YAMPA AND GREEN RIVERS WATER TEMPERATURE SIMULATION DINOSAUR NATIONAL MONUMENT

WATER
RESOURCES
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WRFSL Report No. 84-1

NATIONAL PARK SERVICE
Department of the Interior

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NATIONAL PARK SERVICE
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Submitted to:

United States Department of the Interior

Fish and Wildlife Service
Colorado River Fishery Project
Salt Lake City, Utah

and

National Park Service
Water Resources Field Support Laboratory
Fort Collins, Colorado

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June 1984

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INTRODUCTION

Background

The U.S. National Park Service has developed a minimum streamflow hydrograph for the continued preservation of natural conditions and processes of the Yampa River in Dinosaur National Monument and its related biological and channel morphological resources. This minimum streamflow hydrograph was derived primarily on the basis of sustaining the sediment transport balance in the Yampa Canyon. To ensure that this simulated hydrograph is appropriate for the biological functions of the aquatic species, a computer simulation of the water temperatures for the reduced discharges was conducted. The U.S. Fish and Wildlife Instream Flow Group (IFG) water temperature computer simulation model was applied to the Yampa River for six historical years of flow record. Relatively cold, average, and hot climatic years of meteorological data were compiled for input to the model. The results show the variation in temperature as a function of discharge.

Objectives

The purpose of this study is to determine the effects on water temperature of the Yampa River in Dinosaur National Monument from a possible reduction in the water discharge. This study is accomplished through an analysis of historical flows. Specifically, the Colorado squawfish, which spawns in the Yampa Canyon in a reach from approximately river mile 16.5 to 20.5, requires certain water temperatures corresponding to certain discharges to ensure a proper spawning behavior response. The National Park Service (NPS) minimum streamflow hydrograph (O'Brien, 1984) was examined to determine its suitability for duplicating historical observed water temperatures. The following specific objectives were outlined to conduct the water temperature simulation of the Yampa and Green Rivers in Dinosaur National Monument.

1) Collect and prepare, as input to the model, meteorological, topographical and channel geometry data for the Yampa and Green Rivers in the northwest Colorado area. Six years of data, representing a range of relatively cold, average, and hot climatic years were chosen for simulation of the period between March 1 and August 15.

2) Construct and arrange data files in the proper format for input to the IFG temperature model to simulate water temperatures on a weekly basis.

3) Calibrate the model for the historical water temperatures.

4) Simulate the water temperatures for composite hydrographs of the NPS minimum streamflow hydrograph and the historical discharges and compare with the historical water temperatures.

METHODS

Model Description

The instream water temperature model, developed by the Instream Flow and Aquatic Systems Group, Western Energy and Land Use Team (WELUT), U.S. Fish and Wildlife Service, was used to model water temperatures in the Yampa River in Dinosaur National Monument. The model documentation (Theurer et al., 1984) provides a complete description of the model. The model predicts instream water temperatures from either historical or synthetic hydrology, meteorology, and stream geometry.

The instream water temperature model has two major components for predicting water temperatures, a regression model and a physical process model. The regression model uses the same input parameters as the physical process model and is used to complete missing data and smooth existing data for headwaters and interior validation locations.

The physical process model consists of six components: (1) a solar model to predict solar radiation penetrating the water surface; (2) a meteorology model that transfers meteorological data from a single station to each point in the stream system; (3) a heat flux model to predict energy balance between the water and surrounding environment; (4) a heat transport model to predict mean daily water temperatures and diurnal fluctuations in temperatures; (5) a shade model to predict solar radiation weighted shading from riparian and topographic shade; and (6) procedures to calibrate the model to known interior water temperatures using certain physical parameters (Theurer and Voos 1982, Theurer 1983).

Input Data

Required input data for the model is meteorology, hydrology, and stream geometry. For the Yampa River modeling only historical meteorology data was used. The years modeled were 1975, 1976, 1977, 1981, 1982, and 1983. The first three years were chosen after reviewing meteorological records and are historical data for a colder than normal year (1975), a near normal historical year (1976), and a warmer than normal year (1977). The years 1981, 1982, and 1983 were included because they coincided with years that data were collected for the endangered Colorado squawfish in the Yampa Canyon. Weekly time periods from March 1 to August 15 were modeled each year.

Meteorological data. Meteorological data for air temperature, wind speed, relative humidity, and percent possible sunshine was obtained from U.S. Weather Bureau records for the study area. Daily meteorological data were summarized to obtain a weekly mean for each parameter.

National Park Service fire weather data collected at Dinosaur National Monument Quarry was used as input to the model as representing the meteorological conditions for the Yampa Canyon. The period of data collection for the six years of record was incomplete at the Quarry site, beginning approximately June 1 each year. This data was supplemented with meteorological data from the nearest station with complete records at Grand Junction for the period from March 1 to May 31. The meteorological records for the Headquarters site at Dinosaur National Monument and for Craig, Colorado were also reviewed during the compilation of the input data files. The final data represents a composite of the available meteorological records.

Hydrology data. The hydrologic parameters of discharge and water temperature were obtained from U.S. Geological Survey gaging stations at Flaming Gorge on the Green River, Maybell on the Yampa River, Lily, Colorado on the Little Snake River, and at Jensen, Utah on the Green River. The daily values were compiled to calculate mean weekly values.

