Characterization of Rainfall-Runoff Response and Estimation of the Effect of Wetland Restoration on Runoff, Heron Lake Basin, Southeastern Minnesota, 1991-97

WRI 00–4095

Prepared in cooperation with the Minnesota Department of Natural Resouces and Heron Lake Watershed District

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Water-Resources Investigations Report 00–4095

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Perry M. Jones and Thomas A. Winterstein

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U.S. Department of the Interior
Bruce Babbitt, Secretary

U.S. Geological Survey
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Conversion Factors, Abbreviations, and Sea Level Datum

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch per hour (in./hr)	0.0254	meter per hour
inch per day (in./day)	25.4	millimeter per day
degrees Fahrenheit	°C = (°F – 32) / 1.8	degrees Celsius

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Water year: The water year is October 1 through September 30 and is named for the calendar year in which it ends.

Characterization of Rainfall-Runoff Response and Estimation of the Effect of Wetland Restoration on Runoff, Heron Lake Basin, Southwestern Minnesota, 1991–97

By Perry M. Jones and Thomas A. Winterstein

ABSTRACT

The U.S. Geological Survey (USGS), in cooperation with the Minnesota Department of Natural Resources and the Heron Lake Watershed District, conducted a study to characterize the rainfall-runoff response and to examine the effects of wetland restoration on the rainfall-runoff response within the Heron Lake Basin in southwestern Minnesota. About 93 percent of the land cover in the Heron Lake Basin consists of agricultural lands, consisting almost entirely of row crops, with less than one percent consisting of wetlands. The Hydrological Simulation Program – Fortran (HSPF), Version 10, was calibrated to continuous discharge data and used to characterize rainfall-runoff responses in the Heron Lake Basin between May 1991 and August 1997. Simulation of the Heron Lake Basin was done as a two-step process: (1) simulations of five small subbasins using data from August 1995 through August 1997, and (2) simulations of the two large basins, Jack and Okabena Creek Basins, using data from May 1991 through September 1996. Simulations of the five small subbasins was done to determine basin parameters for the land segments and assess rainfall-runoff response variability in the basin. Simulations of the two larger basins were done to verify the basin parameters and assess rainfall-runoff responses over a larger area and for a longer time period. Best-fit calibrations of the five subbasin simulations indicate that the rainfall-runoff response is uniform throughout the Heron Lake Basin, and 48 percent of the total rainfall for storms becomes direct (surface and interflow) runoff. Rainfall-runoff response variations result from variations in the distribution, intensity, timing, and duration of rainfall; soil moisture; evapotranspiration rates; and the presence of lakes in the basin. In the spring, the amount and distribution of rainfall tends to govern the runoff response. High evapotranspiration rates in the summer result in a depletion of moisture from the soils, substantially affecting the rainfall-runoff relation. Five wetland restoration simulations were run for each of five subbasins using data from August 1995 through August 1997, and for the two larger basins, Jack and Okabena Creek Basins, using data from May 1991 through September 1996. Results from linear regression analysis of total simulated direct runoff and total rainfall data for simulated storms in the wetland-restoration simulations indicate that the portion of total rainfall that becomes runoff will be reduced by 46 percent if 45 percent of current cropland is converted to wetland. The addition of wetlands reduced peak runoff in most of the simulations, but the reduction varied with antecedent soil moisture, the magnitude of the peak flow, and the presence of current wetlands and lakes. Reductions in the simulated total and peak runoff from the Jack Creek Basin for most of the simulated storms were greatest when additional wetlands were simulated in the North Branch Jack Creek or the Upper Jack Creek Subbasins. In the Okabena Creek Basin, reductions in simulated peak runoff for most of the storms were greatest when additional wetlands were simulated in the Lower Okabena Creek Subbasin.

INTRODUCTION

Flooding of agricultural lands and roadways within the Heron Lake Basin (fig. 1) is a serious economic and environmental problem (McCombs-Knutson Associates, Inc., 1982). Seasonal flooding can occur during and following snowmelt and late spring rains after soils have been partially saturated. The late spring lake-level rises of Heron Lake can range from about 4 to 6 ft, resulting in damage to crops and roadway structures. Storm flooding can cause a lake-level rise of about 3 ft within about 48 hours (J. Solstad, Minnesota Department of Natural Resources, oral commun., 1994). Flooding not only damages agricultural production and roadway structures, but also results in a number of problems associated with sediment transport. Stream bank erosion and associated sediment discharge into Heron Lake following storms can result in increased siltation in the lake and adjacent lowlands. Runoff from agricultural lands

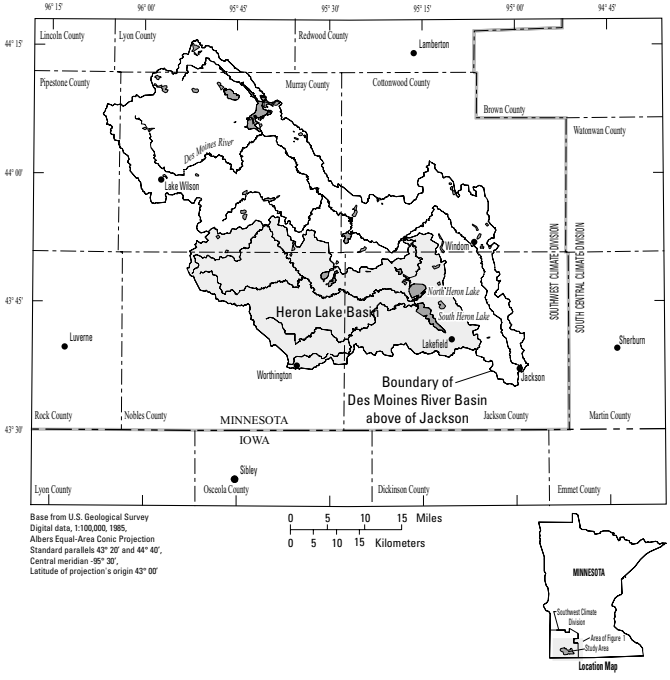


Figure 1. Des Moines River Basin above Jackson, Minnesota and the Heron Lake Basin.

also may carry pesticides and nutrients in both dissolved and particulate forms.

Concern about flooding at Heron Lake began at about the turn of the century (McCombs-Knutson Associates, Inc., 1982), but flooding problems have increased during the past 50 years (J. Solstad, Minnesota Department of Natural Resources, oral commun., 1994). Lake levels were low during the 1930's, when discharge from the lake periodically ceased (U.S. Geological Survey, 1959, p. 523). High lake levels have been recorded from the 1970's (McCombs-Knutson Associates, Inc., 1982) to the present (J. Solstad, Minnesota Department of Natural Resources, oral commun., 1994).

Increased flooding in the Heron Lake Basin could be the result of increased precipitation or changes in the rainfall-runoff response of the basin. Precipitation in the southwest part of Minnesota has increased over the past 50 years. This increase can be seen from the composite precipitation record for the Southwest Climatic Division of Minnesota (fig. 2). The average 10-year precipitation has increased from 25.8 in. for 1941–50 to 27.5 in. for 1988–97.

The response of a river to rainfall is a characteristic of the river basin. Basins with different land uses, topog-

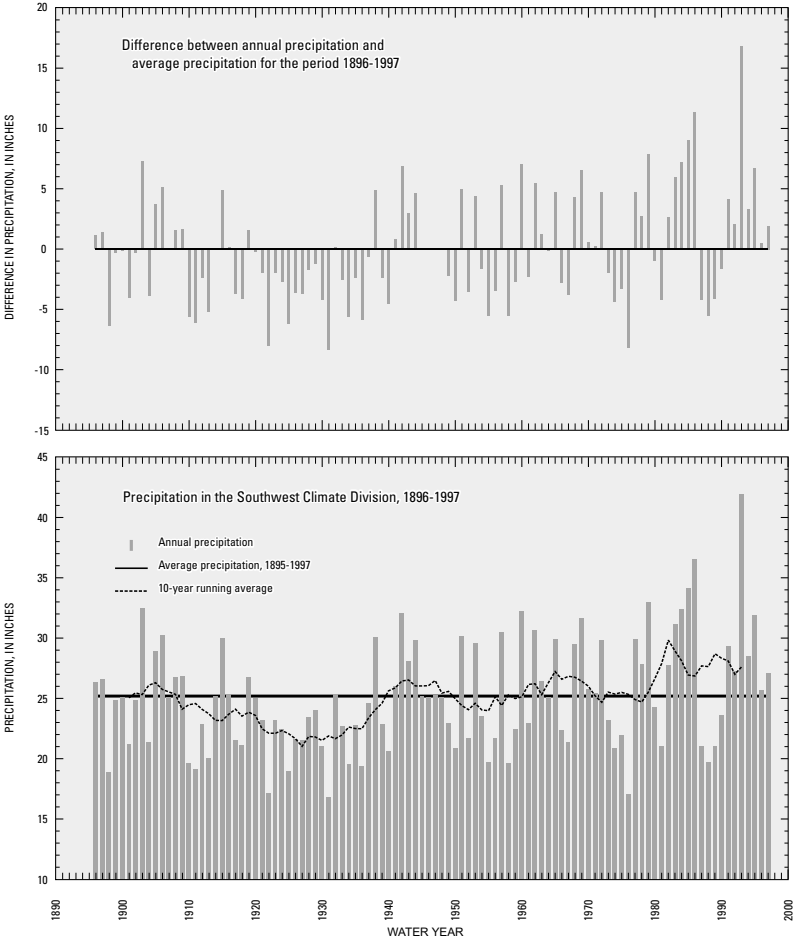


Figure 2. Precipitation in the Southwest Climate Division of Minnesota, 1896-1997 water years (Midwest Climate Center, 1998).

raphy, and soil types respond differently to rainfall. For example, basins composed of steep-sided valleys and little storage may be prone to flash floods while adjoining basins, composed of rolling terrain with many lakes and wetlands, may rarely flood. Changes to basin features that affect the rainfall-runoff response can alter the type, frequency, and severity of floods. The rainfall-runoff response can be altered by changes in land use, in basin storage, and to the river system within the basin. Land-use changes in agricultural regions include changes in crop types, drainage and irrigation practices, and tillage practices. Decreases in basin storage occur in agricultural areas when wetlands are drained to increase cropland. Changes in the storage of a river system may result through changes in channelization or damming.

Farming practices in the Heron Lake Basin have changed over the past 50 years (R. Goedtke, Middle Des Moines Watershed District, oral commun., 1994). Formerly, farms were smaller, with untilled land used for raising livestock (Van der Valk, 1989, p. 159–160). Untilled land in low-lying areas created effective storage volume for runoff and provided vegetated buffer zones alongside streams. Present farms are larger and produce row crops, mostly corn and soybeans with less untilled land. With increased row cropping and associated drain tiles, grasslands and wetlands are converted to croplands, potentially decreasing water storage and evapotranspiration and increasing runoff to waterways. Drainage and conversion of wetlands to tillable agricultural lands started in the United States at the turn of the century and was common prior to 1985, when provisions of the Food Security Act were enacted to discourage this practice (Mitsch and Gosselink, 1993, p. 545–549; National Research Council, 1995, p. 56). Ditches and tiles that drain former wetlands collect overland runoff and transport it quickly to rivers, perhaps causing an unnaturally large and rapid rise in the water level of Heron Lake.

Wetland restoration could possibly reduce flooding in the Heron Lake Basin. Wetland restoration is an increasingly popular method for improving water quality and reducing flooding in basins. Implementation of Federal and State legislation in the 1980's that established the Conservation Reserve Program (CRP) and Reinvest in Minnesota (RIM) program resulted in the restoration of many wetlands throughout southwestern Minnesota (Galatowitsch and Van der Valk, 1994).

Wetlands can reduce downgradient flood volumes and peaks in two ways (Carter and others, 1978). First, wetlands reduce the volume of water released to base flow and total annual runoff, because some water is lost to evaporation from wetland surfaces. These evaporative losses lower water levels, creating storage volume in the basin. Second, wetlands can reduce flood peaks by delaying the release of water to ditches and streams after snowmelt or rainfall. Pothole wetlands can store water temporarily. Some water may be diverted into temporary bank storage around the wetland and released slowly as the water level drops. Other water may enter the ground-water flow system and move to a distant point of discharge. Riparian wetlands can also help reduce storm-water peaks by providing overbank storage and reducing channel conveyance.

Purpose and Scope

As a result of flooding concerns in the Heron Lake Basin, the USGS began a cooperative study with the Minnesota Department of Natural Resources and Heron Lake Watershed District in 1994. The main objective of this study was to characterize the rainfall-runoff response and examine the effects of wetland restoration on the rainfall-runoff response of the Heron Lake Basin, southwestern Minnesota. The purpose of this report is to present results from analyses of the rainfall-runoff responses in the Heron Lake Basin and the Des Moines River Basin, a large, agricultural basin that includes the Heron Lake Basin (fig. 1), and from the analysis of the effects of wetland restoration on rainfall-runoff response within the Heron Lake Basin.

Methods

The rainfall-runoff response was characterized using a two-step analytical approach: (1) an analysis of the historical rainfall-runoff response in the Des Moines River Basin, and (2) a calibrated, rainfall-runoff model using the model Hydrological Simulation Program – Fortran (HSPF) Version 10 (Bicknell and others, 1993), and continuous discharge data collected between May 1991 and August 1997. The calibrated, rainfall-runoff model was used to examine the effects of wetland restoration on rainfall-runoff response within the Heron Lake Basin.

Analysis of the historical rainfall-runoff response of the Des Moines River Basin above Jackson, Minnesota, was done using rainfall and runoff records from 1936–97. Rainfall-runoff response in the Des Moines River Basin was analyzed because insufficient hydrologic data were available to characterize the historical rainfall-runoff response of the Heron Lake Basin.

HSPF was simulated for the Heron Lake Basin in two steps: (1) model simulations of five subbasins within the basin were calibrated using continuous stream-discharge data from August 1995 through August 1997; and (2) model simulations for two larger basins, Jack Creek and Okabena Creek, were calibrated for May 1991 through August 1996. Simulations of the five small subbasins were done to determine basin parameters for the land segments and assess rainfall-runoff response variability in the basin. Simulations of the two larger basins were done to verify the basin parameters and assess rainfall-runoff responses over a larger area and for a longer time period. Both spatial and temporal verification are consid-

ered a rather stringent test of the calibrated model.

The calibrated HSPF model was used to simulate the effects of restored wetlands and the location of restored wetlands on the rainfall-runoff response of the basin. The wetland-restoration scenarios were developed in collaboration with the Minnesota Department of Natural Resources and the Heron Lake Watershed District.

Description of the Heron Lake Basin

The Heron Lake Basin is in Jackson, Nobles, Cottonwood, and Murray Counties in southwestern Minnesota (fig. 1). It covers 476 mi^2 and is part of the upper Des Moines River Basin, hydrologic unit 07100001 (U.S. Geological Survey, 1974). The climate of the Heron Lake Basin is continental: cold winters and hot summers. The normal mean annual temperature (1961–90) at Windom, Minnesota is 44.2 °F, and the normal annual precipitation is 27.96 in. (Minnesota State Climatologist, 1998b). January is the coldest and driest month and July is the warmest and wettest month at Windom. Normal January temperature is 11.4 °F, normal July temperature is 72.9 °F, normal January precipitation is 0.61 in., and normal July precipitation is 4.08 in. at Windom. In the past, Heron Lake had a reputation for waterfowl production and hunting (Choate and Huber, 1970).

The Heron Lake Basin is located on the Coteau Des Prairies, a flatiron-shaped upland that separates lowlands formerly occupied by the Des Moines and James Lobes of the late Wisconsin Laurentide Ice Sheet (Patterson, 1997, p. 1 and 9). The basin lies in a region of the Bemis Moraine of the Des Moines Lobe (Patterson, 1997, p. 11). The topography of the basin ranges from flat near Heron Lake to rolling at the eastern and western edges of the basin. The land-surface elevation ranges from about 1,450 ft above sea level near Heron Lake to about 1,750 ft at the western edge of the basin.

The Agricultural Experiment Station of the University of Minnesota mapped four geomorphic areas in the Heron Lake Basin (fig. 3). The geomorphic areas illustrate physiographic features and identify the nature of present materials in which the soils have developed (Harms and others, 1981, p. 4). These areas are the (1) Lake-Benton-Adrian Coteau, undulating, loamy; (2) Ivanhoe-Worthington Coteau, gently sloping, loamy; (3) Blue Earth Till Plain, undulating, loamy; and (4) Blue Earth Till Plain, clayey. A late Wisconsin glacial lake occupied about the same area as the Blue Earth Till Plain, clayey geomorphic area shown in figure 3 (Harms and others, 1981; Patterson, 1997).

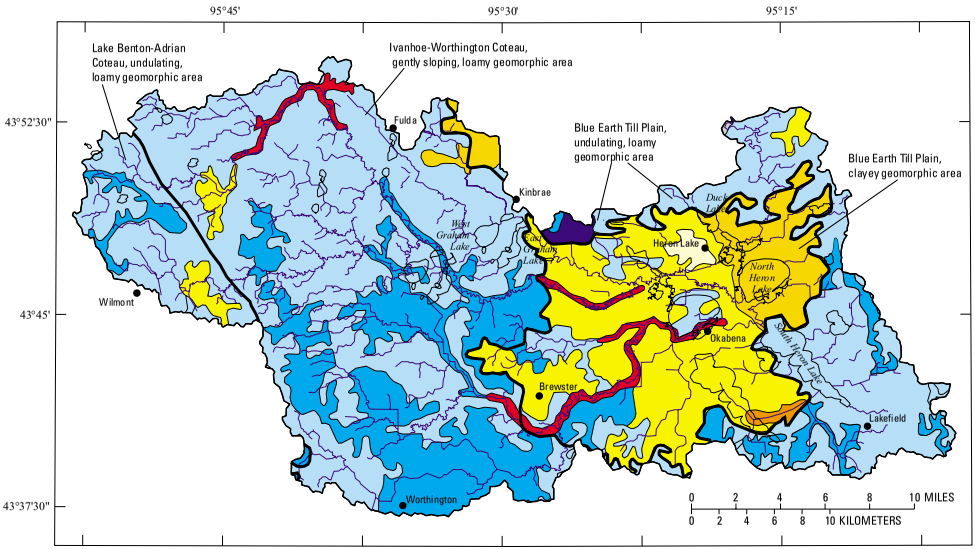
The Lake Benton-Adrian Coteau geomorphic area consists of loess-mantled ground moraine. The relief is marked predominantly by long, irregular slopes. The loess has filled in irregularities of the glacial till plain. The Ivanhoe-Worthington Coteau, gently sloping, loamy geomorphic area consists of a series of terminal and end moraines with ground moraines separating them. The topography ranges from gently undulating to steeply rolling and hilly. The Blue Earth Till Plain, undulating, loamy geomorphic area consists of a gently undulating to rolling till plain. Nearly level to depressional, poorly-drained topography is common throughout the loamy area. The Blue Earth Till Plain, clayey geomorphic area consists of clay-mantled till plain. The dominant landform is one of a nearly level to depressional till plain.

Within geomorphic areas, soils were grouped into soil landscape units developed from detailed soil surveys or field work by the Agricultural Experiment Station (fig. 3) (Harms and others, 1981, p. 4). The soils were grouped into units based upon the texture of the soil material in the top 5 ft, the texture of the soil material below 5 ft, drainage, and color. Most of the Heron Lake Basin falls into three soil landscape units: (1) well-drained, loamy soil over loamy material (54.5 percent); (2) poorly drained, loamy soil over loamy material (19.7 percent); and (3) poorly drained, clayey soil over loamy material (16.7 percent). Well-drained, loamy soil over loamy material is present mostly in the uplands. Poorly drained, loamy soil over loamy materials is present mostly in the lowlands of the western Coteau region; whereas, poorly drained clayey soil is present over most of the Blue Earth Till Plain Area of the basin. Once drained, all of the soils are well suited for agriculture.

Two lake systems, the Heron Lake System and the Graham Lake System, lie within the Heron Lake Basin. The Heron Lake System consists of three connected lakes, North Heron Lake, South Heron Lake, and Duck Lake; and a marsh, North Marsh, which lie in the eastern portion of the basin (fig. 4). The area of the Heron Lake System is about 12.9 mi^2, which is uncommonly large for southwestern Minnesota.

Water flow through the Heron Lake System generally is to the northeast towards the Des Moines River. Water from South Heron Lake drains into North Heron Lake through Division Creek during most of the year. However, during dry periods, this flow can be reversed. Water from North Heron Lake and from Duck Lake drains into North Marsh. Outflow from North Marsh is through the Heron Lake Outlet Channel to the Des Moines River. A Minnesota Department of Natural Resources dam at the outlet of the marsh controls water levels in North Marsh during periods of low flow. During low-flow conditions, the channel between Duck Lake and North Marsh frequently dries up (McCombs-Knutson Associates, Inc., 1982, p. 17).

The Graham Lake System lies in the north-central portion of the basin and consists of three connected lakes: West Graham Lake, East Graham Lake, and Jack Lake. The area of the Graham



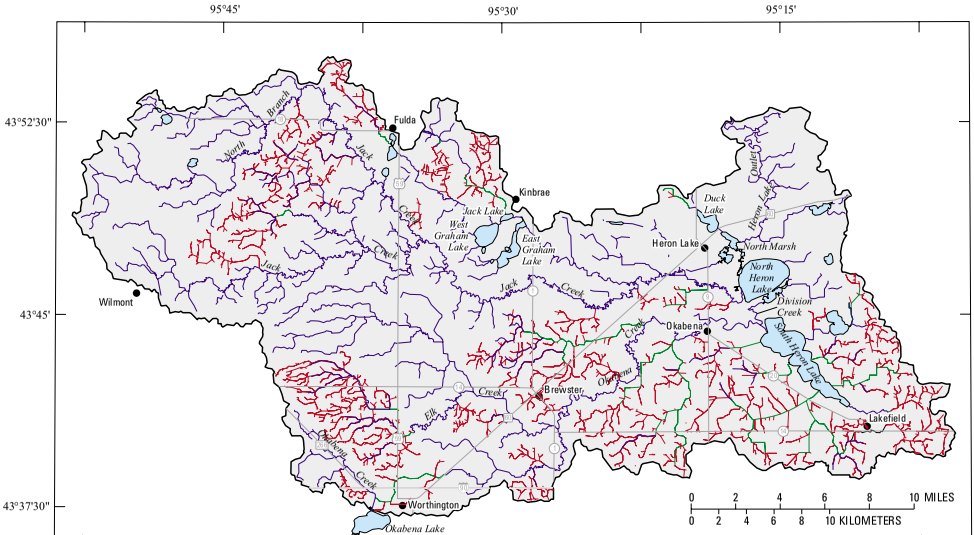
Base digitized from U.S. Geological Survey 1:24,000 maps, various dates.
Albers Equal-Area Conic Projection, standard parallels 43°30' and 44°40',
Central meridian -95°30', latitude of projection's origin 43°.

Soil landscape units and
Geomorphic data modified
from Harms and others, 1981

EXPLANATION

- Dark colored, well-drained sandy soil over sandy material, 108 acres (0.0%)
- Dark colored, well-drained loamy soil over loamy material, 165,900 acres (54.5%)
- Dark colored, poorly-drained loamy soil over loamy material, 59,900 acres (19.7%)
- Dark colored, poorly-drained loamy soil over sandy material, 1,250 acres (0.4%)
- Dark colored, well-drained clayey soil over loamy material, 1,460 acres (0.5%)
- Dark colored, poorly-drained clayey soil over loamy material, 51,000 acres (16.7%)
- Dark colored, poorly-drained clayey soil over clayey material, 17,200 acres (5.7%)
- Peat over loamy material, 1,020 acres (0.3%)
- Alluvial soils, 6,760 acres (2.2%)
- Boundary of geomorphic area
- Boundary of study area

Figure 3. Soil landscape units and geomorphic areas in the Heron Lake Basin, Minnesota.



Base digitized from U.S. Geological Survey 1:24,000 maps, various dates. Albers Equal-Area Conic Projection, standard parallels 43°20' and 44°40', Central meridian -95°30', latitude of projection's origin 43°

Data for public ditches and tiles from Water Resources Center, Mankato State University. (C. Berg, Water Resources Center, written commun., 1995)

EXPLANATION

- Heron Lake Basin
- Boundary of study area
- Streams
- Public ditches
- Public tiles

Figure 4. Hydrography in the Heron Lake Basin, Minnesota.

Lake System is 1.7 mi^2. Tributaries northwest of the Graham Lake System feed into West Graham Lake and Jack Lake on their north shores. Discharge from both of these lakes flows eastward into East Graham Lake. Discharge from the lake system occurs through an outlet at the northeast end of East Graham Lake.

Two Creeks, Jack Creek and Okabena Creek, flow through the basin and discharge to Heron Lake. Jack Creek flows through the northern portion of the Heron Lake Basin and discharges into North Heron Lake. Discharge from the East Graham Lake Outlet flows into Jack Creek west of the town of Heron Lake. The Jack Creek basin is 205 mi^2 in area.

Okabena Creek flows through the southern portion of the basin, discharging into Division Creek. The flow in the upper reach of Okabena Creek normally is diverted out of the Heron Lake Basin into the Little Sioux River Basin through Okabena Lake in Worthington (fig. 4). However, during periods of high flow, the flow in Okabena Creek is split between the Little Sioux River Basin and the Heron Lake Basin. Records are not kept of the amount of water discharged into the Heron Lake Basin from the diversion (Duane Hatfield, City of Worthington, oral commun., 1997). The Okabena Creek Basin is 147 mi^2 in area including the diverted, upper portion of the basin, and 138 mi^2 in area excluding the diverted part of the basin.

About 93 percent of the land use in the Heron Lake Basin is agricultural, consisting almost entirely of row crops (Minnesota Land Management Information Center, 1998). In 1996, approximately 52 percent of the crop acreage in the basin was corn and about 45 percent was soybeans (Minnesota Agricultural Statistics Service, 1997). The rest of the basin consists of grasslands; deciduous forests; wetlands; the small communities of Heron Lake, Brewster, Okabena, and Kinbrae; portions of the city of Worthington; and small farmsteads. Presently, less than one percent of the basin consists of wetlands. Jackson and Nobles Counties, which include most of the Heron Lake Basin, have less than 1 percent of the wetlands that were present at the time of settlement by European-Americans. Wetlands have been reduced in the two counties from greater than 284,000 acres in the late 1800's to presently about 2,000 acres (Anderson and Craig, 1984).

Public ditches and drain tiles are extensive and distributed throughout the Heron Lake Basin (fig. 4). The Heron Lake Watershed District issues permits for the installation of new agricultural drain tiles. The amount of new tile permitted by the Watershed District from February 1971 to October 1996 (J. Voit, Heron Lake Watershed District, written commun., 1996) was tabulated by public-land-survey section (1 mi^2 in area). The results are shown in figure 5. The highest amount of permitted new tile in a section was 28.6 miles. As in much of the agricultural lands of north-central United States, drainage of wetlands for agricultural purposes has increased substantially over the past 50 years (Mitsch and Gosselink, 1993, p. 545–549).

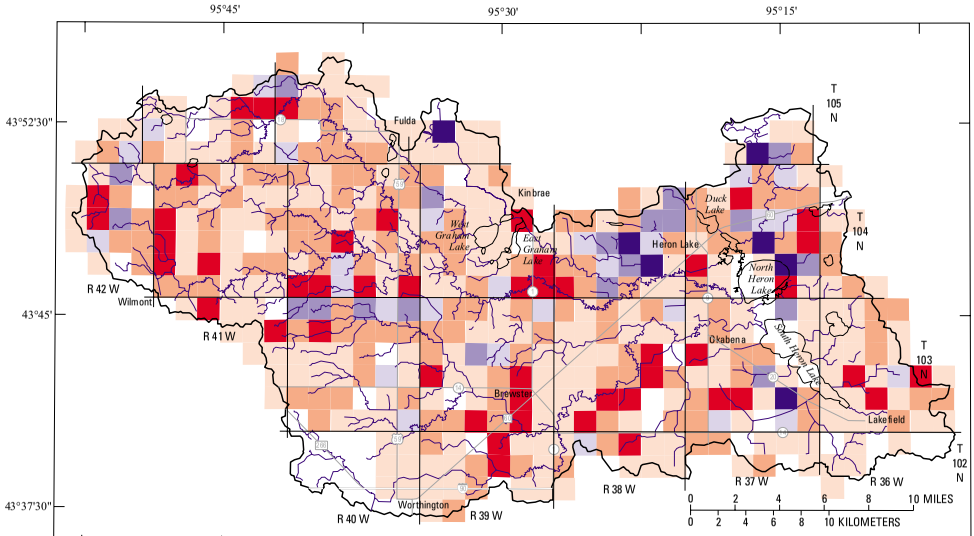
Acknowledgments

The authors gratefully thank the Heron Lake Watershed District for providing assistance needed to complete this project. The District maintained stream gages on North Branch Jack Creek, Jack Creek near Kinbrae, East Graham Lake Outlet, Okabena Creek near Brewster, and Elk Creek near Brewster, and maintained the weather station near Wilmont. Mr. Lee Carlson and Ms. Jan Voit of the Heron Lake Watershed District provided much assistance during the course of this project. The authors thank Mr. Dave Einck and Mr. Wayne Fenske for giving permission to install weather stations on their farms. Mr. Einck also constructed the platform for the weather station on his farm. The authors thank Ms. Barbara Westgore for allowing the installation of a precipitation gage at Creekside Farm. The authors thank the North Heron Lake Game Producers Association and Mr. Greg Spoden, Mr. James Solstad, and Mr. James Sehl of the Minnesota Department of Natural Resources for their assistance during the project. The authors thank Mr. James E. Almendinger, formerly of the U.S. Geological Survey, for his work in the initial development and implementation of the project. The authors thank Mr. Charles S. Melching of Marquette University for his technical assistance in the development and calibration of model simulations and for his technical review of this report. The authors thank Mr. Gregory A. Payne of the U.S. Geological Survey for his technical review of this report and Mr. Robert Borgstede and Ms. Ginger Amos of the U.S. Geological Survey for their assistance in the development of the report.

RAINFALL-RUNOFF RESPONSE IN THE DES MOINES RIVER BASIN

The relation between precipitation and runoff in the Des Moines River Basin above Jackson, Minnesota, was examined using monthly and annual values of precipitation and runoff. The purpose of this examination was to provide insight into the historical rainfall-runoff relation for the Heron Lake Basin and to provide a framework for the discussion of the model simulation of recent rainfall-runoff responses in the Heron Lake Basin. The Des Moines River Basin was selected for historical rainfall-runoff examination instead of the Heron Lake Basin because of the lack of historical runoff data in the Heron Lake Basin. The Des Moines River at Jackson, Minnesota, has a 62-year, runoff record (1936–97). Also, the Des Moines River Basin includes the Heron Lake Basin, which composes about 39 percent of the Des Moines River Basin above Jackson, Minnesota.

In the annual and monthly analyses, precipitation and runoff data are com-



Base digitized from U.S. Geological Survey 1:24,000 maps, various dates.
Albers Equal-Area Conic Projection, standard parallels 43°20' and 44°40',
Central meridian -95°30', latitude of projection's origin 43°

Drain tile data modified from Heron Lake Watershed District (J. Voit, Heron Lake Watershed District, written commun., 1996).

EXPLANATION

- Less than 1.5 miles of tile (217 sections)
- 1.5 miles to 3.75 miles of tile (142 sections)
- 3.76 miles to 5 miles of tile (48 sections)
- 5.01 miles to 8.4 miles of tile (27 sections)
- 8.41 miles to 12 miles of tile (20 sections)
- Greater than 12 miles of tile (7 sections)
- No data
- Boundary of study area

Figure 5. Miles of permitted, new agricultural drain tile by public-land-survey sections in the Heron Lake Basin, Minnesota, February 1971 to October 1996.

piled on a water-year basis. The water year is from October 1 to September 30 and is named for the calendar year in which it ends. The water year is used rather than the calendar year because it begins and ends in a period of low precipitation. Therefore, precipitation from one water year has little effect on the runoff of the next year.

The precipitation record used in this analysis is the composite precipitation record for the Southwest Climate Division of Minnesota prepared by the National Weather Service (Midwest Climate Center, 1998). Precipitation in the Southwest Climate Division generally is lowest in January and greatest in June (fig. 6). The range in monthly precipitation also is greatest in June. Eighty percent of the June values for 1936–97 were between 2.0–6.5 in. The range in monthly precipitation values is low during the winter months. The average annual precipitation for the water years 1936–97 is 26.25 in., and the range of annual precipitation is 17.07–41.96 in.

Runoff in the Des Moines River Basin generally is least in February and greatest in April (fig. 6). The range in monthly runoff values was much less than for precipitation values, with the greatest range occurring in April (0.1–2.9 in.). The average annual runoff for the water years 1936–97 is 4.29 in., and the range of annual runoff is 0.17–23.34 in.

Potential evapotranspiration is the amount of water that could be returned to the atmosphere through evaporation and transpiration if moisture in the soil always was sufficient to supply all the water that could be evaporated and transpired in the basin. Because the soil dries out between rainstorms, actual evapotranspiration always is less than potential evapotranspiration. Median monthly potential evapotranspiration values calculated for the Southwest Climate Division of Minnesota using the Thornthwaite method (Sellinger, 1996) are shown in figure 7. Potential evapotranspiration is highest in the summer months, decreasing to near zero in the winter months (fig. 7).

The volume of runoff from the Des Moines River Basin is controlled by (1) precipitation and snowmelt during the early spring months; (2) precipitation, evapotranspiration, and soil moisture in the late spring and summer months; and (3) precipitation and soil moisture in the autumn months. Precipitation in the Des Moines River Basin normally is stored as snow and ice during the winter months. As a result, flow in the Des Moines River during the winter months is almost entirely from ground water. The stored precipitation is released in March and April during the spring runoff, producing the highest runoff amounts of the year (fig. 7). Evapotranspiration increases enough during summer so that, even though median precipitation increases from 3.29 in. in May to 4.19 in. in June, the median runoff for the Des Moines River decreases slightly from 0.42 to 0.41 in. (fig. 7). Finally, as precipitation decreases in late summer and autumn the runoff for the Des Moines River continues to decrease until it reaches its low in February of the following year.

Annual precipitation in the Southwest Climate Division of Minnesota and annual runoff in the Des Moines River Basin have increased since the mid-1960's and the mid-1970's as shown in figure 8. The 10-year average annual precipitation increased from 25.9 in. for 1936–45 to 27.5 in. for 1988–97. The 10-year average runoff increased from 3.4 in. to 7.4 in. for the same periods.

The precipitation and runoff data were smoothed using LOcally-WEighted Scatterplot Smoothing (LOWESS) (Helsel and Hirsch, 1992, p. 288–291) to determine trends in the data (fig. 8). A smoothing factor, f, of 0.5 gave the most informative trend lines. The LOWESS lines show overall increases in precipitation and runoff for 1947 through 1987.

The LOWESS lines are not shown for the entire period of record because the LOWESS lines are biased by large and small events near the ends of the record. To test the bias the authors constructed extended precipitation and runoff data sets. The period of record was extended by adding data that were selected from a random distribution with the same mean and variance as the data set. LOWESS lines were fitted to the extended data record. The results indicate that a LOWESS line fitted to the period of record probably is incorrect for 1936–46 and 1988–97 because of large and small event biases.

A level trend line for annual precipitation and an increasing trend line for annual runoff would indicate that changes in the basin's hydrologic characteristics are causing the increased annual runoff. Because there is an increasing trend line for annual precipitation, the increased annual runoff could solely result from the increased precipitation or could result from a combination of increased precipitation and changes in basin characteristics. A double-mass analysis (Searcy and Hardison, 1960) was done to see if the rainfall-runoff relation between annual precipitation and runoff had changed during 1936–97. The first step in the double-mass analysis is to develop an equation for estimating runoff from precipitation. A linear regression model was used to estimate annual runoff from precipitation using the annual runoff and precipitation data from 1936–97. The equation of the model is given in figure 9. The annual precipitation and estimated annual runoff were cumulated and plotted (fig. 9). Because the resulting curve is linear, the rainfall-runoff relation did not change. The increase in annual runoff is directly related to the increase in annual precipitation and is not related to changes in basin characteristics.

The relation between annual precipitation and runoff in the Des Moines River Basin is shown in figure 10. In general, annual runoff increases as annual precipitation increases; however, great variance is present in the

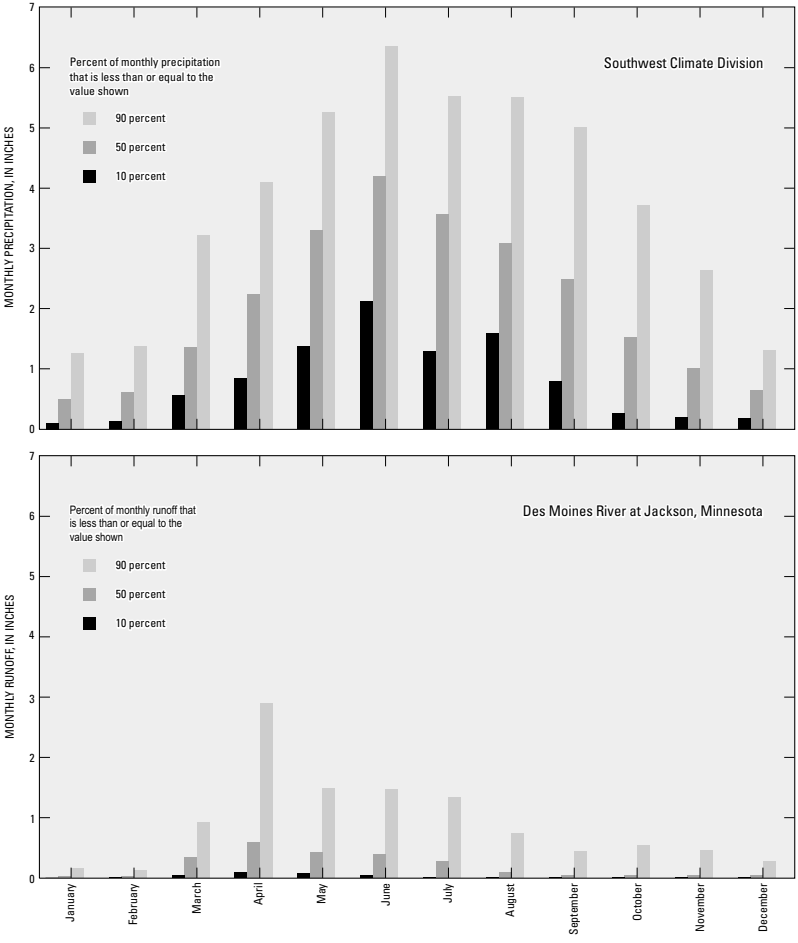


Figure 6. Monthly precipitation for the Southwest Climate Division of Minnesota and monthly runoff for the Des Moines River at Jackson, Minnesota, 1936-97 water years.

