleville</td>
<td>1763</td>
<td>1961-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>1745</td>
<td>1939-73</td>
<td>Panguitch</td>
</tr>
<tr>
<td>East Fork</td>
<td>1839</td>
<td>1961-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>1850</td>
<td>1957-73</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>1875</td>
<td>1961-64</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1971-73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1880</td>
<td>1934-73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1844-5</td>
<td>1961-1965</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1873</td>
<td>1964-73</td>
<td></td>
</tr>
</tbody>
</table>

aData 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 unaged 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 unaged 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.

<table>
<thead>
<tr>
<th>Stream inflows (Main stem)</th>
<th>Circleville</th>
<th>East Fork</th>
<th>Plute-Marysvale</th>
<th>Sigurd</th>
<th>Salina</th>
<th>Sanpitch</th>
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</thead>
<tbody>
<tr>
<td>Precipitation &amp; Temperature gaging stations</td>
<td>Circleville</td>
<td>Bryce Canyon</td>
<td>Piute dam</td>
<td>Marysvale</td>
<td>Richfield</td>
<td>Salina</td>
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<tr>
<td>Major Reservoir storage considered</td>
<td></td>
<td>Otter Creek Reservoir</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transmountain diversions</td>
</tr>
</tbody>
</table>
Table 3. Crop distribution and vegetation patterns by subbasin.a

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

*aFigures are in acres.*
Table 4. Optimum value of parameters obtained after calibration.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description (Mnemonic)</th>
<th>Circleville</th>
<th>East Fork</th>
<th>Piute-Marysville</th>
<th>Sigurd</th>
<th>Salina</th>
<th>Sanpitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Snowmelt rate</td>
<td>0.225</td>
<td>0.15</td>
<td>0.5</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>2</td>
<td>Temperature above which snow melts, °F</td>
<td>30</td>
<td>15</td>
<td>20.</td>
<td>18.</td>
<td>21.0</td>
<td>24.</td>
</tr>
<tr>
<td>3</td>
<td>Temperature below which snow falls, °F</td>
<td>40</td>
<td>34</td>
<td>30.5</td>
<td>29.</td>
<td>28.</td>
<td>44.</td>
</tr>
<tr>
<td>4</td>
<td>Initial snow water content inches</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>Stream correlation</td>
<td>0.1</td>
<td>0.60</td>
<td>0.5</td>
<td>0.0</td>
<td>0.45</td>
<td>1.24</td>
</tr>
<tr>
<td>6</td>
<td>Snow correlation (acre-feet/inch)</td>
<td>2500</td>
<td>0.0</td>
<td>3200</td>
<td>2700</td>
<td>2400</td>
<td>4500</td>
</tr>
<tr>
<td>7</td>
<td>Precipitation correlation (acre-feet/inch)</td>
<td>400</td>
<td>0.0</td>
<td>3000</td>
<td>0.0</td>
<td>1500</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>Precipitation threshold above which surface runoff occurs (inches)</td>
<td>0.0</td>
<td>0.0</td>
<td>1.5</td>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
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<tr>
<td>9</td>
<td>Coefficient for influent flow from stream</td>
<td>0.3</td>
<td>0.0</td>
<td>0.1</td>
<td>0.08</td>
<td>0.45</td>
<td>0.1</td>
</tr>
<tr>
<td>10</td>
<td>Coefficient for influent flow from stream</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>11</td>
<td>Smoothing coefficient in groundwater function</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>12</td>
<td>Initial groundwater flow rate (acre-feet/month)</td>
<td>3000.</td>
<td>1000.</td>
<td>2800.</td>
<td>3000.</td>
<td>2000.</td>
<td>2500.</td>
</tr>
<tr>
<td>13</td>
<td>Proportion of groundwater outflow that does not return to stream surface as effluent</td>
<td>0.0</td>
<td>1.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description (Mnemonic)</td>
<td>Circleville</td>
<td>East Fork</td>
<td>Piute-Marysvale</td>
<td>Sigurd</td>
<td>Salina</td>
<td>Sanpitch</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>-------------</td>
<td>-----------</td>
<td>-----------------</td>
<td>--------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>14</td>
<td>Efficiency of delivery and application</td>
<td>0.55</td>
<td>0.4</td>
<td>0.4</td>
<td>0.8</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>15</td>
<td>Soil moisture capacity (inches)</td>
<td>7.5</td>
<td>8.5</td>
<td>6.0</td>
<td>6.0</td>
<td>8.0</td>
<td>6.0</td>
</tr>
<tr>
<td>16</td>
<td>Critical soil moisture level below which ET becomes limited because of moisture stress (inches)</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
<td>3.0</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>17</td>
<td>Initial soil moisture level (inches)</td>
<td>6.0</td>
<td>8.5</td>
<td>4.5</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>18</td>
<td>Agricultural groundwater return flow delay time (months)</td>
<td>3.0</td>
<td>0.5</td>
<td>0.5</td>
<td>3.0</td>
<td>5.0</td>
<td>0.5</td>
</tr>
<tr>
<td>19</td>
<td>Initial agricultural return flow rate (inches/month)</td>
<td>4.0</td>
<td>2.0</td>
<td>4.0</td>
<td>2.0</td>
<td>5.5</td>
<td>4.0</td>
</tr>
<tr>
<td>20-27</td>
<td>IC for spring flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>28</td>
<td>Canal conveyance efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000.0</td>
</tr>
<tr>
<td>29</td>
<td>Adjusting coefficient for PPT on phreatophyte land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>30</td>
<td>Proportion of phreatophyte use from groundwater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>31</td>
<td>Spring flow adjusting coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>32</td>
<td>Consumptive use on urban land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>33</td>
<td>Consumptive use on undeveloped land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>34</td>
<td>Coefficient for GW recharge and surface runoff</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>35</td>
<td>K for calculating spring flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.0</td>
</tr>
<tr>
<td>36</td>
<td>GWIN used in calculating spring flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>37</td>
<td>Groundwater inflow adjusting coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>38</td>
<td>Municipal and industrial adjusting coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>39</td>
<td>M &amp; I consumptive use adjusting coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>40</td>
<td>Proportion of surface runoff gaged</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.40</td>
</tr>
</tbody>
</table>
Figure 4. Circleville Subbasins observed vs. computed runoff.
Figure 5. East Fork Subbasin observed and computed runoff.
Figure 6. Marysvale-Piute Subbasin observed and computed runoff.