Stream geometry. Stream geometry parameters of stream width, latitude, elevation, streambed roughness, and stream shading are required for the model. These parameters were obtained from U.S. Geological Survey topographic maps and from field measurements.

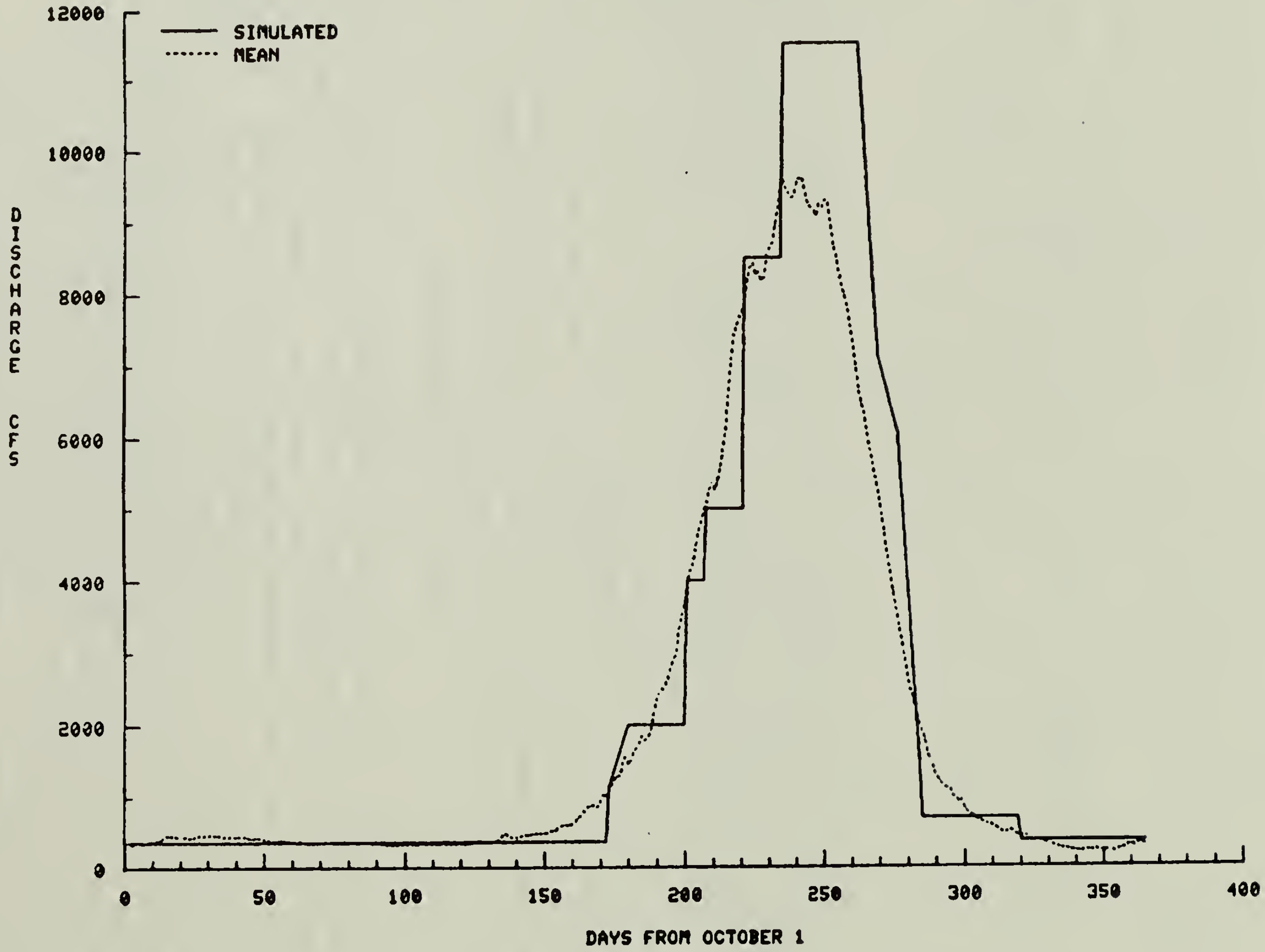
Model Calibration

The model was calibrated using the Jensen gage as a validation point. The input discharges and temperatures at the headwaters were modeled throughout the Yampa and Green Rivers in Dinosaur National Monument to the Jensen gage using the historical meteorological data. The predicted water temperature at Jensen was compared to the actual water temperature measured at Jensen. The error between the actual and predicted water temperature was calculated and the input meteorology (specifically air temperature) was adjusted accordingly for the next simulation. This recursive process was continued until acceptable error limits were obtained. The final calibrated meteorological data set was used for all model runs made with the simulated discharges.