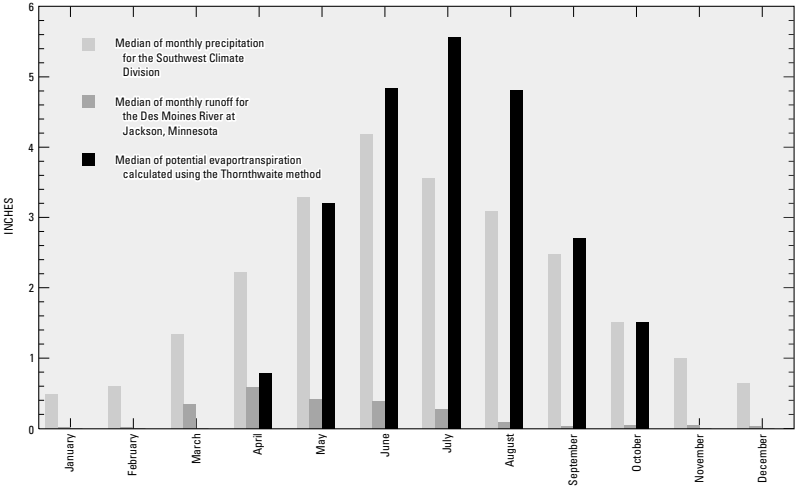


Figure 7. Median monthly precipitation and potential evapotranspiration in the Southwest Climate Division of Minnesota and median monthly runoff for the Des Moines River at Jackson, Minnesota, 1936-97 water years.

measured relation. For instance, the annual runoff associated with 30 in. of annual precipitation ranges from about 0.3 to 13 in. This large variation reflects the complexities of the rainfall-runoff processes. Only part of precipitation becomes runoff. Precipitation also can be evaporated or transpired back to the atmosphere, or become part of the deep ground-water system.

The rainfall-runoff relation becomes more complex when runoff from rainstorms or snowmelt is considered. Many factors affect the fate of precipitation, such as the timing and intensity of rainfall; soil-moisture content; evapotranspiration; the presence of frozen ground; and the timing and intensity of snowmelt. Because of the complexities of the rainfall-runoff process, statistical analysis cannot show whether changes in peak runoff or runoff volume from storms or snowmelt are a result of changes in precipitation or changes in land use (Miller and Frink, 1984).

RAINFALL-RUNOFF RELATIONS IN THE HERON LAKE BASIN

A model was developed to characterize rainfall-runoff relations in the Heron Lake Basin between 1991 and 1997. The model is calibrated to a given basin through the adjustment of parameters for the basin, which are assumed to be relatively constant over time. These basin parameters control the simulation of infiltration rates, overland-flow processes, ground-water recession rates, and other terrestrial and riverine hydrologic processes. Basin parameters are defined by assessing soil type, land use, and other factors that affect the hydrology of the basin. The model requires input time-series data before output time-series data can be produced. Input time-series data include precipitation, air temperature, wind direction, and other data needed to calculate the hydrologic response of the basin to rainfall. Output time-series data are stream discharge values that are compared to measured stream discharge values to calibrate and verify the model. When run in continuous-time mode, the

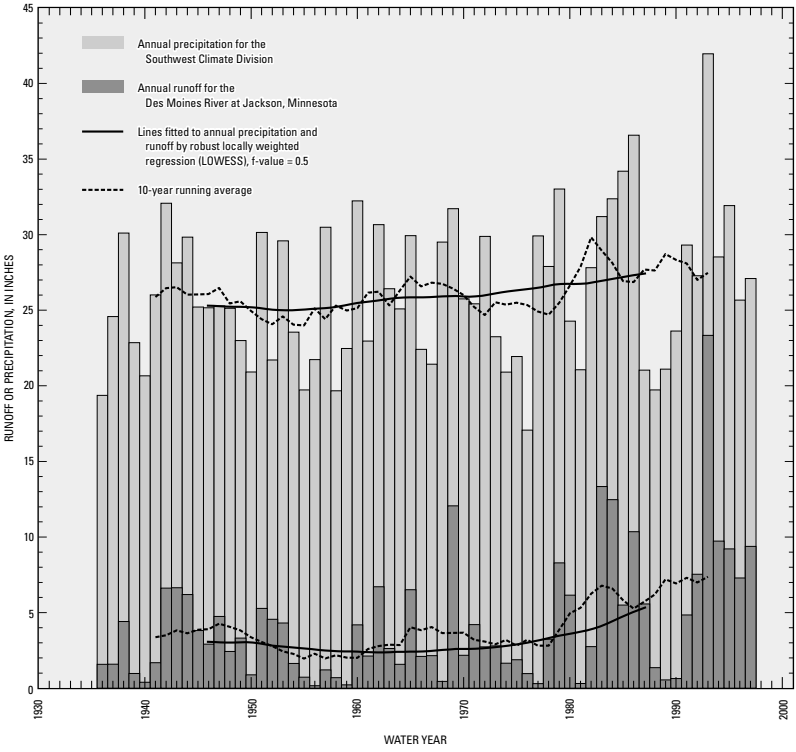


Figure 8. Annual precipitation for the Southwest Climate Division of Minnesota and annual runoff for the Des Moines River at Jackson, Minnesota, 1936-97 water years.

model approximates antecedent conditions for each storm and can estimate runoff under conditions that vary within short time periods. Once calibrated and verified, the model can be used to address complexities that control the hydrologic response of the basin to various changes to the landscape, including the restoration of wetlands.

The Hydrological Simulation Program—Fortran (HSPF) model

The USGS-supported model Hydrological Simulation Program – Fortran (HSPF) Version 10, was used to characterize rainfall-runoff responses in the Heron Lake Basin from May 1991 through August 1997. HSPF has the capability to simulate hydrologic and associated water-quality processes on pervious and impervious land surfaces and in streams (Bicknell and others, 1993, p. 9). Runoff is routed through channels, reservoirs, or lakes; and the movement of nutrients, pesticides, and suspended sediment through a basin can

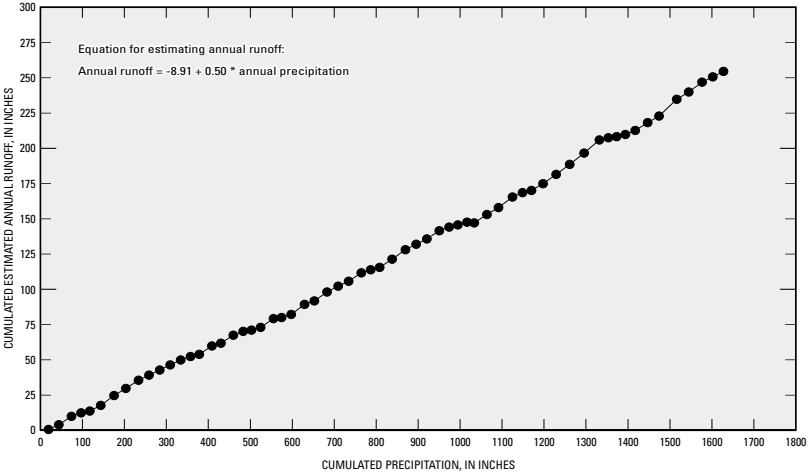


Figure 9. Double-mass curve of annual precipitation for the Southwest Climate Division of Minnesota and estimated annual runoff for the Des Moines River at Jackson, Minnesota, 1936-97 water years.

be simulated. The model operates on a continuous basis, in contrast to event-based models, and, therefore, can simulate low-flow periods between storms as well as high flows during storms and snowmelt.

HSPF is a conceptual model, approximating hydrologic processes through a series of interconnecting water storages (Duncker and others, 1995, p.17–18) (fig. 11). Water enters the conceptual basin as precipitation and melting snow, and leaves the basin through evaporation, transpiration, ground-water movement, and stream discharge. Prior to percolation in the ground, water can evaporate, be stored as plant interception or in surface depressions, or runoff to streams (fig. 11). Subsurface flow processes are simulated through movement between upper-zone storage, lower-zone storage, and active ground-water storage. The upper zone usually represents the shallow root zone, consisting of surface vegetation, ground litter, and the upper several inches of soil (Duncker and others, 1995, p. 18). The amounts of overland flow and interflow are affected by the amount of water entering upper-zone storage. The lower zone represents soil and other geologic materials from which deep-rooted vegetation obtains water. The active ground-water zone contains ground water that is either discharged as base flow to streams or released as evapotranspiration. The amount and flux of water between these storages and outflow to the streams are controlled by specified basin parameters.

HSPF requires that the basin be partitioned into land segments and the waterways be sectioned into reach/reservoirs. Each land segment represents a portion of the basin in which factors that affect the hydrology of the basin, such as slope, soil type, land use, and vegetation cover, do not change over space and time. The land segment can be either pervious or impervious. In the model, streams, rivers and other water channels are divided into reach/reservoirs, and water is routed through and between the reach/reservoirs.

Parameters for the land segments and reach/reservoirs and the instructions used by the HSPF model are con-

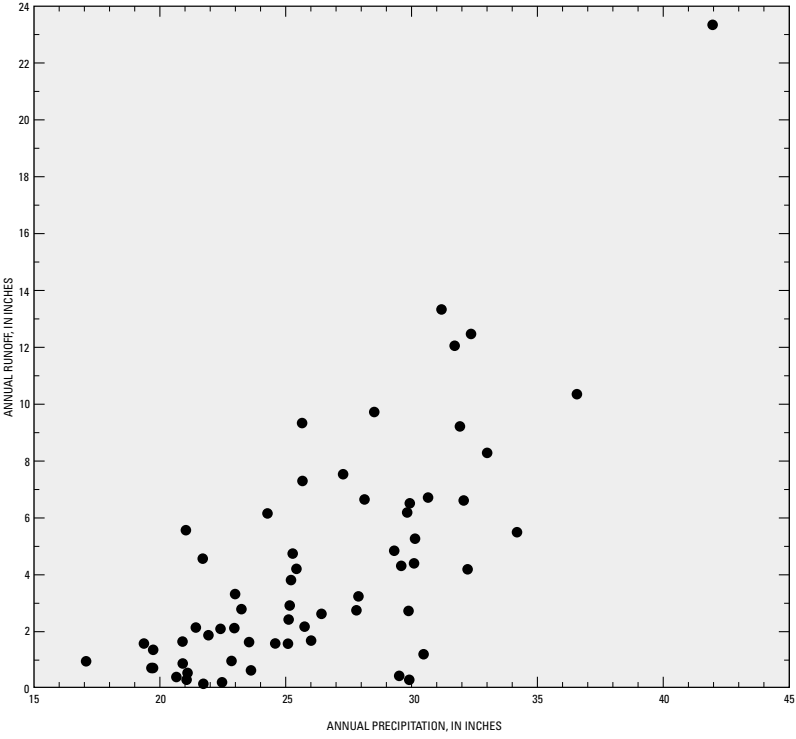


Figure 10. Relation between annual precipitation for the Southwest Climate Division of Minnesota and annual runoff for the Des Moines River at Jackson, Minnesota, 1936-97 water years.

tained in the User Control Input (UCI) files (Appendix).

The model of the Heron Lake Basin

HSPF was simulated for the Heron Lake Basin in two-steps: (1) simulations of five small subbasins using data from August 1995 through August 1997, and (2) simulations of the two large basins, Jack and Okabena Creek Basins, using data from May 1991 through August 1996. Simulations of the five small subbasins were done to determine basin parameters for the land segments and assess rainfall-runoff response variability in the subbasins. Simulations of the two larger basins were done to verify the basin parameters and assess rainfall-runoff responses for a longer time period.

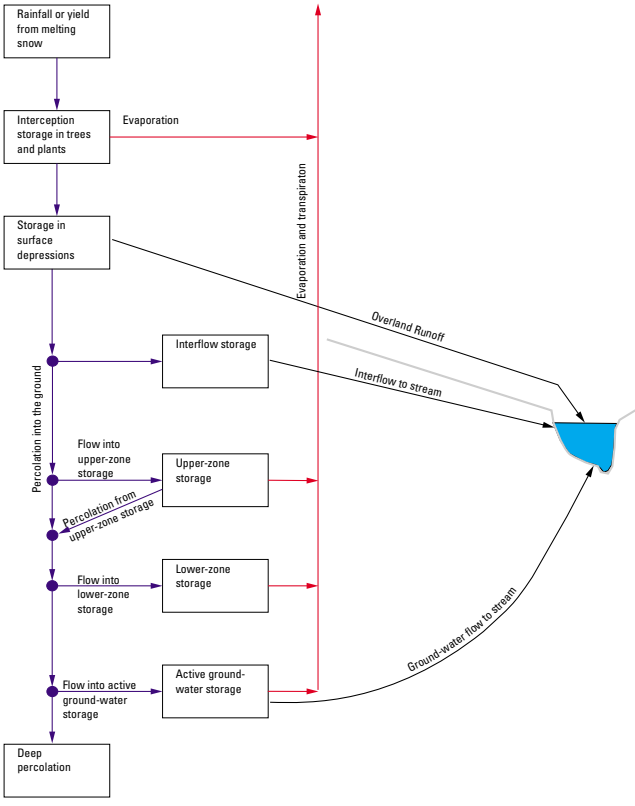


Figure 11. General schematic of the Hydrological Simulation Program-Fortran (HSPF) model processes (Bicknell and others, 1993).

Three of the five subbasins simulated with the HSPF model are in the Jack Creek Basin. These subbasins are upstream of the following streamflow gaging stations: Jack Creek near Kinbrae (Upper Jack Creek Subbasin), North Branch Jack Creek near Kinbrae (North Branch Jack Creek Subbasin), and the East Graham Lake Outlet on County State Aid Highway 1, near Kinbrae (East Graham Lake Outlet Subbasin) (fig. 12). The other two subbasins are in the Okabena Creek Basin upstream of the following streamflow gaging stations: Elk Creek on County State Aid Highway 1, near Brewster (Elk Creek Subbasin) and Okabena Creek on County State Aid Highway 14, near Brewster (Middle/Upper Okabena Creek Subbasin). HSPF simulations were conducted for the Jack Creek and Okabena Creek Basins upstream of the streamflow gaging stations on Jack Creek on township road near Heron Lake and Okabena Creek above Okabena, respectively. These portions of the Jack Creek and Okabena Creek Basins represent about 73 percent of the Heron Lake Basin. The eastern one-quarter of the Heron Lake Basin was not simulated because of the lack of stream-gaging records and because this portion of the basin is thought to contribute a relatively small amount of runoff to the Heron Lake System.

Segmentation of the model

Each of the basins and subbasins were partitioned into land segments and reach/reservoirs through analysis of available spatial data with geographical information system (GIS) software. The basins were partitioned into six different land-cover segments based on land use and crop type. These segments were urban areas, wetlands/water, grasslands, corn fields, soybean fields, and other land uses (table 1). The urban areas (cities of Worthington, Fulda, Brewster, and Kinbrae) were simulated as impervious land-cover segments; whereas, the other five land-cover segments were simulated as pervious land segments. Isolated lakes, ponds and waterways that do not drain directly into Jack or Okabena Creeks were simulated as wetlands/water land segments. The acreage of row croplands in the basin was divided evenly between the corn and soybean land-cover segments because (1) 97 percent of the row crops in the basins are either corn or soybeans, (2) an annual rotation is done between the two crop types, and (3) in any given year, corn and soybean production in the basin is approximately equal (Jim Nesseth, Jackson County Extension Service, oral commun., 1998). Differences in soil types throughout the watershed do not play a significant role in the type of crop grown, and, therefore, were not considered during the segmentation of row croplands. The other-land-uses segment consisted mainly of farmsteads and forests.

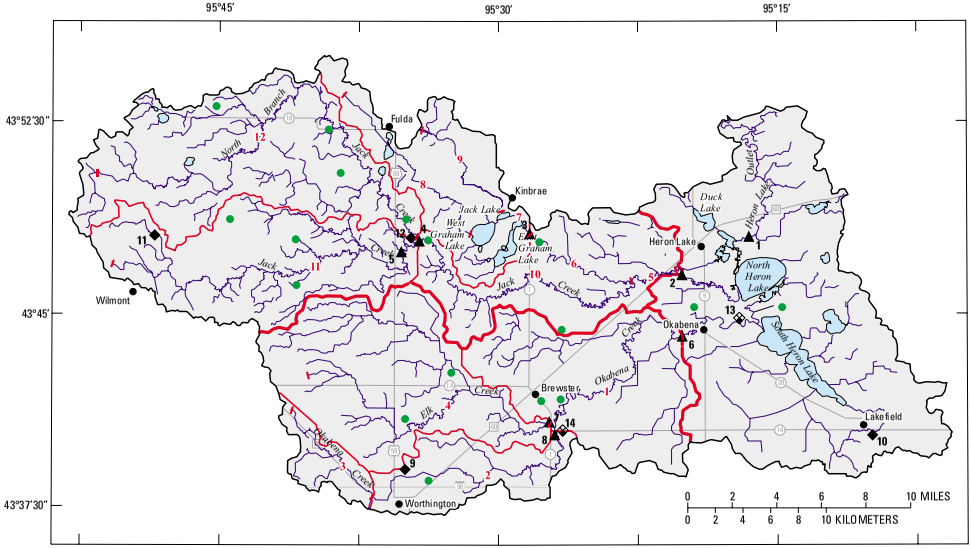
Soil type and slope were not considered during land-cover-segment partitioning. Experience with HSPF and the Stanford Watershed Model (the forerunner of HSPF) has shown that soil type is secondary to land use as a partitioning factor in HSPF simulations (C.S. Melching, formerly of the U.S. Geological Survey, written commun., 1998). The effect of soil type on basin parameters used in the model usually is undetectable unless extreme differences in soil types (sandy loams compared to silt and clay loams) are present in the basin. Slopes were relatively uniform throughout the Heron Lake Basin.

Initial basin parameters for land segments were obtained from four sources: (1) previous HSPF simulations of basins with similar hydrology to the Heron Lake Basin, (2) soil surveys, (3) hydrologic journal articles, and (4) evaluation of available data from the basin. Many of the initial basin parameters were taken from an HSPF simulation done by the Minnesota Pollution Control Agency of the Watonwan River Basin, which is northeast of the Heron Lake Basin (Ron Jacobson, Minnesota Pollution Control Agency, written commun.,1998). The length and slope of overland flow plains (denoted in the model as LSUR and SLSUR, respectively) were determined from topographic analyses of USGS 7.5-minute quadrangles of each of the basins and subbasins.

Jack and Okabena Creeks and their tributaries were segmented into 12 reach/reservoirs (table 2). The length of the reaches ranged from 3.0 to 43.40 miles, with the segmentation of many of these reach/reservoirs based on the location of stream gages. These reach/reservoirs represent portions of the main streams in each of the subbasins (fig. 12). Agricultural drainage ditches and tiles were not segmented as reach/reservoirs because available mapped areas indicated that the density of the drainage network was too high to simulate individual ditches and tiles. However, their hydrologic effects on the basins were considered when establishing basin parameters for the land segments. Manning's n roughness coefficients for the reach/reservoirs were determined using the procedures outlined in Supplement B of Fasken (1963).

Data sets used

Hourly precipitation, potential evapotranspiration (PET), air temperature, dew-point temperature, wind speed, and solar radiation data were inputs to each of the model simulations. Precipitation and PET values were the main inputs used in the model to simulate streamflows between spring snowmelt and initial snowfall in the late fall and early winter months. PET values were calculated from air temperature, relative humidity, solar radiation, and wind speed data collected at weather stations. The FAO-modified Penman Equation and monthly crop coefficients for corn were used to compute PET values (Doorenbos and Pruitt, 1977). During the months when snow was present, air temperature, dew-point temperature, wind speed, and solar radiation data were used, in addition to precipitation data, to determine snow accumula-



Base digitized from U.S. Geological Survey 1:24,000 maps, various dates.
Albers Equal-Area Conic Projection, standard parallels 43°20′ and 44°40′,
Central meridian -95°30′, latitude of projection's origin 43°

EXPLANATION

- Heron Lake Basin
- Boundary of simulated basin
- Boundary of subbasin
- Channel reach and reach number (See Table 2)
- Local precipitation observer
- Streams
- Streamflow-gaging station
  1. 05474990 Heron Lake Outlet below spillway near Heron Lake
  2. 05474975 Jack Creek on township road near Heron Lake
  3. 05474965 East Graham Lake Outlet on County State Aid Highway 1, near Kinbrae
  4. 05474950 North Branch Jack Creek near Kinbrae
  5. 05474945 Jack Creek near Kinbrae
  6. 05474915 Okabena Creek above Okabena
  7. 05474900 Elk Creek on County State Aid Highway 1, near Brewster
  8. 05474895 Okabena Creek on County State Aid Highway 14, near Brewster
- Weather Station
  (National Weather Service)
  9. Worthington 2 NNE (climatological data)
  10. Lakefield (hourly precipitation)
  (U.S. Geological Survey)
  11. Near Wilmont
  12. North Branch Jack Creek near Kinbrae
- Precipitation gage
  13. Near Okabena
  14. At gaging station 05474895

Figure 12. Weather stations and streamflow-gaging stations in the Heron Lake Basin, Minnesota.

Table 1. Areas of land-cover segments for subbasins and basins in the Heron Lake Basin, Minnesota

[All areas are in acres; CSAH, County State Aid Highway]

Subbasin or basin (associated streamflow gaging station and station number are in parenthesis)		Drainage area	Impervious land segment (Urban)	Pervious land segments				
				Wetlands/ water	Grasslands	Corn fields	Soybean fields	Other land uses
Upper Jack Creek (Jack Creek near Kinbrae, 05474945)		35,605	0	96	1,905	16,508	16,508	588
North Branch Jack Creek (North Branch Jack Creek near Kinbrae, 05474950)		45,499	0	469	2,861	20,681	20,681	807
East Graham Lake Outlet (East Graham Lake Outlet on CSAH 1, near Kinbrae, 05474965)		22,980	195	1,467	1,021	9,883	9,883	531
Elk Creek (Elk Creek on CSAH 1, near Brewster, 05474900)		39,074	30	0	1,516	18,764	18,764	0
Middle/Upper Okabena Creek (Okabena Creek on CSAH 14, near Brewster, 05474895)	with diversion	13,961	1,408	143	973	5,605	5,605	227
	without diversion	19,570	1,705	163	1,492	7,941	7,941	328
Jack Creek (Jack Creek on township road near Heron Lake, 05474975)		130,415	195	2,120	7,663	58,990	58,990	2,457
Okabena Creek (Okabena Creek above Okabena, 05474915)	With diversion	85,662	1,581	165	3,357	39,977	39,977	605
	Without diversion	91,271	1,878	185	3,876	42,313	42,313	706

tion rates and snowmelt runoff. Precipitation data were apportioned in each of the simulations using the Theissen polygon method (Fetter, 1980).

Data collected from two hourly precipitation gages, seven streamflow-gaging stations, and five weather stations were used in the model simulations (fig. 12 and table 3). Five of these stations or gages operated prior to the start of the study; whereas, nine of the stations or gages were installed and monitored as part of the study. One of the weather stations, Lamberton Southwest Experimental Station near Lamberton, Minnesota, was located outside of the Heron Lake Basin, approximately 25 miles north of the basin (fig. 1). The other stations and gages were located within the basin.

Prior to April 1996, hourly precipitation data were collected only at two National Weather Service (NWS) stations in the basin, Worthington 2 NNE, and Lakefield (fig. 12 and table 3). The nearest station to the basin collecting weather data besides precipitation data was the NWS station Lamberton Southwest Experimental Station at Lamberton, Minnesota (fig. 1). The precipitation data collected from the Worthington 2 NNE and Lakefield stations had missing data between 1991 and 1996. Precipitation for these missing record periods was estimated using hourly and daily precipitation data collected at NWS weather stations located at Luverne and Sherburn, Minnesota, and Sibley, Iowa (fig. 1). Hourly air temperature, relative humidity, wind speed, and solar radiation data collected at the Lamberton Station were used as input to the simulations and to calculate hourly PET values for the simulations prior to April 1996.

To improve input precipitation data to the Jack and Okabena Creek Basin simulations, daily precipitation data from 17 volunteer-maintained sites of the Minnesota Volunteer Weather Observation Network (Minnesota State Climatologist, 1998a) were converted to hourly data using the USGS program METCMP (K.M. Flynn, U.S. Geological Survey, written commun., 1997). The daily precipitation data were con-

Table 2. Characteristics of reach/reservoirs simulated in the Hydrological Simulation Program–Fortran (HSPF) model for the Heron Lake Basin, Minnesota

[mi, mile; ft, feet; mi^2, square mile; CSAH, County State Aid Highway; --, no value]

Reach number (shown in figure 12)	Reach	Nearest downstream gage	Reach length (mi)	Water-surface elevation drop across reach (ft)	Drainage area (mi^2)	Manning's n roughness coefficient
1	Lower Okabena Creek	Okabena Creek above Okabena	18.2	54	50.98	0.052
2	Middle Okabena Creek	Okabena Creek on CSAH 14, near Brewster	23.06	120	21.81	0.052
3	Upper Okabena Creek	Okabena Creek on CSAH 14, near Brewster	6.70	90	8.76	0.040
4	Elk Creek	Elk Creek on CSAH 1, near Brewster	20.09	240	61.05	0.046
5	Lower Jack Creek	Jack Creek on township road near Heron Lake	4.22	4	11.93	0.052
6	East Graham Lakes Confluence to Jack Creek	Jack Creek on township road near Heron Lake	8.41	22	6.99	0.052
7	East Graham Lakes Outlet	East Graham Lake Outlet on CSAH 1, near Kinbrae	3.0	3	3.56	--
8	West Graham Lakes Inlet	East Graham Lake Outlet on CSAH 1, near Kinbrae	12.3	44	19.90	0.040
9	Jack Lake Inlet	East Graham Lake Outlet on CSAH 1, near Kinbrae	10.5	64	12.47	0.046
10	Middle Jack Creek	Jack Creek on township road near Heron Lake	26.59	69	22.21	0.052
11	Upper Jack Creek	Jack Creek near Kinbrae	32.86	240	55.63	0.046
12	North Branch Jack Creek	North Branch Jack Creek near Kinbrae	43.40	270	71.09	0.046

verted to hourly data based upon the hourly data from the NWS stations at Worthington 2 NNE and Lakefield. The records from the 17 sites are not complete for 1991–96. Average hourly precipitation values were computed for each subbasin and used in the simulations of Jack and Okabena Creek Basins.

The USGS operated two weather stations, near Wilmont and at North Branch Jack Creek near Kinbrae, and two tipping-bucket rain gages, at Okabena Creek on County State Aid Highway 14, near Brewster and near Okabena, between April 1996 and November 1997 to improve weather data collection in the basin. Data were collected every 15 minutes and averaged hourly at the weather stations and rain gages. Precipitation, air temperature, relative humidity, wind speed, wind direction, and solar radiation data were collected at the weather stations. The weather station data were collected year round except for precipitation. Precipitation data were collected at the weather stations and rain gages only during the open-water season (air temperature above freezing). During the closed-water season (air-temperature below freezing), precipitation data from the Worthington 2 NNE and Lakefield NWS stations were used in the simulations.

Streamflow-gaging stations were installed at the mouth of each of the subbasins in August 1995 to provide discharge data for calibration of the five subbasin simulations (fig. 12 and table 3). These five stations (stations 05474895, 05474945, 05474965, 05474900, and 05474950) operated during the open-water season of each year between August 1995 and August 1997. Because the stations operated only between March and November during the monitoring years, calibration during most of the snowmelt events was not possible. The number of discharge measurements made at each station from March 1995 through August 1997 ranged between 18 and 24. Rating curves were developed for the five stations from these measurements. Discharge values for the stations were computed from analysis of the rating curves and recorded stream-stage data. The rating curves for the stations also were used to develop discharge tables for the reach/reservoirs used in the five subbasin simulations.

Table 3. Data sources used in the Hydrological Simulation Program–Fortran (HSPF) simulations of the Heron Lake Basin, Minnesota
[CSAH, County State Aid Highway]

Source of data	Station identification number	Station name	Period of record used in simulations	Type of gage
National Weather Service/ National Climatic Data Center	219170	Worthington 2 NNE	May 1991–August 1996	Hourly precipitation
National Weather Service/ National Climatic Data Center	214453	Lakefield	May 1991–August 1996	Hourly precipitation
U.S. Geological Survey	05474895	Okabena Creek on CSAH 14, near Brewster	August 1995–July 1997	Stream discharge, hourly precipitation
U.S. Geological Survey	05474945	Jack Creek near Kinbrae	August 1995–July 1997	Stream discharge
U.S. Geological Survey	05474965	East Graham Lake Outlet on CSAH 1, near Kinbrae	August 1995–July 1997	Stream discharge
U.S. Geological Survey	05474900	Elk Creek on CSAH 1, near Brewster	August 1995–July 1997	Stream discharge
U.S. Geological Survey	05474950	North Branch Jack Creek near Kinbrae	August 1995–July 1997	Stream discharge, hourly precipitation, air temperature, wind speed, wind direction, relative humidity, solar radiation
U.S. Geological Survey	434804095483401	Weather Station near Wilmont	April 1996– July 1997	Hourly precipitation, air temperature, wind speed, wind direction, relative humidity, solar radiation
U.S. Geological Survey	434448095171101	Precipitation Gage near Okabena	May 1996–July 1997	Hourly precipitation
National Weather Service/ National Climatic Data Center	214546	Lamberton Southwest Experimental Station	May 1991–August 1996	Air Temperature, wind speed, wind direction, relative humidity, solar radiation
Minnesota Department of Natural Resources	none	(17 local observers)	May 1991–August 1996	Daily precipitation
Minnesota Department of Natural Resources	05474975	Jack Creek on township road near Heron Lake	May 1991–August 1996	Stream discharge
Minnesota Department of Natural Resources	05474915	Okabena Creek above Okabena	May 1991–August 1996	Stream discharge

Discharge data used for verification of the simulations of Jack and Okabena Creek Basins between 1991 and 1996 were collected at the streamflow-gaging stations on Jack Creek on township road near Heron Lake and on Okabena Creek above Okabena (fig. 12 and table 3). Rating curves were developed from 21 and 20 discharge measurements made at the Jack and Okabena Creek gaging stations, respectively, between August 1991 and September 1996. Discharge values were obtained from analysis of rating curves and recorded stream-stage data at each of the gages. The rating curves for the two gages also were used to develop discharge tables for the reach/reservoirs used in the model simulations of the two basins. The two gages were operated between March and November during the monitoring years. Therefore, verification using stream discharge records was not possible for most of the simulated winter months and snowmelt events.

Model calibration and verification methods

Model simulations of the subbasins were calibrated using measured flow data, and then model simulations of the larger basins were used to verify the usefulness of the model. Calibration of HSPF simulations consists of adjusting the basin parameters within reasonable limits until the model can reproduce, within some acceptable range, measured streamflows resulting from measured precipitation. The main steps involved in the calibration process were to accurately simulate water volumes on an annual and continuous period-of-record basis and visually match measured and simulated storm runoff. The main steps in the verifica-

tion process were to assess the accuracy of simulated water balances on an annual and continuous period of record and evaluate the ability of the model to simulate storm runoff in the large basins.

Often, it is difficult to simulate each storm over time; therefore, the model should be calibrated using several storms. Intense storms often affect only a small portion of a basin and may not be recorded by the precipitation gaging network. As a result, the precipitation record used in the simulations often does not accurately reflect rainfall over the entire basin, resulting in large differences between simulated and measured streamflow (Duncker and others, 1995, p.17).

Model simulations were calibrated for the five subbasins from August 1995 through August 1997. The model simulations were calibrated for the five subbasins, rather than the two larger basins, because streamflow, precipitation, and weather parameters were monitored more intensely and accurately in the subbasins during the 1995–97 calibration period than in the 1991–96 simulation period for the larger basins. For each of the subbasins, simulated and measured water volumes were calculated for monitoring periods in 1995, 1996, and 1997. Simulated and measured volumes were compared by determining the percentage error for each of the monitoring periods. Daily volumes of simulated and measured flow were plotted for each of the subbasins and compared visually.

Runoff responses to rainfall events were calibrated in each of the subbasins through the adjustment of the following pervious land-segment parameters: lower-zone nominal storage (LZSN), index to the infiltration capacity of the soil (INFILT), monthly upper-zone nominal storage (MON-UZSN), interflow inflow parameter (INTFW), interflow recession parameter (IRC), ground-water recession flow parameters (KVARY), and basic ground-water recession rate (AGWRC).

The snowmelt periods were calibrated primarily through the adjustment of three HSPF snow parameters: winter precipitation multiplication factor (SNOWCF), the parameter that adapts snow evaporation to field conditions (CCFACT), and the maximum water content of the snowpack (MWATER). Although most of the gages were operational in the spring following snowmelt, two of the streamflow gages, Elk Creek on County State Aid Highway 1, near Brewster and Jack Creek near Kinbrae, were operational in mid-March during 1996 and 1997, early enough to record runoff during snowmelt. Discharge records for these two gages were used to calibrate snow parameters in the model.

No adjustments were made to the model parameters for simulation of rainfall-runoff processes on wetlands, grasslands, and other-land-use segments during the calibration process, as these three land segments incorporated less than 3 percent of the simulated basin. Most of the model parameters for the wetlands, grasslands, and other-land-use segments were obtained from the calibrated corn and soybean land-segment parameters, when appropriate. Other land-segment parameters were estimated through comparison with HSPF simulations of other agricultural basins in Iowa and Minnesota (Donigian and others, 1993; and Ron Jacobson, Minnesota Pollution Control Agency, written commun., respectively).

To assess the effect of the diversion of the upper reach of Okabena Creek on model simulations, two simulations each were done of the Okabena Creek Basin and the Middle/Upper Okabena Creek Subbasin. The first simulation did not include the upper part of the Okabena Creek Basin above the diversion at Worthington (referred to as “with diversion”), and the second simulation did include the upper part of the basin (referred to as “without diversion”). Each of the simulations were calibrated to measured stream discharge records and compared with respect to their ability to simulate the measured record.

Once calibration was completed, model parameters from the subbasin simulations were used to conduct simulations of the Jack Creek Basin and the Okabena Creek Basin. This verification was based on comparison of simulated stream discharge values with measured discharge for the period from May 1991 through August 1996.

Streamflow-gaging stations were operated discontinuously in each basin between July 1987 and September 1996. However, model simulations between July 1987 and March 1991 had substantial errors. These errors could be the result of the sparse precipitation record that was available for the basins. Only two NWS weather stations and two volunteer-maintained sites were operating between July 1987 and March 1991. These modeling errors also could be the result of sparse streamflow records for the period. Only two discharge measurements were made at each of the gages between 1987 and 1990. As a result, the period before April 1991 was not included in the verification of the model.

Simulated and measured runoff amounts were calculated for the two larger basins for 1991–96 to verify the model. Simulated and measured volumes were compared by determining the percentage error for each of the monitoring periods. In addition, the coefficient of model-fit efficiency and the correlation coefficient were calculated for the Jack Creek Basin and the two simulations of the Okabena Creek Basin. The coefficient of model-fit efficiency, E, (Duncker and others, 1995, p. 22) is:

$$E = \frac{\sum_{i=1}^{N}(Qo_i - Qo)^2 - \sum_{i=1}^{N}(Qo_i - Qs_i)^2}{\sum_{i=1}^{N}(Qo_i - Qo)^2}$$

where Qo_i is the measured runoff volume for month i,

Qs_i is the simulated runoff volume for month *i*,

Qo is the average measured monthly runoff volume, and

N is the number of monitoring months in the 1991–96 simulation.

The correlation coefficient, *C*, (Duncker and others, 1995 p. 22) is calculated as:

$$C = \frac{\sum_{i=1}^{N}(Qo_i - Qo)\times(Qs_i - Qs)}{\left[\sum_{i=1}^{N}(Qo_i - Qo)^2 \times \sum_{i=1}^{N}(Qs_i - Qs)^2\right]^{1/2}},$$

where *Qs* is the average simulated monthly runoff volume.

These coeficients were not computed for the subbasins used for calibration because of the short record for the subbasins.

Results of calibration and verification

Simulated and measured annual water volumes and percentage errors for the model calibrations of the five subbasins are listed in table 4. Percentage error is the difference between total simulated runoff and total measured runoff for a period of time [100 x (simulated volume – measured volume)/ measured volume]. Donigian and others (1984) determined that annual and monthly simulations are very good when percentage error is less than 10, good when it is between 10 and 15, and fair when it is between 15 and 25. The simulations for each of the subbasins for 1995–97 were very good, except for the Middle/Upper Okabena Creek Subbasin simulation without the diversion. The large percentage error for this simulation suggests that flow was diverted at Worthington during part of the simulation period. For the annual monitoring periods during 1995–97 for the 5 subbasins, 8 of the simulations are very good, 3 are good, and 3 are fair (table 4). Four of the simulations were less than fair.

The effect of the Okabena Creek diversion at Worthington can be seen by comparing the simulated results with and without the diversion. The 1995 and 1997 Middle/Upper Okabena Creek simulations without the diversion are less than fair, oversimulating flow in the creek (table 4). The 1995 and 1997 Middle/Upper Okabena Creek simulations with the diversion were very good and good, respectively. These results suggest that the diversion was operating during most of the 1995 and 1997 monitoring periods. Simulations of the 1996 monitoring period suggest that the diversion may not have been operating during most of the monitoring period. The 1996 simulation with the diversion was only a fair fit, undersimulating flow in the creek; whereas, the 1996 simulation without the diversion was very good (table 4). Most of the undersimulation of 1996 flows with the diversion occurred after a storm on June 16. This undersimulation suggests that the diversion may not have been operating following the storm and(or) that the precipitation-gaging network was not dense enough to accurately represent rainfall in the basin.

The extremely high error for the 1995 North Branch Jack Creek simulation was a result of an oversimulation of runoff from a storm on September 29–30. This oversimulation may be a result of an oversimulation of antecedent moisture in the upper and lower zones of the model prior to the storm and(or) an inaccurate representation of rainfall in the basin. The second explanation is likely because rainfall data for the 1995 simulation was limited to data from the Worthington 2 NNE weather station, located approximately 10 miles south of the North Branch Jack Creek Subbasin.

The visual fit between measured and simulated discharge varied between subbasins and different monitoring periods. For example, the fit between measured and simulated daily discharge for the Upper Jack Creek Subbasin (Jack Creek near Kinbrae streamflow-gaging station) was visually good for the 1996 monitoring period (fig. 13), except during the spring snowmelt runoff in late March and early April and during a one-inch rainfall event occurring in mid May. The snowmelt routine of the HSPF model does not account for variations in snow depth over a basin; therefore, snowmelt events are difficult to simulate using the model. In the 1997 simulation, the visual fit is not as good, particularly for base flow conditions (fig. 13). However, during both monitoring periods, the response timing of the model to rainfall events correlates well with measured runoff responses. The 1996 simulated peak flow matches well with measured peaks during the year, with a poorer, but still good, fit in 1997 (fig. 13). Similar fits were obtained between observed and simulated discharge for the North Branch Jack Creek Subbasin simulation, except for a slightly-poorer peak fit to a mid-June 1996 storm (fig. 14).

The visual fit between measured and simulated discharge for the East Graham Lake Outlet Subbasin is better for the 1997 simulation than for the 1996 simulation, with the overall fit poorer than the fits for the Upper Jack Creek Subbasin and North Branch Jack Creek Subbasin simulations (figs. 13 and 14). In 1996, the model undersimulated discharge during the second half of May and for the mid-June storm; oversimulated discharge during April, first half of May, and first half of June; and simulated low-flow discharge fairly well between July and November. The model oversimulated discharge for the March 1997 snowmelt, but simulated discharge well between April and July 1997. The high degree of complexity in routing flow through the Graham Lake System probably results in the poorer visual fit for the simulation of the East Graham Lake Outlet Subbasin than for the simulations of the Upper Jack Creek and North Branch Jack Creek Subbasins.