Model Years 1962-64

- Observed
- Computed

R = 0.973
Figure 7. Sigurd Subbasin computed and observed runoff.
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.
Figure 8. Salina Subbasin observed and computed runoff.

Model Years 1962–64

- Observed
- Computed

$R = 0.945$
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:

\[ \text{Input} = \text{Output} \pm \text{Change in Storage} \quad \ldots \ldots (1) \]

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:

<table>
<thead>
<tr>
<th>Inflows</th>
<th>Outflows</th>
<th>Storages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Overland runoff</td>
<td>Snow</td>
</tr>
<tr>
<td>Surface inflow (river main stem, tributaries, snowmelt, imports, spring flows, pumped groundwater)</td>
<td>Subsurface interflow</td>
<td>Soil moisture</td>
</tr>
<tr>
<td>Subsurface inflows</td>
<td>Groundwater outflow</td>
<td>Surface reservoirs</td>
</tr>
<tr>
<td></td>
<td>Exports</td>
<td>Groundwater storage</td>
</tr>
</tbody>
</table>

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-
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 unaged), 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.

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 compute 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 ungauged 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 pan evaporation 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:

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface inflow</td>
<td>1500 x 20</td>
<td>$30,000</td>
</tr>
<tr>
<td>Surface outflow measuring</td>
<td>1500 x 60</td>
<td>$90,000</td>
</tr>
<tr>
<td>Precipitation equipment</td>
<td>1000 x 12</td>
<td>$12,000</td>
</tr>
<tr>
<td>Radiation equipment</td>
<td>1000 x 6</td>
<td>$6,000</td>
</tr>
<tr>
<td>Deep percolation measuring</td>
<td>1000 x 6</td>
<td>$6,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$144,000</strong></td>
</tr>
</tbody>
</table>
Figure 11. A typical calibration of Circle Valley area for December 1972 showing observed and computed runoff.
## Labor Costs

<table>
<thead>
<tr>
<th>Equipment installation</th>
<th>20 x 1000</th>
<th>$20,000</th>
</tr>
</thead>
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<tr>
<td></td>
<td>60 x 1000</td>
<td>60,000</td>
</tr>
<tr>
<td></td>
<td>12 x 500</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>6 x 500</td>
<td>3,000</td>
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<tr>
<td></td>
<td>6 x 1000</td>
<td>6,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$95,000</td>
</tr>
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</table>

## Data Collection/2 Years

<table>
<thead>
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<th>Labor</th>
<th>$20,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td>$10,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$30,000</td>
</tr>
</tbody>
</table>

## Model Application

<table>
<thead>
<tr>
<th>60 x 1000</th>
<th>$60,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$329,000</td>
</tr>
</tbody>
</table>

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 subbasins, 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.
REFERENCES


APPENDIX

SMALL SPACE AND TIME INCREMENT MODEL
C *** MANAGEMENT **MGMT**
C *** DAILY MODEL - HYDROLOGY
REAL LABL, MIC, MES, KS, MS, MCS
COMMON/BLK1/CONV, CNV, CONVY, SPAC, SCAC, OH, OBJ, OAH, BASID(5), IB, CSV,
1WH, K,W, KNT, SHA, PR(45), NFR, POL(12), CKC(12), PPKC(12), CPCK(16, 12),
2NSB, MDG(15), OUTD(48, 32), LABL(48), IRES, MDAY(31), NMD,
3ITX, MDAY(31), MDAY(31), TM(31)
COMMON/BLK2/AGW(732), DP, RES(14), KMN, KMX, JMN, JMX, SMA, SMN, PET,
1RAV, AND, RSR, CNL, MANG, TOLAF, CONVY, CONV1, OUT(48, 13), SMV(12),
3CONUP, CONUPN, CMS(12), IDGO, IDSPR, PKCM(12), IDTM(12), REL
COMMON/BLK3/ HD(12, 31, 1)
C ** MGMT ** READ FROM CARDS
C *** MR= READ FROM MAG TAPE
READ(K,100) KR, MR
1 CONTINUE
100 FORMAT(1615)
READ(KR,100)ITY, IPL
IF(ITY)99,1,3
3 GOTO(4,5,9,11,ITY)
ITY=1 READ DATA WITH DATPR  IPL=1 BASIC ONLY  #2 SUBBASIN ONLY
ITY=2 SET-UP PARAMETERS
ITY=3 OPERATE AND PRINT
ITY=4 CALIBRATION CALL CALBRT ETC.
ITY=3 MANAGEMENT  #4 RESERVOIR DATA
ITY=5 ACREAGE DATA AND PAR
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 HDMSM(IENT,IRET)
GOTO 1
11 CALL CALBRT(KR, MR)
GOTO 1
99 STOP
END
C CALIBRATION **CALBRT**
SUBROUTINE CALBRT(KR, MR)
REAL LABL, MIC, MES, KS, MS, MCS
COMMON/BLK1/CONV, CNV, CONVY, SPAC, SCAC, OH, OBJ, OAH, BASID(5), IB, CSV,
1WH, KG, IDTA, SHA, PR(45), NFR, POL(12), CKC(12), PPKC(16, 12),
2NSB, MDG(15), OUTD(48, 32), LABL(48), IRES, MDAY(31), NMD,
3ITX, MDAY(31), MDAY(31), TM(31)
COMMON/BLK2/AGW(732), DP, RES(14), KMN, KMX, JMN, JMX, SMA, SMN, PET,
1RAV, AND, RSR, CNL, MANG, TOLAF, CONVY, CONV1, OUT(48, 13), SMV(12),
3CONUP, CONUPN, CMS(12), IDGO, IDSPR, PKCM(12), IDTM(12), REL
COMMON/BLK3/ HD(12, 31, 1)
DIMENSION XIN(5, 45), XM(45), XPM(45), DF(45), OBI(5), NDF(4)
1, PL(45), PNM(45), NL(45)
1 CONTINUE
100 FORMAT(1615)
READ(KR,100)ITY, IPL
IF(ITY)99,1,3
3 GOTO(4,5,9,11,ITY)
C IPL=1 READ DATA WITH DATPR  IPL=1 BASIC ONLY  #2 SUBBASIN ONLY
C #2 READ INITIAL VEC
AND OPERATE AND PRINT WITH DATA IN CALIBRATION READ BOUNDS AND LEVELS, ETC.