RESULTS AND DISCUSSION

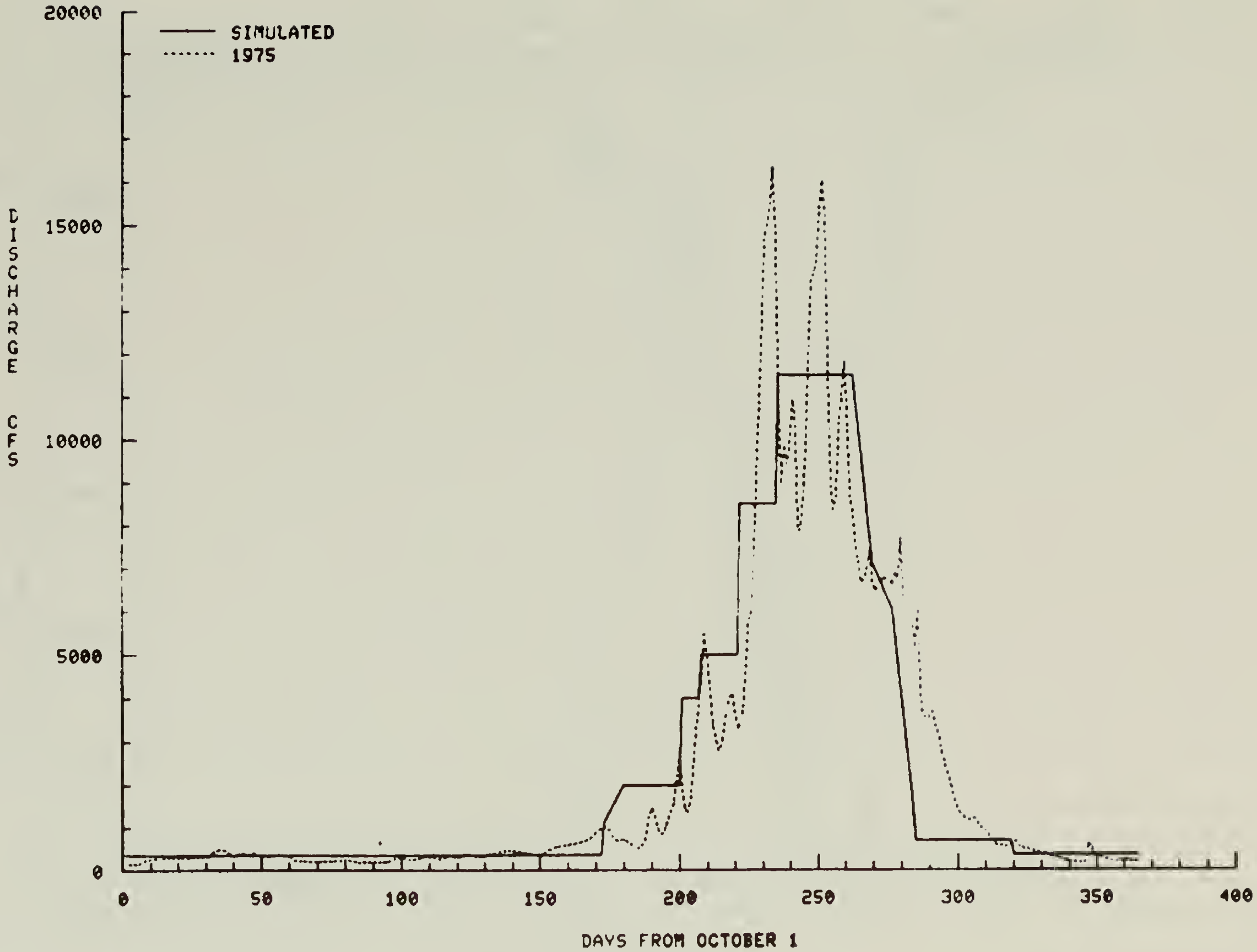
The NPS minimum streamflow hydrograph is a series of discharges required to sustain the natural conditions and processes of the channel morphological and biological resources. These resources include sediment load and channel substrate, aquatic biology, and riparian vegetation. The minimum streamflow hydrograph is shown in Figure 1. When superimposed on a historical flow year, the simulated discharge or the natural discharge, whichever is less for the given week, is incorporated into a composite hydrograph for that particular year (Figures 2-7). The composite hydrograph always represents an annual flow volume less than the historically recorded volume. The reduced discharges were analyzed for the effects on water temperatures.

The meteorological conditions were sucessfully calibrated to duplicate the water temperature conditions at the Jensen gaging station on the Green River in Jensen, Utah, downstream of the Dinosaur National