The visual fit between measured and simulated peak flows for the Elk Creek Subbasin simulation is good,

Table 4. Measured water balances and water balances simulated with the Hydrological Simulation Program–Fortran (HSPF) for subbasins in the Heron Lake Basin, Minnesota

[in., inch; Percentage error simulations are very good (less than 10 percent), good (10–15 percent), and fair (15–25 percent)]

Subbasin		August to October 1995			March to November 1996			March to July 1997			Total during simulation period		
		Measured runoff (in.)	Simulated runoff (in.)	Error (percent)	Measured runoff (in.)	Simulated runoff (in.)	Error (percent)	Measured runoff (in.)	Simulated runoff (in.)	Error (percent)	Measured runoff (in.)	Simulated runoff (in.)	Error (percent)
Upper Jack Creek		1.18	1.39	17.80	7.44	6.54	-13.76	7.34	7.42	1.08	15.96	15.35	-3.82
North Branch Jack Creek		0.66	1.34	103.03	5.70	5.49	-3.83	6.00	5.22	-13.00	12.37	12.05	-2.59
East Graham Lake Outlet		0.68	0.65	-4.41	4.86	4.74	-2.53	7.96	9.19	15.45	13.50	14.59	8.07
Elk Creek		1.38	1.47	6.52	6.27	4.61	-26.47	7.42	7.84	5.66	15.07	13.92	-7.63
Middle/Upper Okabena Creek	with Diversion	2.03	2.00	-1.48	6.22	5.08	-18.33	3.79	4.19	10.55	12.05	11.27	-6.47
	without Diversion	1.45	1.91	31.72	4.44	4.87	9.68	2.70	4.09	51.48	8.60	10.87	26.40

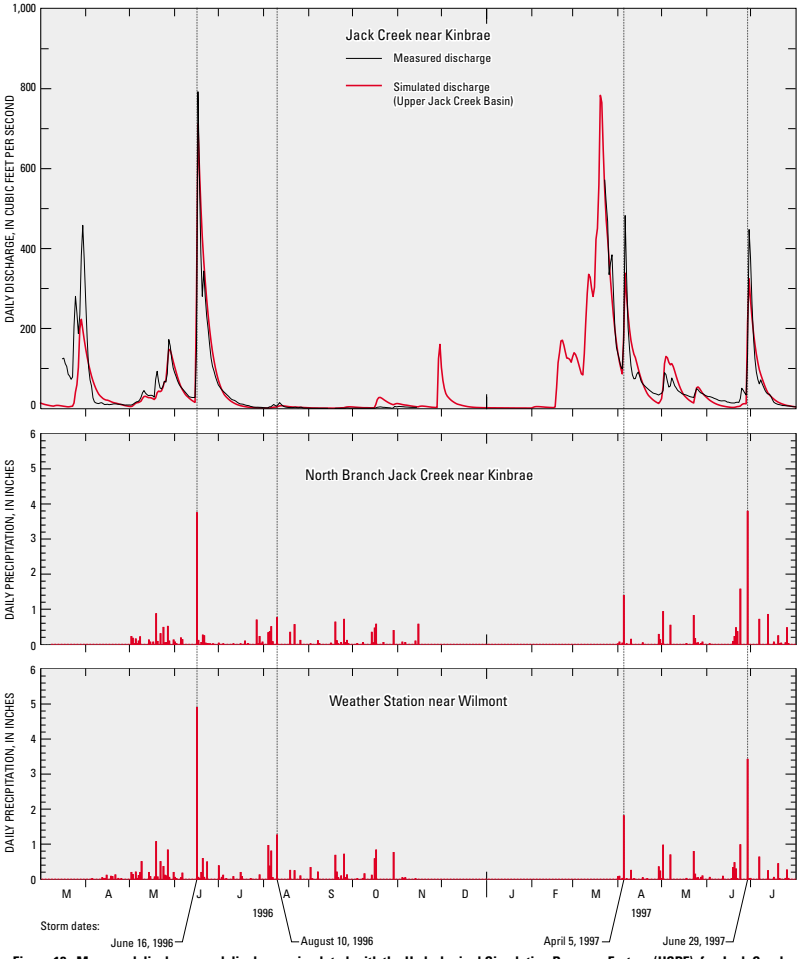


Figure 13. Measured discharge and discharge simulated with the Hydrological Simulation Program-Fortran (HSPF) for Jack Creek near Kinbrae gage and daily precipitation for North Branch Jack Creek near Kinbrae precipitation gage and weather station near Wilmont, Minnesota, March 1996-July 1997.

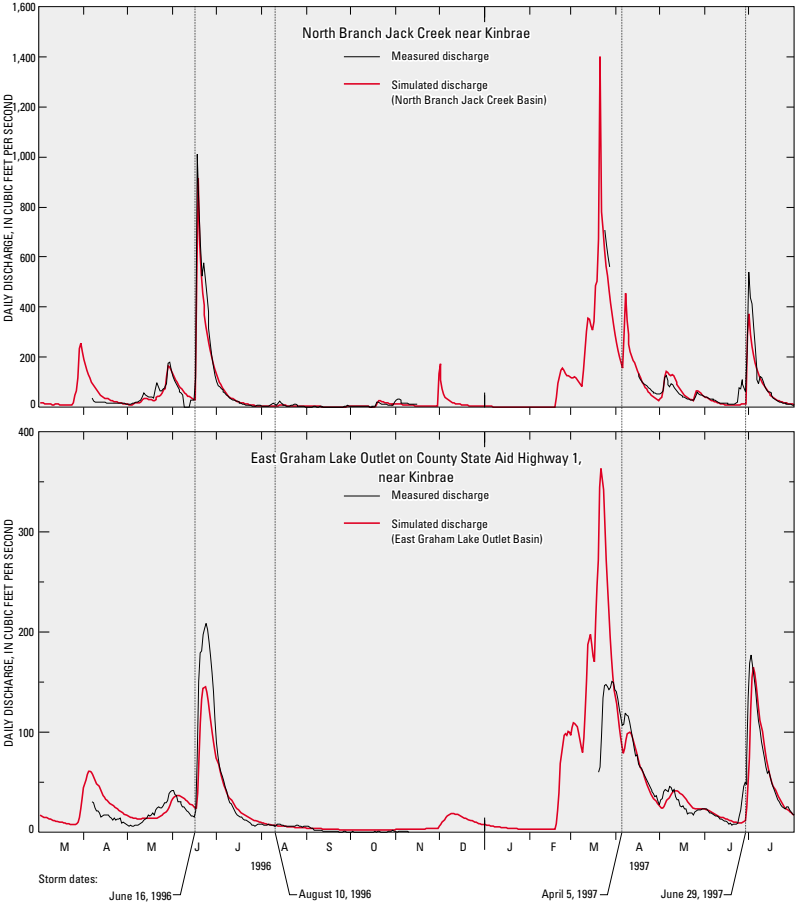


Figure 14. Measured discharge and discharge simulated with the Hydrological Simulation Program-Fortran (HSPF) for North Branch Jack Creek near Kinbrae and East Graham Lake Outlet on County State Aid Highway 1, near Kinbrae gages, Minnesota, March 1996-July 1997.

except for a poor representation of the peak flow during a storm in June 1996 (fig. 15). Similar to the Upper Jack Creek Subbasin and North Branch Jack Creek Subbasin simulations, the simulated base flow for Elk Creek fits the measured base flow conditions in 1996, but not in 1997 (figs. 13, 14 and 15). A major reason for the less-than-fair fit for peak flows during the 1996 monitoring period is the undersimulation of runoff after the June 1996 storm. The June 1996 poor fit probably resulted from the rain-gage network not being dense enough to produce a good estimate of rainfall over the subbasin. On the first day of the storm, June 16, rainfall varied from 1.4 in. in the southern portion of the subbasin to almost 5 in. in the northern portion (fig. 13 and 15).

Simulated discharge values of the Middle/Upper Okabena Creek Subbasin with and without the diversions are visually a fair match to measured discharge values. Simulated discharges, without the diversion, were greater than simulated discharges with the diversion (fig. 16). The model oversimulated peak flows in 1996 and 1997, except for the June 1996 storm that was undersimulated, similar to the Elk Creek Subbasin simulation. The low-flow discharge values are undersimulated for many periods in 1996 and 1997. Accurate simulation of measured discharge in the Middle/Upper Okabena Creek Subbasin without knowledge of diversion regulation is difficult because the diversion has a substantial effect on downstream measured discharge.

The pervious land-segment parameters resulting from the model calibration are listed in table 5. The land-segment parameters generally define conceptual relations between the processes that control runoff. However, when relating the best-fit land-segment parameters to field conditions, one must consider that a number of sets of parameters in HSPF could produce similar results. Most of the land-segment parameters cannot be physically measured, and therefore they should not be related directly to parameters that can be measured in the field.

Because greater than 97 percent of the simulated basin consisted of corn and soybean fields, the calibration process mostly involved adjustment of the corn and soybean land-segment parameters. In general, differences between the corn and soybean land-segment parameters used in each of the subbasin calibrations are small (table 5). Notable differences in parameter values among the subbasins are seen in the MGMELT, INFILT, IRC, and LSUR parameters. The MGMELT values are 0.002 for all of the subbasins except for the Elk Creek Subbasin, which has a value of 0.003. The MGMELT value for the Elk Creek Subbasin was determined from calibration of 1996 and 1997 snowmelt. The slightly-higher maximum rate of snowmelt by ground heat in the Elk Creek Subbasin may be a result of a lack of shadowing effects around wetlands and forest in the subbasin, increasing the potential for higher rates of snowmelt. A larger infiltration-capacity index, INFILT = 0.06 in./hr, determined for the East Graham Lake Outlet Subbasin was most likely a result of a larger acreage of wetlands/water land segments in the subbasin compared to the other subbasins (table 1). The larger interflow recession parameter, IRC = 0.86, for the North Branch Jack Creek Subbasin may also be a reflection of a larger acreage of wetlands/water land segment in the subbasin compared to the Upper Jack, Elk, and Middle/Upper Okabena Creek Subbasins (table 1). Studies have shown that the interflow recession parameter tends to be larger for larger basins (Duncker and Melching, 1998, p. 49). The North Branch Jack Creek Subbasin is one of the largest subbasins simulated in the study (table 1), which may explain the larger interflow recession parameter. In general, differences in LSUR parameters between the subbasins had minimal effect on simulated discharges, and are determined from measurable physical features of the subbasins. The variations among subbasins with respect to LSUR were not significant to the modeling results and need no further discussion.

Nominal storage values for the upper (MON-UZSN) and lower zones (LZSN) in the model were less than values used in HSPF simulations of other tiled croplands in Iowa and Minnesota (Donigian and others, 1993; and Ron Jacobson, Minnesota Pollution Control Agency, written commun., 1998, respectively). The low MON-UZSN values may be reflective of the efficiency of the tiles at removing water from the croplands following a storm. The efficient removal of water results in a small amount of stored water; therefore, the MON-UZSN and LZSN values are small. The limited amount of flow data and the large amount of tiles in the basin limit the model's ability to distinguish the hydrologic effects of soil properties and tiling.

Calibration of this model was done using 2 years of discontinuous records for five subbasins. Most studies of HSPF recommend that model calibration is adequate when using a simulation period of 3 to 5 years or more of continuous record (Duncker and others, 1995, p. 27).

Verification of the model was accomplished using simulations of Jack and Okabena Creek Basins. Simulated and measured water volumes and annual percentage errors for Jack and Okabena Creek Basins for May 1991 through September 1996 are listed in table 6. For these simulations, the fit of total simulated discharge to measured discharge for the entire monitoring period was very good, with a percentage error less than 10.

On an annual basis, the percentage errors between simulated and measured runoff values are quite different between Jack and Okabena Creek Basins. The model errors during five of the six annual monitoring periods for Jack Creek Basin are below 10 percent, indicating a very good fit (table 6). The only exception was for 1995 for which

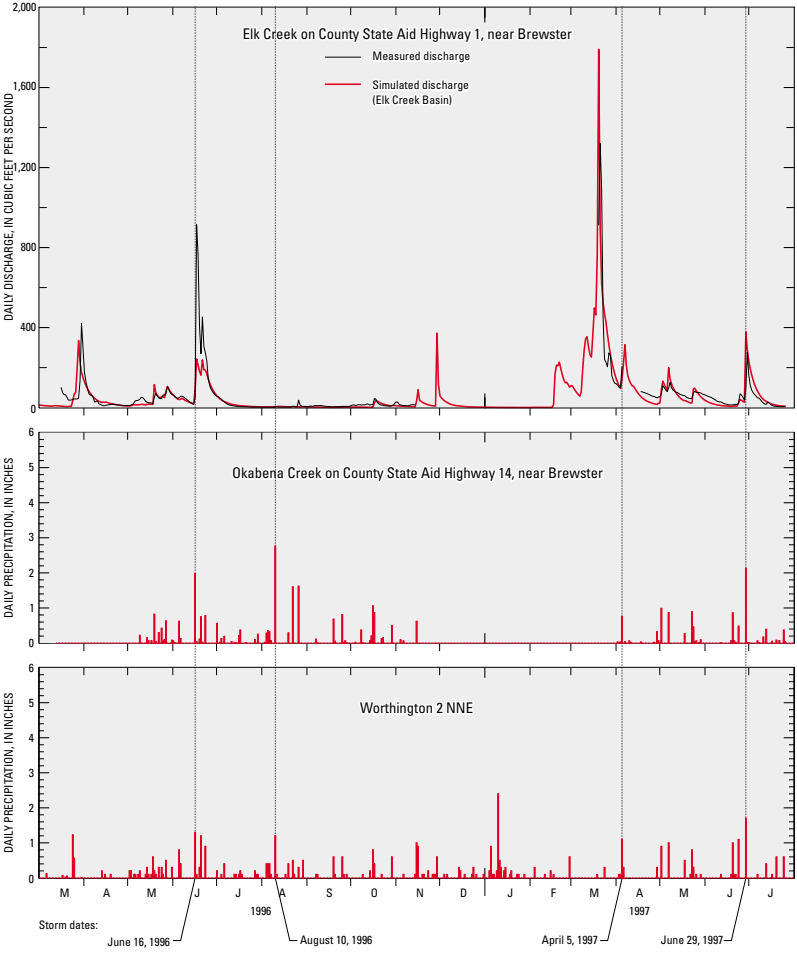


Figure 15. Measured discharge and discharge simulated with the Hydrological Simulation Program-Fortran (HSPF) for Elk Creek on County State Aid Highway 1, near Brewster gage, daily precipitation for Okabena Creek on County State Aid Highway 14, near Brewster precipitation gage and Worthington 2 NNE weather station, Minnesota, March 1996-July 1997.

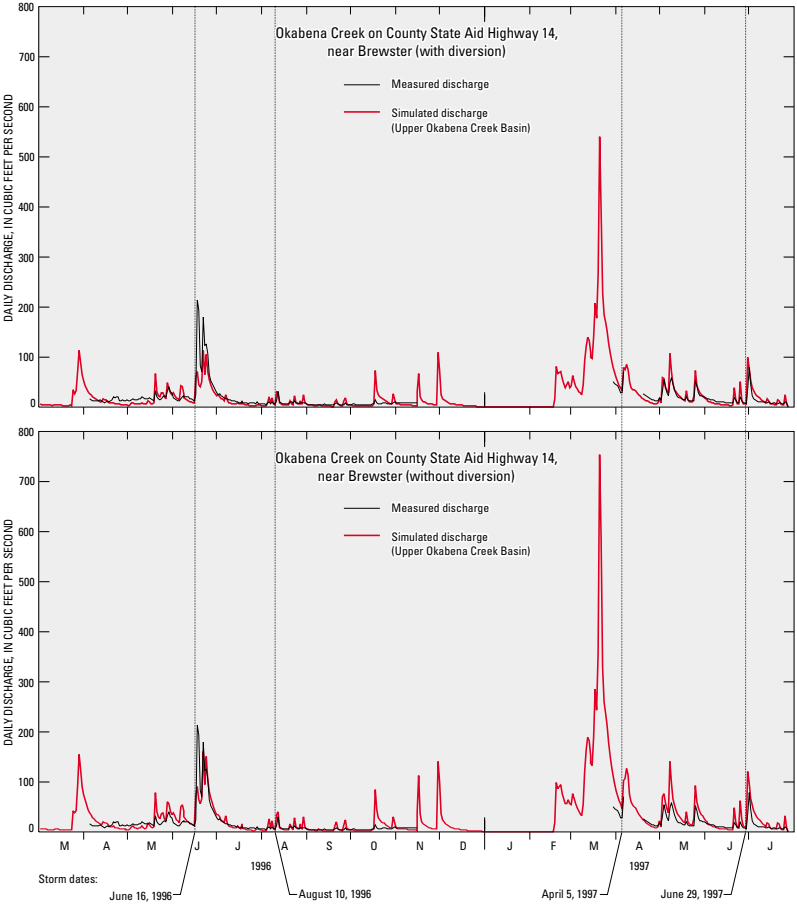


Figure 16. Measured discharge and discharge simulated with the Hydrological Simulation Program-Fortran (HSPF) (with and without diversion) for Okabena Creek on County State Aid Highway 14, near Brewster gage, Minnesota, March 1996-July 1997.

Table 5. Pervious land-segment parameters for the best-fit calibrations of subbasins in Heron Lake Basin, Minnesota, using the Hydrological Simulation Program–Fortran (HSPF)

[CSAH, County State Aid Highway; in./day, inches per day; in., inch; in./hr, inches per hour; ft, feet; --, no value]

HSPF Parameters	Corn and soybeans						Wetlands (All subbasins)	Grasslands (All subbasins)	Other-land-uses (All subbasins)
					Middle/Upper Okabena Creek				
	Upper Jack Creek	North Branch Jack Creek	East Graham Lake Outlet	Elk Creek	With diversion	Without diversion			
SNOWCF[1](dimensionless)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CCFACT[2](dimensionless)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
MGMELT[3](in./day)	.002	.002	.002	.003	.002	.002	.002	.002	.002
LZSN[4] (in.)	4.2	4.2	4.2	4.2	4.2	4.2	3.0	4.2	4.2
INFILT[5] (in./hr)	.025	.025	.06	.025	.025	.025	.4	.06	.06
LSUR[6] (ft)	410	403	431	335	513	513	350	335–513	335–513
SLSUR[7](dimensionless)	.006	.006	.006	.006	.006	.006	.006	.006	.006
KVARY[8] (1/in.)	.3	.3	.3	.3	.3	.3	.3	.3	.3
AGWRC[9] (1/day)	.94	.94	.94	.94	.94	.94	.94	.94	.94
NSUR[10](dimensionless)	---	---	---	---	---	---	.4	.2	.2
INTFW[11](dimensionless)	3.4	3.4	3.4	3.4	3.4	3.4	3.0	3.4	3.4
IRC[12] (1/day)	.83	.86	.83	.83	.83	.83	.83	.83	.83
MON-INTERCEP[13] (in.)	.03–.16	.03–.16	.03–.16	.03–.16	.03–.16	.03–.16	.03–.05	.06–.10	.06–.13
MON-MANNING[14](dimensionless)	.16–.20	.16–.20	.16–.20	.16–.20	.16–.20	.16–.20	---	---	---
MON-LZETP[15](dimensionless)	.20–.82	.20–.82	.20–.82	.20–.82	.20–.82	.20–.82	.20–.60	.20–.60	.20–.60
MON-UZSN[16] (in.)	.12–.14	.12–.14	.12–.14	.12–.14	.12–.14	.12–.14	2.5	1.0	1.0

[1]SNOWCF is the factor by which recorded precipitation data will be multiplied, if the simulation indicates it is snowfall, to account for poor catch efficiency under snow conditions (dimensionless)

[2]CCFACT is a parameter that adapts the snow evaporation (sublimation) equation to field conditions (dimensionless)

[3]MGMELT is the maximum rate of snowmelt by ground heat, in depth of water equivalent per day. This is the value that applies when the pack temperature is at the freezing point (in./day)

[4]LZSN is the lower-zone nominal storage (in.)

[5]INFILT is an index to the infiltration capacity of the soil (in./hr)

[6]LSUR is the length of the assumed overland flow plane (ft)

[7]SLSUR is the slope of the assumed overland flow plane (dimensionless)

[8]KVARY is a parameter that affects the behavior of ground-water recession flow, enabling it to be nonexponential in its decay with time (1/in.)

[9]AGWRC is the basic ground-water recession rate if KVARY is zero and there is no inflow to ground water (rate of flow today/rate yesterday) (1/day)

[10]NSUR is Manning's n for the assumed overland flow plane (dimensionless)

[11]INTFW is the interflow inflow parameter (dimensionless)

[12]IRC is the interflow recession parameter. Under zero inflow, this is the ratio of interflow outflow rate today/rate yesterday (1/day)

[13]MON-INTERCEP is the interception storage capacity at the beginning of each month. Twelve values were determined, one for each month. (in.)

[14]MON-MANNING is the monthly value of Manning's n for overland flow. Twelve values were determined, one for each month. (dimensionless)

[15]MON-LZETP is the lower-zone evapotranspiration parameter at the beginning of each month. Twelve values were determined, one for each month. (dimensionless)

[16]MON-UZSN is the upper-zone nominal storage at the start of each month. Twelve values were determined, one for each month. (in.)

Table 6. Measured water balances and water balances simulated with the Hydrological Simulation Program–Fortran (HSPF) for the Jack and Okabena Creek Basins of the Heron Lake Basin, Minnesota, 1991–96

[in., inch; Percentage error simulations are: very good (less than 10 percent), good (10–15 percent), and fair (15–25 percent)]

				Okabena Creek					
	Jack Creek			With diversion			Without diversion		
Year	Measured runoff (in.)	Simulated runoff (in.)	Error (percent)	Measured runoff (in.)	Simulated runoff (in.)	Error (percent)	Measured runoff (in.)	Simulated runoff (in.)	Error (percent)
May to November 1991	3.55	3.74	5.35	4.92	5.28	7.32	4.62	5.30	14.71
April to November 1992	5.90	5.78	-2.03	6.61	7.83	18.46	6.21	7.90	27.21
March to November 1993	18.35	18.44	0.49	23.71	16.65	-29.78	22.26	16.70	-24.98
April to November 1994	6.92	7.11	2.75	7.08	7.65	8.05	6.64	7.63	14.91
March to December 1995	8.55	10.17	18.95	8.77	11.63	32.61	8.23	11.62	41.19
April to August 1996	4.33	4.02	-7.16	4.49	3.16	-29.62	4.22	3.19	-24.41
Total	47.60	49.26	3.49	55.58	52.20	-6.08	52.18	52.34	0.31

the simulation fit was only fair (between 15 and 25 percent). In contrast, the fits for the Okabena Creek Basin simulation with diversion are very good for two years, fair for one year, and less than fair for three years (table 6). The fit for the simulation without diversion is good for two years, fair for two years, and less than fair for two years. Annual percentage errors for the Okabena Creek Basin simulations were both positive and negative, indicating that the two simulations both oversimulated and undersimulated measured discharges during the annual monitoring periods.

Model-verification statistics suggest that the simulated monthly discharges for Jack and Okabena Creek are satisfactory representations of measured monthly discharges during 1991–96. Coefficients of model-fit efficiency and correlation coefficients for the Jack and Okabena Creek Basin simulations are presented in table 7. The coefficients of model-fit efficiency ranged from 0.83 to 0.85, with the highest value calculated for the Okabena Creek simulation without the diversion. The correlation coefficients for Jack and Okabena Creek simulations ranged from 0.929 to 0.932 (table 7). These coefficients of model-fit efficiency and correlation coefficients are comparable to coefficients for other calibrated HSPF models reported in the literature (Duncker and Melching, 1998, p. 18–19, 51).

On a monthly basis, the percentage errors were less than 10 percent (very good) for 10 of the 32 months of simulation for the Jack Creek Basin and the Okabena Creek Basin with the diversion (table 7). The fits were very good for only 7 months of the Okabena Creek Basin simulation without the diversion. Simulated discharges for 17 of the 32 months of simulation for the Jack Creek Basin were within 25 percent of measured discharges (fair or better), whereas 15 months of simulated discharge for both Okabena Creek Basin simulations are within 25 percent of measured discharges.

Visually, the simulated daily discharge for the Jack Creek Basin matches the measured daily discharge record well for 1991–96 (fig. 17). Simulated peak- and base-flow values were similar to mimic measured-flow values throughout the simulation. Notable exceptions were simulations of peak flows during snowmelt and spring storms during 1993, peak flows during 1995, and an oversimulation of fall streamflow during 1995. The undersimulation of runoff during April 1993 could be the result of inaccurate representation of rainfall in the basin or undersimulation of April soil moisture resulting from snowmelt simulated too early, during February and March. The oversimulation of peak runoff following storms during May 1993 and October 1995 could be the result of inaccurate representation of rainfall caused by the low density of rain gages in the basin. Rainfall may have been inaccurately represented even though daily rainfall data collected at 17 volunteer sites was converted to hourly values. Also, stream flows were very low for a month prior to the October 1995 storms (fig. 17). The model may have oversimulated the amount of soil moisture during this low-discharge period, resulting in an oversimulation of the runoff from the following storms.

On a daily basis, the matches between simulated and measured discharge for both simulations of the Okabena Creek Basin were not as good as the match for the Jack Creek Basin simulation (fig. 17). Peak-flow matches were poor for storms during June 1991, May 1992, May 1993, August 1994, April 1995, and June 1996. For these six storms, runoff for three storms was undersimulated and runoff for the other three storms was oversimulated. These poor fits are not unexpected because similar results were seen in the Elk and Middle/Upper Okabena Creek Subbasin simulations for 1995–97 (figs. 15 and 16). The match between simulated and measured discharge during low-flow conditions for the Okabena Creek Basin without the diversion is very good (fig. 17).

Results from verification vary between the Jack Creek Basin and the Okabena Creek Basin simulations. Annual and monthly percentage errors, model statistics, and visual inspection of daily discharge values for the Jack

Table 7. Model-verification statistics for the Jack and Okabena Creek Basins of the Heron Lake Basin, Minnesota, 1991–96, simulated with the Hydrological Simulation Program–Fortran (HSPF)

[Simulation of a 32-month period]

	Jack Creek	Okabena Creek	
		With diversion	Without diversion
Coefficient of model-fit efficiency	0.83	0.83	0.85
Correlation coefficient	.931	.929	.932
Number of months when the difference between simulated and observed average monthly discharge was less than 10 percent (very good fit)	10	10	7
Number of months when the difference between simulated and observed average monthly discharge was less than 25 percent (fair fit or better)	17	15	15

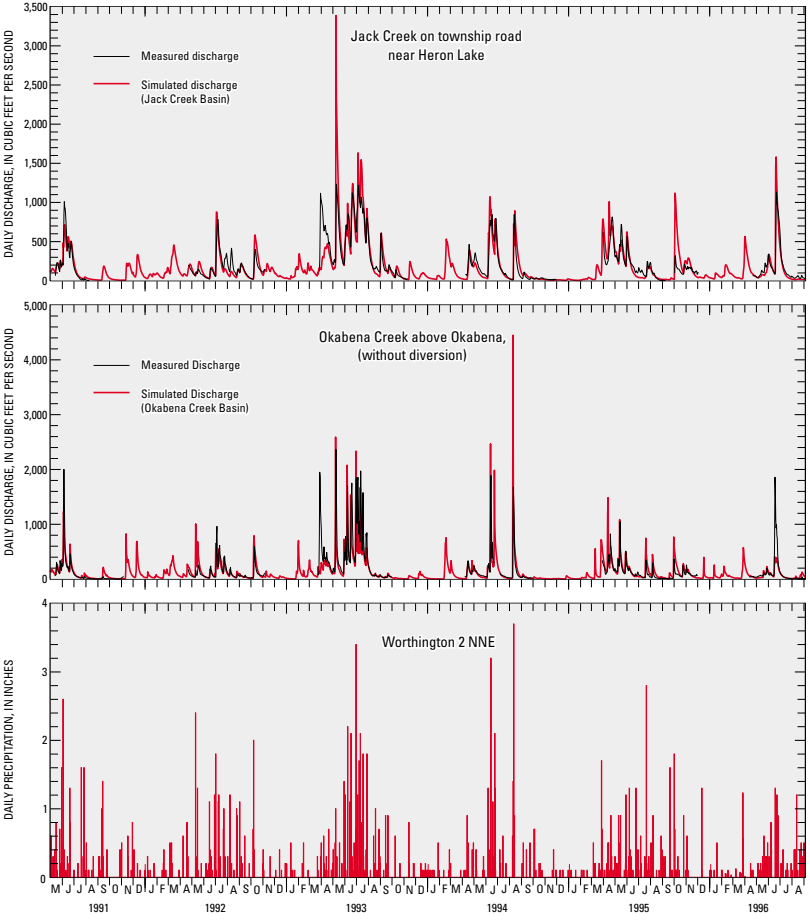


Figure 17. Measured discharge and discharge simulated with Hydrological Simulation Program-Fortran (HSPF) for Jack Creek on Township Road near Heron Lake and Okabena Creek above Okabena (without diversion) gages and daily precipitation for Worthington 2 NNE weather station, Minnesota, May 1991 - August 1996.

Creek Basin simulation indicate that the simulation represents measured discharge quite well. The simulation did not match peak flows well during some storms, probably because the precipitation gage network represented rainfall inaccurately. Annual percentage error and visual inspection of the two Okabena Creek Basin simulations indicate that simulated stream discharges are, at best, only a fair representation of measured discharge data, in part because of a lack of diversion records.

Characterization of rainfall-runoff response

Best-fit calibrations of the subbasin simulations indicate that the rainfall-runoff response is uniform throughout the Heron Lake Basin because the pervious-land-segment parameters are very similar for the five subbasins (table 5). Analyses of calibrated storm simulations show that runoff varies linearly with rainfall, with deviations from this linear relation resulting from variations in soil moisture, rainfall intensity, and rainfall distribution. The simulated rainfall-runoff relation is affected by lakes in the basin, but is not affected by changes in slope and topography within the basin.

Rainfall and simulated runoff values for selected storms were compared to assess the rainfall-runoff relation in the basin. Total simulated surface and interflow runoff, which represent direct runoff to the streams, were determined for seven storms in the Jack and Okabena Creek Basins and five storms in the subbasins, and were plotted against total rainfall for the storms (fig. 18).

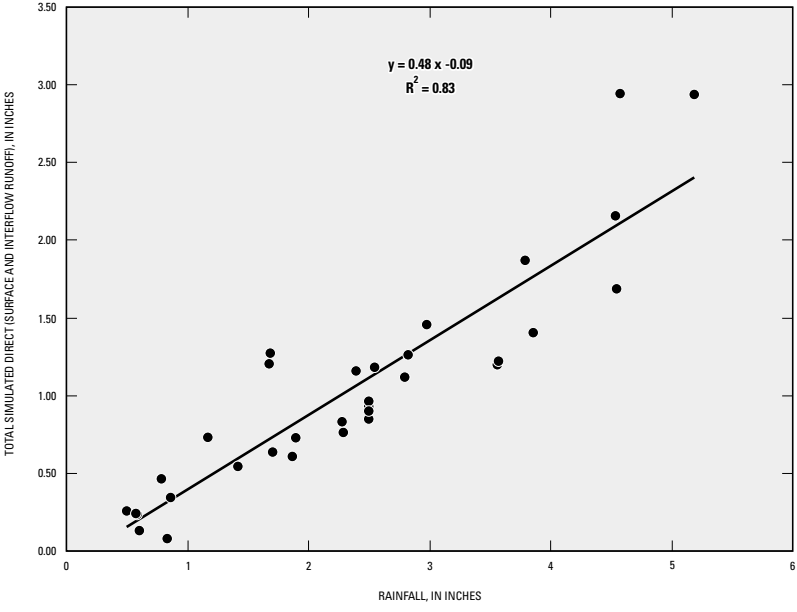


Figure 18. Total simulated direct (surface and interflow) runoff obtained from the Hydrological Simulation Program-Fortran (HSPF) simulations in relation to rainfall for selected storms in the Heron Lake Basin, Minnesota.

The following storms were evaluated for the subbasin simulations: September 30–October 1, 1995; May 27–28, 1996; June 16, 1996; April 5, 1997; and June 29, 1997. For the Jack and Okabena Creek Basin simulations, runoff from the following storms was evaluated: April 12–13, 1991; August 29–30, 1993; May 8–12, 1995; May 26–27, 1995; September 30–October 1, 1995; May 27–28, 1996; and June 16, 1996. A linear regression model for this data has an R^2 value of 0.83, a slope of 0.48, and a y-intercept of -0.09.

In this linear model, the slope represents the portion of total rainfall that becomes direct runoff (48 percent). The rest of the rainfall (52 percent) either is lost to the atmosphere through evapotranspiration, is stored in unsaturated soils, enters plants, or is recharged to the ground-water system. Increased variability at high rainfall values may indicate a decreasing importance of soil-moisture storage in the relation during high rainfall. The x-intercept of the relation (0.19) can be related to the minimum amount of rainfall, in inches, required for runoff to occur in the basin. From analysis of the measured rainfall-runoff responses in the basin, this value is more representative of hydrologic conditions present during the spring months, when water storage is high in soils and geologic materials. The linear relation is a poor fit to some of the higher rainfall storms (rainfall more than about 4 inches) (fig. 18). This poor fit may indicate that the slope of the relation is changing as rainfall amounts exceed a threshold value for the soil's infiltration ability. However, there is insufficient data to confirm this change in the relation.

Variable amounts of water present in the simulated upper and lower zones of the model prior to storms account for some of the error in the linear rainfall-runoff relation. To reduce this error, a multiple regression analysis of total direct runoff, rainfall, and total simulated upper- and lower-zone storage prior to rainfall was done, producing the following relation:

$$RO = 0.57RF + 0.16SS - 0.83$$

where RO is the total simulated direct runoff during and following a storm (in.),

RF is the total rainfall during a storm (in.), an

SS is the total simulated upper- and lower-zone storage prior to a storm (in.).

The R^2 value for this relation is 0.87.

Under high moisture-storage conditions commonly present during the spring months (total simulated upper- and lower-zone storage is approximately 4.5 to 5.0 in.), less than 0.2 in. of rainfall is required to produce direct runoff in the basin. Under low moisture-storage conditions (total simulated upper- and lower-zone storage is approximately 2.0 in.), runoff does not occur until 0.9 in. of rain has fallen. This relation correlates well with measured rainfall and runoff data. Error in this relation may result from variations in the distribution, intensity, timing, and duration of rainfall; evapotranspiration rates; losses to ground-water recharge; and the presence of lakes in the basin.

The model simulations were particularly sensitive to spatial and temporal variations in rainfall. This sensitivity is indicated in the simulated runoff responses to four storms at Jack Creek near Kinbrae and Elk Creek on County State Aid Highway 1, near Brewster streamflow-gaging stations. The four storms are June 16, 1996; August 10, 1996; April 5, 1997; and June 29, 1997 (figs. 13 and 15). Rainfall distribution can vary widely in the Heron Lake Basin. For example, during the June 16, 1996 storm, daily rainfall amounts were high in the north, 3.76 and 4.92 in. at the North Branch Jack Creek and Wilmont Stations, respectively. In the south, daily rainfall amounts were lower, 1.30 and 1.97 in. at the Worthington 2 NNE and Okabena Creek near Brewster gages, respectively. The greatest amounts of rainfall in the Elk Creek Subbasin occurred in the northern parts of the subbasin, relatively far from the Elk Creek streamflow-gaging station (fig. 12); whereas, the heavy rainfall occurred throughout the Upper Jack Creek Subbasin. As a result, most runoff in the Elk Creek Subbasin had a longer travel time to the gaging station than runoff in the Upper Jack Creek Subbasin. The observed runoff response in both subbasins confirms this concept. Runoff response from this storm initially occurred three hours after initial rainfall at the Upper Jack Creek Subbasin gaging station and five hours after initial rainfall at the Elk Creek Subbasin gaging station. Peak flow at the Upper Jack Creek gaging station was 892 ft^3/s occurring 23 hours after initial rainfall, and peak flow at the Elk Creek gaging station was 1,330 ft^3/s occurring 37 hours after initial rainfall.

Seasonal variations in the rainfall-runoff response result from variations in soil-moisture content and evapotranspiration rates. In the spring, soil-moisture contents are relatively high because of snowmelt, high rainfall amounts, and low evapotranspiration rates. Therefore, the amount and distribution of rainfall that falls on the ground tends to govern the runoff response. For example, the storm on April 5, 1997 lasted for 16 hours, with a total of 1.37 and 1.80 in. at the northern precipitation gaging stations (fig. 13) and 0.76 and 0.90) in. of rain at the southern precipitation gaging stations (fig. 15). Within an hour of initial precipitation, runoff increases occurred at both the Elk Creek and Upper Jack Creek gaging stations because of the high amounts of antecedent soil moisture present following snowmelt. Peak flow at the Upper Jack Creek gaging station was 495 ft^3/s and occurred 26 hours after the initial precipitation; whereas, peak flow at the Elk Creek gaging station was 675 ft^3/s and occurred 29 hours after the initial start of precipitation.

High evapotranspiration rates in the summer result in a depletion of soil moisture, substantially affecting the rainfall-runoff relation. Most of summer precipitation that reaches land surface enters the moisture-depleted soil, greatly reducing the amount of runoff. This effect can be seen in results from model simulations of the August 10, 1996 storm. Prior to August 10, 1996, antecedent soil moisture was low in the basin as indicated by low stream-discharges (both less than 5 ft^3/s) at the Elk Creek and Upper Jack Creek gaging stations. Simulation results of the August 10, 1996 storm indicated that much of the precipitation that fell on the ground entered a moisture-depleted soil. During the storm, the daily rainfall amounts were quite similar to amounts measured during the April 5, 1997 storm, except that the amounts were greater in the south than the north. Daily rainfall amounts varied from 0.76 and 1.26 in. for the northern stations (fig. 13), to 1.10 and 2.76 in. for the southern precipitation gages, with the greater rainfall amounts occurring near Brewster (fig. 15). Compared to the April 5, 1997 storm, little runoff occurred following the August 10, 1996 storm. The initial rise in discharge at both gaging stations began two hours after initial rainfall, which was much later than the initial discharge rise from the April 5, 1997 storm. The longer time for the initial rise resulting from the August 10, 1996 storm is reflective of drier soils. Peak flows at the Elk Creek gaging station following the August 10, 1996 storm occurred within 4 hours, reaching only a maximum discharge of 24.5 ft^3/s. Discharge at the Elk Creek gaging station quickly dropped back to values prior to the storm within 48 hours. The runoff response at the Upper Jack Creek gaging station to the August 10, 1996 storm was longer than the response at the Elk Creek gaging station. Peak flow at the Upper Jack Creek gaging station occurred 38 hours following initial precipitation, peaking at only 14.9 ft^3/s. This gradual rise in Upper Jack Creek probably resulted from more rainfall in the western portion of the basin than in the eastern portion, resulting in a relatively long time for most of the water to reach the gaging station.

Soil-moisture has less effect on rainfall-runoff response during very intense storms. For example, during the eight-hour storm on June 29, 1997, more than 0.75 in. of rain occurred throughout the basin during the first hour of the storm. The initial discharge increase at the Elk Creek and Upper Jack Creek gaging stations occurred within an hour, even though soil-moisture was low. Low soil-moisture contents are corroborated by low discharge measured prior to the June 29, 1997 storm (25.7 and 29.9 ft^3/s for the Elk and Upper Jack Creek gaging stations, respectively) and low water storage in the model simulations (a total of 2 in. in the upper- and lower-zones of the simulations). The rapid discharge responses to the rainfall event resulted from high-intensity rainfall during the storm.