CALL DATPR(IPL,KR,MP)
GO TO 1

READ(KR,101)(XIN(1,L),L=1,NPR)

FORMAT(10F8,3)

FOR L=1,NPR

OPR(L)=XIN(1,L)

END SIMULATION MODELS AND PRINT RESULTS IENT=1 IRET=1 TP="" GO TO 10

IENT=0 IRET=1 IP=""

10 CALL HDOSH(IENT,IRET)
GO TO 1

INPUT PATTERN SEARCH BOUNDS AND LEVELS

READ(KR,101)(PL(L),L=1,NPR)
READ(KR,101)(PH(L),L=1,NPR)
READ(KR,101)(NL(L),L=1,NPR)

CONTINUE

OBJ(1)=OBJ
OH = ORH
AM = MAH

INITIALIZE MINIMUM CONDITIONS
PHMN=OBJ
PRMN=OBJ

DO14 L=1,NPR
XHN(L)=XIN(1,L)
XPM(L)=XIN(1,L)

DF(L)=PHCL)-PL(L)

TAKE NEW PAGE WRITE PH,PL, NL
WRITE(6,102)

102 FORMAT(1M1/19X,3HPAR,8X,2HPH,8X,2HPM,8X,2HDF,8X,2HNH//)

DO15 L=1,NPR

WRITE(6,103)PL(L),DF(L),NL(L)

FORMAT(15X,17,3X,6F10.3,17)

FORMAT(1M1/20X,5HPHASE,13,2X,5HPM,10.1)

FORMAT(5X,1F7.3)

FORMAT(1M1/6X,13HPAR,10X,3F11.3,5F11.1)

BEGIN PHASE LOOP

DO99 K=1,NPH

WRITE(6,104)PHMN
WRITE(6,105)(XIN(K,L),L=1,NPR)
WRITE(6,106)

BEGIN PAR LOOP

DO80 J=1,NPR

BEGIN INCR LOOP

DO70 I=1,NLO

IF(I.NE.1) GO TO 48

WRITE(6,107)NL(J)

DO80 I=1,NLO

END
40 XI$=(I-1)
PR(J)=PL(J)+DS*XI
D3*PR(J)
IF(D3=01)49,41,41
IF(D3=02)49,42,49
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),ORJ,OH,AH
GO TO 65
64 WRITE(6,108)J,I,XIN(K,J),OBJ(K),OH,AH
OBJ=ORJ(K)
C IF NEW PAR, INITIALIZE LOCAL MIN
65 IF(I.GT.1) GO TO 67
PRMN=OBJ
XMN(J)=PR(J)
GO TO 51
67 IF(OBJ=PRMN)50,51,51
PRMN=OBJ
XMN(J)=PR(J)
51 IF(OBJ=PRMN)52,70,70
PHMN=OBJ
D03L=1,NPP
52 XPM(L)=PM(L)
53 CONTINUE
C CK LOCAL AND PHASE MINS
GO TO 51
50 IF(NOP=PRMN)51,51,51
51 IF(OBJ=PRMN)52,70,70
PHMN=OBJ
D03L=1,NPP
52 XPM(L)=PM(L)
53 CONTINUE
C RESET PR(J) TO FIXED LEVEL FOR NEXT PAR.
IF(NOP=1)71,72,72
71 PR(J)=XIN(K,J)
GO TO 80
72 PH(J)=XMN(J)
80 CONTINUE
81 NOP=NOP+1
71 IF(NOOP.EQ.1) GO TO 83
80 D092L=1,NPR
81 PR(L)=XMN(L)
CALL HYDSM(1,3)
PRMN=OBJ
C SELECT BEST VECTOR FOR NEXT PHASE
83 IF(PRMN=PRMN)4,88,88
84 D085L=1,NPR
XIN(K+1,L)=XPM(L)
85 PR(L)=XMN(L)
GO TO 88
86 D087L=1,NPR
XIN(K+1,L)=XPM(L)
87 PR(L)=XPM(L)
88 CALL HYDSM(1,1)
OBJ(K+1)=ORJ
OH=OH
AH=AH
90 CONTINUE
C WRITE OUT INITIAL VECTOR TABLE
109 FORMAT(1H1//27X,15HINITIAL VECTORS//19X,5HPHASE,7X,1H1,9X,1H2,9X,
11H3,9X,1H4,9X,1H5//12X,3HOBJ,5F10.0/)
WRITE(6,110)
110 FORMAT(12X,3HPAR/)
NPT=NPT+1
D091 L=1,NPR
91 WRITE(6,111)L,(XIN(M,L),M=1,NPT)
111 FORMAT(12X,13,5F10.3)
SUBROUTINE DATPR

SUBROUTINE DATPR(IPL,KR,MP)

REAL LAMB, MC,MES, KS, MS, MC
COMMON/BK1/CONV, CNV, CONP, SPAC, SCAC, OBS, OBS, OAH, BASID, M, IH, CSV,
W, KG, IDTA, SHAV, PKH, NPR, PDL, CK, PK, PKC, PKC, PKC, PKC, PKC,
NSH, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS, HS,
7, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
D, 0.