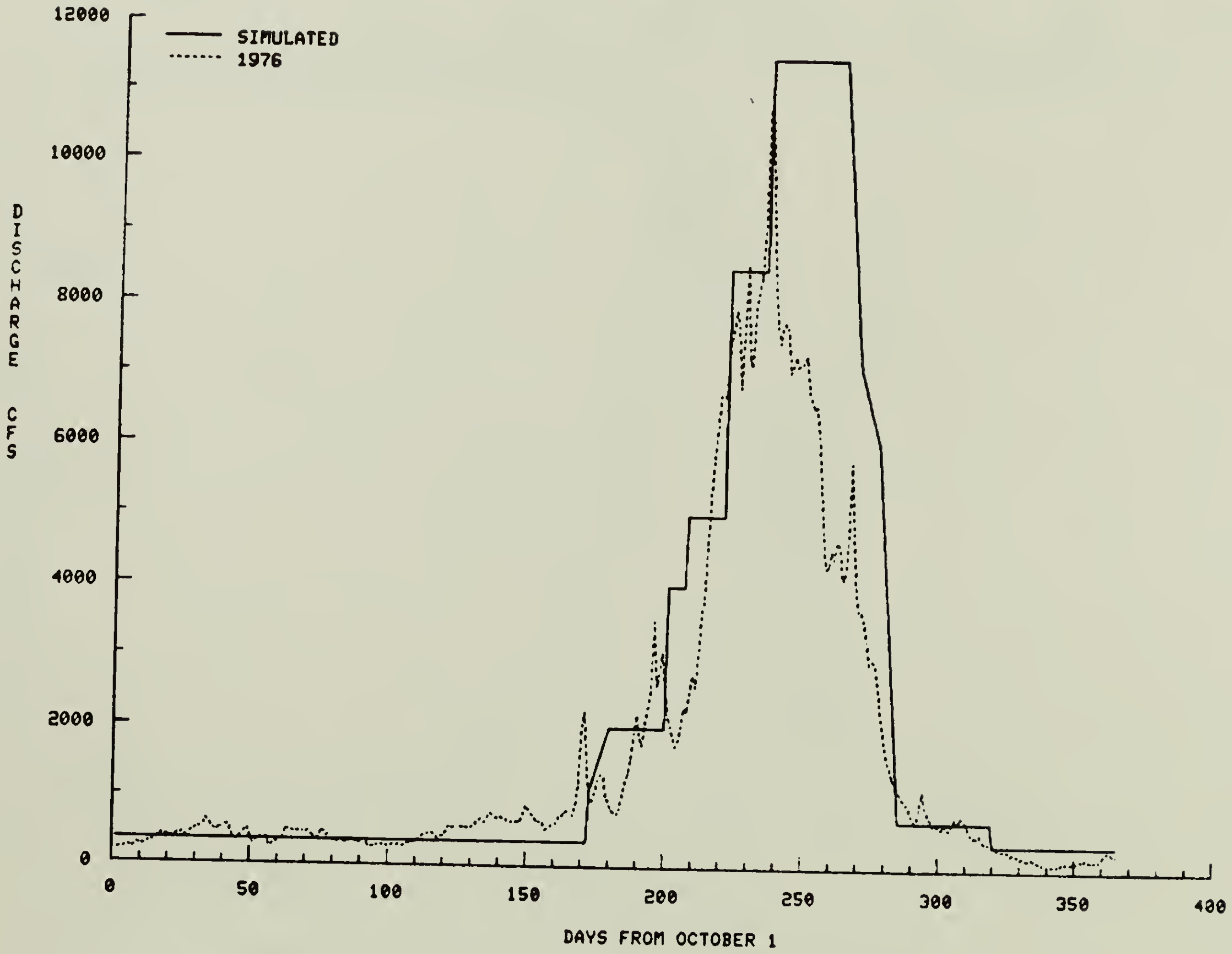
SIMULATED AND MEAN ANNUAL HYDROGRAPHS

Figure 1



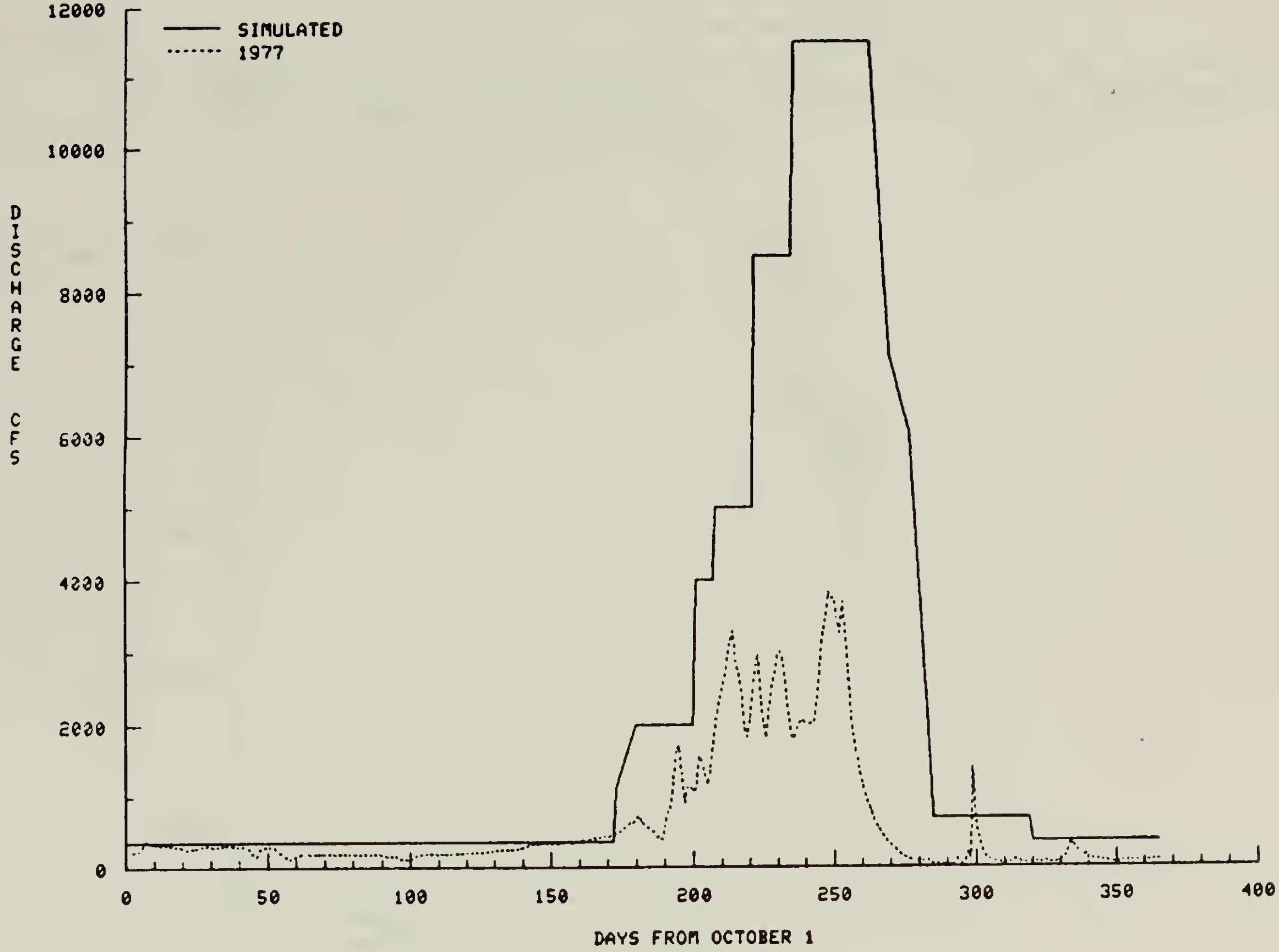
SIMULATED AND 1975 HYDROGRAPHS

Figure 2



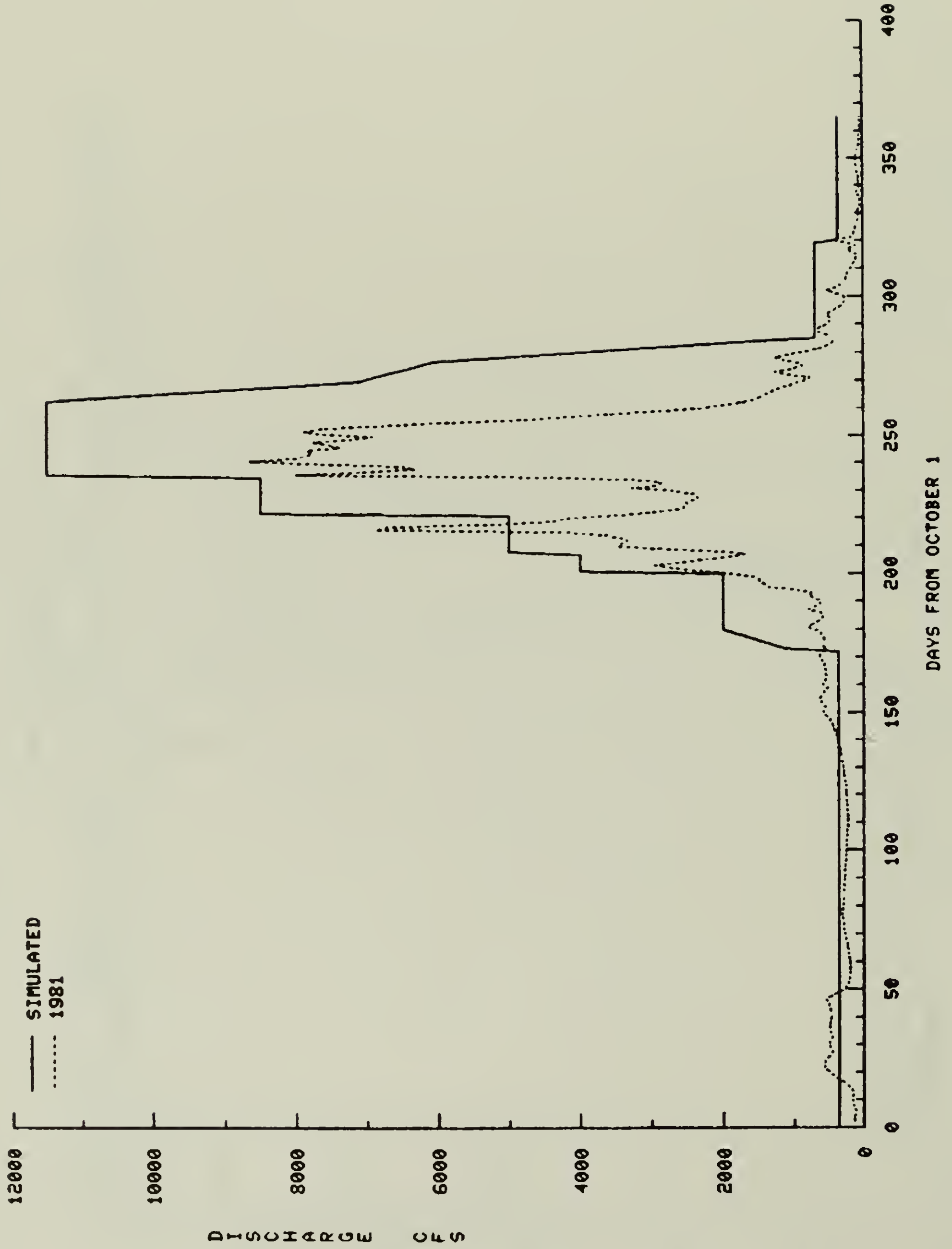
SIMULATED AND 1976 HYDROGRAPHS

Figure 3

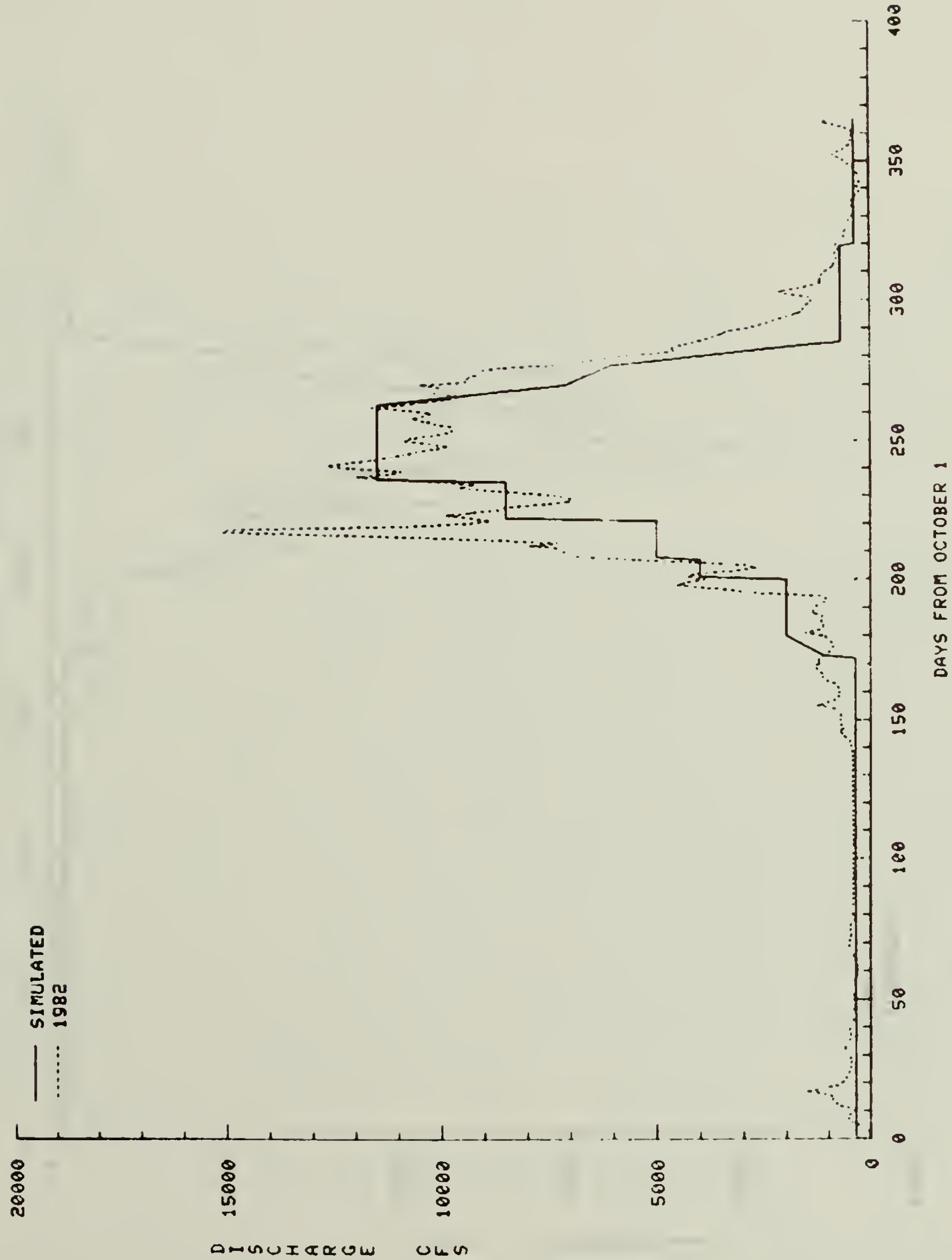


SIMULATED AND 1977 HYDROGRAPHS

Figure 4

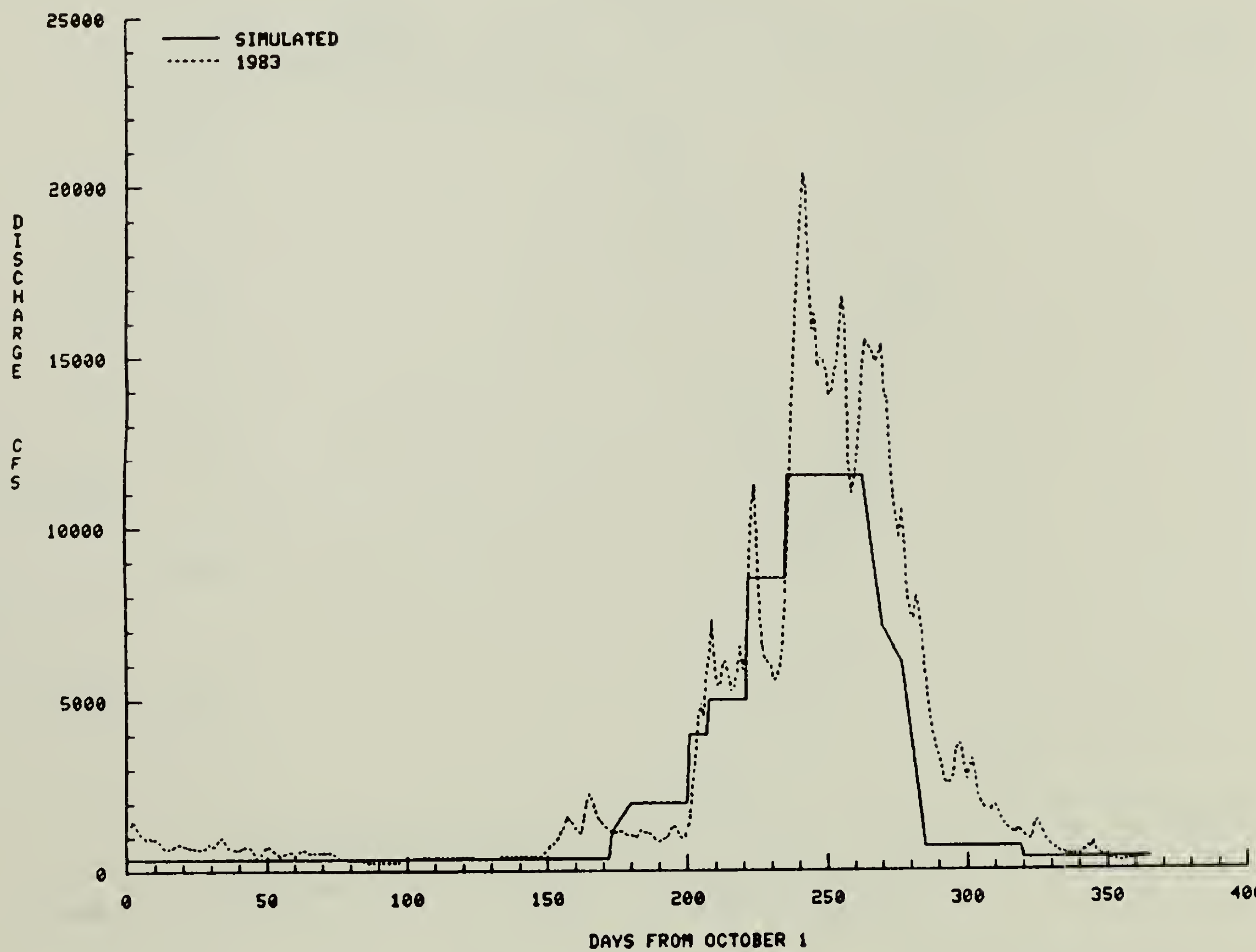


SIMULATED AND 1981 HYDROGRAPHS



SIMULATED AND 1982 HYDROGRAPHS

Figure 6



SIMULATED AND 1983 HYDROGRAPHS

Figure 7

Monument boundary. The results of the calibration are shown in Table 1 and Figures 8-13. The mean error for all six years of study for the 24 weekly time increments was 0.14°C with the single maximum error for a given time increment of 2.33°C. Some years were more accurately calibrated than others because of the sporadic availability