The presence of lakes in the East Graham Lake Outlet Subbasin had a significant effect on the rainfall-runoff response. The time from initial rainfall to peak flow at the East Graham Lake Outlet gaging station was much longer than any time from initial rainfall to peak flow at the other subbasin gaging stations, even though the East Graham Lake Outlet Subbasin is one of the smallest subbasins (table 1). During most storms, time from initial rainfall to peak runoff at the mouth of the other four subbasins was between 5 to 38 hours, depending upon the intensity, duration, and spatial extent of the storm. The time from initial rainfall to peak runoff at the mouth at the East Graham Lake Outlet gaging station occurred between 100 to 250 hours. The large water-storage capacity in the Graham Lakes System attenuates the effect of rainfall on runoff. The presence of the lakes increased the time from initial rainfall to peak flow, decreased the peak flow value, and increased the total runoff-response time. For example, during the June 16–17, 1996 storm, the peak flow at the East Graham Lake Outlet gaging station was 180 ft^3/s, 79 hours after initial rainfall. Comparatively, the peak flow at the Upper Jack Creek gaging station was 892 ft^3/s, 23 hours after initial rainfall, and the peak flow at the Elk Creek gaging station was 1,330 ft^3/s, 37 hours after initial rainfall. The duration of the runoff event for the Upper Jack Creek, Elk Creek, and East Graham Lake Outlet gaging stations were 22, 23, and 31 days, respectively, for the June 16–17 storm.

The presence of more lakes and other surface water bodies, the larger basin area, and the longer mainstem channel in the Jack Creek Basin resulted in a more gradual rainfall-runoff response in the Jack Creek Basin than in the Okabena Creek Basin in the model simulations (fig. 17). The Okabena Creek Basin is approximately 70 percent the size of the Jack Creek Basin. Peak flows at the Jack Creek Basin gaging station usually occur later than peak flows at the Okabena Creek Basin gaging station. For example during the June 16, 1996 storm, peak flow at the Okabena Creek gaging station was 2,020 ft^3/s, 54 hours after initial rainfall. Peak flow at the Jack Creek gaging station was 1,180 ft^3/s, 85 hours after initial rainfall. The duration of runoff response for the June 16, 1996 storm was longer at the Jack Creek gaging station than the Okabena Creek gaging station, lasting 29 and 22 days, respectively.

The HSPF simulations of the basins and subbasins in the Heron Lake Basin are not substantially sensitive to variations in slope and topography. The simulations mimicked measured runoff well, even though slope and topography were not taken into account in the land segmentation process. Other hydrologic models may be more sensitive to changes in slope and topography and, therefore, may produce different results.

ESTIMATION OF THE EFFECTS OF WETLAND RESTORATION ON RUNOFF IN THE HERON LAKE BASIN

The restoration of wetlands in the Heron Lake Basin may reduce peak and total runoff by increasing available depressional storage and by increasing the potential for evaporation and transpiration. For example, in the East Graham Lake Outlet Subbasin, which has a larger percentage of lakes and wetlands than the other subbasins, peak runoff was substantially less than in the other subbasins.

Approximately 1,100 acres of wetlands are present in the Heron Lake Basin, with 800 of these acres being restored wetlands (Randy Markl, Minnesota Department of Natural Resources, written commun., 1998). Of the 1,100 acres, about 800 acres of wetlands are within the simulated portion of the Heron Lake Basin.

Model simulations using the calibrated HSPF model were conducted to assess the hydrologic impact of wetland restoration on runoff response in the Heron Lake Basin. Modeling scenarios were designed to address the effect of adding new wetlands and the location of these wetlands on rainfall-runoff relations within the Heron Lake Basin. The simulations were not designed to distinguish between different types of wetlands. Wetlands are represented in the model as wetlands/water land segments, which represent wetlands, lakes and other water bodies not connected to the reach/reservoir system.

Riparian wetlands adjacent to streams provide hydraulic and hydrologic benefits. Additional storage in riparian wetlands and increased resistance to downstream flow provided by additional wetland vegetation reduces peak discharges following storms. These hydraulic effects on flood flows of riparian wetlands are not included in the simulated wetland restoration scenarios because untestable modifications would be necessary to the tables (FTABLEs) that describe the relation between depth in a reach/reservoir and its volume, surface area, and discharge. The simulated wetland restoration scenarios primarily focus on upland storage provided by wetlands, and, thus, the total reduction of peak flows resulting from a program of upland and riparian wetland restoration is underestimated in the simulations.

Initial land-segment parameters were estimated based on an HSPF simulation of the nearby Watonwan River Basin, which was done by the Minnesota Pollution Control Agency (Ron Jacobson, Minnesota Pollution Control Agency, written commun., 1998). The wetlands/water land segments simulate wetlands and other water bodies in the basin through (1) decreases in the lower-zone nominal storage, interflow inflow, Manning's n value, monthly interception storage capacity, and monthly lower-zone evapotranspiration parameter values, and (2) increases in upper-zone nominal storage and infiltration capacity index values relative to cropland (table 5).

The ability to effectively calibrate the wetlands/water land-segment parameters was poor because less than 1 percent of the Heron Lake Basin consists of wetlands. As a result, manipulation of the wetlands/water land-segment parameters had little effect on simulated runoff during calibration. Therefore, it is important to remember that the wetlands/water land-segment parameters were not fully calibrated when reviewing the results of the wetland-restoration simulations. If wetlands are restored in the basin and additional runoff record is collected, it may be possible to improve the calibration of the wetlands/water land-segment parameters for future wetland-restoration simulations.

Five wetland-restoration simulations were conducted for each of the five subbasins using data from August 1995 through August 1997 and for the Jack Creek and Okabena Creek Basins using data from May 1991 through August 1996 (table 8). In the simulations, wetland acreage was increased through the conversion of corn and soybean land segments to wetlands/water land segments. In practice, most of the actual wetland restoration projects involve conversion of low-production croplands to wetlands. The percentages of wetlands in a basin or subbasin for each simulation ranged from double the current acreage of wetlands to 45 percent of basin or subbasin area (table 8). About 45 percent of Jackson and Nobles Counties were wetlands before European settlement (Anderson and Craig, 1984). The Elk Creek Subbasin currently has no wetlands, and, therefore, 100 acres of corn and soybean land segments were arbitrarily converted to wetlands/water land segments for the first wetland restoration simulation. The 5 percent and 10 percent simulations were not run for the East Graham Lake Outlet Subbasin because 6.4 percent of the subbasin is currently wetlands and other water bodies.

For each simulation, the total simulated direct (surface and interflow) runoff was calculated for seven storms in the Jack Creek and Okabena Creek basins and five storms in the subbasins. The discharge and timing of peak runoff also was determined for each of the storms. The selection of storms was based on the relative isolation of a storm from other storms. The more isolated storms offered the best opportunity to assess direct runoff values. However, during some of the simulations, direct runoff values could not be determined because subsequent rainfall occurred prior to the cessation of runoff.

The addition of wetlands/water land segments reduced the amount of runoff in all simulations, with the amount of reduction increasing with additional wetland acreage (tables 9 and 10). Doubling the acreage of existing wetlands reduced the amount of runoff

Table 8. Wetlands/water land-segment acreage used in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of subbasins in the Heron Lake Basin, Minnesota

[All values are acres, except values in parentheses are percent of basin in wetlands/water; ---,no value]

Subbasin or basin	Calibrated model wetlands/water area	Wetland-restoration simulations				
		Doubling current wetlands/water area	5 percent of basin area converted to wetlands/water	10 percent of basin area converted to wetlands/water	20 percent of basin area converted to wetlands/water	45 percent of basin area converted to wetlands/water
Upper Jack Creek	96.4 (< 1)	192.8 (1)	1,780.3	3,560.5	7,121.0	16,022.3
North Branch Jack Creek	469.5 (1)	939.0 (2)	2,275.0	4,549.9	9,099.8	20,474.6
East Graham Lake Outlet	1467.8 (6)	2,935.6 (13)	---	---	4,596.0	10,341.1
Elk Creek	0	100.0 (< 1)	1,953.7	3,907.4	7,814.8	17,583.3
Middle/Upper Okabena Creek	163.1 (1)	326.2 (2)	978.5	1,957.0	3,914.0	8,806.5
Jack Creek	2,122.7 (2)	4,245.2 (3)	8,307.3	13,679.0	26,082.0	58,687.0
Okabena Creek	185.3 (< 1)	370.6 (1)	4,563.6	9,127.2	18,254.2	41,072.0

Table 9. Total direct runoff for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of subbasins in the Heron Lake Basin, Minnesota

[All values in inches of runoff, except values in parentheses are percent reduction in total runoff; ---, no value]

Subbasin	Storm	Calibrated model	Wetland-restoration simulations				
			Doubled current wetlands/water area	5 percent of basin area converted to wetlands/water	10 percent of basin area converted to wetlands/water	20 percent of basin area converted to wetlands/water	45 percent of basin area converted to wetlands/water
Upper Jack Creek	Sept. 30–Oct. 1, 1995	0.93	0.93 (0)	0.88 (5)	0.83 (11)	0.73 (22)	0.48 (48)
	May 27–28, 1996	.46	.46 (0)	.44 (4)	.42 (9)	.37 (20)	.24 (48)
	June 16, 1996	2.94	2.93 (0)	2.80 (5)	2.64 (10)	2.34 (20)	1.58 (46)
	April 5, 1997	1.21	1.20 (0)	1.15 (5)	1.09 (10)	.96 (20)	.65 (46)
	June 29, 1997	1.22	1.22 (0)	1.16 (5)	1.10 (10)	.98 (20)	.66 (46)
North Branch Jack Creek	Sept. 30– Oct. 1, 1995	.90	.89 (1)	.86 (4)	.81 (11)	.72 (20)	.47 (48)
	May 27–28, 1996	.46	.46 (0)	.44 (4)	.42 (9)	.37 (20)	.25 (46)
	June 16, 1996	2.94	2.91 (1)	2.82 (4)	2.67 (9)	2.36 (20)	1.59 (46)
	April 5, 1997	1.27	1.26 (0)	1.22 (4)	1.16 (9)	1.02 (20)	.69 (46)
	June 29, 1997	1.20	1.19 (0)	1.15 (4)	1.09 (9)	.97 (21)	.66 (45)
East Graham Lake Outlet	Sept. 30–Oct. 1, 1995	.43	.40 (7)	---	---	.36 (16)	.25 (42)
	May 27–28, 1996	.13	.12 (8)	---	---	.11 (15)	.08 (38)
	June 16, 1996	1.40	1.31 (6)	---	---	1.19 (15)	.80 (43)
	April 5, 1997	.55	.51 (7)	---	---	.48 (13)	.34 (38)
	June 29, 1997	1.87	1.74 (7)	---	---	1.59 (15)	1.07 (43)
Elk Creek	Sept. 30–Oct. 1, 1995	.96	.96 (0)	.91 (5)	.86 (10)	.76 (21)	.52 (46)
	May 27–28, 1996	.24	.24 (0)	.22 (8)	.21 (12)	.19 (21)	.13 (46)
	June 16, 1996	---	---	---	---	---	---
	April 5, 1997	.73	.73 (0)	.69 (5)	.66 (10)	.58 (21)	.40 (45)
	June 29, 1997	1.16	1.15 (0)	1.10 (5)	1.04 (10)	.92 (21)	.62 (47)
Middle/Upper Okabena Creek (with diversion)	Sept. 30–Oct. 1, 1995	.85	.84 (1)	.82 (4)	.78 (8)	.70 (18)	.50 (41)
	May 27–28, 1996	.26	.26 (0)	.25 (4)	.23 (12)	.21 (19)	.14 (46)
	June 16, 1996	---	---	---	---	---	---
	April 5, 1997	---	---	---	---	---	---
	June 29, 1997	.64	.63 (2)	.61 (4)	.58 (9)	.52 (19)	.37 (42)

by less than 3 percent, except for the East Graham Lake Outlet Subbasin, which has a large acreage of wetlands and lakes. Increasing the wetland acreage to 45 percent of basin or subbasin area reduced the amount of runoff by as much as 48 percent. Except for the East Graham Lake Outlet Subbasin, the amount of runoff reduction among different wetland restoration simulations varied little among the subbasins and basins.

Total direct runoff values were plotted against total rainfall for the storms, and linear regression models were fitted for each series of wetlands/water land-segment acreage. The slope, x-intercept, and R^2 values for these models and the linear regression model fitted for the calibrated-model results are listed in table 11. The addition of wetland acreage gradually reduced the slopes of the linear regressions from 0.48 in the calibrated model to 0.26 in the simulation with 45 percent of the basin's drainage area consisting of wetlands and water. These slopes indicate that the portion of total storm rainfall that becomes direct runoff will be reduced by 46 percent when 45 percent

Table 10. Total direct runoff for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of Jack Creek and Okabena Creek Basins in the Heron Lake Basin, Minnesota

[All values in inches of runoff, except values in parentheses are percent reduction in total runoff; ---, no value]

Basin	Storm	Calibrated model	Wetland-restoration simulations				
			Doubled current wetlands/water area	5 percent of basin area converted to wetlands/water	10 percent of basin area converted to wetlands/water	20 percent of basin area converted to wetlands/water	45 percent of basin area converted to wetlands/water
Jack Creek	April 12–13, 1991	1.08	1.06 (2)	1.02 (6)	.97 (10)	.86 (20)	.57 (47)
	Aug. 29–30, 1993	.83	.82 (1)	.80 (4)	.75 (10)	.67 (19)	.46 (45)
	May 8–12, 1995	.74	.74 (0)	.71 (4)	.68 (8)	.60 (19)	.41 (45)
	May 26–27, 1995	.74	.73 (1)	.70 (5)	.67 (9)	.59 (20)	.39 (48)
	Sept. 30–Oct. 1, 1995	1.69	1.67 (1)	1.61 (5)	1.52 (10)	1.35 (20)	.90 (47)
	May 27–28, 1996	.34	.34 (0)	.33 (3)	.31 (9)	.27 (21)	.18 (47)
	June 16, 1996	2.16	2.13 (2)	2.06 (5)	1.96 (9)	1.74 (19)	1.17 (46)
Okabena Creek (with diversion)	April 12–13, 1991	1.46	1.46 (0)	1.39 (5)	1.31 (10)	1.16 (21)	.78 (47)
	Aug. 29–30, 1993	.08	.08 (0)	.08 (0)	.07 (13)	.07 (13)	.05 (38)
	May 8–12, 1995	1.18	1.18 (0)	1.12 (5)	1.06 (10)	.95 (19)	.66 (44)
	May 26–27, 1995	.60	.60 (0)	.57 (5)	.54 (10)	.48 (20)	.33 (45)
	Sept. 30–Oct. 1, 1995	1.26	1.26 (0)	1.20 (5)	1.14 (10)	1.01 (20)	.69 (45)
	May 27–28, 1996	.24	.24 (0)	.23 (4)	.22 (8)	.19 (21)	.13 (46)
	June 16, 1996	---	---	---	---	---	---

Table 11. Slopes, x-intercepts, and R^2 values for linear regression models of total direct runoff as a function of rainfall for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of basins and subbasins in the Heron Lake Basin, Minnesota

Wetland-restoration simulation	Slope	x-intercept	R^2 values
Calibrated model	0.48	0.19	0.83
Doubled current wetlands/water area	.47	.17	.82
5 percent of basin or subbasin area converted to wetlands/water	.46	.17	.81
10 percent of basin or subbasin area converted to wetlands/water	.44	.18	.81
20 percent of basin or subbasin area converted to wetlands/water	.39	.18	.83
45 percent of basin or subbasin area converted to wetlands/water	.26	.15	.83

of the basin is converted to wetlands. Doubling the current wetland acreage would only reduce the portion of total storm rainfall that becomes direct runoff by 2 percent. Minor variations in the x-intercept and R^2 values of the regression models resulted for the different wetland-restoration simulations. These x-intercept values indicate that additional wetland acreage has little effect on the minimum amount of rainfall, in inches, required for runoff to result from the basin.

The effect of additional wetlands on peak runoff varied among subbasins and storms, depending upon antecedent soil-moisture content, the magnitude of the peak flow, and the current presence of wetlands and lakes (tables 12 and 13). Peak runoff was reduced in all of the simulations with the addition of wetlands, except following two storms in the East Graham Lake Outlet Subbasin, one storm in the Elk Creek Subbasin, and one storm in the Okabena Creek Basin. The largest reductions in peak runoff with additional wetlands tended to occur following late-spring, summer, and fall storms, when soil moisture was low. Additional wetlands had less of an effect on storms occurring in the spring, when soil moisture was high. The average and median percent reduction in simulated peak flow from the current landscape to 45 percent of the basin acreage in wetlands for April and May storms were 19.2 and 10.3 percent; whereas, these values for storms between June and October were 25.1 and 29.9 percent. The addition of wetlands tended to reduce peak runoff to a larger extent for storms resulting in larger peak flows. Additional wetlands had a smaller effect on reducing peak flows in basins where more wetlands and lakes currently are present. Simulated peak flows following storms in the East Graham Lake Outlet Subbasin tended to increase or be reduced to a much smaller extent with the addition of wetlands than peak flows in the other subbasins (table 12). Reductions in peak flow may be occurring in upper portions of the East Graham Lake Outlet Subbasin, but available storage in the Graham Lake System, located in the lower portion of the simulated subbasin, may be minimizing the effect of these reductions at the downstream gaging station.

The time interval between initial rainfall and peak runoff increased with the addition of wetlands in most of the simulations of Jack Creek Basin and its subbasins, but changed little in simulations of Okabena Creek Basin and its subbasins (tables 12 and 13). The time increase tended to be greater in simulations of smaller peak flows, where the percentage of total storm runoff stored in the additional wetlands was larger.

The effect of location of restored wetlands on rainfall-runoff response was assessed in simulations of the Jack Creek and Okabena Creek Basins. In these simulations, 8,000 acres of corn and soybean land segments were converted to wetlands in different subbasins. For the Jack Creek Basin, wetland acreage was increased in separate simulations for five subbasins: Upper Jack Creek, North Branch Jack Creek, East Graham Lake Outlet, Middle Jack Creek, and Lower Jack Creek. For the Okabena Creek Basin, wetland acreage was increased in separate simulations for three subbasins: Elk Creek, Middle/Upper Okabena Creek, and Lower Okabena Creek.

Effects of these wetland restorations on total runoff, peak runoff, and time between initial rainfall and peak runoff values are listed in tables 14 and 15. Reductions in the simulated total and peak runoff from the Jack Creek Basin for most of the simulated storms were largest when wetland restorations were simulated in the North Branch Jack Creek or the Upper Jack Creek Subbasins. The time increase between initial rainfall and peak runoff also was greater when additional wetlands were simulated in these two subbasins for most of the storms. In the Okabena Creek Basin, reductions in simulated peak runoff for most of the storms were largest when wetland restorations were simulated in the Lower Okabena Creek Subbasin. The reduction in total runoff varied little between wetland-restoration location simulations in the Okabena Creek Basin. Similarly, the time between initial rainfall and peak runoff varied little from the calibrated model in most of the wetland-restoration location simulations in the Okabena Creek Basin.

Table 12. Peak runoff and time between initial rainfall and peak runoff for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of subbasins in the Heron Lake Basin, Minnesota

[Values in parentheses are percent reduction in peak runoff; ft^3/s, cubic feet per second; ---, no value]

				Wetland-restoration simulations									
		Calibrated Model		Doubled current wetlands/water area		5 percent of subbasin area converted to wetlands/water		10 percent of subbasin converted to wetlands/water		20 percent of subbasin converted to wetlands/water		45 percent of subbasin converted to wetlands/water	
Subbasin	Storm	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)
Upper Jack Creek	Sept. 30–Oct. 1, 1995	178	34	177 (1)	35	172 (3)	36	166 (7)	37	154(13)	39	125 (30)	44
	May 27– 28, 1996	139	38	139 (0)	39	137 (1)	39	134 (4)	40	129 (7)	42	116 (17)	46
	June 16, 1996	782	20	780 (0)	20	743 (5)	20	702 (10)	20	622 (20)	20	433 (45)	28
	April 5, 1997	407	13	406 (0)	13	392 (4)	13	376 (8)	13	344 (15)	13	270 (34)	20
	June 29, 1997	393	6	392 (0)	6	374 (5)	6	354 (10)	6	314 (20)	6	217 (45)	7
North Branch Jack Creek	Sept. 30–Oct. 1, 1995	200	30	199 (1)	31	195 (3)	32	188 (6)	33	175 (13)	36	144 (28)	44
	May 27–28, 1996	166	32	166 (0)	33	164 (1)	34	161 (3)	35	155 (7)	38	141 (15)	45
	June 16, 1996	1,580	19	1,540 (3)	19	1,400 (11)	19	1,190 (25)	20	966 (39)	20	630 (60)	20
	April 5, 1997	646	12	638 (1)	12	616 (5)	12	579 (10)	12	511 (21)	12	369 (43)	14
	June 29, 1997	576	6	567 (2)	6	544 (6)	6	504 (13)	6	426 (26)	6	283 (51)	6
East Graham Lake Outlet	Sept. 30–Oct. 1, 1995	25.3	247	25.9 (-2)	251	---	---	---	---	26.6 (-5)	256	29.1 (-15)	273
	May 27–28, 1996	36.9	156	36.6 (1)	159	---	---	---	---	36.3 (2)	159	35.2 (5)	158
	June 16, 1996	145	144	140 (3)	148	---	---	---	---	133 (8)	151	111 (23)	166
	April 5, 1997	101	98	101 (0)	100	---	---	---	---	102 (-1)	100	104 (-3)	101
	June 29, 1997	165	100	153 ((7)	109	---	---	---	---	143 (13)	114	107 (35)	131
Elk Creek	Sept. 30–Oct. 1, 1995	624	20	622 (0)	20	591 (5)	20	557 (11)	20	491 (21)	20	329 (47)	20
	May 27–28, 1996	109	24	109 (0)	24	108 (1)	24	107 (2)	24	104 (5)	24	99 (9)	25
	June 16, 1996	249	22	249 (0)	22	241 (3)	24	233 (6)	26	219 (12)	30	183 (27)	33
	April 5, 1997	227	22	227 (0)	22	228 (0)	22	229 (-1)	23	230 (-1)	23	235 (-4)	24
	June 29, 1997	802	5	800 (0)	5	761 (5)	5	719 (10)	5	635 (21)	5	429 (47)	5
Middle/Upper Okabena Creek (with diversion)	Sept. 30–Oct. 1, 1995	306	22	305 (0)	22	300 (2)	22	293 (4)	22	279 (9)	22	245 (20)	22
	May 27–28, 1996	83.6	8	83.5 (0)	8	83.3 (0)	8	83.0 (1)	8	82.4 (1)	8	80.9 (3)	8
	June 16, 1996	114	19	114 (0)	19	113 (1)	19	112 (2)	19	110 (4)	19	106 (7)	19
	April 5, 1997	149	10	149 (0)	10	149 (0)	10	148 (1)	10	148 (1)	10	147 (1)	10
	June 29, 1997	205	6	204 (0)	6	203 (1)	6	200 (2)	6	195 (5)	6	181 (12)	6

Table 13. Peak runoff and time between initial rainfall and peak runoff for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of Jack Creek and Okabena Creek Basins in the Heron Lake Basin, Minnesota

[Values in parentheses are percent reduction in peak runoff; ft^3/s, cubic feet per second; ---, no value]

				Wetland-restoration simulations									
		Calibrated Model		Doubled current wetlands/water area		5 percent of basin area converted to wetlands/water		10 percent of basin area converted to wetlands/water		20 percent of basin area converted to wetlands/water		45 percent of basin area converted to wetlands/water	
Basin	Storm	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)
Jack Creek	April 12 - 13, 1991	963	34	954 (1)	34	912 (5)	35	855 (11)	37	745 (23)	42	524 (46)	57
	Aug. 29 -30, 1993	627	87	627 (0)	88	626 (0)	88	623 (1)	89	619 (1)	91	613 (2)	95
	May 8 - 12, 1995	520	78	52 (0)	80	520 (0)	80	519 (0)	80	518 (0)	81	515 (1)	83
	May 26 - 27, 1995	654	72	651 (0)	72	636 (3)	74	615 (6)	75	572 (13)	80	482 (26)	94
	Sept. 30 - Oct. 1, 1995	1,140	54	1,130 (1)	54	1,110 (3)	54	1,060 (7)	55	970 (15)	59	799 (30)	86
	May 27 - 28, 1996	339	85	338 (0)	86	335 (1)	86	331 (2)	87	322 (5)	89	301 (11)	94
	June 16, 1996	1,670	40	1,660 (1)	40	1,610 (4)	41	1,550 (7)	42	1,410 (16)	44	1,070 (36)	51
Okabena Creek (with diver-sion)	April 12 - 13, 1991	2,130	9	2,040 (4)	9	1,940 (9)	10	1,840 (14)	10	1,640 (23)	10	1,130 (47)	11
	Aug. 29 -30, 1993	91.7	34	91.9 (0)	36	97.5 (-6)	35	105 (-15)	34	119 (-30)	34	152 (-66)	35
	May 8 - 12, 1995	1,890	120	1,890 (0)	120	1,800 (5)	120	1,710 (10)	121	1,540 (19)	121	1,090 (42)	121
	May 26 - 27, 1995	956	31	955 (0)	31	917 (4)	31	875 (8)	31	786 (18)	31	553 (42)	31
	Sept. 30 - Oct. 1, 1995	1,010	27	1,000 (1)	27	966 (4)	27	924 (9)	27	836 (17)	29	622 (38)	30
	May 27 - 28, 1996	250	28	249 (0)	28	247 (1)	28	244 (2)	28	238 (5)	28	224 (10)	28
	June 16, 1996	440	37	440 (0)	37	429 (3)	37	418 (5)	37	396 (10)	37	341 (23)	36

Table 14. Peak runoff, time between initial rainfall and peak runoff, and total runoff for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of selected subbasins of Jack Creek Basin in the Heron Lake Basin, Minnesota

[ft^3/s, cubic feet per second; in., inch]

			Wetland-restoration simulations									
	Calibrated Model		8,000 acres in Upper Jack Creek Subbasin converted to wetlands/water		8,000 acres in North Branch Jack Creek Subbasin converted to wetlands/water		8,000 acres in East Graham Lake Outlet Subbasin converted to wetlands/water		8,000 acres in Middle Jack Creek Subbasin converted to wetlands/water		8,000 acres in Lower Jack Creek Subbasin converted to wetlands/water	
Storm	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)
April 12–13, 1991	963	34	865	35	855	37	963	34	911	35	968	34
Aug. 29–30, 1993	627	87	637	87	601	90	634	88	642	87	634	87
May 8–12, 1995	520	78	519	80	519	81	522	80	521	80	516	80
May 26–27, 1995	654	72	636	72	605	76	655	72	611	80	659	72
Sept. 30–Oct. 1, 1995	1,140	54	1,090	52	1,050	57	1,140	54	1,100	54	1,130	54
May 27–28, 1996	339	85	331	87	330	87	339	85	337	86	341	86
June 16, 1996	1,670	40	1,530	40	1,540	43	1,660	40	1,640	40	1,680	40
	Total runoff (in.)		Total runoff (in.)		Total runoff (in.)		Total runoff (in.)		Total runoff (in.)		Total runoff (in.)	
April 12–13, 1991	1.08		.99		.99		1.03		1.00		1.08	
Aug. 29–30, 1993	.83		.81		.70		.83		.82		.83	
May 8–12, 1995	.74		.70		.68		.72		.69		.71	
May 26–27, 1995	.74		.68		.67		.72		.67		.73	
Sept. 30–Oct. 1, 1995	1.69		1.55		1.56		1.66		1.56		1.61	
May 27–28, 1996	.34		.31		.31		.33		.33		.34	
June 16, 1996	2.16		1.97		1.97		2.06		2.11		2.16	

Table 15. Peak runoff, time between initial rainfall and peak runoff, and total runoff for selected storms in the Hydrological Simulation Program–Fortran (HSPF) wetland-restoration simulations of selected subbasins of Okabena Creek Basin in the Heron Lake Basin, Minnesota

[ft^3/s, cubic feet per second; in., inch]

			Wetland-restoration simulations					
	Calibrated Model		8,000 acres in Elk Creek Subbasin converted to wetlands/water		8,000 acres in Middle/ Upper Okabena Creek Subbasin converted to wetlands/water		8,000 acres in Lower Okabena Creek Subbasin converted to wetlands/ water	
Storm	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)	Peak runoff (ft^3/s)	Time to peak runoff (hours)
April 12–13, 1991	2,130	9	1,900	9	1,980	9	1,790	11
Aug. 29–30, 1993	91.7	34	106	34	104	36	99.3	34
May 8–12, 1995	1,890	120	1,890	120	1,890	120	1,470	121
May 26–27, 1995	956	31	937	31	951	31	773	31
Sept. 30–Oct. 1, 1995	1,010	27	888	29	958	27	973	27
May 27–28, 1996	250	28	247	28	247	28	240	29
June 16, 1996	440	37	416	37	432	36	418	38
	Total runoff (in.)		Total runoff (in.)		Total runoff (in.)		Total runoff (in.)	
April 12–13, 1991	1.46		1.33		1.33		1.33	
Aug. 29–30, 1993	.08		.08		.08		.07	
May 8–12, 1995	1.18		1.09		1.09		1.05	
May 26–27, 1995	.60		.55		.56		.54	
Sept. 30–Oct. 1, 1995	1.26		1.14		1.16		1.15	
May 27–28, 1996	.24		.22		.22		.22	
June 16, 1996	---		---		---		---	

SUMMARY AND CONCLUSIONS

The USGS, in cooperation with the Minnesota Department of Natural Resources and Heron Lake Watershed District, conducted a study to characterize the rainfall-runoff response and to examine the effects of wetland restoration on the rainfall-runoff response within the Heron Lake Basin, southwestern Minnesota. About 93 percent of the land cover in the Heron Lake Basin consists of agricultural lands, consisting almost entirely of row crops, with less than one percent consisting of wetlands.

Annual precipitation in the Southwest Climate Division of Minnesota and annual runoff in the Des Moines River Basin have increased since the mid-1960's and the mid-1970's. The 10-year average of annual precipitation increased from 25.9 in. for 1936–45 to 27.5 in. for 1988–97. The 10-year average of annual runoff increased from 3.4 in. to 7.4 in. for the same period. Analyses of annual precipitation and annual runoff data show increasing trends in precipitation and runoff from 1947 to 1987. A double-mass analysis of the rainfall-runoff relation in the Des Moines River Basin showed that the increase in annual runoff can be explained by the increase in annual rainfall.

The Hydrological Simulation Program – Fortran (HSPF), Version 10, was calibrated to continuous discharge data and used to characterize rainfall-runoff responses in the Heron Lake Basin between May 1991 and August 1997. Simulation of the Heron Lake Basin was done as a two-step process: (1) simulations of five small subbasins using data from August 1995 through August 1997, and (2) simulations of the two large basins, Jack and Okabena Creek Basins, using data from May 1991 through September 1996. Simulations of the five small subbasins were done to determine basin parameters for the land segments and assess rainfall-runoff response variability in the basin. Simulations of the two larger basins were done to verify the basin parameters and assess rainfall-runoff responses over a larger area and for a longer time period.

Percentage errors between total simulated runoff and total measured runoff for each of the subbasins for 1995–97 were less than 10, except for the Middle/Upper Okabena Creek Subbasin simulation without the diversion. Best-fit calibrations of the five subbasin simulations indicate that the rainfall-runoff response is uniform throughout the Heron Lake Basin because the pervious-land-segment parameters are very similar for each of the five subbasins.

For the two large basins, the percentage errors between total simulated runoff and total measured runoff of the entire 1991–96 monitoring period were less than 10. Modeling errors in simulated flows during five of the six annual monitoring periods for the Jack Creek Basin are below 10 percent, indicating a very good fit. In contrast, the percentage errors between total annual simulated runoff and measured runoff for Okabena Creek Basin with the diversion were less than 10 for two years, between 15 and 25 for one year, and greater than 25 for three years. The coefficients of model-fit efficiency for monthly flows from the Jack and Okabena Creek simulations ranged from 0.83 to 0.85, with the highest efficiency value calculated for the Okabena Creek simulation without the diversion. The correlation coefficients for the Jack and Okabena Creek simulations ranged from 0.929 to 0.932. Visual inspection of daily discharge values for the Jack Creek Basin simulation indicates that HSPF does a good job of simulating measured discharge. Visual inspection of the Okabena Creek Basin simulations indicate that the simulated daily discharges are, at best, only a fair match to measured discharge data, in part because of a lack of diversion records.

Analyses of calibrated storm simulations show that storm runoff varies linearly with rainfall in the Heron Lake Basin, but deviates from this linear relation as a result of variations in soil moisture, rainfall intensity, and rainfall distribution. The simulated rainfall-runoff relation is affected by lakes in the basin, but is not affected by changes in slope and topography within the basin. Results from a linear regression analysis of total simulated direct (surface and interflow) runoff and total rainfall data indicate that 48 percent of the total rainfall for storms in the Heron Lake Basin becomes direct runoff.

A multiple regression analysis of total direct runoff, rainfall, and total simulated upper- and lower-zone storage prior to rainfall indicated that water storage in the basin is an important parameter in determining the amount of rainfall required to initiate runoff. Under high storage conditions commonly present during the spring months (total simulated upper- and lower-zone storage approximately 4.5–5.0 in.), less than 0.2 in. of rainfall is required to produce direct runoff in the basin. Runoff does not occur until 0.9 in. of rain has fallen under low storage conditions (total simulated upper- and lower-zone storage approximately 2.0 in.).

Seasonal variations in the rainfall-runoff response result from variations in soil moisture and evapotranspiration rates. In the spring, soil moisture are relatively high, and the amount and distribution of rainfall that falls on the ground tends to govern the runoff response. High evapotranspiration rates in the summer result in a depletion of moisture from the soils, substantially affecting the rainfall-runoff relation. Soil moisture has less of an effect on rainfall-runoff response during very intense rainfall events.

The effect of restoring wetlands and the location of restored wetlands on the rainfall-runoff relation within the Heron Lake Basin were investigated by running a series of hypothetical wetland-restoration modeling scenerios. Data from August 1995 through August 1997 was used in wetland-restoration simulations of the five subbasins, and data from May 1991 through September 1996 was used in wetland-restoration simulations of the Jack and Okabena Creek Basins.

Results from linear regression analysis of total simulated direct runoff and total rainfall data for simulated storms in the wetland-restoration simulations indicate that the portion of total rainfall that becomes direct runoff will be reduced by 46 percent if 45 percent of current cropland is converted to wetland. Doubling the current wetland acreage would only reduce the portion of total storm rainfall that becomes direct runoff by two percent; whereas, increasing the wetland acreage to 45 percent reduced the amount of runoff by as much as 48 percent.

The addition of wetlands reduced peak runoff in most of the simulations, but the reduction varied with antecedent soil-moisture, the magnitude of the peak flow, and the current presence of wetlands and lakes. The average and median percent reductions in simulated peak flow resulting from converting the current landscape to 45 percent wetlands were 19.2 and 10.3 percent for April and May storms; whereas, these values for June-October storms were 25.1 and 29.9 percent. The largest reductions in peak runoff tended to occur for simulations of late-spring, summer, and fall storms, when soil moisture was low, and when peak flows were larger. Restored wetlands had a smaller effect on reducing simulated peak flows in basins that have more wetlands and lakes.

Simulated total and peak runoff reductions from the Jack Creek Basin for most of the storms were the greatest when wetland restorations were simulated in North Branch Jack Creek and Upper Jack Creek Subbasins. In the Okabena Creek Basin, reductions in simulated peak runoff for most of the storms were the greatest when additional wetlands were simulated in the Lower Okabena Creek Subbasin.

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APPENDIX

This appendix contains the User's Control Input (UCI) files for the nine calibrated simulations of the five subbasins and two basins in the Heron Lake Basin. The UCI files are in this order: the six simulations for the subbasins (Upper Jack Creek, North Branch Jack Creek, East Graham Lake Outlet, Elk creek, Middle/Upper Okabena Creek with diversion, and Middle/Upper Okabena Creek without diversion) and the three simulations for the Jack Creek and the Okabena Creek Basins (Jack Creek, Okabena Creek with diversion, and Okabena Creek without diversion).