DIMENSION K(12), CAC(16), I(16), DCA(16), PCAP(16), FMT(10), DO(12, 32),
ITX(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 ACCEAGE AND PARAMETERS ONLY
C ** ITX=0 ** PRINT DAILY DATA
1 GET(10, 20, 30, 40, 50, I-1, IPL
9 READ(KR, 100) NSG, NMO, ITX
MMDAY=0
READ(KR, IP0) MDAY(M), M=1, NMO)
DO 5 I=1, NMO
5 MMDAY=MMDAY+MDAY(I)
100 FORMAT(16I5)
101 FORMAT(2PA4)
READ(MR, 101) (HOG(I), I=1, 15)
READ(MR, 101) (VAD(I), I=1, 12)
READ(MR, 101) (LAMB(I), I=1, 16)
READ(MR, 101) (PKCM(I), I=1, 12)
READ(MR, 101) (CMS(I), I=1, 16)
C***** READ PROPORTION DAYLIGHT HOURS AND USE COEFFICIENTS
READ(MR, 102) (PDL(I), I=1, 12)
102 FORMAT(16I5)
111 READ(NP, 102) (PKC(L, I), I=1, 12)
C ** WRITE INITIAL DATA
WRITE(6, 103)
133 FORMAT(1H1, 5A4, 12I5)
WRITE(6, 100) NSR, NMO, ITX, MMDAY
WRITE(6, 100) (MDAY(I), I=1, NMO)
WRITE(6, 110) (HOG(I), I=1, 15)
WRITE(6, 110) (VAD(I), I=1, 12)
WRITE(6, 110) (LAMB(I), I=1, 12)
WRITE(6, 110) (PKCM(I), I=1, 12)
WRITE(6, 110) (CMS(I), I=1, 12)
WRITE(6, 110) (PKC(L, I), I=1, 12)
WRITE(5, 102) (CPB(L, I), I=1, 12)
DO 12 I=1, 16
12 WRITE(5, 102) (CPB(L, I), I=1, 12)
C *** READ SUBBASIN DATA
20 READ(KR, 104) (BASID(I), I=1, 15), NPR, HANG, IDGA, IGSR, IRES, IB
READ(KR, 102) W3, TOLAF
READ(KR, 205) (PR(I), I=1, NPR)
104 FORMAT(5A4, 12I5)
C *** READ CROP ACREAGES
DO 21 I=1, 16
21 CAC(I)*=0.0
106 FORMAT(16X, 13, F7.0, 13, F7.0, 13, F7.0, 13, F7.0, 13, F7.0, 13, F7.0, 13, F7.0)
READ (KPI, 108) (II(I), DCA(I), I=1, 11)
READ (KPI, 106) (II(I), DCA(I), I=12, 16)
DO 25 I=1, 16
L=II(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 (KPI, 356) URLs, UNDLN
TOTA = URLN + UNDLN + SCAC + SPAC
CONV1 = TOTA / 12.
CONV2 = (TOTA - SPAC) / 12.
350 FORMAT (10F8.0)
C *** COMPUTE PROPORTIONS
DO 28 I = 1, 16
26 PCAP(I) = CAC(I) / SCAC
GOTO 28
27 PCAP(I) = CAC(I) / SPAC
28 CONTINUE
C *** COMPUTE SCALE FACTORS
CSV = 1.7 / SCAC
CONV = SCAC / 12.
CONVP = SPAC / 12.
CNV = 12.0 / SCAC
CONUR = URLN / 12.
CONUN = UNDLN / 12.
C ** COMPUTE WEIGHTED USE COEF.
DO 35 L = 1, 16
29 SCP = CPKC(L, 1) * PCAP(L)
IF (L = 12) = 32, 33, 33
32 SCKC = SCKC + SCP
GOTO 34
33 SCKC = SCKC + 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, IGDO, IGSPR, 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 (10FA, 3)
WRITE (6, 107)
WRITE (6, 107) CSV, CONV, CONVP, CNV
107 FORMAT (18X, 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, 15)
108 FORMAT (/1X, 7F10, 5/)
WRITE (*) 32
WRITE(6,102)(CKC(I),I=1,12)
WRITE(6,108)
WRITE(6,102)(PKC(I),I=1,12)
WRITE(6,107) CONUR,CONUK,TOTA
WRITE(6,108)
503 CONTINUE
IF(IOPL.EQ.5)RETURN
C *** INPUT HYDROLOGIC DATA
READ(KR,190) (N(I),I=1,12)
DO 36 I=1,NMO
TM(I)=0.
JJ=MDAY(I)
DO 37 L=1,JJ
DO 38 K=1,12
38 HK(I,L,K)=0.
37 CONTINUE
36 CONTINUE
DO 70 I=1,12
NN=N(I)
IF(NN.LE.0)GOTO 7H
IF(I.GT.2)GOTO 50
C ** INPUT TEMP AND PPT
XC=NN
CDL=XC/XC
READ(MR,191) (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 HK(J,K,I)=HK(J,K,I)+DD(J,K)*CDL
46 CONTINUE
45 CONTINUE
C COMPUTE AVERAGE MONTHLY TEMPERATURE
IF(I.EQ.1) GOTO 52
GO TO 54
52 DO 53 J=1,NMO
JJ=MDAY(JJ)
XN=JJ
CDM=1./XN
DO 55 K=1,JJ
TMC(J)=TMC(J)+HK(J,K,I)*CDM
54 CONTINUE
GO TO 70
C ** INPUT STREAMFLOW DATA
50 M=2
READ(MR,191) (FMT(L),L=1,10)
DO 59 L=1,NN
DO 58 J=1,NMO
JJ=MDAY(JJ)
58 READ(MR,FMT)IX(JJ),(DD(J,K),K=1,JJ)
57 DO 55 J=1,NMO
JJ=MDAY(JJ)
55 READ(MR,FMT)IX(JJ),(DD(J,K),K=1,JJ)
54 CONTINUE
GO TO 70
C *** WRITE DATA BY TYPE AND MONTH
C ** HYDROLOGIC **
* IF(ITX) 504,504,81
504 CONTINUE
DO AR I=1,12
DO JS=1,NMO
J=DAY(J)
END
WRITE(K,709)I,J,(HD(J,K),K=1,JJ)
109 FORMAT(2X,I13,5F11.2/12X,5F11.2/12X,5F11.2/12X,
16F11.2/12X,5F11.2/12X)
C CONTINUE