of water temperature records for Maybell and Lily gaging stations on the Yampa and Little Snake Rivers respectively. Whereas the water temperature records on the Green River at Flaming Gorge and Jensen were nearly complete, the Maybell was only about 60 percent and the Lily gage about 80 percent complete. Those missing water temperature data were simulated using the regression models in the water temperature computer model package. The accuracy of the calibration underscores the reliability in regressing the water temperature simulation at these two gaging stations.

The historical water temperatures for the six years of study were predicted at Mathers Hole (river mile 17.5) representing the cobble reach of the Yampa River from river mile 20.5 to river mile 16.5 upstream of the Green River confluence. This is the river reach where Colorado squawfish spawn during the months of July and August (U.S. Fish and Wildlife Service (USFWS), 1984). Migration of the Colorado squawfish to the spawning reach was observed to begin at water temperatures approximately 16°C. Spawning behavior was observed when water temperatures exceeded 19-20°C. The water temperature at Mathers Hole for the historical discharges and the predicted composite discharges (simulated) are shown in Figures 14-19.

The greatest deviation from the historical water temperatures at Mathers Hole for the simulated composite water discharges occurred for those water years with greatest water volumes and surpluses (see Table 2 and Figures 2-7). Those years displaying the greatest deviation include 1975, 1982, and 1983. The water temperature deviation from the historical is greatest for 1983 (Figure 19), the year of highest discharge and volume of the years studied. A reduction in water discharge from that historically measured, results in an increase in water temperature during the months of July and August for the same meteorological conditions. The NPS minimum streamflow hydrograph has no effect on the date when the water temperature of 16°C is exceeded except for 1983, when it is reached approximately one week earlier in the year. The 20°C departure water temperature for spawning of the Colorado squawfish would be reached about two weeks earlier in the summer of 1983. It would also reach earlier in 1975 and 1982 by 1.5 and 0.5 weeks respectively. In four of the six study years (with the exclusion of 1976 and 1977) the annual peak water temperature for the composite flows are higher than the historical flows.