Upper Jack Creek Basin

```
RUN
GLOBAL
  Upper Jack Creek Basin
  START       1995  8 26  0  0  END    1997  8  2  0  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      25   upperjack.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   upperjack.out
END FILES
***
***  Error file:  upperjack.message
***  Output file: upperjack.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  upperjack.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND      21
      PERLND      22
      PERLND      23
      PERLND      24
      PERLND      25
      RCHRES      13
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 21 - Wetlands
***  PERLND 22 - Grasslands
***  PERLND 23 - Corn
***  PERLND 24 - Soybeans
***  PERLND 25 - Other land uses
***  RCHRES 13 - Reservior upgradient of USGS Jack Creek Gage
***
PERLND
  ACTIVITY
    <PLS >               Active Sections                              ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
   21   25    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, ATMP and SNOW Blocks,
***  simulating water flow through and snow in the system, correcting for air
***  temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
   21   25    4    4    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
```

```
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                          User  t-series Engl Metr***
                                           in  out          ***
   21     Wetlands                1    1    1    1   90    0
   22     Grasslands              1    1    1    1   90    0
   23     Corn                    1    1    1    1   90    0
   24     Soybeans                1    1    1    1   90    0
   25     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
   21   25      74.0      73.0
  END ATEMP-DAT
***
***  Elevation of the Wilmont Weather Station = 1694 ft
***  Mean elevation of PERLND 10 = 1620 ft
***  El-diff = 1694 - 1620 = 74
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                          ***
   21   25    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
   21   24      43.8     1620.       0.0      1.00       0.3
   25           43.8     1620.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                  ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                   (in/day)***
   21   25      0.10      32.0      0.05       1.5       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                          ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                           (degF)
   21   25       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
***
***  Since the Heron Lake Simulations start in either early April, late
***  April, or July (when no snow is present), no initial snow parameters
***  are necessary.  Values used in the SNOW-INIT1 Block have no impact
***  on the simulations
***
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
```

```
   21   25      0.01       0.0       1.0
  END SNOW-INIT2
***
***  Similar to SNOW-INIT1 Block, the values used in the SNOW-INIT2 Block
***  have no impact on the simulations.  All simulations begin in spring
***  or summer, when no snow is present.
***
  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
   21         1    1    1    1    0    0    0    0    1
   22         1    1    1    1    0    0    0    0    1
   23         1    1    1    1    1    1    0    0    1
   24         1    1    1    1    1    1    0    0    1
   25         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)               (1/in)    (1/day
   21            0.0     3.000     0.400     350.0     0.006     0.300     0.940
   22   24       0.0     4.200     0.025     410.0     0.006     0.300     0.940
   25            0.15    4.200     0.025     410.0     0.006     0.300     0.940
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
   21   25      35.0      30.0       2.0       2.0     0.001     0.000     0.000
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
   21          0.000     2.500       0.4     3.000     0.830     0.350
   22          0.000     1.000       0.2     3.400     0.830     0.350
   23   24     0.000     0.800       0.1     3.400     0.830     0.350
   25          0.000     1.000       0.2     3.400     0.830     0.350
  END PWAT-PARM4
***  Interception storage capacity values (CEPSC) at start of each month
***  are stored in the MON-INTERCEP table below, so the CEPSC value is
***  ignored.  Upper zone nominal storage (UZSN) also will vary monthly,
***  with values listed in the MON-UZSN table below.  Since monthly
***  Manning's n values will be used, NSUR value is ignored in model.
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
   21   25      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
***   21   25 0.03 0.03 0.02 0.01 0.01 0.04 0.10 0.15 0.17 0.12 0.03 0.03
   21      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
   22      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
   23      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
   24      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
   25      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
```

```
   23   24 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   21      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
   22      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
   23   24 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
   25      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS > Lower zone evapotranspiration parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   21      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
   22      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
   23   24 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
   25      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
   21   25       0.0       0.0      0.01       0.0      0.01      0.01      0.30
  END PWAT-STATE1
END PERLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
   13   13    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   13         6    4    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***                Name        Nexits   Unit Systems   Printer
*** RCHRES                                t-series  Engl Metr LKFG
*** x -  x                                  in  out
   13        Jack Cr above 12     1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
*** RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
*** x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
   13        0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                (in)
  <range-><----><----><--------><--------><--------><--------><-------->  ***
   13       0.0  13.0     32.9     240.0     82.11       0.5      0.01
  END HYDR-PARM2
  HYDR-INIT
***         Initial conditions for HYDR section
*** RCHRES       VOL Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
   13          13.65  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
```

```
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN***
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   152 PRCP  10 ENGL          0.62     PERLND  21  25 EXTNL  PREC   1 1
WDM1   151 PRCP  10 ENGL          0.38     PERLND  21  25 EXTNL  PREC   1 1
WDM1   191 PET   10 ENGL           1.0     PERLND  21  25 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND  21  25 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND  21  25 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND  21  25 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND  21  25 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  151         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS North
***              Branch Jack Creek weather station between April 1996 and
***              August 1997. Because the North Branch Jack Creek weather
***              station was not operated during the winter, values for the
***              period November 16, 1996, through March 31, 1997, is from
***              the Worthington2 NNE weather station. Data from the NWS
***              Windom weather station was disaggregated from daily to
***              hourly data and used to fill in a period when neither the
***              Lakefield or Worthington2 NNE weather stations had data,
***              February and March, 1996. Data is in inches
***
***  152    Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS Wilmont
***              weather station between April 1996 and August 1997. Because
***              the Wilmont weather station was not operated during the
***              winter, values for the period November 16, 1996, through
***              March 31, 1997, is from the Worthington2 NNE weather
***              station. Data from the NWS Windom weather station was
***              disaggregated from daily to hourly data and used to fill in
***              a period when neither the Lakefield or Worthington2 NNE
***              weather stations had data, February and March, 1996. Data is
***              in inches
***  191         Hourly modified FAO Penman potential evapotranspiration
***              values in inches. This was created by combining the hourly
***              modified FAO Penman evapotranspiration data from Lamberton
***              Experimental Station, 1987 to April1996, with the hourly
***              modified FAO Penman evapotranspiration values calculated
***              from the data collected at the USGS weather station at
***              Wilmont, April 1996 through August 1997.
***
***  702         Hourly dewpoint temperature values (degrees F). This data
***              set was created by combining hourly dewpoint temperature
```

```
***             values calculated from data from Lamberton Experimental
***             Station, 1987 to April1996, with hourly dewpoint temperature
***             values calculated from data collected at the USGS weather
***             station at Wilmont, April 1996 through August 1997.
***
***  712        Hourly air temperature values (degrees F). This data set
***             was created by combining hourly air temperature values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly air temperature values from the USGS weather station
***             at Wilmont, April 1996 through August 1997.
***
***  721        Hourly wind speed in miles per hour. This data set was
***             created by combining hourly wind speed values from Lamberton
***             Experimental Station, 1987 to April1996, with hourly wind
***             speed values from the USGS weather station at North Branch
***             Jack Creek, April 1996 through August 1997.
***
***  731        Hourly solar radiation in Langleys/hour. This data set was
***             created by combining hourly solar radiation values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly solar radiation values from the USGS weather station
***             at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x         <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** RCHRES  13 HYDR   RO     1 1 1.0           WDM1   482 FLOW     ENGL      REP
RCHRES  13 ROFLOW ROVOL  1 1 0.0003370     WDM1   429 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000281     WDM1   430 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000281     WDM1   431 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000281     WDM1   432 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000281     WDM1   433 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000281     WDM1   434 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000281AVER WDM1   435 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000281AVER WDM1   436 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES               Data set No.: 482
*** ROVOL (QDEP) - Total volume of outflow from RCHRES   Data set No.: 429
*** SURO - Surface outflow                               Data set No.: 430
*** IFWO - Interflow outflow                             Data set No.: 431
*** AGWO - Active groundwater outflow                    Data set No.: 432
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 433
*** SAET - Total simulated ET                            Data set No.: 434
*** UZSX - Upper zone storage                            Data set No.: 435
*** LZSX - Lower zone storage                            Data set No.: 436
***
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND  21                        96.4     RCHRES  13      1
PERLND  22                      1882.9     RCHRES  13      1
PERLND  23                     16500.9     RCHRES  13      1
PERLND  24                     16500.9     RCHRES  13      1
PERLND  25                       588.1     RCHRES  13      1
```

```
PERLND  21                        96.4     COPY   100     90
PERLND  22                      1882.9     COPY   100     90
PERLND  23                     16500.9     COPY   100     90
PERLND  24                     16500.9     COPY   100     90
PERLND  25                       588.1     COPY   100     90
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL   0 0
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                    COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                    COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                    COPY           INPUT  MEAN   3
PERLND     PWATER PET                     COPY           INPUT  MEAN   4
PERLND     PWATER TAET                    COPY           INPUT  MEAN   5
PERLND     PWATER UZS                     COPY           INPUT  MEAN   6
PERLND     PWATER LZS                     COPY           INPUT  MEAN   7
  END MASS-LINK   90
END MASS-LINK
FTABLES
  FTABLE     13
 ROWS COLS ***
   25    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
       0.00       0.0       0.0       0.0        0.
       0.2      39.83     13.65      0.78    12787.
       0.4      69.70     24.08      3.94     4433.
       0.6      83.64     47.68     10.30     3361.
       0.8      97.58     82.87     20.39     2951.
       1.0     107.54    120.41     32.59     2682.
       1.2     115.51    137.26     42.01     2372.
       1.4     123.47    159.05     52.07     2218.
       1.6     127.46    182.80     62.71     2116.
       1.8     135.42    211.55     73.88     2079.
       2.0     143.39    241.07     85.56     2046.
       2.2     147.37    272.79     97.70     2027.
       2.4     151.36    306.46    110.30     2017.
       3.0     167.29    415.29    150.70     2001.
       4.0     183.22    612.09    225.80     1968.
       5.0     191.19    827.29    309.70     1939.
       6.0     197.16   1052.34    400.90     1906.
       7.0     201.14   1288.81    498.70     1876.
       8.0     203.13   1528.61    602.50     1842.
       9.0     205.13   1777.00    711.90     1812.
      10.0     207.12   2006.00    819.00     1778.
      12.0     209.12   2464.00   1020.00     1754.
```

```
     14.0     211.12   2922.00   1220.00     1739.
     18.0     215.12   3857.00   1620.00     1729.
     22.0     219.12   4803.00   2020.00     1726.

  END FTABLE 13

END FTABLES

END RUN
```

North Branch Jack Creek Basin

```
RUN
GLOBAL
  North Branch Jack Creek Basin
  START       1995  8 26  0  0  END    1997  8  1 24  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      25   nbjack.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   nbjack.out
END FILES
***
***  Error file:  nbjack.message
***  Output file: nbjack.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  nbjack.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     921
      PERLND     922
      PERLND     923
      PERLND     924
      PERLND     925
      RCHRES      14
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 921 - Wetlands in RCHRES 14 basin
***  PERLND 922 - Grasslands in RCHRES 14 basin
***  PERLND 923 - Corn in RCHRES 14 basin
***  PERLND 924 - Soybeans in RCHRES 14 basin
***  PERLND 925 - Other land uses in RCHRES 14 basin
***  RCHRES 14 -  Reach/reservior upgradient of USGS North Branch of Jack Creek
***              Gage
***
PERLND
  ACTIVITY
    <PLS >               Active Sections                                ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  921  925    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, ATMP and SNOW Blocks,
***  simulating water flow through and snow in the system, correcting for air
***  temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  921  925    6    6    3    4    4    4    4    4    4    4    4    4    1   12
```

```
  END PRINT-INFO
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                         User  t-series Engl Metr***
                                           in  out           ***
  921     Wetlands                1    1    1    1   90    0
  922     Grasslands              1    1    1    1   90    0
  923     Corn                    1    1    1    1   90    0
  924     Soybeans                1    1    1    1   90    0
  925     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  921  925     120.0      73.0
  END ATEMP-DAT
***
***  Mean Elevation of PERLND 9 = 1610 ft
***  Mean Elevation of North Branch Jack Creek Weather Station = 1490 ft
***  El-diff = 1610 - 1490 = 120 ft
***
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Silumated ***
    # -  #ICEFG                                          ***
  921  925    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
  921  924      43.9     1610.      0.00      1.00       0.3
  925           43.9     1610.      0.15      1.00       0.3
  END SNOW-PARM1
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                  ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
  921  925      0.10      32.0      0.05      1.50      0.20     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                          ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                          (degF)
  921  925       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***             (in)      (in)              ***
  921  925      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                  Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
```

```
  921         1    1    1    1    0    0    0    0    1
  922         1    1    1    1    0    0    0    0    1
  923         1    1    1    1    1    1    0    0    1
  924         1    1    1    1    1    1    0    0    1
  925         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)               (1/in)   (1/day)
  921            0.0     3.000     0.400     403.0     0.006     0.300     0.940
  922  924       0.0     4.200     0.025     403.0     0.006     0.300     0.940
  925           0.15     4.200     0.025     403.0     0.006     0.300     0.940
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  921  925      35.0      30.0       2.0       2.0     0.001     0.000     0.000
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  921          1.000     2.500       0.4     3.000     0.860     0.350
  922          1.000     1.000       0.2     3.400     0.860     0.350
  923          1.000     0.800       0.1     3.400     0.860     0.350
  924          1.000     0.800       0.1     3.400     0.860     0.350
  925          1.000     1.000       0.2     3.400     0.860     0.350
  END PWAT-PARM4
***  Interception storage capacity values (CEPSC) at start of each month
***  are stored in the MON-INTERCEP table below, so the CEPSC value is
***  ignored.  Upper zone nominal storage (UZSN) will also vary monthly,
***  with values listed in the MON-UZSN table below.  Since monthly
***  Manning’s n values will be used, NSUR value is ignored in model.
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  921  925      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  921      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  922      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  923      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  924      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  925      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  923  924 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  921  922 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  923  924 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  925      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS > Lower zone evapotranspiration parameter at start of each month
```

```
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  921      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  922      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  923  924 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  925      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  921  925       0.0       0.0     0.001       0.0     0.001     0.001      0.01
  END PWAT-STATE1
END PERLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
   14   14    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   14   14    6    3    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
   14        N. Branch Jack Cr    1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
*** RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
*** x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
   14        0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x            (miles)      (ft)      (ft)                (in)
  <range-><----><----><--------><--------><--------><--------><-------->  ***
   14       0.0 14.0      43.4     270.0     87.69       0.5      0.01
  END HYDR-PARM2
  HYDR-INIT
***
*** The number of acre feet was obtained from ftable by assuming a 2.0 ft depth
***
***         Initial conditions for HYDR section
*** RCHRES       VOL Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
   14          10.00  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN***
  100         0    7
  END TIMESERIES
```

```
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   151 PRCP  10 ENGL           0.35     PERLND 921 925 EXTNL  PREC   1 1
WDM1   152 PRCP  10 ENGL           0.65     PERLND 921 925 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL            1.0     PERLND 921 925 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL            1.0     PERLND 921 925 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL            1.0     PERLND 921 925 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL            1.0     PERLND 921 925 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL            1.0     PERLND 921 925 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  151         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS North
***              Branch Jack Creek weather station between April 1996 and
***              August 1997. Because the North Branch Jack Creek weather
***              station was not operated during the winter, values for the
***              period November 16, 1996, through March 31, 1997, is from
***              the Worthington2 NNE weather station. Data from the NWS
***              Windom weather station was disaggregated from daily to
***              hourly data and used to fill in a period when neither the
***              Lakefield or Worthington2 NNE weather stations had data,
***              February and March, 1996. Data is in inches
***
***  152    Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS Wilmont
***              weather station between April 1996 and August 1997. Because
***              the Wilmont weather station was not operated during the
***              winter, values for the period November 16, 1996, through
***              March 31, 1997, is from the Worthington2 NNE weather
***              station. Data from the NWS Windom weather station was
***              disaggregated from daily to hourly data and used to fill in
***              a period when neither the Lakefield or Worthington2 NNE
***              weather stations had data, February and March, 1996. Data is
***              in inches
***  190         Hourly modified FAO Penman potential evapotranspiration values
***              in inches. This was created by combining the hourly modified
***              FAO Penman evapotranspiration data from Lamberton
***              Experimental Station, 1987 to April1996, with the hourly
***              modified FAO Penman evapotranspiration values calculated
***              from the data collected at the USGS weather station at North
***              Branch Jack Creek, April 1996 through August 1997.
***
***  702         Hourly dewpoint temperature values (degrees F). This data
***              set was created by combining hourly dewpoint temperature
***              values calculated from data from Lamberton Experimental
***              Station, 1987 to April1996, with hourly dewpoint temperature
***              values calculated from data collected at the USGS weather
***              station at Wilmont, April 1996 through August 1997.
***
***  712         Hourly air temperature values (degrees F). This data set
***              was created by combining hourly air temperature values from
***              Lamberton Experimental Station, 1987 to April1996, with
```

```
***              hourly air temperature values from the USGS weather station
***              at Wilmont, April 1996 through August 1997.
***
***  721         Hourly wind speed in miles per hour. This data set was
***              created by combining hourly wind speed values from Lamberton
***              Experimental Station, 1987 to April1996, with hourly wind
***              speed values from the USGS weather station at North Branch
***              Jack Creek, April 1996 through August 1997.
***
***  731         Hourly solar radiation in Langleys/hour. This data set was
***              created by combining hourly solar radiation values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly solar radiation values from the USGS weather station
***              at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** RCHRES  14 HYDR   RO     1 1 1.0           WDM1   483 FLOW     ENGL      REP
RCHRES  14 ROFLOW ROVOL  1 1 0.0002637     WDM1   437 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000220     WDM1   438 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000220     WDM1   439 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000220     WDM1   440 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000220     WDM1   441 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000220     WDM1   442 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000220AVER WDM1   443 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000220AVER WDM1   444 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES               Data set No.: 483
*** ROVOL (QDEP) - Total volume of outflow from RCHRES   Data set No.: 437
*** SURO - Surface outflow                               Data set No.: 438
*** IFWO - Interflow outflow                             Data set No.: 439
*** AGWO - Active groundwater outflow                    Data set No.: 440
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 441
*** SAET - Total simulated ET                            Data set No.: 442
*** UZSX - Upper zone storage                            Data set No.: 443
*** LZSX - Lower zone storage                            Data set No.: 444
***
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 921                       469.5     RCHRES  14      1
PERLND 922                      2861.4     RCHRES  14      1
PERLND 923                     20683.7     RCHRES  14      1
PERLND 924                     20683.7     RCHRES  14      1
PERLND 925                       805.5     RCHRES  14      1
PERLND 921                       469.5     COPY   100     90
PERLND 922                      2861.4     COPY   100     90
PERLND 923                     20683.7     COPY   100     90
PERLND 924                     20683.7     COPY   100     90
PERLND 925                       805.5     COPY   100     90
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
```

```
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO   0 0 0.0833333     RCHRES         INFLOW IVOL   0 0
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                    COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                    COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                    COPY           INPUT  MEAN   3
PERLND     PWATER PET                     COPY           INPUT  MEAN   4
PERLND     PWATER TAET                    COPY           INPUT  MEAN   5
PERLND     PWATER UZS                     COPY           INPUT  MEAN   6
PERLND     PWATER LZS                     COPY           INPUT  MEAN   7
  END MASS-LINK   90
END MASS-LINK
FTABLES
  FTABLE     14
 ROWS COLS ***
   25    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
       0.00       0.0       0.0       0.0        0.
       0.2       44.7      50.       4.31     8432.
       0.4       52.6      70.      11.58     4389.
       0.6       84.1      95.      20.60     3348.
       0.8       89.4     120.      31.00     2810.
       1.0       97.3     150.      42.73     2549.
       1.2      102.6     170.      55.09     2240.
       1.4      105.2     200.      68.98     2105.
       1.6      110.4     235.      81.10     2104.
       1.8      115.7     270.      93.74     2091.
       2.0      120.9     300.      106.7     2041.
       2.2      126.2     330.      120.0     1997.
       2.4      134.1     370.      133.5     2012.
       3.0      152.6     480.      175.9     1981.
       4.0      181.5     675.      252.1     1944.
       5.0      181.5     860.      333.2     1874.
       6.0      181.5    1070.      430.0     1807.
       7.0      181.5    1310.      583.4     1630.
       8.0      181.5    1560.      760.0     1490.
       9.0      181.5    1920.      992.4     1405.
      10.0      181.5    2104.     1260.      1212.
      12.0      181.5    2245.     1834.       889.
      16.0      181.5    2289.     3024.       550.
      20.0      181.5    2293.     4224.       394.
      30.0      181.5    2295.     6624.       252.
  END FTABLE 14

END FTABLES

END RUN
```

East Graham Lake Outlet Basin

```
RUN
GLOBAL
  East Graham Lake Outlet Basin
  START       1995  8 26  0  0  END    1997  8  2 24  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      25   eastgrm.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   eastgrm.out
END FILES
***
***  Error file:  eastgrm.message
***  Output file: eastgrm.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  eastgraham.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     821
      PERLND     822
      PERLND     823
      PERLND     824
      PERLND     825
      IMPLND     840
      RCHRES      10
      RCHRES      11
      RCHRES       9
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 821 - Wetlands
***  PERLND 822 - Grasslands
***  PERLND 823 - Corn
***  PERLND 824 - Soybeans
***  PERLND 825 - Other land uses
***  IMPLND 840 - Urban/Residential
***  RCHRES  9 - Reach/reservior upgradient of USGS East Graham Lake Outlet Gage
***              to West Graham Lake and Jack Lake
***  RCHRES 10 - Reach/reservior upgradient of West Graham Lake
***  RCHRES 11 - Reach/reservior upgradient of Jack Lake
***
PERLND
  ACTIVITY
    <PLS >              Active Sections                              ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  821  825    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, ATMP and SNOW Blocks,
***  simulating water flow through and snow in the system, correcting for
```

```
***  air temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  821  825    6    6    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                          User  t-series Engl Metr***
                                           in  out          ***
  821     Wetlands                1    1    1    1   90    0
  822     Grasslands              1    1    1    1   90    0
  823     Corn                    1    1    1    1   90    0
  824     Soybeans                1    1    1    1   90    0
  825     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  821  825     -10.0      73.0
  END ATEMP-DAT
***
***  Elevation for the North Branch Jack Creek Weather Station = 1490 ft
***  Mean elevation of PERLND 8 = 1480 ft (El-diff = 1480-1490=-10)
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                          ***
  821  825    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                            (in)  ***
***  821  825      43.8     1480.       0.0      1.40       0.5
  821  824      43.8     1480.      0.00      1.00       0.3
  825           43.8     1480.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                  ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
  821  825      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                          ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***            (in)       (in)    (in)                            (degF)
  821  825       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
```

```
***            (in)      (in)                ***
  821  825      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  821  822    1    1    1    1    0    0    0    0    1
  823  824    1    1    1    1    1    1    0    0    1
  825         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  821            0.0     3.000     0.400     350.0     0.006     0.300     0.940
  822  824       0.0     4.200     0.060     431.0     0.006     0.300     0.940
  825           0.15     4.200     0.060     431.0     0.006     0.300     0.940
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  821  825      35.0      30.0       2.0       2.0     0.001     0.000     0.000
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  821          1.000     2.500       0.4     3.000     0.830     0.350
  822          1.000     1.000       0.2     3.400     0.830     0.350
  823  824     1.000     0.800       0.1     3.400     0.830     0.350
  825          1.000     1.000       0.2     3.400     0.830     0.350
  END PWAT-PARM4
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  821  825      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  821      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  822      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  823      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  824      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  825      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  823  824 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  821  822 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  823  824 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  825      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS > Lower zone evapotranspiration parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  821      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
```

```
  822      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  823  824 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  825      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  821  825       0.0       0.0      0.01       0.0      0.10      0.01      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >                Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  840  840    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  840  840    6    6    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                            in  out
  840  840Urbn/Resdt                    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  840  840     -10.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  840  840    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  840  840      43.8    1480.0      0.00      1.00       0.3
  END SNOW-PARM1
  SNOW-PARM2
*** <ILS >  Snow input info: Part 2                                   ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                      (degF)                                (in/day)***
  840  840      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                           ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***            (in)       (in)    (in)                          (degF)
  840  840       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
```

```
***            (in)      (in)                ***
  840  840      0.01       0.0       1.0
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  840  840    1    1    1    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (ft)
  840  840     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  840  840 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  840  840     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    9   11    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    9   11    6    4    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
    9        Above EGLO           1         1    1   90    0    0
   10        Above WGL            1         1    1   90    0    0
   11        Above JackL          1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
*** RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
*** x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
```

```
    9   11   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                (in)
  <range-><---><----><--------><--------><--------><--------><-------->  ***
    9       0.0  9.0       3.0       3.0     93.29       0.5      0.01
   10       0.0 10.0      12.3      44.0     93.29       0.5      0.01
   11       0.0 11.0      10.5      64.0     93.29       0.5      0.01
*** The values for LEN and DELTH are arbitrary for reach-reservoir 9
  END HYDR-PARM2
  HYDR-INIT
***          Initial conditions for HYDR section
*** RCHRES       VOL Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    9         100.00  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   10         109.00  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   11          21.00  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMM***
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   151 PRCP  10 ENGL           1.0     PERLND 821 825 EXTNL  PREC   1 1
WDM1   151 PRCP  10 ENGL           1.0     IMPLND 840 840 EXTNL  PREC   1 1
WDM1   191 PET   10 ENGL           1.0     PERLND 821 825 EXTNL  PETINP 1 1
WDM1   191 PET   10 ENGL           1.0     IMPLND 840 840 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 821 825 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 840 840 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 821 825 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 840 840 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 821 825 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 840 840 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 821 825 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 840 840 EXTNL  DTMPG  1 1
WDM1   803 CLND  10 ENGL           1.0     RCHRES   9  11 EXTNL  COLIND 1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***  151         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS North
***              Branch Jack Creek weather station between April 1996 and
***              August 1997. Because the North Branch Jack Creek weather
***              station was not operated during the winter, values for the
***              period November 16, 1996, through March 31, 1997, is from
***              the Worthington2 NNE weather station. Data from the NWS
***              Windom weather station was disaggregated from daily to
***              hourly data and used to fill in a period when neither the
***              Lakefield or Worthington2 NNE weather stations had data,
```

```
***              February and March, 1996. Data is in inches
***
***  191         Hourly modified FAO Penman potential evapotranspiration
***              values in inches. This was created by combining the hourly
***              modified FAO Penman evapotranspiration data from Lamberton
***              Experimental Station, 1987 to April1996, with the hourly
***              modified FAO Penman evapotranspiration values calculated
***              from the data collected at the USGS weather station at
***              Wilmont, April 1996 through August 1997.
***
***  702         Hourly dewpoint temperature values (degrees F). This data
***              set was created by combining hourly dewpoint temperature
***              values calculated from data from Lamberton Experimental
***              Station, 1987 to April1996, with hourly dewpoint temperature
***              values calculated from data collected at the USGS weather
***              station at Wilmont, April 1996 through August 1997.
***
***  712         Hourly air temperature values (degrees F). This data set
***              was created by combining hourly air temperature values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly air temperature values from the USGS weather station
***              at Wilmont, April 1996 through August 1997.
***
***  721         Hourly wind speed in miles per hour. This data set was
***              created by combining hourly wind speed values from Lamberton
***              Experimental Station, 1987 to April1996, with hourly wind
***              speed values from the USGS weather station at North Branch
***              Jack Creek, April 1996 through August 1997.
***
***  731         Hourly solar radiation in Langleys/hour. This data set was
***              created by combining hourly solar radiation values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly solar radiation values from the USGS weather station
***              at North Branch Jack Creek, April 1996 through August 1997.
***
***  803         Column rating index for the streamflow gaging station at
***              East Graham Lake Outlet on County State Aid Highway 1, near
***              Kinbrae.
***


EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** RCHRES   9 HYDR   RO     1 1 1.0           WDM1   484 FLOW     ENGL      REP
RCHRES   9 ROFLOW ROVOL  1 1 0.0005222     WDM1   445 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000435     WDM1   446 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000435     WDM1   447 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000435     WDM1   448 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000435     WDM1   449 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000435     WDM1   450 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000435AVER WDM1   451 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000435AVER WDM1   452 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES               Data set No.: 484
```

```
*** ROVOL (QDEP) - Total volume of outflow from RCHRES   Data set No.: 445
*** SURO - Surface outflow                               Data set No.: 446
*** IFWO - Interflow outflow                             Data set No.: 447
*** AGWO - Active groundwater outflow                    Data set No.: 448
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 449
*** SAET - Total simulated ET                            Data set No.: 450
*** UZSX - Upper zone storage                            Data set No.: 451
*** LZSX - Lower zone storage                            Data set No.: 452
***
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 821                       146.8     RCHRES   9      1
PERLND 822                       102.0     RCHRES   9      1
PERLND 823                       989.2     RCHRES   9      1
PERLND 824                       989.2     RCHRES   9      1
PERLND 825                        53.1     RCHRES   9      1
IMPLND 840                         0.0     RCHRES   9      2
PERLND 821                       807.3     RCHRES  10      1
PERLND 822                       561.3     RCHRES  10      1
PERLND 823                      5440.5     RCHRES  10      1
PERLND 824                      5440.5     RCHRES  10      1
PERLND 825                       292.2     RCHRES  10      1
IMPLND 840                       195.2     RCHRES  10      2
PERLND 821                       513.7     RCHRES  11      1
PERLND 822                       357.2     RCHRES  11      1
PERLND 823                      3462.2     RCHRES  11      1
PERLND 824                      3462.2     RCHRES  11      1
PERLND 825                       186.0     RCHRES  11      1
IMPLND 840                         0.0     RCHRES  11      2
RCHRES  10                                 RCHRES   9      3
RCHRES  11                                 RCHRES   9      3
PERLND 821                      1467.8     COPY   100     90
PERLND 822                      1020.5     COPY   100     90
PERLND 823                      9891.9     COPY   100     90
PERLND 824                      9891.9     COPY   100     90
PERLND 825                       531.3     COPY   100     90
IMPLND 840                       195.2     COPY   100     91
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
```

```
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   4
PERLND     PWATER TAET                     COPY           INPUT  MEAN   5
PERLND     PWATER UZS                      COPY           INPUT  MEAN   6
PERLND     PWATER LZS                      COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE     9
 ROWS COLS ***
   19   4
     DEPTH      AREA    VOLUME    DISCH1    DISCH2    DISCH3 ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS)     (CFS) ***
      0.00     498.2       0.0       0.0       0.0       0.0
      0.2      498.2      99.6      0.22      0.46      1.39
      0.4      498.2     199.3      1.38      2.25      4.64
      0.6      498.2     298.9      4.09      5.80      9.44
      0.8      498.2     398.5      8.59     11.33     15.65
      1.0      498.2     498.2     15.30     19.11     23.20
      1.2      498.2     597.8     24.50     29.32     32.11
      1.4      498.2     697.4     36.71     42.09     42.26
      1.6      498.2     797.1     52.21     57.19     53.36
      1.8      498.2     896.7     71.33     74.91     65.52
      2.0      498.2     996.3     94.30     95.50     78.86
      2.2      502.0    1099.7    121.4     119.4      93.30
      2.4      505.8    1203.0    152.5     146.4     108.7
      3.0      517.3    1513.0    274.      246.6     161.6
      4.0      536.5    2029.7    486.      484.0     270.
      5.0      557.1    2586.1   1050.      815.0     397.
      6.0      577.7    3142.5   1700.     1235.      548.
      7.0      599.9    3828.3   2530.     1775.      720.
      8.0      622.1    4514.0   3590.     2040.      910.
  END FTABLE 9

  FTABLE    10
 ROWS COLS ***
   19   4
     DEPTH      AREA    VOLUME    DISCH1    DISCH2    DISCH3 ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS)     (CFS) ***
      0.00     521.2       0.0       0.0       0.0       0.0
      0.2      524.8     108.7      0.22      0.46      1.39
      0.4      528.5     217.4      1.38      2.25      4.64
      0.6      532.2     326.1      4.09      5.80      9.44
      0.8      535.9     434.8      8.59     11.33     15.65
      1.0      539.6     543.4     15.30     19.11     23.20
      1.2      543.3     652.1     24.50     29.32     32.11
      1.4      544.4     761.0     36.71     42.09     42.26
```

```
      1.6      544.7     870.0     52.21     57.19     53.36
      1.8      544.9     979.0     71.33     74.91     65.52
      2.0      545.2    1088.0     94.30     95.50     78.86
      2.2      549.4    1117.5    121.4     119.4      93.30
      2.4      553.7    1147.0    152.5     146.4     108.7
      3.0      566.5    1236.3    274.      246.6     161.6
      4.0      587.7    1385.8    486.      484.0     270.
      5.0      609.0    1536.3   1050.      815.0     397.
      6.0      630.3    1688.6   1700.     1235.      548.
      7.0      651.6    1841.9   2530.     1775.      720.
      8.0      672.9    1996.9   3590.     2040.      910.
  END FTABLE 10

  FTABLE    11
 ROWS COLS ***
   19   4
     DEPTH      AREA    VOLUME    DISCH1    DISCH2    DISCH3 ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS)     (CFS) ***
      0.00      80.4       0.0       0.0       0.0       0.0
      0.2       83.7      20.2      0.22      0.46      1.39
      0.4       87.1      40.3      1.38      2.25      4.64
      0.6       90.5      60.5      4.09      5.80      9.44
      0.8       93.9      80.7      8.59     11.33     15.65
      1.0       97.3     100.8     15.30     19.11     23.20
      1.2      100.7     121.0     24.50     29.32     32.11
      1.4      101.7     141.4     36.71     42.09     42.26
      1.6      102.0     161.9     52.21     57.19     53.36
      1.8      102.2     182.3     71.33     74.91     65.52
      2.0      102.5     202.8     94.30     95.50     78.86
      2.2      103.3     223.9    121.4     119.4      93.30
      2.4      104.2     244.9    152.5     146.4     108.7
      3.0      106.7     308.8    274.      246.6     161.6
      4.0      110.9     415.9    486.      484.0     270.
      5.0      115.5     461.2   1050.      815.0     397.
      6.0      119.9     508.0   1700.     1235.      548.
      7.0      124.4     555.9   2530.     1775.      720.
      8.0      128.8     605.2   3590.     2040.      910.
  END FTABLE 11
END FTABLES

END RUN
```

Elk Creek Basin

```
RUN
GLOBAL
  Elk Creek Basin
  START       1995  8 25  0  0  END    1997  7 26  0  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      27   elkcreek.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   elkcreek.out
END FILES
***
***  Error file:  elkcreek.message
***  Output file: elkcreek.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  elkcreek.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     421
      PERLND     422
      PERLND     423
      PERLND     424
      PERLND     425
      IMPLND     440
      RCHRES       5
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 421 - Wetlands
***  PERLND 422 - Grasslands
***  PERLND 423 - Corn
***  PERLND 424 - Soybean
***  PERLND 425 - Other land uses
***  IMPLND 440 - Urban/Residential
***  RCHRES 5 - Reservior upgradient of USGS Elk Creek Gage
***
PERLND
  ACTIVITY
    <PLS >                Active Sections                              ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  421  425    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, ATMP and SNOW Blocks,
***  simulating water flow through and snow in the system, correcting for
***  air temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
```

```
  421  425    6    6    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                          User  t-series Engl Metr***
                                                in  out          ***
  421     Wetlands                1    1    1    1   90    0
  422     Grasslands              1    1    1    1   90    0
  423     Corn                    1    1    1    1   90    0
  424     Soybeans                1    1    1    1   90    0
  425     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  421  425      120.      73.0
  END ATEMP-DAT
***
***  Mean Elevation of PERLND 4 = 1580 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1580 - 1460 = 120 ft
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                          ***
  421  425    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
  421  424      43.7     1580.      0.00       1.0       0.3
  425           43.7     1580.      0.15       1.0       0.3
  END SNOW-PARM1
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                   ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
  421  425      0.10      32.0      0.05       1.5       0.2     0.003
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                           ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                           (degF)
  421  425       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  421  425      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                   Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  421  422    1    1    1    1    0    0    0    0    1
```

```
  423  424    1    1    1    1    1    1    0    0    1
  425         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)               (1/in)   (1/day)
  421            0.0     3.000     0.400     350.0     0.006     0.300      0.94
  422  424       0.0     4.200     0.025     335.0     0.006     0.300      0.94
  425           0.15     4.200     0.025     335.0     0.006     0.300      0.94
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  421  425      35.0      30.0       2.0       2.0     0.001     0.000     0.000
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  421          0.000     2.500       0.4     3.000     0.830     0.350
  422          0.000     1.000       0.2     3.400     0.830     0.350
  423  424     0.000     0.800       0.1     3.400     0.830     0.350
  425          0.000     1.000       0.2     3.400     0.830     0.350
  END PWAT-PARM4
***  Interception storage capacity values (CEPSC) at start of each month
***  are stored in the MON-INTERCEP table below, so the CEPSC value is
***  ignored.  Upper zone nominal storage (UZSN) will also vary monthly,
***  with values listed in the MON-UZSN table below.  Since monthly
***  Manning's n values will be used, NSUR value is ignored in model.
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  421  425      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  421      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  422      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  423      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  424      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  425      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  423  424 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  421  422 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  423  424 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  425      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  421      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  422      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  423  424 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
```

```
  425      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  421  425       0.0       0.0      0.01       0.0      0.01      0.01      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  440  440    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  440  440    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                            in  out
  440  440Urbn/Resdt                   1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  440  440     120.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  440  440    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  440  440      43.7    1580.0      0.00      1.00       0.3
  END SNOW-PARM1
  SNOW-PARM2
*** <ILS >  Snow input info: Part 2                                   ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                      (degF)                                (in/day)***
  440  440      0.10      32.0      0.05      1.50       0.2     0.003
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                           ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***          (in)       (in)    (in)                           (degF)
  440  440       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  440  440      0.01       0.0       1.0
```

```
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  440  440    1    1    1    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                         (ft)
  440  440     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  440  440 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  440  440     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    5    5    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    5    5    6    4    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                              t-series  Engl Metr LKFG
*** x -  x                                in  out
    5     Elk Cr above USGS gage  1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    5    5   0  1  1  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
```

```
*** x -  x             (miles)      (ft)      (ft)                (in)
    5    5  0.0  5.0      20.1     240.0      81.0       0.5      0.01
  END HYDR-PARM2
***
*** The number of acre feet was obtained from ftable by assuming a 2.5 ft depth
***
  HYDR-INIT
***         Initial conditions for HYDR section
*** RCHRES       VO  Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    5    5      33.7  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    8
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   153 PRCP  10 ENGL          0.12     PERLND 421 425 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL          0.57     PERLND 421 425 EXTNL  PREC   1 1
WDM1   151 PRCP  10 ENGL          0.29     PERLND 421 425 EXTNL  PREC   1 1
WDM1   152 PRCP  10 ENGL          0.02     PERLND 421 425 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           1.0     IMPLND 440 440 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 421 425 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL           1.0     IMPLND 440 440 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 421 425 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 440 440 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 421 425 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 440 440 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 421 425 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 440 440 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 421 425 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 440 440 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  150         Precipitation data collected from Worthington 2 NNE weather
***              station. Portions of the data were missing between 1991 and
***              1997. Precipitation for these missing record periods was
***              estimated using hourly and daily precipitation data
***              collected at NWS weather stations located at Luverne and
***              Sherburn, Minnesota and Sibley, Iowa, USGS weather stations
***              at North Branch Jack Creek and Wilmont, and USGS
***              precipitation gages at (1) Okabena Creek on County State Aid
***              Highway 14, near Brewster and (2) near Okabena. Data is in
***              inches.
***
***  151         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS North
***              Branch Jack Creek weather station between April 1996 and
```

```
***             August 1997. Because the North Branch Jack Creek weather
***             station was not operated during the winter, values for the
***             period November 16, 1996, through March 31, 1997, is from
***             the Worthington2 NNE weather station. Data from the NWS
***             Windom weather station was disaggregated from daily to
***             hourly data and used to fill in a period when neither the
***             Lakefield or Worthington2 NNE weather stations had data,
***             February and March, 1996. Data is in inches
***
***  152    Precipitation data collected from Worthington 2 NNE weather
***             station between 1991 and April 1996 and from USGS Wilmont
***             weather station between April 1996 and August 1997. Because
***             the Wilmont weather station was not operated during the
***             winter, values for the period November 16, 1996, through
***             March 31, 1997, is from the Worthington2 NNE weather
***             station. Data from the NWS Windom weather station was
***             disaggregated from daily to hourly data and used to fill in
***             a period when neither the Lakefield or Worthington2 NNE
***             weather stations had data, February and March, 1996. Data is
***             in inches
***  153        Precipitation data collected from Worthington 2 NNE weather
***             station between 1991 and April 1996 and from USGS
***             precipitation gage at Okabena Creek on County State Aid
***             Highway 14, near Brewster between April 1996 and August
***             1997. Because the North Branch Jack Creek weather station
***             was not operated during the winter, values for the period
***             November 16, 1996, through March 31, 1997, is from the
***             Worthington2 NNE weather station. Data from the NWS Windom
***             weather station was disaggregated from daily to hourly data
***             and used to fill in a period when neither the Lakefield or
***             Worthington2 NNE weather stations had data, February and
***             March, 1996. Data is in inches
***
***  190        Hourly modified FAO Penman potential evapotranspiration values
***             in inches. This was created by combining the hourly modified
***             FAO Penman evapotranspiration data from Lamberton
***             Experimental Station, 1987 to April1996, with the hourly
***             modified FAO Penman evapotranspiration values calculated
***             from the data collected at the USGS weather station at North
***             Branch Jack Creek, April 1996 through August 1997.
***
***  702        Hourly dewpoint temperature values (degrees F). This data
***             set was created by combining hourly dewpoint temperature
***             values calculated from data from Lamberton Experimental
***             Station, 1987 to April1996, with hourly dewpoint temperature
***             values calculated from data collected at the USGS weather
***             station at Wilmont, April 1996 through August 1997.
***
***  712        Hourly air temperature values (degrees F). This data set
***             was created by combining hourly air temperature values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly air temperature values from the USGS weather station
***             at Wilmont, April 1996 through August 1997.
***
***  721        Hourly wind speed in miles per hour. This data set was
***             created by combining hourly wind speed values from Lamberton
***             Experimental Station, 1987 to April1996, with hourly wind
```

```
***              speed values from the USGS weather station at North Branch
***              Jack Creek, April 1996 through August 1997.
***
***  731         Hourly solar radiation in Langleys/hour. This data set was
***              created by combining hourly solar radiation values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly solar radiation values from the USGS weather station
***              at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
***RCHRES   5 HYDR   RO     1 1               WDM1   582 FLOW     ENGL      REPL
RCHRES   5 ROFLOW ROVOL  1 1 0.0003071     WDM1   529 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000256     WDM1   530 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000256     WDM1   531 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000256     WDM1   532 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000256     WDM1   533 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000256     WDM1   534 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000256AVER WDM1   535 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000256AVER WDM1   536 LZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   8 1 0.0000256AVER WDM1   816 SNOW   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES               Data set No.: 582
*** ROVOL - Total volume of outflow from RCHRES          Data set No.: 529
*** SURO - Surface outflow                               Data set No.: 530
*** IFWO - Interflow outflow                             Data set No.: 531
*** AGWO - Active groundwater outflow                    Data set No.: 532
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 533
*** SAET - Total simulated ET                            Data set No.: 534
*** UZSX - Upper zone storage                            Data set No.: 535
*** LZSX - Lower zone storage                            Data set No.: 536
*** SNOW - Snow Depth Data set No.: 816
***
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 421                         0.0     RCHRES   5      1
PERLND 422                      1517.2     RCHRES   5      1
PERLND 423                     18761.4     RCHRES   5      1
PERLND 424                     18761.4     RCHRES   5      1
PERLND 425                         0.0     RCHRES   5      1
IMPLND 440                        29.7     RCHRES   5      2
PERLND 421                         0.0     COPY   100     90
PERLND 422                      1517.2     COPY   100     90
PERLND 423                     18761.4     COPY   100     90
PERLND 424                     18761.4     COPY   100     90
PERLND 425                         0.0     COPY   100     90
IMPLND 440                        29.7     COPY   100     91
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
```

```
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                    COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                    COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                    COPY           INPUT  MEAN   3
PERLND     PWATER PET                     COPY           INPUT  MEAN   4
PERLND     PWATER TAET                    COPY           INPUT  MEAN   5
PERLND     PWATER UZS                     COPY           INPUT  MEAN   6
PERLND     PWATER LZS                     COPY           INPUT  MEAN   7
PERLND     SNOW   PDEPTH                  COPY           INPUT  MEAN   8
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                    COPY           INPUT  MEAN   1
IMPLND     IWATER PET                     COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                   COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE      5
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.63      44.0      26.7       3.2     6058.
      0.94      45.3      40.5       9.1     3231.
      1.25      46.7      55.0      31.1     1284.
      1.57      48.0      70.0      64.0      794.
      1.88      49.3      85.0      85.2      724.
      2.50      51.9     116.7     135.5      625.
      3.13      54.6     150.0     195.0      558.
      3.75      57.2     184.9     262.0      512.
      5.00      62.5     259.7     417.0      452.
      6.25      67.8     341.2     598.0      414.
      7.50      73.1     429.2     800.0      390.
     10.00      78.4     652.2    1280.0      370.
     15.00    1179.9    5127.9   11452.0      325.
     20.00    1917.9   12872.5   31408.0      298.
  END FTABLE  5
END FTABLES
END RUN
```