81 WRITE(K,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(1MX,7F10.7)
WRITE(K,302)
302 FORMAT(1MX,1MX,1MXMANAGEMENT //)
WRITE(K,100) (IDTM(I),I=1,12)
C *** READ CARDS FOR RESERVOIR MANAGEMENT
READ(KR,303) (SMLV(I),I=1,12)
WRITE(K,303) (SMLV(I),I=1,12)
303 FORMAT(1MX,12F5.2)
RETURN
400 READ(KR,304) (RES(I),I=1,14)
WRITE(K,304)
304 FORMAT(1MX,9X,9XRESERVOIR //)
WRITE(K,107) (RES(I),I=1,14)
RETURN
END
C**** HYDROLOGIC SIMULATION ***HYDSM***
SUBROUTINE HYDSM(INT,IRET)
REAL LBL/BLK/CONV,CSV,CONV,SPAC,SCAC,OBH,ORJ,GAH,BASID(5),I8,Csv,
WKG,IDTA,SHAV,PR(45),NPR,PD(12),CKC(12),PK(12),CPKC(16,12),
2NS,HC(GC(18),OUTD(48,32),LABL(48),IRES,HDAY,NMO,
3ITX,HDAY311,VAD(12),TM(31)
COMMON/BLK1/CONV,CSV,CONV,SPAC,SCAC,OBH,ORJ,GAH,BASID(5),I8,Csv,
WKG,IDTA,SHAV,PR(45),NPR,PD(12),CKC(12),PK(12),CPKC(16,12),
2NS,HC(GC(18),OUTD(48,32),LABL(48),IRES,HDAY,NMO,
3ITX,HDAY311,VAD(12),TM(31)
COMMON/BLK2/AGW(732),DP,RES(14),KMN,KMX,JMN,JMX,SMAX,SMIN,PET,
1RAV,ARD,RSR,CLN,MAN,TOLA,CONV,CONV1,OUT(48,13),SMLV(12),
3CONV,CONUN,CM5(12),ISGO,ISPR,PKCM1(12),I0TM(12),REF
COMMON/BLK3/HO(12,31,1)
DIMENSION DNP(732)
IPRT=0
IF(INT+IRET.LE.3)IPRT=1
C INITIALIZE OBJECTIVE FUNCTIONS
OBH=0.0
OBJ=0.0
GAH=0.0
EMS=MIC
NAS=0
SNW1=PR(4)
CL=PR(9)
CKB=PR(10)
C2=PR(10)
CKD=PR(11)
GW=PR(12)
GGC=GW
MCS=PR(15)
MES=PR(15)
MIC=PR(17)
MS=MIC
SM1=PR(17)
ARF1=PR(19)
QG=ARF1
SPIC=PR(20)
ECV=PR(21)
EAP1=PR(14)
XKG=PF(34)
PTK=PR(35)
PSP=PR(36)
SKG=PR(37)
GWCN=PR(38)
JJJ=MDAY(1)
DO 9 9=1,JJJ
JJ=JJJ
9 AG(L)=SKG/XJ
C *** PR(18)= AG GW RETURN FLOW DELAY TIME (DAYS)
INTA=PR(18)
C INITIALIZE ANNUAL VALUES
DO 10 L=1,48
10 OUT(L,13)=0.0
DO 11 L=1,MDAY
11 AG(L)=AG(L)=AG(L)
C DO FOR EACH MONTH
DO 200 J=1,12
JJ=MDAY(J)
DO 7 I=1,48
7 OUTD(I,JJ+1)=0.,
C DO FOR EACH DAY
DO 190 KK=1,JJ
KCI=*
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(CGI,J,K,7)
CALL HSP(OMW,J,K,9)
CALL HSP(EMIDIV,J,K,10)
ARP=0.0
R3R=0.0
RAY=0.0
GRIV=RIV+TRB
TEMP=G
EMIDIV=EMIDIV+PR(31)
CFEMI=PKCMI(K)+PR(32)
CALL EPOT(T,MDAY,PDL,CKC,PET,ETPH,TM,J,PKC,JJ,PHET)
2 CONTINUE
IF(IERE.S.EQ.0)GOTO 14
CALL RESVR(K,1,ETF,IPRT,J,JJ)
C DETERMINE RAIN, SNOW AND SNOWMELT
14 RAIN=0.0
SNM=0.0
IF(T=PR(3))15,16,16
15 SNW1=SNW1+PPT
GOTO 17
16 RAIN=PPT
17 IF(T=PR(3))19,19,18
18 IF(SNW1.LE.A.0)GOTO 19
SNW2=SNW1*EXP(-PR(1)*(T-PR(2)))
SNMT=SNW1=SNW2
IF(SNW1.LT.SNMT)SNMT=SNW1
SNW1=SNW1=SNMT
RPSM=RAIN+SNMT
RPM=1PSM
```plaintext
RMPH=RPMT*PR(22)*CONPV
C*** IF MANG=1 LIMIT QCNL TO WAD BUT USE GAGEU RECORDS
C 1 USE QCNL AS RECORDED
C 2 CALC QCNL AND USE WITHOUT LIMIT TO SATISFY PET
C 3 CALC QCNL BUT LIMIT TO WAD
5 QCNL=QCNL
GO TO 6
C MANAGEMENT STUDY CANAL DIVERSIONS
C PUT LEACHING WATER READ IN (HD(J,K,6))
4 ETP1=ETP
31 IF(INTM(J)) 35,35,36
35 ETAH,
GO TO 3A
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=QCNL+(ETN*CONV) /(EAP*(1.-PTW)*(ECV-PSP))
CNL*QCNL
C CALCULATE UNGAGED FLOWS
6 PNHT=(PHT=RPMT)*CONPV
IF(PNHT.LT.PNHT)PNHT=0.
PNHT=PR(7)*(PPT=PR(8))
IF(IB.GT.0.) PNHT=PR(7)*(RAIN=PR(8))
IF(PNHT.LT.0.) PNHT=0.
PSUNG=PR(6)*SNMT+PWNG
UNG=COR*PR(5)+PSUNG
UNG=UNG
C MANAGEMENT STUDY RESERVOIR OPERATION
IF(IRFS.EQ.0)GOTO 113
CALL FESRV(K,2,ETF,IPRT,J,JJ)
113 CONTINUE
C*** CALCULATE INFLUENT GW
116 STGW=9.
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)
QTN=TVUNG+OPUM+TRB+RSP+URSF*STGW=UNGW
C CALCULATE PHREATOMETRIC USE
PHSF=ETP*CONPV-RMPH
IF(PHSF.GT.0.) GOTO 186
QIN=QIN+PHSF
185 PHSF=0.
PHGW=0.
GO TO 290
186 IF(QIN.GE.PHSF) GOTO 187
PHGW=QIN*PR(23)
DIF=PHSF-PHGW
IF(QIN.GE.DIF) GOTO 189
PHSF=QIN
GO TO 290
187 PHGW=PR(23)*PHSF
189 PHSF=PHSF-PHGW
292 QIN=QIN+PHSF
36
```
QSI=QIN
QSPR=SPRIC*PR(24)
EMSPR=MS
C
SAVE INITIAL DP FOR ROUTING IN DDP
DO 85 I=1,M