Middle/Upper Okabena Creek Basin--with diversion

```
RUN
GLOBAL
  Middle/Upper Okabena Creek Basin--with diversion
  START       1995  8 25  0  0  END    1997  7 26  0  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      27   upperoka_with.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   upperoka_with.out
END FILES
***
***  Error file:  upperoka_with.message
***  Output file: upperoka_with.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  upperoka_with.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     521
      PERLND     522
      PERLND     523
      PERLND     524
      PERLND     525
      IMPLND     540
      RCHRES       3
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 521 - Wetlands in RCHRES 3 basin
***  PERLND 522 - Grasslands in RCHRES 3 basin
***  PERLND 523 - Corn in RCHRES 3 basin
***  PERLND 524 - Soybeans in RCHRES 3 basin
***  PERLND 525 - Other land uses in RCHRES 3 basin
***  IMPLND 540 - Urban/Residential in RCHRES 3 basin
***  RCHRES 3 - Reservoir between USGS Okabena Creek Gage and the City
***             of Worthington, MN
***
PERLND
  ACTIVITY
    <PLS >               Active Sections                              ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  521  525    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, SNOW, and ATMP blocks,
***  simulating water flow through and snow in the system, correcting for
***  air temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
```

```
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  521  525    6    6    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                          User  t-series Engl Metr***
                                            in  out          ***
  521     Wetlands                1    1    1    1   90    0
  522     Grasslands              1    1    1    1   90    0
  523     Corn                    1    1    1    1   90    0
  524     Soybeans                1    1    1    1   90    0
  525     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  521  525      100.      73.0
  END ATEMP-DAT
***
***  Mean Elevation of PERLND 5 = 1560 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1560 - 1460 = 100 ft
***
***  Mean Elevation of PERLND 6 = 1590 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1590 - 1460 = 130 ft
***
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                           ***
  521  525    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
  521  524      43.7     1560.      0.00      1.00       0.3
  525           43.7     1560.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                      ***
    # -  #     RDCSN    TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                    (degF)                                    (in/day)***
  521  525      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                              ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                            (degF)
  521  525       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
```

```
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  521  525      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  521         1    1    1    1    0    0    0    0    1
  522         1    1    1    1    0    0    0    0    1
  523         1    1    1    1    1    1    0    0    1
  524         1    1    1    1    1    1    0    0    1
  525         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  521            0.0     3.000     0.400     513.0     0.006     0.300     0.940
  522  524       0.0     4.200     0.025     513.0     0.006     0.300     0.940
  525           0.15     4.200     0.025     513.0     0.006     0.300     0.940
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  521  525      35.0      30.0       2.0       2.0     0.001     0.000     0.000
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  521          1.000     2.500       0.4     3.000     0.830     0.350
  522          1.000     1.000       0.2     3.400     0.830     0.350
  523  524     1.000     0.800       0.1     3.400     0.830     0.350
  525          1.000     1.000       0.2     3.400     0.830     0.350
  END PWAT-PARM4
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  521  525      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  521      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  522      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  523      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  524      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  525      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  523  524 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  521  522 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  523  524 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  525      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
```

```
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  521      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  522      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  523  524 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  525      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  521  525       0.0       0.0      0.01       0.0      0.01      0.01      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  540  540    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  540  540    6    6    6    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                            in  out
  540  540Urbn/Resdt                   1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  540  540     100.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  540  540    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  540  540      43.7    1560.0      0.00      1.00       0.3
  END SNOW-PARM1
  SNOW-PARM2
*** <ILS >  Snow input info: Part 2                                  ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
  540  540      0.10      32.0      0.05       1.5       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                          ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***          (in)       (in)    (in)                            (degF)
  540  540       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
```

```
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)               ***
  540  540      0.01       0.0       1.0
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  540  540    1    1    1    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (ft)
  540  540     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  540  540 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  540  540     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    3    3    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    3    3    6    4    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
    3     Okabena Cr above USGS   1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
```

```
    x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    3    3   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                (in)
    3       0.0  3.0      23.1     120.0      83.5       0.5      0.01
  END HYDR-PARM2
  HYDR-INIT
***         Initial conditions for HYDR section
*** RCHRES       VO  Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    3           26.70  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   153 PRCP  10 ENGL          0.35     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL          0.65     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           1.0     IMPLND 540 540 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 521 525 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL           1.0     IMPLND 540 540 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 521 525 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 540 540 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 521 525 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 540 540 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 521 525 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 540 540 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 521 525 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 540 540 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  150         Precipitation data collected from Worthington 2 NNE weather
***              station. Portions of the data were missing between 1991 and
***              1997. Precipitation for these missing record periods was
***              estimated using hourly and daily precipitation data
***              collected at NWS weather stations located at Luverne and
***              Sherburn, Minnesota and Sibley, Iowa, USGS weather stations
***              at North Branch Jack Creek and Wilmont, and USGS
***              precipitation gages at (1) Okabena Creek on County State Aid
***              Highway 14, near Brewster and (2) near Okabena. Data is in
***              inches.
***
***  153         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS
***              precipitation gage at Okabena Creek on County State Aid
```

```
***             Highway 14, near Brewster between April 1996 and August
***             1997. Because the North Branch Jack Creek weather station
***             was not operated during the winter, values for the period
***             November 16, 1996, through March 31, 1997, is from the
***             Worthington2 NNE weather station. Data from the NWS Windom
***             weather station was disaggregated from daily to hourly data
***             and used to fill in a period when neither the Lakefield or
***             Worthington2 NNE weather stations had data, February and
***             March, 1996. Data is in inches
***
***  190        Hourly modified FAO Penman potential evapotranspiration values
***             in inches. This was created by combining the hourly modified
***             FAO Penman evapotranspiration data from Lamberton
***             Experimental Station, 1987 to April1996, with the hourly
***             modified FAO Penman evapotranspiration values calculated
***             from the data collected at the USGS weather station at North
***             Branch Jack Creek, April 1996 through August 1997.
***
***  702        Hourly dewpoint temperature values (degrees F). This data
***             set was created by combining hourly dewpoint temperature
***             values calculated from data from Lamberton Experimental
***             Station, 1987 to April1996, with hourly dewpoint temperature
***             values calculated from data collected at the USGS weather
***             station at Wilmont, April 1996 through August 1997.
***
***  712        Hourly air temperature values (degrees F). This data set
***             was created by combining hourly air temperature values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly air temperature values from the USGS weather station
***             at Wilmont, April 1996 through August 1997.
***
***  721        Hourly wind speed in miles per hour. This data set was
***             created by combining hourly wind speed values from Lamberton
***             Experimental Station, 1987 to April1996, with hourly wind
***             speed values from the USGS weather station at North Branch
***             Jack Creek, April 1996 through August 1997.
***
***  731        Hourly solar radiation in Langleys/hour. This data set was
***             created by combining hourly solar radiation values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly solar radiation values from the USGS weather station
***             at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
***RCHRES   3 HYDR   RO     1 1               WDM1   583 FLOW     ENGL      REPL
RCHRES   3 ROFLOW ROVOL  1 1 0.0008595     WDM1   537 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000716     WDM1   538 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000716     WDM1   539 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000716     WDM1   540 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000716     WDM1   541 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000716     WDM1   542 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000716AVER WDM1   543 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000716AVER WDM1   544 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
```

```
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES               Data set No.: 583
*** ROVOL - Total volume of outflow from RCHRES          Data set No.: 537
*** SURO - Surface outflow                               Data set No.: 538
*** IFWO - Interflow outflow                             Data set No.: 539
*** AGWO - Active groundwater outflow                    Data set No.: 540
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 541
*** SAET - Total simulated ET                            Data set No.: 542
*** UZSX - Upper zone storage                            Data set No.: 543
*** LZSX - Lower zone storage                            Data set No.: 544
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 521                       143.3     RCHRES   3      1
PERLND 522                       973.6     RCHRES   3      1
PERLND 523                      5593.5     RCHRES   3      1
PERLND 524                      5593.5     RCHRES   3      1
PERLND 525                       227.5     RCHRES   3      1
IMPLND 540                      1408.5     RCHRES   3      2
PERLND 521                       143.3     COPY   100     90
PERLND 522                       973.6     COPY   100     90
PERLND 523                      5593.5     COPY   100     90
PERLND 524                      5593.5     COPY   100     90
PERLND 525                       227.5     COPY   100     90
IMPLND 540                      1408.5     COPY   100     91
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
***
***  The 0.833333 mulitplier converts flow in acre-inches in the PERLNDS to
***  acre-ft
***
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                    COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                    COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                    COPY           INPUT  MEAN   3
PERLND     PWATER PET                     COPY           INPUT  MEAN   4
PERLND     PWATER TAET                    COPY           INPUT  MEAN   5
PERLND     PWATER UZS                     COPY           INPUT  MEAN   6
PERLND     PWATER LZS                     COPY           INPUT  MEAN   7
```

```
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE      3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      1.63      48.0      29.0       6.5     3225.
      1.94      49.6      44.5      25.5     1269.
      2.25      51.2      60.0      50.9      856.
      2.88      54.5      93.0      77.3      873.
      3.50      57.8     128.1     107.5      865.
      4.13      61.0     165.2     142.2      843.
      4.75      64.3     204.4     180.2      824.
      6.00      70.8     288.8     267.4      784.
      7.25      77.3     381.4     367.9      753.
      8.50      83.9     482.2     481.2      728.
     11.00     666.2     729.5     748.0      708.
     13.50    1248.5    1002.7    1055.0      690.
  END FTABLE  3
END FTABLES
END RUN
```

Middle/Upper Okabena Creek Basin--without diversion

```
RUN
GLOBAL
  Middle/Upper Okabena Creek Basin--without diversion
  START       1995  8 25  0  0  END    1997  7 26  0  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      27   upperoka_without.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   upperoka_without.out
END FILES
***
***  Error file:  upperoka_without.message
***  Output file: upperoka_without.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  upperoka_without.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     621
      PERLND     622
      PERLND     623
      PERLND     624
      PERLND     625
      IMPLND     640
      RCHRES       4
      PERLND     521
      PERLND     522
      PERLND     523
      PERLND     524
      PERLND     525
      IMPLND     540
      RCHRES       3
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 521 - Wetlands in RCHRES 3 basin
***  PERLND 522 - Grasslands in RCHRES 3 basin
***  PERLND 523 - Corn in RCHRES 3 basin
***  PERLND 524 - Soybeans in RCHRES 3 basin
***  PERLND 525 - Other land uses in RCHRES 3 basin
***  IMPLND 540 - Urban/Residential in RCHRES 3 basin
***  PERLND 621 - Wetlands in RCHRES 4 basin
***  PERLND 622 - Grasslands in RCHRES 4 basin
***  PERLND 623 - Corn in RCHRES 4 basin
***  PERLND 624 - Soybeans in RCHRES 4 basin
***  PERLND 625 - Other land uses in RCHRES 4 basin
***  IMPLND 640 - Urban/Residential in RCHRES 4 basin
***  RCHRES 3 - Reservoir between USGS Okabena Creek Gage and the City
***             of Worthington, MN
***  RCHRES 4 - Reservior of Okabena Creek upgradient of the City of
```

```
***             Worthington, MN (optional)
***
PERLND
  ACTIVITY
    <PLS >                Active Sections                                 ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  521  525    1    1    1    0    0    0    0    0    0    0    0    0
  621  625    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, SNOW, and ATMP blocks,
***  simulating water flow through and snow in the system, correcting for
***  air temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  521  525    4    4    3    4    4    4    4    4    4    4    4    4    1   12
  621  625    4    4    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                          User  t-series Engl Metr***
                                            in  out          ***
  521     Wetlands                1    1    1    1   90    0
  522     Grasslands              1    1    1    1   90    0
  523     Corn                    1    1    1    1   90    0
  524     Soybeans                1    1    1    1   90    0
  525     Otherlandu              1    1    1    1   90    0
  621     Wetlands                1    1    1    1   90    0
  622     Grasslands              1    1    1    1   90    0
  623     Corn                    1    1    1    1   90    0
  624     Soybeans                1    1    1    1   90    0
  625     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  521  525      100.      73.0
  621  625      130.      73.0
  END ATEMP-DAT
***
***  Mean Elevation of PERLND 5 = 1560 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1560 - 1460 = 100 ft
***
***  Mean Elevation of PERLND 6 = 1590 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1590 - 1460 = 130 ft
***
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                            ***
  521  525    1
  621  625    1
  END ICE-FLAG
```

```
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
  521  524      43.7     1560.      0.00      1.00       0.3
  525           43.7     1560.      0.15      1.00       0.3
  621  624      43.7     1590.      0.00      1.00       0.3
  625           43.7     1590.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                  ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
  521  525      0.10      32.0      0.05      1.50       0.2     0.002
  621  625      0.10      32.0      0.05      1.5       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                          ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***          (in)       (in)    (in)                          (degF)
  521  525       0.0       0.0       0.0       0.2     375.0      32.0
  621  625       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  521  525      0.01       0.0       1.0
  621  625      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  521  522    1    1    1    1    0    0    0    0    1
  523  524    1    1    1    1    1    1    0    0    1
  525         1    1    1    1    0    0    0    0    1
  621  622    1    1    1    1    0    0    0    0    1
  623  624    1    1    1    1    1    1    0    0    1
  625         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)                (1/in)   (1/day)
  521            0.0       3.0     0.400     350.0     0.006       0.3     0.940
  522  524       0.0       4.2     0.025     513.0     0.006       0.3     0.940
  525           0.15       4.2     0.025     513.0     0.006       0.3     0.940
  621            0.0       3.0     0.400     350.0     0.006       0.3     0.94
  622  624       0.0       4.2     0.025     445.0     0.006       0.3     0.94
  625           0.15       4.2     0.025     445.0     0.006       0.3     0.94
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  521  525      35.0      30.0       2.0       2.0     0.001       0.0       0.0
```

```
  621  625      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                        (1/day)
  521            1.0       2.5       0.4       3.0      0.83      0.35
  522            1.0       1.0       0.2       3.4      0.83      0.35
  523  524       1.0       0.8       0.1       3.4      0.83      0.35
  525            1.0       1.0       0.2       3.4      0.83      0.35
  621            1.0       2.5       0.4       3.0      0.83      0.35
  622            1.0       1.0       0.2       3.4      0.83      0.35
  623  624       1.0       0.8       0.1       3.4      0.83      0.35
  625            1.0       1.0       0.2       3.4      0.83      0.35
  END PWAT-PARM4
***
***  First set of values:
***  Interception storage capacity values (CEPSC) at start of each month
***  are stored in the MON-INTERCEP table below, so the CEPSC value is
***  ignored.  Upper zone nominal storage (UZSN) will also vary monthly,
***  with values listed in the MON-UZSN table below.  Since monthly
***  Manning's n values will be used, NSUR value is ignored in model
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  521  525      20.0       0.1
  621  625      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  521      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  522      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  523      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  524      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  525      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  621      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  622      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  623      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  624      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  625      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  523  524 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  623  624 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  521  522 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  523  524 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  525      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  621  622 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  623  624 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  625      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
```

```
  521      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  522      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  523  524 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  525      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  621      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  622      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  623  624 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  625      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  521  525       0.0       0.0      0.01       0.0      0.01      0.01      0.30
  621  625       0.0       0.0      0.01       0.0      0.01      0.01      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  540  540    1    1    1    0    0    0
  640  640    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  540  540    4    4    4    4    4    4    1   12
  640  640    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                            in  out
  540  540Urbn/Resdt                   1    1   90    0
  640  640Urbn/Resdt                   1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  540  540     100.0      73.0
  640  640     130.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  540  540    1
  640  640    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  540  540      43.7    1560.0      0.00      1.00       0.3
  640  640      43.7    1590.0      0.00      1.00       0.3
  END SNOW-PARM1
  SNOW-PARM2
*** <ILS >  Snow input info: Part 2                                    ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
```

```
***                      (degF)                                  (in/day)***
  540  540      0.10      32.0      0.05       1.5       0.2     0.002
  640  640      0.10      32.0      0.05       1.5       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                            ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                           (degF)
  540  540       0.0       0.0       0.0       0.2     375.0      32.0
  640  640       0.0       0.0       0.0       0.2     375.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  540  540      0.01       0.0       1.0
  640  640      0.01       0.0       1.0
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  540  540    1    1    1    0    0
  640  640    1    1    1    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                         (ft)
  540  540     300.0     0.006       0.1       0.0
  640  640     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  540  540 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  640  640 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  540  540     0.001     0.001
  640  640     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
```

```
    3    3    1    0    0    0    0    0    0    0    0    0
    4    4    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    3    3    4    4    6    6    6    6    6    6    6    6    1   12
    4    4    4    4    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name         Nexits   Unit Systems   Printer
*** RCHRES                                t-series  Engl Metr LKFG
*** x -  x                                  in  out
    3     Okabena Cr above USGS   1         1    1   90    0    0
    4     Okabena Cr above Wort   1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    3    3   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
    4    4   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x            (miles)      (ft)      (ft)                (in)
    3       0.0  3.0      23.1     120.0      83.5       0.5      0.01
    4       0.0  4.0       6.7      90.0      83.5       0.5      0.01
  END HYDR-PARM2
  HYDR-INIT
***         Initial conditions for HYDR section
*** RCHRES       VO  Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    3           26.70  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    4            2.00  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   153 PRCP  10 ENGL          0.35     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL          0.65     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           1.0     IMPLND 540 540 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 521 525 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL           1.0     IMPLND 540 540 EXTNL  PETINP 1 1
WDM1   150 PRCP  10 ENGL           1.0     PERLND 621 625 EXTNL  PREC
WDM1   150 PRCP  10 ENGL           1.0     IMPLND 640 640 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 621 625 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL           1.0     IMPLND 640 640 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 521 525 EXTNL  GATMP  1 1
```

```
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 540 540 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 521 525 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 540 540 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 521 525 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 540 540 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 521 525 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 540 540 EXTNL  DTMPG  1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 621 625 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 640 640 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 621 625 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 640 640 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 621 625 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 640 640 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 621 625 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 640 640 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  150         Precipitation data collected from Worthington 2 NNE weather
***              station. Portions of the data were missing between 1991 and
***              1997. Precipitation for these missing record periods was
***              estimated using hourly and daily precipitation data
***              collected at NWS weather stations located at Luverne and
***              Sherburn, Minnesota and Sibley, Iowa, USGS weather stations
***              at North Branch Jack Creek and Wilmont, and USGS
***              precipitation gages at (1) Okabena Creek on County State Aid
***              Highway 14, near Brewster and (2) near Okabena. Data is in
***              inches.
***
***  153         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS
***              precipitation gage at Okabena Creek on County State Aid
***              Highway 14, near Brewster between April 1996 and August
***              1997. Because the North Branch Jack Creek weather station
***              was not operated during the winter, values for the period
***              November 16, 1996, through March 31, 1997, is from the
***              Worthington2 NNE weather station. Data from the NWS Windom
***              weather station was disaggregated from daily to hourly data
***              and used to fill in a period when neither the Lakefield or
***              Worthington2 NNE weather stations had data, February and
***              March, 1996. Data is in inches
***
***  190         Hourly modified FAO Penman potential evapotranspiration values
***              in inches. This was created by combining the hourly modified
***              FAO Penman evapotranspiration data from Lamberton
***              Experimental Station, 1987 to April1996, with the hourly
***              modified FAO Penman evapotranspiration values calculated
***              from the data collected at the USGS weather station at North
***              Branch Jack Creek, April 1996 through August 1997.
***
***  702         Hourly dewpoint temperature values (degrees F). This data
***              set was created by combining hourly dewpoint temperature
***              values calculated from data from Lamberton Experimental
***              Station, 1987 to April1996, with hourly dewpoint temperature
***              values calculated from data collected at the USGS weather
```

```
***              station at Wilmont, April 1996 through August 1997.
***
***  712         Hourly air temperature values (degrees F). This data set
***              was created by combining hourly air temperature values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly air temperature values from the USGS weather station
***              at Wilmont, April 1996 through August 1997.
***
***  721         Hourly wind speed in miles per hour. This data set was
***              created by combining hourly wind speed values from Lamberton
***              Experimental Station, 1987 to April1996, with hourly wind
***              speed values from the USGS weather station at North Branch
***              Jack Creek, April 1996 through August 1997.
***
***  731         Hourly solar radiation in Langleys/hour. This data set was
***              created by combining hourly solar radiation values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly solar radiation values from the USGS weather station
***              at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
***RCHRES   3 HYDR   RO     1 1               WDM1   583 FLOW     ENGL      REPL
RCHRES   3 ROFLOW ROVOL  1 1 0.0006132     WDM1   537 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000511     WDM1   538 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000511     WDM1   539 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000511     WDM1   540 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000511     WDM1   541 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000511     WDM1   542 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000511AVER WDM1   543 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000511AVER WDM1   544 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES              Data set No.: 583
*** ROVOL - Total volume of outflow from RCHRES         Data set No.: 537
*** SURO - Surface outflow                              Data set No.: 538
*** IFWO - Interflow outflow                            Data set No.: 539
*** AGWO - Active groundwater outflow                   Data set No.: 540
*** PETX - Potential ET, adjusted for snow/air temp     Data set No.: 541
*** SAET - Total simulated ET                           Data set No.: 542
*** UZSX - Upper zone storage                           Data set No.: 543
*** LZSX - Lower zone storage                           Data set No.: 544
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 521                       143.3     RCHRES   3      1
PERLND 522                       973.6     RCHRES   3      1
PERLND 523                      5593.5     RCHRES   3      1
PERLND 524                      5593.5     RCHRES   3      1
PERLND 525                       227.3     RCHRES   3      1
IMPLND 540                      1408.5     RCHRES   3      2
PERLND 521                       143.3     COPY   100     90
PERLND 522                       973.6     COPY   100     90
PERLND 523                      5593.5     COPY   100     90
```

```
PERLND 524                      5593.5     COPY   100     90
PERLND 525                       227.3     COPY   100     90
IMPLND 540                      1408.5     COPY   100     91
PERLND 621                        19.8     RCHRES   4      1
PERLND 622                       518.9     RCHRES   4      1
PERLND 623                      2330.3     RCHRES   4      1
PERLND 624                      2330.3     RCHRES   4      1
PERLND 625                       101.3     RCHRES   4      1
IMPLND 640                       296.5     RCHRES   4      2
PERLND 621                        19.8     COPY   100     90
PERLND 622                       518.9     COPY   100     90
PERLND 623                      2330.3     COPY   100     90
PERLND 624                      2330.3     COPY   100     90
PERLND 625                       101.3     COPY   100     90
IMPLND 640                       296.5     COPY   100     91
RCHRES   4                                 RCHRES   3      3
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
***
***  The 0.833333 mulitplier converts flow in acre-inches in the PERLNDS to
***  acre-ft
***
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                    COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                    COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                    COPY           INPUT  MEAN   3
PERLND     PWATER PET                     COPY           INPUT  MEAN   4
PERLND     PWATER TAET                    COPY           INPUT  MEAN   5
PERLND     PWATER UZS                     COPY           INPUT  MEAN   6
PERLND     PWATER LZS                     COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                    COPY           INPUT  MEAN   1
IMPLND     IWATER PET                     COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                   COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
```

```
  FTABLE      3
 ROWS COLS ***
   13    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
       0.00       0.0       0.0       0.0        0.
       1.63      48.0      29.0       6.5     3225.
       1.94      49.6      44.5      25.5     1269.
       2.25      51.2      60.0      50.9      856.
       2.88      54.5      93.0      77.3      873.
       3.50      57.8     128.1     107.5      865.
       4.13      61.0     165.2     142.2      843.
       4.75      64.3     204.4     180.2      824.
       6.00      70.8     288.8     267.4      784.
       7.25      77.3     381.4     367.9      753.
       8.50      83.9     482.2     481.2      728.
      11.00     666.2     729.5     748.0      708.
      13.50    1248.5    1002.7    1055.0      690.
  END FTABLE  3
  FTABLE      4
 ROWS COLS ***
   15    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
       0.00       0.0       0.0       0.0        0.
       0.42       6.5       2.7       3.3      601.
       0.83       6.5       5.4       9.8      402.
       1.25       6.5       8.1      18.2      324.
       1.67       6.5      10.8      27.9      282.
       2.08       6.5      13.5      38.6      254.
       2.50       6.5      16.2      50.1      235.
       3.33       6.5      21.7      74.7      211.
       4.17       6.5      27.1     100.8      195.
       5.00       6.5      32.5     128.0      184.
       6.67      96.7     118.5     412.1      209.
       8.33     187.0     354.9    1604.      161.
      10.00     277.2     741.7    4252.      127.
      11.67     367.4    1278.9    8808.      105.
      13.33     457.7    1966.5   15675.       91.
  END FTABLE  4
END FTABLES
END RUN
```

Jack Creek Basin

```
RUN
GLOBAL
  Jack Creek Basin
  START       1987  7 16  0  0  END    1996  9  1 24  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      25   jackcreek.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   jackcreek.out
END FILES
***
***  Error file:  jackcreek.message
***  Output file: jackcreek.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  jackcreek.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND      21
      PERLND      22
      PERLND      23
      PERLND      24
      PERLND      25
      RCHRES      13
      PERLND     921
      PERLND     922
      PERLND     923
      PERLND     924
      PERLND     925
      RCHRES      14
      PERLND     721
      PERLND     722
      PERLND     723
      PERLND     724
      PERLND     725
      RCHRES      12
      PERLND     821
      PERLND     822
      PERLND     823
      PERLND     824
      PERLND     825
      IMPLND     840
      RCHRES      10
      RCHRES      11
      RCHRES       9
      PERLND     726
      PERLND     727
      PERLND     728
      PERLND     729
      PERLND     730
      RCHRES       8
```

```
      PERLND     731
      PERLND     732
      PERLND     733
      PERLND     734
      PERLND     735
      RCHRES       7
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 21 - Wetlands in RCHRES 13 basin
***  PERLND 22 - Grasslands in RCHRES 13 basin
***  PERLND 23 - Corn in RCHRES 13 basin
***  PERLND 24 - Soybeans in RCHRES 13 basin
***  PERLND 25 - Other land uses in RCHRES 13 basin
***  RCHRES 13 - Reservior upgradient of USGS Jack Creek Gage
***  PERLND 921 - Wetlands in RCHRES 14 basin
***  PERLND 922 - Grasslands in RCHRES 14 basin
***  PERLND 923 - Corn in RCHRES 14 basin
***  PERLND 924 - Soybeans in RCHRES 14 basin
***  PERLND 925 - Other land uses in RCHRES 14 basin
***  RCHRES 14 - Reservior upgradient of USGS North Branch of Jack Creek
***              Gage
***  PERLND 721 - Wetlands in RCHRES 12 basin
***  PERLND 722 - Grasslands in RCHRES 12 basin
***  PERLND 723 - Corn in RCHRES 12 basin
***  PERLND 724 - Soybeans in RCHRES 12 basin
***  PERLND 725 - Other land uses in RCHRES 12 basin
***  RCHRES 12 - Reservior between Confluence of Graham Lakes Outlet and
***              Jack Creek and USGS Jack and North Branch of Jack Creek
***              Gages
***  PERLND 821 - Wetlands in REACHRES 9, 10, 11 basin
***  PERLND 822 - Grasslands in REACHRES 9, 10, 11 basin
***  PERLND 823 - Corn in REACHRES 9, 10, 11 basin
***  PERLND 824 - Soybeans in REACHRES 9, 10, 11 basin
***  PERLND 825 - Other land uses in REACHRES 9, 10, 11 basin
***  IMPLND 840 - Urban/Residential in REACHRES 10 basin
***  RCHRES  9 - Reservior upgradient of USGS East Graham Lake Outlet Gage
***              to West Graham Lake and Jack Lake
***  RCHRES 10 - Reservior upgradient of West Graham Lake
***  RCHRES 11 - Reservior upgradient of Jack Lake
***  PERLND 726 - Wetlands in RCHRES 8 basin
***  PERLND 727 - Grasslands in RCHRES 8 basin
***  PERLND 728 - Corn in RCHRES 8 basin
***  PERLND 729 - Soybeans in RCHRES 8 basin
***  PERLND 730 - Other land uses in RCHRES 8 basin
***  RCHRES  8 - Reservior between Confluence of Graham Lakes Outlet and
***              USGS East Graham Lake Outlet Gage
***  PERLND 731 - Wetlands in RCHRES 7 basin
***  PERLND 732 - Grasslands in RCHRES 7 basin
***  PERLND 733 - Corn in RCHRES 7 basin
***  PERLND 734 - Soybeans in RCHRES 7 basin
***  PERLND 735 - Other land uses in RCHRES 7 basin
***  RCHRES  7 - Reservior between Jack (MDNR) Gage and Confluence of
***              Graham Lakes Outlet and Jack Creek
***
PERLND
```

```
  ACTIVITY
    <PLS >                Active Sections                                  ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
   21   25    1    1    1    0    0    0    0    0    0    0    0    0
  721  735    1    1    1    0    0    0    0    0    0    0    0    0
  821  825    1    1    1    0    0    0    0    0    0    0    0    0
  921  925    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER,ATMP, and SNOW Block,
***  simulating water flow through and snow in the system, correcting air temp.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
   21   25    6    6    6    4    4    4    4    4    4    4    4    4    1   12
  721  735    6    6    6    4    4    4    4    4    4    4    4    4    1   12
  821  825    6    6    6    4    4    4    4    4    4    4    4    4    1   12
  921  925    6    6    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
    <PLS >         Name        NBLKS   Unit-systems   Printer***
    x -  x                        User  t-series Engl Metr***
                                         in  out          ***
   21     Wetlands13               1    1    1    1    90    0
   22     Grasslnd13               1    1    1    1    90    0
   23     Corn13                   1    1    1    1    90    0
   24     Soybeans13               1    1    1    1    90    0
   25     Otherlnd13               1    1    1    1    90    0
  721     Wetlands12               1    1    1    1    90    0
  722     Grasslnd12               1    1    1    1    90    0
  723     Corn12                   1    1    1    1    90    0
  724     Soybeans12               1    1    1    1    90    0
  725     Otherlnd12               1    1    1    1    90    0
  726     Wetlands8                1    1    1    1    90    0
  727     Grassland8               1    1    1    1    90    0
  728     Corn8                    1    1    1    1    90    0
  729     Soybeans8                1    1    1    1    90    0
  730     Otherland8               1    1    1    1    90    0
  731     Wetlands7                1    1    1    1    90    0
  732     Grassland7               1    1    1    1    90    0
  733     Corn7                    1    1    1    1    90    0
  734     Soybeans7                1    1    1    1    90    0
  735     Otherland7               1    1    1    1    90    0
  821     Wetlands9                1    1    1    1    90    0
  822     Grassland9               1    1    1    1    90    0
  823     Corn9                    1    1    1    1    90    0
  824     Soybeans9                1    1    1    1    90    0
  825     Otherland9               1    1    1    1    90    0
  921     Wetlands14               1    1    1    1    90    0
  922     Grasslnd14               1    1    1    1    90    0
  923     Corn14                   1    1    1    1    90    0
  924     Soybeans14               1    1    1    1    90    0
  925     Otherlnd14               1    1    1    1    90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
```

```
    # -  #      (ft)    (deg F)   ***
   21   25      202.      73.0
  721  735       22.      73.0
  821  825       62.      73.0
  921  925      192.      73.0
  END ATEMP-DAT
***
***  Elevation for the Sioux Falls Weather Station = 1418 ft
***  Mean elevation of PERLND 21-25 = 1620 ft (El-diff = 1620-1418=202)
***  Mean elevation of PERLND 721-735 = 1440 ft (El-diff = 1440-1418=22)
***  Mean elevation of PERLND 821-825 = 1480 ft (El-diff = 1480-1418=62)
***  Mean elevation of PERLND 921-925 = 1610 ft (El-diff = 1610-1418=192)
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                          ***
   21   25    1
  721  735    1
  821  825    1
  921  925    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
   21   24      43.8     1620.      0.00      1.00       0.3
   25           43.8     1620.      0.15      1.00       0.3
  721  724      43.8     1440.      0.00      1.00       0.3
  725           43.8     1440.      0.15      1.00       0.3
  726  729      43.8     1440.      0.00      1.00       0.3
  730           43.8     1440.      0.15      1.00       0.3
  731  734      43.8     1440.      0.00      1.00       0.3
  735           43.8     1440.      0.15      1.00       0.3
  821  824      43.8     1480.      0.00      1.00       0.3
  825           43.8     1480.      0.15      1.00       0.3
  921  924      43.9     1610.      0.00      1.00       0.3
  925           43.9     1610.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                  ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
   21   25      0.10      32.0      0.05      1.50      0.20     0.002
  721  735      0.10      32.0      0.05      1.50      0.20     0.002
  821  825      0.10      32.0      0.05      1.50      0.20     0.002
  921  925      0.10      32.0      0.05      1.50      0.20     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                          ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)      (in)    (in)                            (degF)
   21   25       0.0       0.0       0.0       0.2       0.0      32.0
  721  735       0.0       0.0       0.0       0.2       0.0      32.0
  821  825       0.0       0.0       0.0       0.2       0.0      32.0
```

```
  921  925       0.0       0.0       0.0       0.2       0.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
   21   25      0.01       0.0       1.0
  721  735      0.01       0.0       1.0
  821  825      0.01       0.0       1.0
  921  925      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                     Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
   21   22    1    1    1    1    0    0    0    0    1
   23   23    1    1    1    1    1    1    0    0    1
   25         1    1    1    1    0    0    0    0    1
  721  722    1    1    1    1    0    0    0    0    1
  723  724    1    1    1    1    1    1    0    0    1
  725         1    1    1    1    0    0    0    0    1
  821  822    1    1    1    1    0    0    0    0    1
  823  824    1    1    1    1    1    1    0    0    1
  825         1    1    1    1    0    0    0    0    1
  921  922    1    1    1    1    0    0    0    0    1
  923  924    1    1    1    1    1    1    0    0    1
  925         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x - x                (in)   (in/hr)      (ft)               (1/in)    (1/day)
   21           0.0       3.0     0.400     350.0     0.006       0.3     0.940
   22  24       0.0       4.2     0.025     410.0     0.006       0.3     0.940
   25          0.15       4.2     0.025     410.0     0.006       0.3     0.940
  721           0.0       3.0     0.400     350.0     0.006       0.3     0.940
  722 724       0.0       4.2     0.025     487.0     0.006       0.3     0.940
  725          0.15       4.2     0.025     487.0     0.006       0.3     0.940
  726           0.0       3.0     0.400     350.0     0.006       0.3     0.940
  727 729       0.0       4.2     0.025     487.0     0.006       0.3     0.940
  730          0.15       4.2     0.025     487.0     0.006       0.3     0.940
  731           0.0       3.0     0.400     350.0     0.006       0.3     0.940
  732 734       0.0       4.2     0.025     487.0     0.006       0.3     0.940
  735          0.15       4.2     0.025     487.0     0.006       0.3     0.940
  821           0.0       3.0     0.400     350.0     0.006       0.3     0.940
  822 824       0.0       4.2     0.060     431.0     0.006       0.3     0.940
  825          0.15       4.2     0.060     431.0     0.006       0.3     0.940
  921           0.0       3.0     0.400     350.0     0.006       0.3     0.940
  922 924       0.0       4.2     0.025     403.0     0.006       0.3     0.940
  925          0.15       4.2     0.025     403.0     0.006       0.3     0.940
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
   21   25      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  721  735      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  821  825      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  921  925      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  END PWAT-PARM3
```

```
  PWAT-PARM4
*** <PLS >      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x       (in)      (in)                          (1/day)
   21             1.0       2.5       0.4       3.0      0.83      0.35
   22             1.0       1.0       0.2       3.4      0.83      0.35
   23   24        1.0       0.8       0.1       3.4      0.83      0.35
   25             1.0       1.0       0.2       3.4      0.83      0.35
  721             1.0       2.5       0.4       3.0      0.83      0.35
  722             1.0       1.0       0.2       3.4      0.83      0.35
  723  724        1.0       0.8       0.1       3.4      0.83      0.35
  725             1.0       1.0       0.2       3.4      0.83      0.35
  726             1.0       2.5       0.4       3.0      0.83      0.35
  727             1.0       1.0       0.2       3.4      0.83      0.35
  728  729        1.0       0.8       0.1       3.4      0.83      0.35
  730             1.0       1.0       0.2       3.4      0.83      0.35
  731             1.0       2.5       0.4       3.0      0.83      0.35
  732             1.0       1.0       0.2       3.4      0.83      0.35
  733  734        1.0       0.8       0.1       3.4      0.83      0.35
  735             1.0       1.0       0.2       3.4      0.83      0.35
  821             1.0       2.5       0.4       3.0      0.83      0.35
  822             1.0       1.0       0.2       3.4      0.83      0.35
  823  824        1.0       0.8       0.1       3.4      0.83      0.35
  825             1.0       1.0       0.2       3.4      0.83      0.35
  921             1.0       2.5       0.4       3.0      0.83      0.35
  922             1.0       1.0       0.2       3.4      0.83      0.35
  923  924        1.0       0.8       0.1       3.4      0.83      0.35
  925             1.0       1.0       0.2       3.4      0.83      0.35
  END PWAT-PARM4
***  Interception storage capacity values (CEPSC) at start of each month
***  are stored in the MON-INTERCEP table below, so the CEPSC value is
***  ignored.  Upper zone nominal storage (UZSN) will also vary monthly,
***  with values listed in the MON-UZSN table below.  Since monthly
***  Manning's n values will be used, NSUR value is ignored in model.
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
   21   25      20.0       0.1
  721  735      20.0       0.1
  821  825      20.0       0.1
  921  925      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   21      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
   22      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
   23      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
   24      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
   25      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  721      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  722      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  723      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  724      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  725      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  726      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  727      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  728      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  729      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
```