DNP(I)=AGF(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,EMDIV,CFEMI,EMICU,EMIRF)
C*** IF HANG = 0 OR 1 DO NOT LIMIT GCNL TO WAD
IF(HANG,LE,0. OR HANG,GE,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*PTN
QDIV=QCV-TWTR
QDIGS=RPM+QDIV/CONV
QAPS=QDIV
STRA=WAD-CNLTWTR+SPILL
C
COMPUTE SOIL MOISTURE LEVEL
WAGS=QDIGS
SM2=SM1+WAGS-PET
DP=SM2-PR(15)
IF(DP)41,43,49
41 IF((SM2-PET(15)))42,43,43
42 ET2=SM1+WAGS-PR(16)
IF(ETT,LT,0.) ET2=0.
ETB=PET=ET2
IF(SM2,LT,0.) SM2=0.
SMG=(SM2+PR(15))*0.5
IF(ETT,LE,0.001) SMG=(SM2+SM1+WAGS)*0.5
DO 45 NSM=1,10
ETC=ETB*SMG/PR(16)
SMH=PR(16)-ETC
IF(ETT,LE,0.001) SMH=SM1+WAGS-ETC
SM2=(SMH+SMG)*0.5
IF(ABS(SM2-SMG),LT,0.005) GO TO 44
IF(SM2,LT,0.) SM2=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.
GOTO 55
49 AET=PET
SM2=PR(15)
C*** CROPLAND DP ROUTED TO GW
55 KIDTA=K.IDTA
67 AGW(KIDTA)=DP
62 CALL GWROUT(ARF2,ARF1,XKG,AGW(K))
ARF=ARF2*CONV
GNIR=ARF
C
ROUT SEEPAGE WATER FROM CANALS
CALL GWROUT (GWCN,GWCNC,PR(39),GWCN)
C*** CALCULATION OF SPRING FLOW
  DUMSP=CWIN+CWIR+STGH+URGW
  C OPTION TO ALLOW QSPR TO BE 0
  IF(QSPR).EQ.0,302,303
303 SPIN=PR(28)*CWIN+DUMSP
  CALL GWROUT(SPROUT,SPRIC,PR(28),SPIN)
  QSPR=PR(28)*SPROUT
  KC=KC+1
  IF(KC.GT.75) TYPE 595
595 FORMAT(//,MKC1 = 75//)
  IF(ABS(QSPR-QSPR1).LT.TOLAF) 301,301,119
C  RESTORE AGW TO NEXT ITERATION
301 NO 84 I=1,MMDAY
  AGW(I)=DDP(I)
84 CONTINUE
  GO TO 140
361 SPRIC=SPROUT
  GO TO 304
362 QSPR=.
304 ARF1=ARF2
  SM=AV=(SM1+SM2)*6.5
  SM1=SM2
  SM=SM1
  CHG=TC*GWHCN
23 CALL HSP(AG,J,KK,A)
C*** ROUTING OF GW THROUGH BASIN
  GG=CWIN+DUMSP-QPUM-QSPR-PHGW
  CALL GWROUT(UQ2,GG2IC,CKG1,GG)
C*** LIMIT Q02 TO BE GE 0
365 IF(IQG0).NE.380,385,380
380 IF(Q02).LT.0,380,380
385 Q02=0
  390 G0=G0+Q02
  G02=G0+G0
  GWH=P(13)+G0
  GEF=G0+GWH
C  PROPORTION OF GAGED SURFACE RUNOFF SRF
  SRF=STR*G_EF
  WEF=SRF*PR(33)
  QQ=SRF*WEF
  DIFF= QQ=QAG
  NAH=NAH+DIFF
C  SCALE DIFF AND DBH TO INCHES OVER CROP AREA
  ADIFF=DIFF*CNV
  OBH=ORH+ADIFF*ADIFF
C  CALL DOUT( ) IF TPRT >0
  EMIR=EMINIV
  UHUC=URUCN
  RP=EMIRE
  EMIC=EMICU
  WAGS=WAGS*CNV
  AETT=AET*CNV
  XSM=XSM*CNV
C  CALL DOUT
  IF(IPRT).NE.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, TPB, J, JJ)
CALL DOUT(KK, 10, UNG, J, JJ)
CALL DOUT(KK, 11, OPUH, J, JJ)
CALL DOUT(KK, 12, QSPK, J, JJ)
CALL DOUT(KK, 13, RSR, J, JJ)
CALL DOUT(KK, 14, UHFS, J, JJ)
CALL DOUT(KK, 15, URGW, J, JJ)
CALL DOUT(KK, 16, GSI, J, JJ)
CALL DOUT(KK, 17, WAQ, J, JJ)
CALL DOUT(KK, 18, OGK, J, JJ)
CALL DOUT(KK, 19, STGK, 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, GKCN, 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, AETY, 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, PHFSF, 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, GW, J, JJ)
CALL DOUT(KK, 40, GSO, J, JJ)
CALL DOUT(KK, 41, GAG, J, JJ)
CALL DOUT(KK, 42, DIFF, J, JJ)
C COMPUTE OBJECTIVE FUNCTION
535 ORJ=0.015*ORH
   IF (ITX, EQ, 0, AND, IPRT, GT, 0) GO TO 196
   GO TO 196
196 CALL PRNT(K, J, JJ)
197 CONTINUE
290 CONTINUE
   IY=1
   IF (IPRT) 197, 197, 195
195 CALL PRNT(K, J, JJ)
197 RETURN
C ** SUBROUTINE TO CALCULATE DAILY ET BY MODIFIED BLANEY-CRIDDLE **
SUBROUTINE EPOT(T, MDAY, PDL, CKC, PET, ETP, ETPH, TM, J, PKC, JJ, PHET)
DIMENSION MDAY(12), PDL(12), CKC(12), PET(12), ETP(12), ETPH(12), PKC(12), JJ(12)
C PDL, CKC ARE MONTHLY VALUES
T=0
C COMPUTE POTENTIAL EVAPTRANSPIRATION
   EKT=0.017*TT-0.314
   IF (EKT, LT, 0.3) EKT=0.3
   XJJ=JJ
   FTF=EKT*T*PDL(J)/XJJ
   PET=CKC(J)*ETF
   ETP=PET
   PHET=PKC(J)*ETF
   ETPH=PHET
   RETURN
END
SUBROUTINE FOR K*CU
SUBROUTINE HREM1(WAD,DIV,CF,CU,RF)
IF(DIV.GT.WAD) DIV=WAD
CF=DIV/CF
RETURN
END