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  730      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  731      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  732      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  733      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  734      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  735      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  821      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  822      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  823      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  824      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  825      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  921      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  922      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  923      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  924      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  925      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP

  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   23   24 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  723  734 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  823  824 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  923  924 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   21   22 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
   23   24 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
   25      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  721  722 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  723  724 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  725  727 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  728  729 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  730  732 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  733  734 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  735      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  821  822 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  823  824 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  825      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  921  922 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  923  924 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  925      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS > Lower zone evapotranspiration parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   21      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
   22      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
   23   24 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
   25      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  721      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  722      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  723  724 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  725      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  726      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  727      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
```

```
  728  729 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  730      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  731      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  732      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  733  734 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  735      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  821      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  822      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  823  824 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  825      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  921      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  922      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  923  924 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  925      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
   21   25       0.0       0.0      0.10       0.0      1.00      0.30      0.30
  721  735       0.0       0.0      0.10       0.0      1.00      0.30      0.30
  821  825       0.0       0.0      0.10       0.0      1.00      0.30      0.30
  921  925       0.0       0.0      0.10       0.0      1.00      0.30      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  840  840    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  840  840    6    6    6    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                            in  out
  840  840Urbn/Resdt                    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  840  840     -10.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  840  840    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  840  840      43.8    1480.0      0.00      1.00       0.3
  END SNOW-PARM1
  SNOW-PARM2
```

```
*** <ILS >  Snow input info: Part 2                                  ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                      (degF)                                  (in/day)***
  840  840      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                          ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***            (in)       (in)    (in)                          (degF)
  840  840       0.0       0.0       0.0       0.2       0.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  840  840      0.01       0.0       1.0
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  840  840    1    1    1    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                         (ft)
  840  840     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  840  840 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  840  840     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    7   14    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  Only the Hydraulic behavior block will be used in the simulation.
***
```

```
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    7   14    6    6    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
    7        Jack Cr above DNR    1         1    1   90    0    0
    8        Trib below EGLO      1         1    1   90    0    0
    9        Above EGLO           1         1    1   90    0    0
   10        Above WGL            1         1    1   90    0    0
   11        Above JackL          1         1    1   90    0    0
   12        Above EGLO conf      1         1    1   90    0    0
   13        Jack Cr above 12     1         1    1   90    0    0
   14        N. Branch Jack Cr    1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
*** RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
*** x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    7   14   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR         KS       DB50
*** x -  x             (miles)      (ft)      (ft)                  (in)
  <range-><----><----><-------><-------><-------><-------><-------->  ***
    7       0.0  7.0       4.2       4.0    1402.9       0.5      0.01
    8       0.0  8.0       8.4      22.0    1411.0       0.5      0.01
    9       0.0  9.0       3.0       3.0     93.29       0.5      0.01
   10       0.0 10.0      12.3      44.0     93.29       0.5      0.01
   11       0.0 11.0      10.5      64.0     93.29       0.5      0.01
   12       0.0 12.0      26.6      69.0    1411.0       0.5      0.01
   13       0.0 13.0      32.9     240.0     82.11       0.5      0.01
   14       0.0 14.0      43.4     270.0     87.69       0.5      0.01
  END HYDR-PARM2
  HYDR-INIT
***
*** The number of acre feet was obtained from ftable by assuming a 2.0 ft depth
***
***         Initial conditions for HYDR section
*** RCHRES       VOL Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    7            200  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    8             60  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    9             40  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   10             20 [A    4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   11          21.00  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   12             50 [A    4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   13          13.65  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   14          10.00  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
```

```
*** x -  x  NPT  NMN***
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   200 PRCP  10 ENGL          0.62     PERLND  21  25 EXTNL  PREC   1 1
WDM1   201 PRCP  10 ENGL          0.38     PERLND  21  25 EXTNL  PREC   1 1
WDM1   191 PET   10 ENGL           1.0     PERLND  21  25 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND  21  25 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND  21  25 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND  21  25 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND  21  25 EXTNL  DTMPG  1 1
WDM1   202 PRCP  10 ENGL          0.46     PERLND 721 735 EXTNL  PREC   1 1
WDM1   203 PRCP  10 ENGL          0.17     PERLND 721 735 EXTNL  PREC   1 1
WDM1   204 PRCP  10 ENGL          0.37     PERLND 721 735 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 721 735 EXTNL  PETINP 1 1
WDM1   711 TEMP  10 ENGL           1.0     PERLND 721 735 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 721 735 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 721 735 EXTNL  SOLRAD 1 1
WDM1   701 DWPT  10 ENGL           1.0     PERLND 721 735 EXTNL  DTMPG  1 1
WDM1   205 PRCP  10 ENGL           1.0     PERLND 821 825 EXTNL  PREC   1 1
WDM1   205 PRCP  10 ENGL           1.0     IMPLND 840 840 EXTNL  PREC   1 1
WDM1   191 PET   10 ENGL           1.0     PERLND 821 825 EXTNL  PETINP 1 1
WDM1   191 PET   10 ENGL           1.0     IMPLND 840 840 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 821 825 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 840 840 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 821 825 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 840 840 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 821 825 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 840 840 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 821 825 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 840 840 EXTNL  DTMPG  1 1
WDM1   803 CLND  10 ENGL           1.0     RCHRES   9  11 EXTNL  COLIND 1 1
WDM1   206 PRCP  10 ENGL          0.35     PERLND 921 925 EXTNL  PREC   1 1
WDM1   207 PRCP  10 ENGL          0.65     PERLND 921 925 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 921 925 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 921 925 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 921 925 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 921 925 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 921 925 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  190         Hourly modified FAO Penman potential evapotranspiration values
***              in inches. This was created by combining the hourly modified
***              FAO Penman evapotranspiration data from Lamberton
***              Experimental Station, 1987 to April1996, with the hourly
***              modified FAO Penman evapotranspiration values calculated
***              from the data collected at the USGS weather station at North
***              Branch Jack Creek, April 1996 through August 1997.
***
***  191         Hourly modified FAO Penman potential evapotranspiration
***              values in inches. This was created by combining the hourly
```

```
***             modified FAO Penman evapotranspiration data from Lamberton
***             Experimental Station, 1987 to April1996, with the hourly
***             modified FAO Penman evapotranspiration values calculated
***             from the data collected at the USGS weather station at
***             Wilmont, April 1996 through August 1997.
***
***  200        Hourly precipitation data in inches. Local daily observer data
***             within the Upper Jack Creek Basin was converted to hourly
***             data and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 152 were used.
***
***  201        Hourly precipitation data in inches. Local daily observer data
***             within the Upper Jack Creek Basin was converted to hourly
***             data and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 151 were used.
***
***  202        Hourly precipitation data in inches. Local daily observer data
***             within the Middle Jack Creek Basin was converted to hourly
***             data and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 151 were used.
***
***  203        Hourly precipitation data in inches. Local daily observer data
***             within the Middle Jack Creek Basin was converted to hourly
***             data and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 153 were used.
***
***  204        Hourly precipitation data in inches. Local daily observer data
***             within the Middle Jack Creek Basin was converted to hourly
***             data and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from the USGS precipitation gage near Okabena were
***             used. Winter values from 1996 through 1997 are from the NWS
***             Lakefield weather station.
***
***  205        Hourly precipitation data in inches. Local daily observer data
***             within the East Graham Lakes Outlet Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 151 were used.
***
***  206        Hourly precipitation data in inches. Local daily observer data
***             within the North Branch Jack Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 151 were used.
***
***  207        Hourly precipitation data in inches. Local daily observer
***             data within the North Branch Jack Creek Basin was converted
***             to hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 152 were used.
***
***  701        Hourly dewpoint temperature values (degrees F). This data set
```

```
***             was created by combining hourly dewpoint temperature values
***             calculated from data from Lamberton Experimental Station,
***             1987 to April1996, with hourly dewpoint temperature values
***             calculated from data collected at the USGS weather station
***             at North Branch Jack Creek, April 1996 through August 1997.
***
***  702        Hourly dewpoint temperature values (degrees F). This data
***             set was created by combining hourly dewpoint temperature
***             values calculated from data from Lamberton Experimental
***             Station, 1987 to April1996, with hourly dewpoint temperature
***             values calculated from data collected at the USGS weather
***             station at Wilmont, April 1996 through August 1997.
***
***  711        Hourly air temperature values (degrees F). This data set
***             was created by combining hourly air temperature values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly air temperature values from the USGS weather station
***             at North Branch Jack Creek, April 1996 through August 1997.
***
***  712        Hourly air temperature values (degrees F). This data set
***             was created by combining hourly air temperature values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly air temperature values from the USGS weather station
***             at Wilmont, April 1996 through August 1997.
***
***  721        Hourly wind speed in miles per hour. This data set was
***             created by combining hourly wind speed values from Lamberton
***             Experimental Station, 1987 to April1996, with hourly wind
***             speed values from the USGS weather station at North Branch
***             Jack Creek, April 1996 through August 1997.
***
***  731        Hourly solar radiation in Langleys/hour. This data set was
***             created by combining hourly solar radiation values from
***             Lamberton Experimental Station, 1987 to April1996, with
***             hourly solar radiation values from the USGS weather station
***             at North Branch Jack Creek, April 1996 through August 1997.
***
***  803        Column rating index for the streamflow gaging station at
***             East Graham Lake Outlet on County State Aid Highway 1, near
***             Kinbrae.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** RCHRES   7 HYDR   RO     1 1 1.0           WDM1   481 FLOW     ENGL      REP
RCHRES   7 ROFLOW ROVOL  1 1 0.0000920     WDM1   420 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000077     WDM1   421 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000077     WDM1   422 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000077     WDM1   423 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000077     WDM1   425 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000077     WDM1   426 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000077AVER WDM1   427 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000077AVER WDM1   428 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
```

```
*** RO - Total rate of outflow from RCHRES               Data set No.: 481
*** ROVOL (QDEP) - Total volume of outflow from RCHRES   Data set No.: 420
*** SURO - Surface outflow                               Data set No.: 421
*** IFWO - Interflow outflow                             Data set No.: 422
*** AGWO - Active groundwater outflow                    Data set No.: 423
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 425
*** SAET - Total simulated ET                            Data set No.: 426
*** UZSX - Upper zone storage                            Data set No.: 427
*** LZSX - Lower zone storage                            Data set No.: 428
***
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND  21                        96.4     RCHRES  13      1
PERLND  22                      1882.9     RCHRES  13      1
PERLND  23                     16500.9     RCHRES  13      1
PERLND  24                     16500.9     RCHRES  13      1
PERLND  25                       588.1     RCHRES  13      1
PERLND 721                        48.1     RCHRES  12      1
PERLND 722                      1012.8     RCHRES  12      1
PERLND 723                      6435.5     RCHRES  12      1
PERLND 724                      6435.5     RCHRES  12      1
PERLND 725                       286.9     RCHRES  12      1
PERLND 726                        15.1     RCHRES   8      1
PERLND 727                       318.8     RCHRES   8      1
PERLND 728                      2026.0     RCHRES   8      1
PERLND 729                      2026.0     RCHRES   8      1
PERLND 730                        90.3     RCHRES   8      1
PERLND 731                        25.8     RCHRES   7      1
PERLND 732                       543.9     RCHRES   7      1
PERLND 733                      3456.1     RCHRES   7      1
PERLND 734                      3456.1     RCHRES   7      1
PERLND 735                       154.1     RCHRES   7      1
PERLND 821                       146.8     RCHRES   9      1
PERLND 822                       102.0     RCHRES   9      1
PERLND 823                       989.2     RCHRES   9      1
PERLND 824                       989.2     RCHRES   9      1
PERLND 825                        53.1     RCHRES   9      1
IMPLND 840                         0.0     RCHRES   9      2
PERLND 821                       807.3     RCHRES  10      1
PERLND 822                       561.3     RCHRES  10      1
PERLND 823                      5440.5     RCHRES  10      1
PERLND 824                      5440.5     RCHRES  10      1
PERLND 825                       292.2     RCHRES  10      1
IMPLND 840                       195.2     RCHRES  10      2
PERLND 821                       513.7     RCHRES  11      1
PERLND 822                       357.2     RCHRES  11      1
PERLND 823                      3462.2     RCHRES  11      1
PERLND 824                      3462.2     RCHRES  11      1
PERLND 825                       186.0     RCHRES  11      1
IMPLND 840                         0.0     RCHRES  11      2
PERLND 921                       469.5     RCHRES  14      1
PERLND 922                      2861.4     RCHRES  14      1
PERLND 923                     20683.7     RCHRES  14      1
PERLND 924                     20683.7     RCHRES  14      1
PERLND 925                       805.5     RCHRES  14      1
RCHRES  13                                 RCHRES  12      3
```

```
RCHRES  14                                RCHRES  12      3
RCHRES  10                                RCHRES   9      3
RCHRES  11                                RCHRES   9      3
RCHRES   9                                RCHRES   8      3
RCHRES   8                                RCHRES   7      3
RCHRES  12                                RCHRES   7      3
PERLND  21                        96.4    COPY   100     90
PERLND  22                      1882.9    COPY   100     90
PERLND  23                     16500.9    COPY   100     90
PERLND  24                     16500.9    COPY   100     90
PERLND  25                       588.1    COPY   100     90
PERLND 721                        48.1    COPY   100     90
PERLND 722                      1012.8    COPY   100     90
PERLND 723                      6435.5    COPY   100     90
PERLND 724                      6435.5    COPY   100     90
PERLND 725                       286.9    COPY   100     90
PERLND 726                        15.1    COPY   100     90
PERLND 727                       318.8    COPY   100     90
PERLND 728                      2026.0    COPY   100     90
PERLND 729                      2026.0    COPY   100     90
PERLND 730                        90.3    COPY   100     90
PERLND 731                        25.8    COPY   100     90
PERLND 732                       543.9    COPY   100     90
PERLND 733                      3456.1    COPY   100     90
PERLND 734                      3456.1    COPY   100     90
PERLND 735                       154.1    COPY   100     90
PERLND 821                      1467.8    COPY   100     90
PERLND 822                      1020.5    COPY   100     90
PERLND 823                      9891.9    COPY   100     90
PERLND 824                      9891.9    COPY   100     90
PERLND 825                       531.3    COPY   100     90
IMPLND 840                       195.2    COPY   100     91
PERLND 921                       469.5    COPY   100     90
PERLND 922                      2861.4    COPY   100     90
PERLND 923                     20683.7    COPY   100     90
PERLND 924                     20683.7    COPY   100     90
PERLND 925                       805.5    COPY   100     90
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
```

```
PERLND     PWATER SURO                      COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                      COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                      COPY           INPUT  MEAN   3
PERLND     PWATER PET                       COPY           INPUT  MEAN   4
PERLND     PWATER TAET                      COPY           INPUT  MEAN   5
PERLND     PWATER UZS                       COPY           INPUT  MEAN   6
PERLND     PWATER LZS                       COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                      COPY           INPUT  MEAN   1
IMPLND     IWATER PET                       COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                     COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
***
***  The MASS-LINK block was only slightly changed from the Hunting.uci file.
***  IMPLND blocks were eliminated since no impervious land segments are being
***  used in the simulation.
***
FTABLES
  FTABLE      7
 ROWS COLS ***
   21    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.2      22.0      20.0      2.13     6817.
      0.4      23.59     22.0      6.39     2500.
      0.6      25.18     24.0     12.15     1434.
      0.8      26.76     26.0     19.18      984.
      1.0      28.35     28.0     27.32      744.
      1.2      29.94     29.5     36.38      589.
      1.4      31.53     31.5     46.09      496.
      1.6      33.12     35.5     55.89      461.
      1.8      34.71     39.5     65.76      436.
      2.0      36.29     42.0     76.65      403.
      2.2      37.88     47.0     85.55      399.
      2.4      39.47     50.0     95.45      380.
      3.0      44.24     64.0    125.3       371.
      4.0      60.50     90.0    180.2       363.
      5.0      64.25    120.0    244.        357.
      6.0      68.00    153.0    320.4       347.
      7.0      71.75    190.0    472.7       292.
      8.0      75.50    225.0    710.1       230.
      9.0      79.25    252.0   1002.        183.
     10.0      83.00    302.0   1350.        162.
  END FTABLE 7
  FTABLE     8
 ROWS COLS ***
   21    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.2       23.9      39.9      2.13    13585.
      0.4       27.1      43.8      6.39     4983.
```

```
     0.6       30.2      47.8     12.15     2857.
     0.8       33.4      51.8     19.18     1961.
     1.0       36.6      55.8     27.32     1482.
     1.2       39.7      58.8     36.38     1173.
     1.4       42.9      62.8     46.09      988.
     1.6       46.0      70.7     55.89      918.
     1.8       49.2      78.7     65.76      869.
     2.0       52.4      83.7     76.65      803.
     2.2       55.6      93.7     85.55      794.
     2.4       58.7      99.6     95.45      757.
     3.0       68.2     127.0     125.3      739.
     4.0       78.2     179.0     180.2      722.
     5.0       79.5     239.0     244.       711.
     6.0       80.7     305.0     320.4      690.
     7.0       82.0     378.0     472.7      581.
     8.0       83.2     448.0     710.1      458.
     9.0       84.4     502.0    1002.       363.
    10.0       85.7     601.0    1350.       323.
 END FTABLE  8
 FTABLE     9
ROWS COLS ***
  19   4
    DEPTH      AREA    VOLUME    DISCH1    DISCH2    DISCH3 ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS)     (CFS) ***
     0.00       0.0       0.0       0.0       0.0       0.0
     0.2      508.8      99.6      0.22      0.46      1.39
     0.4      520.6     199.2      1.38      2.25      4.64
     0.6      532.4     298.8      4.09      5.80      9.44
     0.8      544.2     398.4      8.59     11.33     15.65
     1.0      556.0     498.0     15.30     19.11     23.20
     1.2      567.8     597.6     24.50     29.32     32.11
     1.4      579.6     697.2     36.71     42.09     42.26
     1.6      591.4     796.8     52.21     57.19     53.36
     1.8      603.2     896.4     71.33     74.91     65.52
     2.0      615.0     996.0     94.30     95.50     78.86
     2.2      671.9    1057.1    121.4     119.4      93.30
     2.4      728.8    1118.2    152.5     146.4     108.7
     3.0      899.5    1301.5    274.      246.6     161.6
     4.0     1184.0    1607.0    486.      484.0     270.
     5.0     1468.5    1912.5   1050.      815.0     397.
     6.0     1753.0    2218.0   1700.     1235.      548.
     7.0     2037.5    2523.5   2530.     1775.      720.
     8.0     2322.0    2829.0   3590.     2040.      910.
 END FTABLE 9
 FTABLE    10
ROWS COLS ***
  19   4
    DEPTH      AREA    VOLUME    DISCH1    DISCH2    DISCH3 ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS)     (CFS) ***
     0.00     521.2       0.0       0.0       0.0       0.0
     0.2      524.8     108.7      0.22      0.46      1.39
     0.4      528.5     217.4      1.38      2.25      4.64
     0.6      532.2     326.1      4.09      5.80      9.44
     0.8      535.9     434.8      8.59     11.33     15.65
     1.0      539.6     543.4     15.30     19.11     23.20
     1.2      543.3     652.1     24.50     29.32     32.11
     1.4      544.4     761.0     36.71     42.09     42.26
```

```
     1.6      544.7     870.0     52.21     57.19     53.36
     1.8      544.9     979.0     71.33     74.91     65.52
     2.0      545.2    1088.0     94.30     95.50     78.86
     2.2      549.4    1117.5    121.4     119.4      93.30
     2.4      553.7    1147.0    152.5     146.4     108.7
     3.0      566.5    1236.3    274.      246.6     161.6
     4.0      587.7    1385.8    486.      484.0     270.
     5.0      609.0    1536.3   1050.      815.0     397.
     6.0      630.3    1688.6   1700.     1235.      548.
     7.0      651.6    1841.9   2530.     1775.      720.
     8.0      672.9    1996.9   3590.     2040.      910.
 END FTABLE 10
 FTABLE    11
ROWS COLS ***
  19   4
    DEPTH      AREA    VOLUME    DISCH1    DISCH2    DISCH3 ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS)     (CFS) ***
     0.00      80.4       0.0       0.0       0.0       0.0
     0.2       83.7      20.2      0.22      0.46      1.39
     0.4       87.1      40.3      1.38      2.25      4.64
     0.6       90.5      60.5      4.09      5.80      9.44
     0.8       93.9      80.7      8.59     11.33     15.65
     1.0       97.3     100.8     15.30     19.11     23.20
     1.2      100.7     121.0     24.50     29.32     32.11
     1.4      101.7     141.4     36.71     42.09     42.26
     1.6      102.0     161.9     52.21     57.19     53.36
     1.8      102.2     182.3     71.33     74.91     65.52
     2.0      102.5     202.8     94.30     95.50     78.86
     2.2      103.3     223.9    121.4     119.4      93.30
     2.4      104.2     244.9    152.5     146.4     108.7
     3.0      106.7     308.8    274.      246.6     161.6
     4.0      110.9     415.9    486.      484.0     270.
     5.0      115.5     461.2   1050.      815.0     397.
     6.0      119.9     508.0   1700.     1235.      548.
     7.0      124.4     555.9   2530.     1775.      720.
     8.0      128.8     605.2   3590.     2040.      910.
 END FTABLE 11
 FTABLE     12
ROWS COLS ***
  21    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.2       75.6    126.00      2.13    42952.
     0.4       85.6    138.60      6.39    15756.
     0.6       95.6    151.20     12.15     9036.
     0.8      105.6    163.80     19.18     6201.
     1.0      115.6    176.40     27.32     4688.
     1.2      125.6    185.80     36.38     3709.
     1.4      135.6    198.40     46.09     3126.
     1.6      145.6    223.60     55.89     2905.
     1.8      155.6    248.80     65.76     2747.
     2.0      165.6    264.60     76.65     2539.
     2.2      175.6    296.10     85.55     2513.
     2.4      185.6    315.00     95.45     2396.
     3.0      215.7    403.20     125.3     2336.
     4.0      247.3    567.00     180.2     2284.
```

```
     5.0      251.2    756.10     244.      2249.
     6.0      255.1    964.00     320.4     2184.
     7.0      259.1   1197.00     472.7     1838.
     8.0      263.0   1417.00     710.1     1449.
     9.0      267.0   1587.00    1002.      1150.
    10.0      270.9   1902.00    1350.      1023.
 END FTABLE 12
 FTABLE     13
ROWS COLS ***
  25    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.2      39.83     13.65      0.78   12787.
     0.4      69.70     24.08      3.94    4433.
     0.6      83.64     47.68     10.30    3361.
     0.8      97.58     82.87     20.39    2951.
     1.0     107.54    120.41     32.59    2682.
     1.2     115.51    137.26     42.01    2372.
     1.4     123.47    159.05     52.07    2218.
     1.6     127.46    182.80     62.71    2116.
     1.8     135.42    211.55     73.88    2079.
     2.0     143.39    241.07     85.56    2046.
     2.2     147.37    272.79     97.70    2027.
     2.4     151.36    306.46    110.30    2017.
     3.0     167.29    415.29    150.70    2001.
     4.0     183.22    612.09    225.80    1968.
     5.0     191.19    827.29    309.70    1939.
     6.0     197.16   1052.34    400.90    1906.
     7.0     201.14   1288.81    498.70    1876.
     8.0     203.13   1528.61    602.50    1842.
     9.0     205.13   1777.00    711.90    1812.
    10.0     207.12   2006.00    819.00    1778.
    12.0     209.12   2464.00   1020.00    1754.
    14.0     211.12   2922.00   1220.00    1739.
    18.0     215.12   3857.00   1620.00    1729.
    22.0     219.12   4803.00   2020.00    1726.
 END FTABLE 13
 FTABLE     14
ROWS COLS ***
  25    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.2       44.7      50.       4.31    8432.
     0.4       52.6      70.      11.58    4389.
     0.6       84.1      95.      20.60    3348.
     0.8       89.4     120.      31.00    2810.
     1.0       97.3     150.      42.73    2549.
     1.2      102.6     170.      55.09    2240.
     1.4      105.2     200.      68.98    2105.
     1.6      110.4     235.      81.10    2104.
     1.8      115.7     270.      93.74    2091.
     2.0      120.9     300.      106.7    2041.
     2.2      126.2     330.      120.0    1997.
     2.4      134.1     370.      133.5    2012.
     3.0      152.6     480.      175.9    1981.
```

```
      4.0      181.5     675.      252.1     1944.
      5.0      181.5     860.      333.2     1874.
      6.0      181.5    1070.      430.0     1807.
      7.0      181.5    1310.      583.4     1630.
      8.0      181.5    1560.      760.0     1490.
      9.0      181.5    1920.      992.4     1405.
     10.0      181.5    2104.     1260.      1212.
     12.0      181.5    2245.     1834.       889.
     16.0      181.5    2289.     3024.       550.
     20.0      181.5    2293.     4224.       394.
     30.0      181.5    2295.     6624.       252.
  END FTABLE 14
END FTABLES
END RUN
```

Okabena Creek Basin--with diversion

```
RUN
GLOBAL
  Okabena Creek Basin--with diversion
  START       1987  7 14  0  0  END    1997  7 25  0  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      27   oka_with.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   oka_with.out
END FILES
***
***  Error file:  oka_with.message
***  Output file: oka_with.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  okabena_with.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     521
      PERLND     522
      PERLND     523
      PERLND     524
      PERLND     525
      IMPLND     540
      RCHRES       3
      PERLND     421
      PERLND     422
      PERLND     423
      PERLND     424
      PERLND     425
      IMPLND     440
      RCHRES       5
      PERLND     321
      PERLND     322
      PERLND     323
      PERLND     324
      PERLND     325
      IMPLND     340
      RCHRES       2
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 521 - Wetlands in RCHRES 3 basin
***  PERLND 522 - Grasslands in RCHRES 3 basin
***  PERLND 523 - Corn in RCHRES 3 basin
***  PERLND 524 - Soybeans in RCHRES 3 basin
***  PERLND 525 - Other land uses in RCHRES 3 basin
***  IMPLND 540 - Urban/Residential in RCHRES 3 basin
***  RCHRES 3 - Reservoir between USGS Okabena Creek Gage and the City
***             of Worthington, MN
```

```
***  PERLND 421 - Wetlands
***  PERLND 422 - Grasslands
***  PERLND 423 - Corn
***  PERLND 424 - Soybean
***  PERLND 425 - Other land uses
***  IMPLND 440 - Urban/Residential
***  RCHRES 5 - Reservior upgradient of USGS Elk Creek Gage
***  PERLND 321 - Wetlands
***  PERLND 322 - Grasslands
***  PERLND 323 - Corn
***  PERLND 324 - Soybean
***  PERLND 325 - Other land uses
***  IMPLND 340 - Urban/Residential
***  RCHRES 2 - Reservior between Okabena (MDNR) Gage and USGS Elk and
***             Okabena Creeks Gages near Brewster, MN
***
PERLND
  ACTIVITY
    <PLS >               Active Sections                                ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  321  325    1    1    1    0    0    0    0    0    0    0    0    0
  421  425    1    1    1    0    0    0    0    0    0    0    0    0
  521  525    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, SNOW, and ATMP blocks,
***  simulating water flow through and snow in the system, correcting for
***  air temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  321  325    6    6    6    4    4    4    4    4    4    4    4    4    1   12
  421  425    6    6    6    4    4    4    4    4    4    4    4    4    1   12
  521  525    6    6    3    4    4    4    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
    <PLS >         Name        NBLKS   Unit-systems   Printer***
    x -  x                        User  t-series Engl Metr***
                                         in  out          ***
  321     Wetlands               1    1    1    1   90    0
  322     Grasslands             1    1    1    1   90    0
  323     Corn                   1    1    1    1   90    0
  324     Soybeans               1    1    1    1   90    0
  325     Otherlandu             1    1    1    1   90    0
  421     Wetlands               1    1    1    1   90    0
  422     Grasslands             1    1    1    1   90    0
  423     Corn                   1    1    1    1   90    0
  424     Soybeans               1    1    1    1   90    0
  425     Otherlandu             1    1    1    1   90    0
  521     Wetlands               1    1    1    1   90    0
  522     Grasslands             1    1    1    1   90    0
  523     Corn                   1    1    1    1   90    0
  524     Soybeans               1    1    1    1   90    0
  525     Otherlandu             1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
```

```
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  321  325       70.      73.0
  421  425      120.      73.0
  521  525      100.      73.0
  END ATEMP-DAT
***
***  Mean Elevation of PERLND 3 = 1530 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1530 - 1460 = 70 ft
***
***  Mean Elevation of PERLND 4 = 1580 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1580 - 1460 = 120 ft
***
***  Mean Elevation of PERLND 5 = 1560 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1560 - 1460 = 100 ft
***
***  Mean Elevation of PERLND 6 = 1590 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1590 - 1460 = 130 ft
***
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                           ***
  321  325    1
  421  425    1
  521  525    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
  321  324      43.7     1530.      0.00      1.00       0.3
  325           43.7     1530.      0.15      1.00       0.3
  421  424      43.7     1580.      0.00       1.0       0.3
  425           43.7     1580.      0.15       1.0       0.3
  521  524      43.7     1560.      0.00      1.00       0.3
  525           43.7     1560.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                    ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                   (in/day)***
  321  325      0.10      32.0      0.05      1.50       0.2     0.002
  421  425      0.10      32.0      0.05      1.50       0.2     0.003
  521  525      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                            ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                           (degF)
```

```
  321  325       0.0       0.0       0.0       0.2       0.0      32.0
  421  425       0.0       0.0       0.0       0.2       0.0      32.0
  521  525       0.0       0.0       0.0       0.2       0.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  321  325      0.01       0.0       1.0
  421  425      0.01       0.0       1.0
  521  525      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  321  322    1    1    1    1    0    0    0    0    1
  323  324    1    1    1    1    1    1    0    0    1
  325         1    1    1    1    0    0    0    0    1
  421  422    1    1    1    1    0    0    0    0    1
  423  424    1    1    1    1    1    1    0    0    1
  425         1    1    1    1    0    0    0    0    1
  521  522    1    1    1    1    0    0    0    0    1
  523  524    1    1    1    1    1    1    0    0    1
  525         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)               (1/in)    (1/day
  321            0.0       3.0     0.400     350.0     0.006       0.3      0.94
  322  324       0.0       4.2     0.025     452.0     0.006       0.3      0.94
  325           0.15       4.2     0.025     452.0     0.006       0.3      0.94
  421            0.0       3.0     0.400     350.0     0.006       0.3      0.94
  422  424       0.0       4.2     0.025     335.0     0.006       0.3      0.94
  425           0.15       4.2     0.025     335.0     0.006       0.3      0.94
  521            0.0       3.0     0.400     350.0     0.006       0.3      0.94
  522  524       0.0       4.2     0.025     513.0     0.006       0.3      0.94
  525           0.15       4.2     0.025     513.0     0.006       0.3      0.94
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  321  325      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  421  425      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  521  525      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                      (1/day)
  321            1.0       2.5       0.4       3.0      0.83      0.35
  322            1.0       1.0       0.2       3.4      0.83      0.35
  323  324       1.0       0.8       0.1       3.4      0.83      0.35
  325            1.0       1.0       0.2       3.4      0.83      0.35
  421            1.0       2.5       0.4       3.0      0.83      0.35
  422            1.0       1.0       0.2       3.4      0.83      0.35
  423  424       1.0       0.8       0.1       3.4      0.83      0.35
  425            1.0       1.0       0.2       3.4      0.83      0.35
  521            1.0       2.5       0.4       3.0      0.83      0.35
```

```
  522            1.0       1.0       0.2       3.4      0.83      0.35
  523  524       1.0       0.8       0.1       3.4      0.83      0.35
  525            1.0       1.0       0.2       3.4      0.83      0.35
  END PWAT-PARM4
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  321  325      20.0       0.1
  421  425      20.0       0.1
  521  525      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  321      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  322      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  323      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  324      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  325      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  421      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  422      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  423      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  424      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  425      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  521      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  522      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  523      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  524      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  525      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  323  324 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  423  424 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  523  524 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  321  322 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  323  324 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  325      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  421  422 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  423  424 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  425      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  521  522 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  523  524 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  525      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  321      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  322      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  323  324 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  325      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  421      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  422      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  423  424 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
```

```
  425      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  521      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  522      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  523  524 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  525      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  321  325       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  421  425       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  521  525       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >                Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  340  340    1    1    1    0    0    0
  440  440    1    1    1    0    0    0
  540  540    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  340  340    6    6    6    4    4    4    1   12
  440  440    6    6    6    4    4    4    1   12
  540  540    6    6    6    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                            in  out
  340  340Ubn/Resdt3                    1    1   90    0
  440  440Ubn/Resdt4                    1    1   90    0
  540  540Ubn/Resdt5                    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  340  340      70.0      73.0
  440  440     120.0      73.0
  540  540     100.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  340  340    1
  440  440    1
  540  540    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  340  340      43.7    1530.0      0.00      1.00       0.3
  440  440      43.7    1580.0      0.00      1.00       0.3
  540  540      43.7    1560.0      0.00      1.00       0.3
```

```
  END SNOW-PARM1
  SNOW-PARM2
*** <ILS >  Snow input info: Part 2                                  ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                      (degF)                                 (in/day)***
  340  340      0.10      32.0      0.05      1.50       0.2     0.002
  440  440      0.10      32.0      0.05      1.50       0.2     0.003
  540  540      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                          ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***            (in)       (in)    (in)                          (degF)
  340  340       0.0       0.0       0.0       0.2       0.0      32.0
  440  440       0.0       0.0       0.0       0.2       0.0      32.0
  540  540       0.0       0.0       0.0       0.2       0.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
***             (in)      (in)              ***
  340  340      0.01       0.0       1.0
  440  440      0.01       0.0       1.0
  540  540      0.01       0.0       1.0
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  340  340    1    1    1    0    0
  440  440    1    1    1    0    0
  540  540    1    1    1    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                         (ft)
  340  340     300.0     0.006       0.1       0.0
  440  440     300.0     0.006       0.1       0.0
  540  540     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  340  340 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  440  440 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  540  540 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
```

```
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  340  340     0.001     0.001
  440  440     0.001     0.001
  540  540     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    2    5    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    2    5    6    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
    2     Okabena Cr above DNR    1         1    1   90    0    0
    3     Okabena Cr above USGS   1         1    1   90    0    0
    5     Elk Cr above USGS gage  1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***         Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    2    5   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                (in)
    2       0.0  2.0      18.2      54.0    1401.5       0.5      0.01
    3       0.0  3.0      23.1     120.0      83.5       0.5      0.01
    5       0.0  5.0      20.1     240.0      81.0       0.5      0.01
  END HYDR-PARM2
***
*** The number of acre feet was obtained from ftable by assuming a 2.5 ft depth
***
  HYDR-INIT
***         Initial conditions for HYDR section
*** RCHRES       VO  Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    2          200.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    3           20.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    5           35.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    7
  END TIMESERIES
```

```
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   208 PRCP  10 ENGL           0.01     PERLND 321 325 EXTNL  PREC   1 1
WDM1   209 PRCP  10 ENGL           0.81     PERLND 321 325 EXTNL  PREC   1 1
WDM1   210 PRCP  10 ENGL           0.18     PERLND 321 325 EXTNL  PREC   1 1
WDM1   209 PRCP  10 ENGL            1.0     IMPLND 340 340 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL            1.0     PERLND 321 325 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL            1.0     IMPLND 340 340 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL            1.0     PERLND 321 325 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL            1.0     IMPLND 340 340 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL            1.0     PERLND 321 325 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL            1.0     IMPLND 340 340 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL            1.0     PERLND 321 325 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL            1.0     IMPLND 340 340 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL            1.0     PERLND 321 325 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL            1.0     IMPLND 340 340 EXTNL  DTMPG  1 1
WDM1   211 PRCP  10 ENGL           0.12     PERLND 421 425 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           0.57     PERLND 421 425 EXTNL  PREC   1 1
WDM1   212 PRCP  10 ENGL           0.29     PERLND 421 425 EXTNL  PREC   1 1
WDM1   213 PRCP  10 ENGL           0.02     PERLND 421 425 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL            1.0     IMPLND 440 440 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL            1.0     PERLND 421 425 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL            1.0     IMPLND 440 440 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL            1.0     PERLND 421 425 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL            1.0     IMPLND 440 440 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL            1.0     PERLND 421 425 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL            1.0     IMPLND 440 440 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL            1.0     PERLND 421 425 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL            1.0     IMPLND 440 440 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL            1.0     PERLND 421 425 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL            1.0     IMPLND 440 440 EXTNL  DTMPG  1 1
WDM1   153 PRCP  10 ENGL           0.35     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           0.65     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL            1.0     IMPLND 540 540 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL            1.0     PERLND 521 525 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL            1.0     IMPLND 540 540 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL            1.0     PERLND 521 525 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL            1.0     IMPLND 540 540 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL            1.0     PERLND 521 525 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL            1.0     IMPLND 540 540 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL            1.0     PERLND 521 525 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL            1.0     IMPLND 540 540 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL            1.0     PERLND 521 525 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL            1.0     IMPLND 540 540 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  150         Precipitation data collected from Worthington 2 NNE weather
***              station. Portions of the data were missing between 1991 and
***              1997. Precipitation for these missing record periods was
***              estimated using hourly and daily precipitation data
***              collected at NWS weather stations located at Luverne and
***              Sherburn, Minnesota and Sibley, Iowa, USGS weather stations
```

```
***             at North Branch Jack Creek and Wilmont, and USGS
***             precipitation gages at (1) Okabena Creek on County State Aid
***             Highway 14, near Brewster and (2) near Okabena. Data is in
***             inches.
***
***  153        Precipitation data collected from Worthington 2 NNE weather
***             station between 1991 and April 1996 and from USGS
***             precipitation gage at Okabena Creek on County State Aid
***             Highway 14, near Brewster between April 1996 and August
***             1997. Because the North Branch Jack Creek weather station
***             was not operated during the winter, values for the period
***             November 16, 1996, through March 31, 1997, is from the
***             Worthington2 NNE weather station. Data from the NWS Windom
***             weather station was disaggregated from daily to hourly data
***             and used to fill in a period when neither the Lakefield or
***             Worthington2 NNE weather stations had data, February and
***             March, 1996. Data is in inches
***
***  190        Hourly modified FAO Penman potential evapotranspiration values
***             in inches. This was created by combining the hourly modified
***             FAO Penman evapotranspiration data from Lamberton
***             Experimental Station, 1987 to April1996, with the hourly
***             modified FAO Penman evapotranspiration values calculated
***             from the data collected at the USGS weather station at North
***             Branch Jack Creek, April 1996 through August 1997.
***
***  208        Hourly precipitation data in inches. Local daily observer
***             data within the Lower Okabena Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 151 were used.
***
***  209        Hourly precipitation data in inches. Local daily observer
***             data within the Lower Okabena Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 153 were used.
***
***  210        Hourly precipitation data in inches. Local daily observer
***             data within the Lower Okabena Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from the USGS precipitation gage near Okabena
***             were used. Winter values from 1996 through 1997 are from the
***             NWS Lakefield weather station.
***
***  211        Hourly precipitation data in inches. Local daily observer
***             data within the Elk Creek Basin was converted to hourly data
***             and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 153 were used.
***
***  702        Hourly dewpoint temperature values (degrees F). This data
***             set was created by combining hourly dewpoint temperature
***             values calculated from data from Lamberton Experimental
***             Station, 1987 to April1996, with hourly dewpoint temperature
***             values calculated from data collected at the USGS weather
```