SUBROUTINE GROUT(Q02,Q01,K,G)
IF(K.LE.12) GO TO 2
Q02=0.01+(Q01-0.01)*EXP(-1.,/K)
GO TO 2
1 Q02=Q01
2 RETURN
END

SUBROUTINE HSP ****
SUBROUTINE HSP(D,J,K,I)
COMMON/BLK3/ NO(12,31,11)
RETURN
END

SUBROUTINE OUT *****
SUBROUTINE OUT(L,K,LX,J,JJ)
COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBJ,HBJ,ISBN(5),IH,CSV,
WHR,KG,INTA,SMAP,PR(45),NPR,DPL(12),CKC(12),CKPC(16,12),
ZNGB,HGB(19),OUTD(48,32),LABL(49),IRES,HMDAY,VM0,
SITX,MAY(31),VAD(12),TM(31)
COMMON/BLK2/AGW(732),DP,RES(14),XMN,XMM,IGN,SMAP,SMAP,PET,
1P4V,AP4,HSP,CNL,MANG,TOLAF,CONV,CONVI,OUT(48,13),SMLV(12),
3CONV,CONV,MS(12),INO,IGNP,PKCMI(12),1DTM(12),REL
OUTD(L,K)=XD
XHS=NXO
XJ=JJ
1 IF(L .EQ. 1,1,2)
2 CONTINUE
3 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD
4 CONTINUE
5 OUTD(L,JJ+1)=XD
6 OUTD(L,JJ+1)=XD
7 CONTINUE
8 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
9 RETURN
10 CONTINUE
11 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
12 CONTINUE
13 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
14 CONTINUE
15 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
16 CONTINUE
17 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
18 CONTINUE
19 OUTD(L,JJ+1)=OUTD(L,JJ+1)+XD/XJ
20 RETURN

SUBROUTINE PRNT ****
SUBROUTINE PRNT(K,J,JJ)
REAL LABL,MC,MES,K5,MS,MCS
COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBJ,OBJH,ISAH,ISBN(5),IH,CSV,
WHR,KG,INTA,SMAP,PR(45),NPR,ADP(12),CKC(12),CPK(12),CPKC(16,12),
ZNGB,HGB(19),OUTD(48,32),LABL(49),IRES,HMDAY,VM0,
SITX,HMDAY(31),VAD(12),TM(31)
RETURN
END

SUBROUTINE FOR WRITING OUT DATA ***PRNT***
SUBROUTINE PRNT(K,J,JJ)
REAL LABL,MC,MES,K5,MS,MCS
COMMON/BLK1/CONV,CNV,CONPV,SPAC,SCAC,OBJ,OBJH,ISAH,ISBN(5),IH,CSV,
WHR,KG,INTA,SMAP,PR(45),NPR,ADP(12),CKC(12),CPK(12),CPKC(16,12),
ZNGB,HGB(19),OUTD(48,32),LABL(49),IRES,HMDAY,VM0,
SITX,HMDAY(31),VAD(12),TM(31)
COMMON /BLK2/AGW(732),DP,RES(14),KMN,KHX,JMN,JHX,SMAX,SMIN,PET,
19A,ARD,RES,CL,ABG,TOLAF,CONV,CONV1,OUT(48,13),SMLV(12),
3CONUR,CONMN,EMS(12),IONN,IONS,PKER(12),IDTM(12),REL
COMMON /BLK3/ HD(12,31,1)
IPRTF=1
NT=1
NTT#42
NT1=7
NT2=8
NT4=#8

C WRITE PRINT DAILY VALUES
C ITX=1 PRINT MONTHLY VALUES
1 IF (IPRTF.EQ.1) WRITE(6,100) (BASID(I),I=1,5),J
100 FORMAT(1H1/20X,5A4,1WX,15)
101 FORMAT(6X,A4,7(6X,A4))
TF(ITX) 200,250,201
201 IF (IPRTF.EQ.2)2,2,4
2 WRITE(6,301)
GO TO 5
4 WRITE(6,303)
5 L1=1
301 FORMAT(4X,5HWATER)
303 FORMAT(4X,9HRESERVOIR)
L2=6
L3=1
L4=7
DO 12 LL=1,2
WRITE(6,101)(HDG(I),I=L3,L4)
12 IF (LL).EQ.1 NT1=4
11 WRITE(6,102)LABL(I),(OUT(I,L),L=L1,L2)
102 FORMAT(6X,A4,7(F10,1))
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(6,550)
550 FORMAT(1H1)
12 CONTINUE
501 CONTINUE
99 IF (RES.LE.0) GOTO 81
C SET UP TO OUTPUT RESERVOIR
IF (NT.GE.2)GOTO 81
IPRTF=3
NT=47
NTT#42
NT1=43
NT2=44
NT3=59
GOTO 1
81 IF (J.NE.NMO) GOTO 85
IF (IREF.LE.9) GOTO 84
C WRITE RESERVOIR EXTREMES
IMN=1
SUBROUTINE RESV (K, IOP, ETF, IPRT, J, J')
REAL LABL, MIC, MES, KS, MS, MC5
COMMON /BLK1/ CONV, CNV, CDKPV, SPAC, SCAC, OBH, OBJ, OAH, OASID(5), I8, CSV,
IHA, KG, IDTA, SHAV, PR(45), HPR, PDL(12), DKC (12), PKC (12), CPKC (16, 12),
2N58, HOC (15), OUT(48, 32), LABL (48), IRES, HMDAY, HMD,
3ITX, HDAY (31), VAD (12), TM (31)
COMMON /BLK2/ AGW (732), DP, PES (14), KMN, KMX, JMN, JMX, SMAX, SMIN, PET,
1RAV, ARD, RSF, CPL, MANG, TOLAF, CONV, CONV1, OUT (48, 13), SMLV (12),
3CONUR, CONHI, CPS (12), IGGC, IQSPR, PKCM1 (12), IDTM (12), REL
COMMON /BLK3/ HD (12, 31, 1)
J=0, KE DAY, ETF MOD BC TEMP FACTOR
RAV=RES WATER AVAL. FOR CANAL DIV.
ARD=ACTUAL CANAL RELEASE (WATER)
RSF=TOTAL RELEASES (WATER)
IF (IOP=2) J=30
10 JK=JK
IF (JK .NE. 2) GOTO 13
C INITIALIZE FIRST DAY, FIRST MONTH
STI=RES (1)
CSTI=PES (2)
SMAX=STI
SMIN=STI
JMN=TYRF=1
JMY=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
ARD=0, C
EVP=CPKC (16, K) * ETF
DSEF=PPT-EVP
CALL AREA (STI, AI, RES)
C OPERATE RESERVOIR
30 CALL HSP (REL, J, K, 12)
EXSR=0, C
RSR=REL+ARD
STI=STI+DST
CALL AREA(ST,AE,RES)
AV=(AI+AE)/2.0
DST=RIN-RSR*DSSEP*AV/12.0
ST=ST+DST
IF(1OP,AE,1)GOTO 32
C COMPUTE WATER AVAILABLE FOR IRRIGATION
PAV=ST-RES(3)
IF(PAV.LE.0.0)RAV=0.0
RETURN
C CHECK EGM STORAGE AGAINST MAX AND MIN
32 IF(ST.GT.RES(4))GOTO 33
33 EXRS=ST-RES(4)
RSR=RSR+EXRS
ST=RES(4)
GOTO 40
34 STC=ST+RSR-RES(3)
IF(STC.GT.35,35,37)
35 ST=ST+RSR
RSR=0.0
APO=0.0
IF(ST.LT.0.7)ST=0.0
GOTO 40
37 RSR=STC
ST=RES(3)
RSR=RSR-REL
IF(RSR).LT.0.0,40,40
38 IF(ARD.GT.61,61,59)
59 IF(ARD=RSRY).LT.40,40,62
62 NAND=ARD
ARD=RSRY
CNL=CHL*APD+APD
GOTO 40
60 ARD=0.0
C INITIALIZE NEXT DAYS STORAGE
40 NST=ST-STI
STI=IST
C SET UP OUT IF IPRT GT 0
41 CALL DOUT(K,43,EVP)
CALL DOUT(K,44,NS)
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
JNX=IVRB+J-1
KMY=K
GOTO 52
51 EMN=SMIN-ST
IF(EMN.LE.0.0)GOTO 52
SMIN=ST
JMN=IVRB+J-1
KHN=K
52 RETURN
END
SUBROUTINE AREA(S,A,RES)
DIMENSION RES(14)
IF (S.LT.0) GO TO 10
IF (S.LT.RES(N)) GO TO 1
C4*RES(11)
A=RES(9)*RES(14)*S**C4
GO TO 10
1 C2*RES(7)
A=RES(5)*RES(5)*S**C2
GO TO 12
10 A=RES(5)
12 RETURN
END