```
***              station at Wilmont, April 1996 through August 1997.
***
***  712         Hourly air temperature values (degrees F). This data set
***              was created by combining hourly air temperature values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly air temperature values from the USGS weather station
***              at Wilmont, April 1996 through August 1997.
***
***  721         Hourly wind speed in miles per hour. This data set was
***              created by combining hourly wind speed values from Lamberton
***              Experimental Station, 1987 to April1996, with hourly wind
***              speed values from the USGS weather station at North Branch
***              Jack Creek, April 1996 through August 1997.
***
***  731         Hourly solar radiation in Langleys/hour. This data set was
***              created by combining hourly solar radiation values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly solar radiation values from the USGS weather station
***              at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
***RCHRES   2 HYDR   RO     1 1              WDM1   581 FLOW     ENGL      REPL
RCHRES   2 ROFLOW ROVOL  1 1 0.0001401     WDM1   520 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000117     WDM1   521 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000117     WDM1   522 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000117     WDM1   523 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000117     WDM1   525 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000117     WDM1   526 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000117AVER WDM1   527 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000117AVER WDM1   528 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES              Data set No.: 581
*** ROVOL - Total volume of outflow from RCHRES         Data set No.: 520
*** SURO - Surface outflow                              Data set No.: 521
*** IFWO - Interflow outflow                            Data set No.: 522
*** AGWO - Active groundwater outflow                   Data set No.: 523
*** PETX - Potential ET, adjusted for snow/air temp     Data set No.: 525
*** SAET - Total simulated ET                           Data set No.: 526
*** UZSX - Upper zone storage                           Data set No.: 527
*** LZSX - Lower zone storage                           Data set No.: 528
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 321                        22.2     RCHRES   2      1
PERLND 322                       867.3     RCHRES   2      1
PERLND 323                     15608.1     RCHRES   2      1
PERLND 324                     15608.1     RCHRES   2      1
PERLND 325                       378.0     RCHRES   2      1
IMPLND 340                       143.3     RCHRES   2      2
PERLND 421                         0.0     RCHRES   5      1
PERLND 422                      1517.2     RCHRES   5      1
PERLND 423                     18761.4     RCHRES   5      1
```

```
PERLND 424                    18761.4     RCHRES   5      1
PERLND 425                        0.0     RCHRES   5      1
IMPLND 440                       29.7     RCHRES   5      2
PERLND 521                      143.3     RCHRES   3      1
PERLND 522                      973.6     RCHRES   3      1
PERLND 523                     5593.5     RCHRES   3      1
PERLND 524                     5593.5     RCHRES   3      1
PERLND 525                      227.3     RCHRES   3      1
IMPLND 540                     1408.5     RCHRES   3      2
RCHRES   3                                RCHRES   2      3
RCHRES   5                                RCHRES   2      3
PERLND 321                       22.2     COPY   100     90
PERLND 322                      867.3     COPY   100     90
PERLND 323                    15608.1     COPY   100     90
PERLND 324                    15608.1     COPY   100     90
PERLND 325                      378.0     COPY   100     90
IMPLND 340                      143.3     COPY   100     91
PERLND 421                        0.0     COPY   100     90
PERLND 422                     1517.2     COPY   100     90
PERLND 423                    18761.4     COPY   100     90
PERLND 424                    18761.4     COPY   100     90
PERLND 425                        0.0     COPY   100     90
IMPLND 440                       29.7     COPY   100     91
PERLND 521                      143.3     COPY   100     90
PERLND 522                      973.6     COPY   100     90
PERLND 523                     5593.5     COPY   100     90
PERLND 524                     5593.5     COPY   100     90
PERLND 525                      227.3     COPY   100     90
IMPLND 540                     1408.5     COPY   100     91
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   4
PERLND     PWATER TAET                     COPY           INPUT  MEAN   5
PERLND     PWATER UZS                      COPY           INPUT  MEAN   6
PERLND     PWATER LZS                      COPY           INPUT  MEAN   7
  END MASS-LINK   90
```

```
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE      2
 ROWS COLS ***
   10    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.83      61.6      48.6      13.0     2789.
      1.67      68.0     102.6      40.0     1826.
      2.50      74.5     162.0     100.0     1440.
      3.33      80.9     226.7     190.0     1224.
      4.17      87.3     296.8     270.0     1081.
      5.00      93.8     372.3     350.0      979.
      6.67     106.6     539.3     490.0      838.
      8.33     119.5     727.7     900.0      745.
     10.00     132.4     937.6    1300.0      676.
  END FTABLE  2
  FTABLE      3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      1.63      48.0      29.0       6.5     3225.
      1.94      49.6      44.5      25.5     1269.
      2.25      51.2      60.0      50.9      856.
      2.88      54.5      93.0      77.3      873.
      3.50      57.8     128.1     107.5      865.
      4.13      61.0     165.2     142.2      843.
      4.75      64.3     204.4     180.2      824.
      6.00      70.8     288.8     267.4      784.
      7.25      77.3     381.4     367.9      753.
      8.50      83.9     482.2     481.2      728.
     11.00     666.2    1419.7     748.0     1378.
     13.50    1248.5    3813.1    1055.0     2624.
  END FTABLE  3
  FTABLE      5
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.63      44.0      26.7       3.2     6058.
      0.94      45.3      40.5       9.1     3231.
      1.25      46.7      55.0      31.1     1284.
      1.57      48.0      70.0      64.0      794.
      1.88      49.3      85.0      85.2      724.
      2.50      51.9     116.7     135.5      625.
      3.13      54.6     150.0     195.0      558.
```

```
      3.75      57.2     184.9     262.0      512.
      5.00      62.5     259.7     417.0      452.
      6.25      67.8     341.2     598.0      414.
      7.50      73.1     429.2     800.0      390.
     10.00      78.4     652.2    1280.0      370.
     15.00    1179.9    5127.9   11452.0      325.
     20.00    1917.9   12872.5   31408.0      298.
  END FTABLE  5
END FTABLES
END RUN
```

Okabena Creek Basin--without diversion

```
RUN
GLOBAL
  Okabena Creek Basin--without diversion
  START       1987  7 15  0  0  END    1997  7 25  0  0
  RUN INTERP OUTPUT LEVEL   10   10
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname------------------------------------------>
MESSU      27   oka_without.message
***  Add full path to wdm file in next line. For example, i:\model\wdm\heron.wdm.
WDM        26   heron.wdm
           90   oka_without.out
END FILES
***
***  Error file:  oka_without.message
***  Output file: oka_without.out
***  Precipitation/PET input file:  heron.wdm
***  Basin specification file:  okabena_without.exs
***
OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     621
      PERLND     622
      PERLND     623
      PERLND     624
      PERLND     625
      IMPLND     640
      RCHRES       4
      PERLND     521
      PERLND     522
      PERLND     523
      PERLND     524
      PERLND     525
      IMPLND     540
      RCHRES       3
      PERLND     421
      PERLND     422
      PERLND     423
      PERLND     424
      PERLND     425
      IMPLND     440
      RCHRES       5
      PERLND     321
      PERLND     322
      PERLND     323
      PERLND     324
      PERLND     325
      IMPLND     340
      RCHRES       2
      COPY       100
    END INGRP
END OPN SEQUENCE
***
***  PERLND 521 - Wetlands in RCHRES 3 basin
```

```
***  PERLND 522 - Grasslands in RCHRES 3 basin
***  PERLND 523 - Corn in RCHRES 3 basin
***  PERLND 524 - Soybeans in RCHRES 3 basin
***  PERLND 525 - Other land uses in RCHRES 3 basin
***  IMPLND 540 - Urban/Residential in RCHRES 3 basin
***  PERLND 621 - Wetlands in RCHRES 4 basin
***  PERLND 622 - Grasslands in RCHRES 4 basin
***  PERLND 623 - Corn in RCHRES 4 basin
***  PERLND 624 - Soybeans in RCHRES 4 basin
***  PERLND 625 - Other land uses in RCHRES 4 basin
***  IMPLND 640 - Urban/Residential in RCHRES 4 basin
***  RCHRES 3 - Reservoir between USGS Okabena Creek Gage and the City
***             of Worthington, MN
***  RCHRES 4 - Reservior of Okabena Creek upgradient of the City of
***             Worthington, MN (optional)
***  PERLND 421 - Wetlands
***  PERLND 422 - Grasslands
***  PERLND 423 - Corn
***  PERLND 424 - Soybean
***  PERLND 425 - Other land uses
***  IMPLND 440 - Urban/Residential
***  RCHRES 5 - Reservior upgradient of USGS Elk Creek Gage
***  PERLND 321 - Wetlands
***  PERLND 322 - Grasslands
***  PERLND 323 - Corn
***  PERLND 324 - Soybean
***  PERLND 325 - Other land uses
***  IMPLND 340 - Urban/Residential
***  RCHRES 2 - Reservior between Okabena (MDNR) Gage and USGS Elk and
***             Okabena Creeks Gages near Brewster, MN
***
PERLND
  ACTIVITY
    <PLS >               Active Sections                                ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  321  325    1    1    1    0    0    0    0    0    0    0    0    0
  421  425    1    1    1    0    0    0    0    0    0    0    0    0
  521  525    1    1    1    0    0    0    0    0    0    0    0    0
  621  625    1    1    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
***
***  This simulation will only be running the PWATER, SNOW, and ATMP blocks,
***  simulating water flow through and snow in the system, correcting for
***  air temperature.
***
  PRINT-INFO
    <PLS> ******************** Print-flags ************************  PIVL  PYR
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  321  325    4    4    4    4    4    4    4    4    4    4    4    4    1   12
  421  425    4    4    4    4    4    4    4    4    4    4    4    4    1   12
  521  525    4    4    4    4    4    4    4    4    4    4    4    4    1   12
  621  625    4    4    4    4    4    4    4    4    4    4    4    4    1  12
  END PRINT-INFO
  GEN-INFO
    <PLS >        Name        NBLKS   Unit-systems   Printer***
    x -  x                          User  t-series Engl Metr***
                                           in  out          ***
```

```
  321     Wetlands                1    1    1    1   90    0
  322     Grasslands              1    1    1    1   90    0
  323     Corn                    1    1    1    1   90    0
  324     Soybeans                1    1    1    1   90    0
  325     Otherlandu              1    1    1    1   90    0
  421     Wetlands                1    1    1    1   90    0
  422     Grasslands              1    1    1    1   90    0
  423     Corn                    1    1    1    1   90    0
  424     Soybeans                1    1    1    1   90    0
  425     Otherlandu              1    1    1    1   90    0
  521     Wetlands                1    1    1    1   90    0
  522     Grasslands              1    1    1    1   90    0
  523     Corn                    1    1    1    1   90    0
  524     Soybeans                1    1    1    1   90    0
  525     Otherlandu              1    1    1    1   90    0
  621     Wetlands                1    1    1    1   90    0
  622     Grasslands              1    1    1    1   90    0
  623     Corn                    1    1    1    1   90    0
  624     Soybeans                1    1    1    1   90    0
  625     Otherlandu              1    1    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
    <PLS >   El-diff    AIRTEMP   ***
    # -  #      (ft)    (deg F)   ***
  321  325       70.      73.0
  421  425      120.      73.0
  521  525      100.      73.0
  621  625      130.      73.0
  END ATEMP-DAT
***
***  Mean Elevation of PERLND 3 = 1530 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1530 - 1460 = 70 ft
***
***  Mean Elevation of PERLND 4 = 1580 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1580 - 1460 = 120 ft
***
***  Mean Elevation of PERLND 5 = 1560 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1560 - 1460 = 100 ft
***
***  Mean Elevation of PERLND 6 = 1590 ft
***  Mean Elevation of Okabena Creek Weather Station = 1460 ft
***  El-diff = 1590 - 1460 = 130 ft
***
***
  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                            ***
  321  325    1
  421  425    1
  521  525    1
  621  625    1
  END ICE-FLAG
  SNOW-PARM1
    <PLS >  Snow input info: Part 1                          ***
```

```
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
***            (Deg)     (ft)                          (in)  ***
  321  324      43.7     1530.      0.00      1.00       0.3
  325           43.7     1530.      0.15      1.00       0.3
  421  424      43.7     1580.      0.00      1.00       0.3
  425           43.7     1580.      0.15      1.00       0.3
  521  524      43.7     1560.      0.00      1.00       0.3
  525           43.7     1560.      0.15      1.00       0.3
  621  624      43.7     1590.      0.00      1.00       0.3
  625           43.7     1590.      0.15      1.00       0.3
  END SNOW-PARM1
***
***  The Latitude (LAT) and mean elevations (MELEV) for the Perlands
***  were estimated from topographic maps.
  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                    ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                     (degF)                                  (in/day)***
  321  325      0.10      32.0      0.05      1.50       0.2     0.002
  421  425      0.10      32.0      0.05      1.50       0.2     0.003
  521  525      0.10      32.0      0.05      1.50       0.2     0.002
  621  625      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                            ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***           (in)       (in)    (in)                            (degF)
  321  325       0.0       0.0       0.0       0.2       0.0      32.0
  421  425       0.0       0.0       0.0       0.2       0.0      32.0
  521  525       0.0       0.0       0.0       0.2       0.0      32.0
  621  625       0.0       0.0       0.0       0.2       0.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
***            (in)      (in)              ***
  321  325      0.01       0.0       1.0
  421  425      0.01       0.0       1.0
  521  525      0.01       0.0       1.0
  621  625      0.01       0.0       1.0
  END SNOW-INIT2
  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  321         1    1    1    1    0    0    0    0    1
  322         1    1    1    1    0    0    0    0    1
  323         1    1    1    1    1    1    0    0    1
  324         1    1    1    1    1    1    0    0    1
  325         1    1    1    1    0    0    0    0    1
  421         1    1    1    1    0    0    0    0    1
  422         1    1    1    1    0    0    0    0    1
  423         1    1    1    1    1    1    0    0    1
  424         1    1    1    1    1    1    0    0    1
  425         1    1    1    1    0    0    0    0    1
  521         1    1    1    1    0    0    0    0    1
  522         1    1    1    1    0    0    0    0    1
  523         1    1    1    1    1    1    0    0    1
```

```
  524         1    1    1    1    1    1    0    0    1
  525         1    1    1    1    0    0    0    0    1
  621         1    1    1    1    0    0    0    0    1
  622         1    1    1    1    0    0    0    0    1
  623         1    1    1    1    1    1    0    0    1
  624         1    1    1    1    1    1    0    0    1
  625         1    1    1    1    0    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
*** <PLS>     FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)               (1/in)   (1/day
  321            0.0       3.0     0.400     350.0     0.006       0.0      0.94
  322  324       0.0       4.2     0.025     452.0     0.006       0.0      0.94
  325           0.15       4.2     0.025     452.0     0.006       0.3      0.94
  421            0.0       3.0     0.400     350.0     0.006       0.3      0.94
  422  424       0.0       4.2     0.025     335.0     0.006       0.3      0.94
  425           0.15       4.2     0.025     335.0     0.006       0.3      0.94
  521            0.0       3.0     0.400     350.0     0.006       0.3      0.94
  522  524       0.0       4.2     0.025     513.0     0.006       0.3      0.94
  525           0.15       4.2     0.025     513.0     0.006       0.3      0.94
  621            0.0       3.0     0.400     350.0     0.006       0.3      0.94
  622  624       0.0       4.2     0.025     445.0     0.006       0.3      0.94
  625           0.15       4.2     0.025     445.0     0.006       0.3      0.94
  END PWAT-PARM2
  PWAT-PARM3
*** <PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  321  325      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  421  425      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  521  525      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  621  625      35.0      30.0       2.0       2.0     0.001       0.0       0.0
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  321            1.0       2.5       0.4       3.0      0.83      0.35
  322            1.0       1.0       0.2       3.4      0.83      0.35
  323  324       1.0       0.8       0.1       3.4      0.83      0.35
  325            1.0       1.0       0.2       3.4      0.83      0.35
  421            1.0       2.5       0.4       3.0      0.83      0.35
  422            1.0       1.0       0.2       3.4      0.83      0.35
  423  424       1.0       0.8       0.1       3.4      0.83      0.35
  425            1.0       1.0       0.2       3.4      0.83      0.35
  521            1.0       2.5       0.4       3.0      0.83      0.35
  522            1.0       1.0       0.2       3.4      0.83      0.35
  523  524       1.0       0.8       0.1       3.4      0.83      0.35
  525            1.0       1.0       0.2       3.4      0.83      0.35
  621            1.0       2.5       0.4       3.0      0.83      0.35
  622            1.0       1.0       0.2       3.4      0.83      0.35
  623  624       1.0       0.8       0.1       3.4      0.83      0.35
  625            1.0       1.0       0.2       3.4      0.83      0.35
  END PWAT-PARM4
***
***  First set of values:
***  Interception storage capacity values (CEPSC) at start of each month
***  are stored in the MON-INTERCEP table below, so the CEPSC value is
***  ignored.  Upper zone nominal storage (UZSN) will also vary monthly,
```

```
***  with values listed in the MON-UZSN table below.  Since monthly
***  Manning's n values will be used, NSUR value is ignored in model.
  PWAT-PARM5
*** <PLS >       FZG      FZGL
*** x -  x
  321  325      20.0       0.1
  421  425      20.0       0.1
  521  525      20.0       0.1
  621  625      20.0       0.1
  END PWAT-PARM5
  MON-INTERCEP
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  321      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  322      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  323      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  324      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  325      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  421      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  422      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  423      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  424      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  425      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  521      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  522      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  523      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  524      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  525      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  621      0.03 0.03 0.03 0.03 0.04 0.05 0.05 0.05 0.05 0.03 0.03 0.03
  622      0.06 0.06 0.07 0.08 0.10 0.10 0.10 0.10 0.10 0.08 0.07 0.06
  623      0.04 0.04 0.04 0.04 0.04 0.07 0.13 0.15 0.16 0.12 0.05 0.04
  624      0.03 0.03 0.03 0.03 0.03 0.04 0.08 0.14 0.14 0.06 0.03 0.03
  625      0.06 0.06 0.07 0.09 0.13 0.13 0.13 0.13 0.13 0.09 0.07 0.06
  END MON-INTERCEP
  MON-UZSN
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  323  324 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  423  424 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  523  524 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  623  624 0.12 0.12 0.13 0.13 0.13 0.13 0.13 0.14 0.14 0.14 0.12 0.12
  END MON-UZSN
  MON-MANNING
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  321  322 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  323  324 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  325      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  421  422 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  423  424 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  425      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  521  522 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  523  524 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  525      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  621  622 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  623  624 0.20 0.20 0.20 0.16 0.16 0.16 0.16 0.18 0.18 0.20 0.20 0.20
  625      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-MANNING
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
```

```
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  321      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  322      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  323  324 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  325      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  421      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  422      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  423  424 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  425      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  521      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  522      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  523  524 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  525      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  621      0.20 0.20 0.30 0.40 0.60 0.60 0.60 0.60 0.60 0.50 0.40 0.20
  622      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  623  624 0.20 0.20 0.20 0.22 0.29 0.62 0.77 0.82 0.72 0.30 0.20 0.20
  625      0.20 0.20 0.30 0.30 0.60 0.57 0.57 0.57 0.57 0.30 0.20 0.20
  END MON-LZETPARM
  PWAT-STATE1
*** <PLS >  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  321  325       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  421  425       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  521  525       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  621  625       0.0       0.0      0.05       0.0      0.50      0.05      0.30
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >                Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  340  340    1    1    1    0    0    0
  440  440    1    1    1    0    0    0
  540  540    1    1    1    0    0    0
  640  640    1    1    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  340  340    4    4    4    4    4    4    1   12
  440  440    4    4    4    4    4    4    1   12
  540  540    4    4    4    4    4    4    1   12
  640  640    4    4    4    4    4    4    1   12
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name              Unit-systems   Printer
*** <ILS >                            t-series Engl Metr
*** x -  x                             in  out
  340  340Ubn/Resdt3                    1    1   90    0
  440  440Ubn/Resdt4                    1    1   90    0
  540  540Ubn/Resdt5                    1    1   90    0
  640  640Urbn/Resdt                    1    1   90    0
  END GEN-INFO
  ATEMP-DAT
*** <ILS >     ELDAT    AIRTEMP
*** x -  x      (ft)    (deg F)
  340  340      70.0      73.0
```

```
  440  440     120.0      73.0
  540  540     100.0      73.0
  640  640     130.0      73.0
  END ATEMP-DAT
  ICE-FLAG
*** <ILS > Ice-
*** x -  x flag
  340  340    1
  440  440    1
  540  540    1
  640  640    1
  END ICE-FLAG
  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** x -  x   degrees      (ft)                          (in)
  340  340      43.7    1530.0      0.00      1.00       0.3
  440  440      43.7    1580.0      0.00      1.00       0.3
  540  540      43.7    1560.0      0.00      1.00       0.3
  640  640      43.7    1590.0      0.00      1.00       0.3
  END SNOW-PARM1
***
***   Changed SHADE from 0.15 to 0.0, SNOWCF from 1.20 to 1.00
***
  SNOW-PARM2
*** <ILS >  Snow input info: Part 2                                  ***
*** # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
***                      (degF)                                (in/day)***
  340  340      0.10      32.0      0.05      1.50       0.2     0.002
  440  440      0.10      32.0      0.05      1.50       0.2     0.003
  540  540      0.10      32.0      0.05      1.50       0.2     0.002
  640  640      0.10      32.0      0.05      1.50       0.2     0.002
  END SNOW-PARM2
  SNOW-INIT1
*** <ILS >  Initial snow conditions: Part 1                          ***
*** # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
***            (in)       (in)    (in)                          (degF)
  340  340       0.0       0.0       0.0       0.2       0.0      32.0
  440  440       0.0       0.0       0.0       0.2       0.0      32.0
  540  540       0.0       0.0       0.0       0.2       0.0      32.0
  640  640       0.0       0.0       0.0       0.2       0.0      32.0
  END SNOW-INIT1
  SNOW-INIT2
*** <ILS >  Initial snow conditions: Part 2 ***
*** # -  #    COVINX    XLNMLT    SKYCLR    ***
***             (in)      (in)              ***
  340  340      0.01       0.0       1.0
  440  440      0.01       0.0       1.0
  540  540      0.01       0.0       1.0
  640  640      0.01       0.0       1.0
  END SNOW-INIT2
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  340  340    1    1    1    0    0
  440  440    1    1    1    0    0
  540  540    1    1    1    0    0
  640  640    1    1    1    0    0
```

```
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                         (ft)
  340  340     300.0     0.006       0.1       0.0
  440  440     300.0     0.006       0.1       0.0
  540  540     300.0     0.006       0.1       0.0
  640  640     300.0     0.006       0.1       0.0
  END IWAT-PARM2
***
***  These values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  340  340 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  440  440 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  540  540 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  640  640 .036 .036 .049 .049 .049 .065 .065 .065 .049 .049 .049 .036
  END MON-RETN
***
***  These retention storage values were obtained from the Watonwan
***  River UCI file created by the Minnesota Pollution Control Agency
***  for the Minnesota River Project.
***
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  340  340     0.001     0.001
  440  440     0.001     0.001
  540  540     0.001     0.001
  640  640     0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    2    5    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    2    5    4    4    6    6    6    6    6    6    6    6    1   12
  END PRINT-INFO
  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                              t-series  Engl Metr LKFG
*** x -  x                                in  out
    2     Okabena Cr above DNR    1         1    1   90    0    0
    3     Okabena Cr above USGS   1         1    1   90    0    0
    4     Okabena Cr above Wort   1         1    1   90    0    0
    5     Elk Cr above USGS gage  1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
```

```
***         Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    2    5   0  0  0  0    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                (in)
    2       0.0  2.0      18.2      54.0    1401.5       0.5      0.01
    3       0.0  3.0      23.1     120.0      83.5       0.5      0.01
    4       0.0  4.0       6.7      90.0      83.5       0.5      0.01
    5       0.0  5.0      20.1     240.0      81.0       0.5      0.01
  END HYDR-PARM2
***
*** The number of acre feet was obtained from ftable by assuming a 2.5 ft depth
***
  HYDR-INIT
***         Initial conditions for HYDR section
*** RCHRES       VO  Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft for each possible   exit  for each possible exit,ft3
    2            200  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    3             20  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    4              5  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
    5             35  4.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM1   208 PRCP  10 ENGL           0.01     PERLND 321 325 EXTNL  PREC   1 1
WDM1   209 PRCP  10 ENGL           0.81     PERLND 321 325 EXTNL  PREC   1 1
WDM1   210 PRCP  10 ENGL           0.18     PERLND 321 325 EXTNL  PREC   1 1
WDM1   209 PRCP  10 ENGL            1.0     IMPLND 340 340 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL            1.0     PERLND 321 325 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL            1.0     IMPLND 340 340 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL            1.0     PERLND 321 325 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL            1.0     IMPLND 340 340 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL            1.0     PERLND 321 325 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL            1.0     IMPLND 340 340 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL            1.0     PERLND 321 325 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL            1.0     IMPLND 340 340 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL            1.0     PERLND 321 325 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL            1.0     IMPLND 340 340 EXTNL  DTMPG  1 1
WDM1   211 PRCP  10 ENGL           0.12     PERLND 421 425 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           0.57     PERLND 421 425 EXTNL  PREC   1 1
WDM1   212 PRCP  10 ENGL           0.29     PERLND 421 425 EXTNL  PREC   1 1
WDM1   213 PRCP  10 ENGL           0.02     PERLND 421 425 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL            1.0     IMPLND 440 440 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL            1.0     PERLND 421 425 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL            1.0     IMPLND 440 440 EXTNL  PETINP 1 1
```

```
WDM1   712 TEMP  10 ENGL           1.0     PERLND 421 425 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 440 440 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 421 425 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 440 440 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 421 425 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 440 440 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 421 425 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 440 440 EXTNL  DTMPG  1 1
WDM1   153 PRCP  10 ENGL          0.35     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL          0.65     PERLND 521 525 EXTNL  PREC   1 1
WDM1   150 PRCP  10 ENGL           1.0     IMPLND 540 540 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 521 525 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL           1.0     IMPLND 540 540 EXTNL  PETINP 1 1
WDM1   150 PRCP  10 ENGL           1.0     PERLND 621 625 EXTNL  PREC
WDM1   150 PRCP  10 ENGL           1.0     IMPLND 640 640 EXTNL  PREC   1 1
WDM1   190 PET   10 ENGL           1.0     PERLND 621 625 EXTNL  PETINP 1 1
WDM1   190 PET   10 ENGL           1.0     IMPLND 640 640 EXTNL  PETINP 1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 521 525 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 540 540 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 521 525 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 540 540 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 521 525 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 540 540 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 521 525 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 540 540 EXTNL  DTMPG  1 1
WDM1   712 TEMP  10 ENGL           1.0     PERLND 621 625 EXTNL  GATMP  1 1
WDM1   712 TEMP  10 ENGL           1.0     IMPLND 640 640 EXTNL  GATMP  1 1
WDM1   721 WIND  10 ENGL           1.0     PERLND 621 625 EXTNL  WINMOV 1 1
WDM1   721 WIND  10 ENGL           1.0     IMPLND 640 640 EXTNL  WINMOV 1 1
WDM1   731 SRAD  10 ENGL           1.0     PERLND 621 625 EXTNL  SOLRAD 1 1
WDM1   731 SRAD  10 ENGL           1.0     IMPLND 640 640 EXTNL  SOLRAD 1 1
WDM1   702 DWPT  10 ENGL           1.0     PERLND 621 625 EXTNL  DTMPG  1 1
WDM1   702 DWPT  10 ENGL           1.0     IMPLND 640 640 EXTNL  DTMPG  1 1
END EXT SOURCES
***
***  Data Set    Description
***  =======     ===========
***
***  150         Precipitation data collected from Worthington 2 NNE weather
***              station. Portions of the data were missing between 1991 and
***              1997. Precipitation for these missing record periods was
***              estimated using hourly and daily precipitation data
***              collected at NWS weather stations located at Luverne and
***              Sherburn, Minnesota and Sibley, Iowa, USGS weather stations
***              at North Branch Jack Creek and Wilmont, and USGS
***              precipitation gages at (1) Okabena Creek on County State Aid
***              Highway 14, near Brewster and (2) near Okabena. Data is in
***              inches.
***
***  153         Precipitation data collected from Worthington 2 NNE weather
***              station between 1991 and April 1996 and from USGS
***              precipitation gage at Okabena Creek on County State Aid
***              Highway 14, near Brewster between April 1996 and August
***              1997. Because the North Branch Jack Creek weather station
***              was not operated during the winter, values for the period
***              November 16, 1996, through March 31, 1997, is from the
***              Worthington2 NNE weather station. Data from the NWS Windom
```

```
***             weather station was disaggregated from daily to hourly data
***             and used to fill in a period when neither the Lakefield or
***             Worthington2 NNE weather stations had data, February and
***             March, 1996. Data is in inches
***
***  190        Hourly modified FAO Penman potential evapotranspiration values
***             in inches. This was created by combining the hourly modified
***             FAO Penman evapotranspiration data from Lamberton
***             Experimental Station, 1987 to April1996, with the hourly
***             modified FAO Penman evapotranspiration values calculated
***             from the data collected at the USGS weather station at North
***             Branch Jack Creek, April 1996 through August 1997.
***
***  208        Hourly precipitation data in inches. Local daily observer
***             data within the Lower Okabena Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 151 were used.
***
***  209        Hourly precipitation data in inches. Local daily observer
***             data within the Lower Okabena Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from data set 153 were used.
***
***  210        Hourly precipitation data in inches. Local daily observer
***             data within the Lower Okabena Creek Basin was converted to
***             hourly data and averaged. These values were used in this
***             data set between 1987 and 1995. From 1996 through August
***             1997, values from the USGS precipitation gage near Okabena
***             were used. Winter values from 1996 through 1997 are from the
***             NWS Lakefield weather station.
***
***  211        Hourly precipitation data in inches. Local daily observer
***             data within the Elk Creek Basin was converted to hourly data
***             and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 153 were used.
***
***  212        Hourly precipitation data in inches. Local daily observer
***             data within the Elk Creek Basin was converted to hourly data
***             and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 151 were used.
***
***  213        Hourly precipitation data in inches. Local daily observer
***             data within the Elk Creek Basin was converted to hourly data
***             and averaged. These values were used in this data set
***             between 1987 and 1995. From 1996 through August 1997, values
***             from data set 152 were used.
***
***  702        Hourly dewpoint temperature values (degrees F). This data
***             set was created by combining hourly dewpoint temperature
***             values calculated from data from Lamberton Experimental
***             Station, 1987 to April1996, with hourly dewpoint temperature
***             values calculated from data collected at the USGS weather
***             station at Wilmont, April 1996 through August 1997.
```

```
***
***  712         Hourly air temperature values (degrees F). This data set
***              was created by combining hourly air temperature values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly air temperature values from the USGS weather station
***              at Wilmont, April 1996 through August 1997.
***
***  721         Hourly wind speed in miles per hour. This data set was
***              created by combining hourly wind speed values from Lamberton
***              Experimental Station, 1987 to April1996, with hourly wind
***              speed values from the USGS weather station at North Branch
***              Jack Creek, April 1996 through August 1997.
***
***  731         Hourly solar radiation in Langleys/hour. This data set was
***              created by combining hourly solar radiation values from
***              Lamberton Experimental Station, 1987 to April1996, with
***              hourly solar radiation values from the USGS weather station
***              at North Branch Jack Creek, April 1996 through August 1997.
***
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
***RCHRES   2 HYDR   RO     1 1               WDM1   581 FLOW     ENGL      REPL
RCHRES   2 ROFLOW ROVOL  1 1 0.0001315     WDM1   520 QDEP   1 ENGL      REPL
COPY   100 OUTPUT MEAN   1 1 0.0000110     WDM1   521 SURO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   2 1 0.0000110     WDM1   522 IFWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   3 1 0.0000110     WDM1   523 AGWO   1 ENGL      REPL
COPY   100 OUTPUT MEAN   4 1 0.0000110     WDM1   525 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1 0.0000110     WDM1   526 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1 0.0000110AVER WDM1   527 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1 0.0000110AVER WDM1   528 LZSX   1 ENGL AGGR REPL
END EXT TARGETS
***
*** Output to heron.wdm file
***
*** RO - Total rate of outflow from RCHRES               Data set No.: 581
*** ROVOL - Total volume of outflow from RCHRES          Data set No.: 520
*** SURO - Surface outflow                               Data set No.: 521
*** IFWO - Interflow outflow                             Data set No.: 522
*** AGWO - Active groundwater outflow                    Data set No.: 523
*** PETX - Potential ET, adjusted for snow/air temp      Data set No.: 525
*** SAET - Total simulated ET                            Data set No.: 526
*** UZSX - Upper zone storage                            Data set No.: 527
*** LZSX - Lower zone storage                            Data set No.: 528
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 321                        22.2     RCHRES   2      1
PERLND 322                       867.3     RCHRES   2      1
PERLND 323                     15608.1     RCHRES   2      1
PERLND 324                     15608.1     RCHRES   2      1
PERLND 325                       378.0     RCHRES   2      1
IMPLND 340                       143.3     RCHRES   2      2
PERLND 421                         0.0     RCHRES   5      1
PERLND 422                      1517.2     RCHRES   5      1
PERLND 423                     18761.4     RCHRES   5      1
PERLND 424                     18761.4     RCHRES   5      1
```

```
PERLND 425                        0.0     RCHRES   5      1
IMPLND 440                       29.7     RCHRES   5      2
PERLND 521                      143.3     RCHRES   3      1
PERLND 522                      973.6     RCHRES   3      1
PERLND 523                     5593.5     RCHRES   3      1
PERLND 524                     5593.5     RCHRES   3      1
PERLND 525                      227.3     RCHRES   3      1
IMPLND 540                     1408.5     RCHRES   3      2
PERLND 621                       19.8     RCHRES   4      1
PERLND 622                      518.9     RCHRES   4      1
PERLND 623                     2330.3     RCHRES   4      1
PERLND 624                     2330.3     RCHRES   4      1
PERLND 625                      101.3     RCHRES   4      1
IMPLND 640                      296.5     RCHRES   4      2
RCHRES   4                                RCHRES   3      3
RCHRES   3                                RCHRES   2      3
RCHRES   5                                RCHRES   2      3
PERLND 321                       22.2     COPY   100     90
PERLND 322                      867.3     COPY   100     90
PERLND 323                    15608.1     COPY   100     90
PERLND 324                    15608.1     COPY   100     90
PERLND 325                      378.0     COPY   100     90
IMPLND 340                      143.3     COPY   100     91
PERLND 421                        0.0     COPY   100     90
PERLND 422                     1517.2     COPY   100     90
PERLND 423                    18761.4     COPY   100     90
PERLND 424                    18761.4     COPY   100     90
PERLND 425                        0.0     COPY   100     90
IMPLND 440                       29.7     COPY   100     91
PERLND 521                      143.3     COPY   100     90
PERLND 522                      973.6     COPY   100     90
PERLND 523                     5593.5     COPY   100     90
PERLND 524                     5593.5     COPY   100     90
PERLND 525                      227.3     COPY   100     90
IMPLND 540                     1408.5     COPY   100     91
PERLND 621                       19.8     COPY   100     90
PERLND 622                      518.9     COPY   100     90
PERLND 623                     2330.3     COPY   100     90
PERLND 624                     2330.3     COPY   100     90
PERLND 625                      101.3     COPY   100     90
IMPLND 640                      296.5     COPY   100     91
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL                    RCHRES         INFLOW IVOL
```

```
  END MASS-LINK    3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   4
PERLND     PWATER TAET                     COPY           INPUT  MEAN   5
PERLND     PWATER UZS                      COPY           INPUT  MEAN   6
PERLND     PWATER LZS                      COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE      2
 ROWS COLS ***
   10    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.83      61.6      48.6      13.0     2789.
      1.67      68.0     102.6      40.0     1826.
      2.50      74.5     162.0     100.0     1440.
      3.33      80.9     226.7     190.0     1224.
      4.17      87.3     296.8     270.0     1081.
      5.00      93.8     372.3     350.0      979.
      6.67     106.6     539.3     490.0      838.
      8.33     119.5     727.7     900.0      745.
     10.00     132.4     937.6    1300.0      676.
  END FTABLE  2
  FTABLE      3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      1.63      48.0      29.0       6.5     3225.
      1.94      49.6      44.5      25.5     1269.
      2.25      51.2      60.0      50.9      856.
      2.88      54.5      93.0      77.3      873.
      3.50      57.8     128.1     107.5      865.
      4.13      61.0     165.2     142.2      843.
      4.75      64.3     204.4     180.2      824.
      6.00      70.8     288.8     267.4      784.
      7.25      77.3     381.4     367.9      753.
      8.50      83.9     482.2     481.2      728.
     11.00     666.2    1419.7     748.0     1378.
     13.50    1248.5    3813.1    1055.0     2624.
  END FTABLE  3
  FTABLE      4
```

```
 ROWS COLS ***
   15    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
       0.00       0.0       0.0       0.0        0.
       0.42       6.5       2.7       3.3      601.
       0.83       6.5       5.4       9.8      402.
       1.25       6.5       8.1      18.2      324.
       1.67       6.5      10.8      27.9      282.
       2.08       6.5      13.5      38.6      254.
       2.50       6.5      16.2      50.1      235.
       3.33       6.5      21.7      74.7      211.
       4.17       6.5      27.1     100.8      195.
       5.00       6.5      32.5     128.0      184.
       6.67      96.7     118.5     412.1      209.
       8.33     187.0     354.9     1604.      161.
      10.00     277.2     741.7     4252.      127.
      11.67     367.4    1278.9     8808.      105.
      13.33     457.7    1966.5    15675.       91.
  END FTABLE  4
  FTABLE      5
 ROWS COLS ***
   15    4
      DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
       0.00       0.0       0.0       0.0        0.
       0.63      44.0      26.7       3.2     6058.
       0.94      45.3      40.5       9.1     3231.
       1.25      46.7      55.0      31.1     1284.
       1.57      48.0      70.0      64.0      794.
       1.88      49.3      85.0      85.2      724.
       2.50      51.9     116.7     135.5      625.
       3.13      54.6     150.0     195.0      558.
       3.75      57.2     184.9     262.0      512.
       5.00      62.5     259.7     417.0      452.
       6.25      67.8     341.2     598.0      414.
       7.50      73.1     429.2     800.0      390.
      10.00      78.4     652.2    1280.0      370.
      15.00    1179.9    5127.9   11452.0      325.
      20.00    1917.9   12872.5   31408.0      298.
  END FTABLE  5
END FTABLES
END RUN
```