CONCLUSIONS AND RECOMMENDATIONS

The NPS minimum streamflow hydrograph resembles, in shape and magnitude, the mean annual hydrograph (Figure 22). This hydrograph has little effect on the flows and water temperatures for low volume years. On wetter than average years, the reduced simulated discharge causes the water temperature to rise faster and peak higher than would have

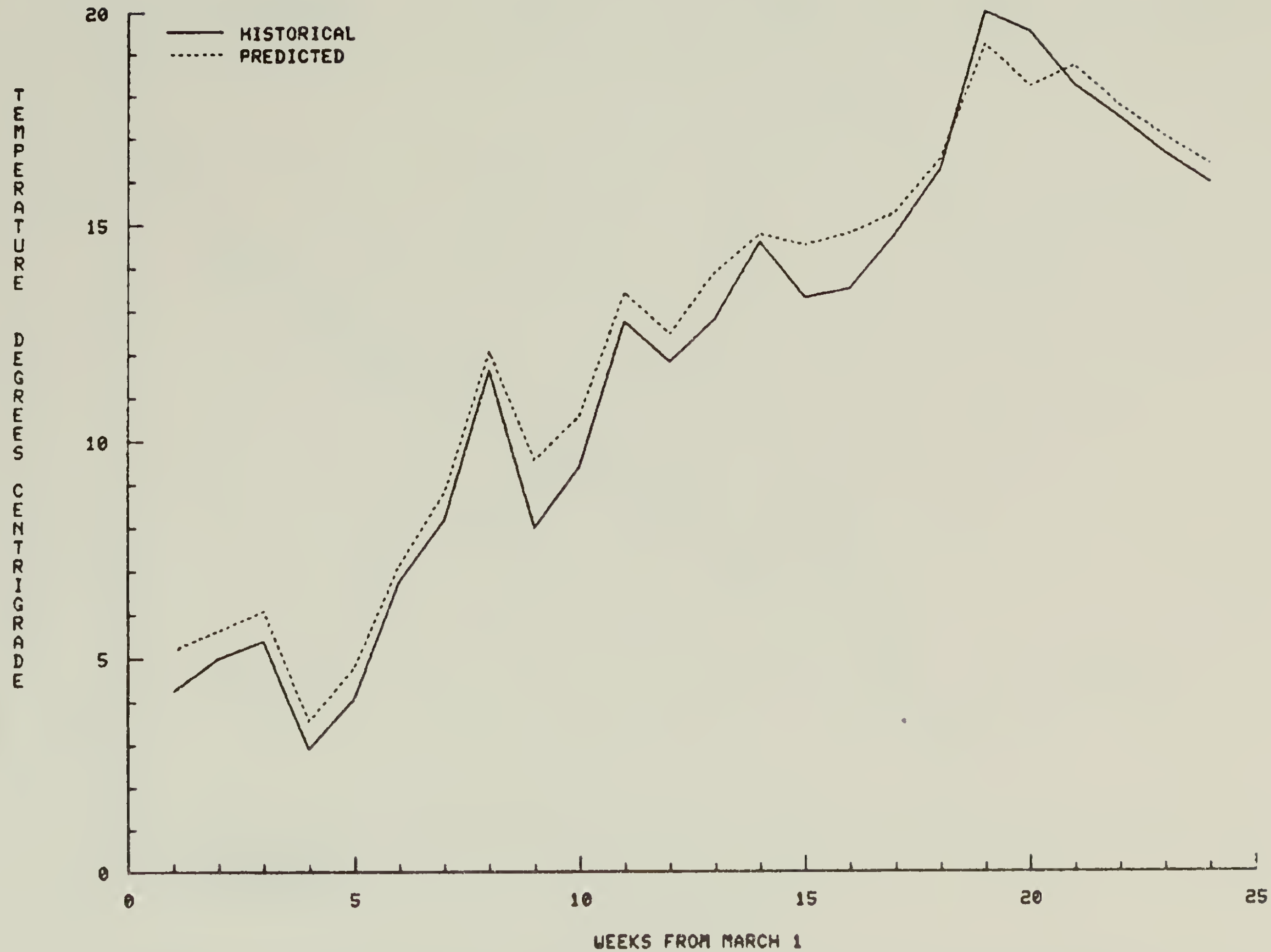
Table 1. Calibration Statistics for the Jensen Gage.

Time Period	Mean Error °C	Maximum Error °C
March 1-7	0.39	0.95
March 8-14	0.23	0.63
March 15-21	0.20	0.68
March 22-28	0.50	1.43
March 29-April 4	0.23	0.72
April 5-11	0.31	0.60
April 12-18	0.19	0.67
April 19-25	0.44	1.78
April 26-May 2	1.21	2.33
May 3-9	0.19	1.17
May 10-16	0.19	0.66
May 17-23	-0.02	0.63
May 24-30	0.25	1.07
May 31-June 6	-0.63	-2.30
June 7-13	-0.28	-1.69
June 14-20	0.22	-1.37
June 21-27	0.04	-1.03
June 28-July 4	-0.31	-1.51
July 5-11	-0.15	1.48
July 12-18	-0.48	-2.04
July 19-25	0.02	-1.03
July 26-Aug. 1	0.03	-0.89
Aug. 2-8	0.24	0.88
Aug. 9-15	0.34	1.01
Average	0.14	

Table 2. Historical and Composite Hydrograph Volumes

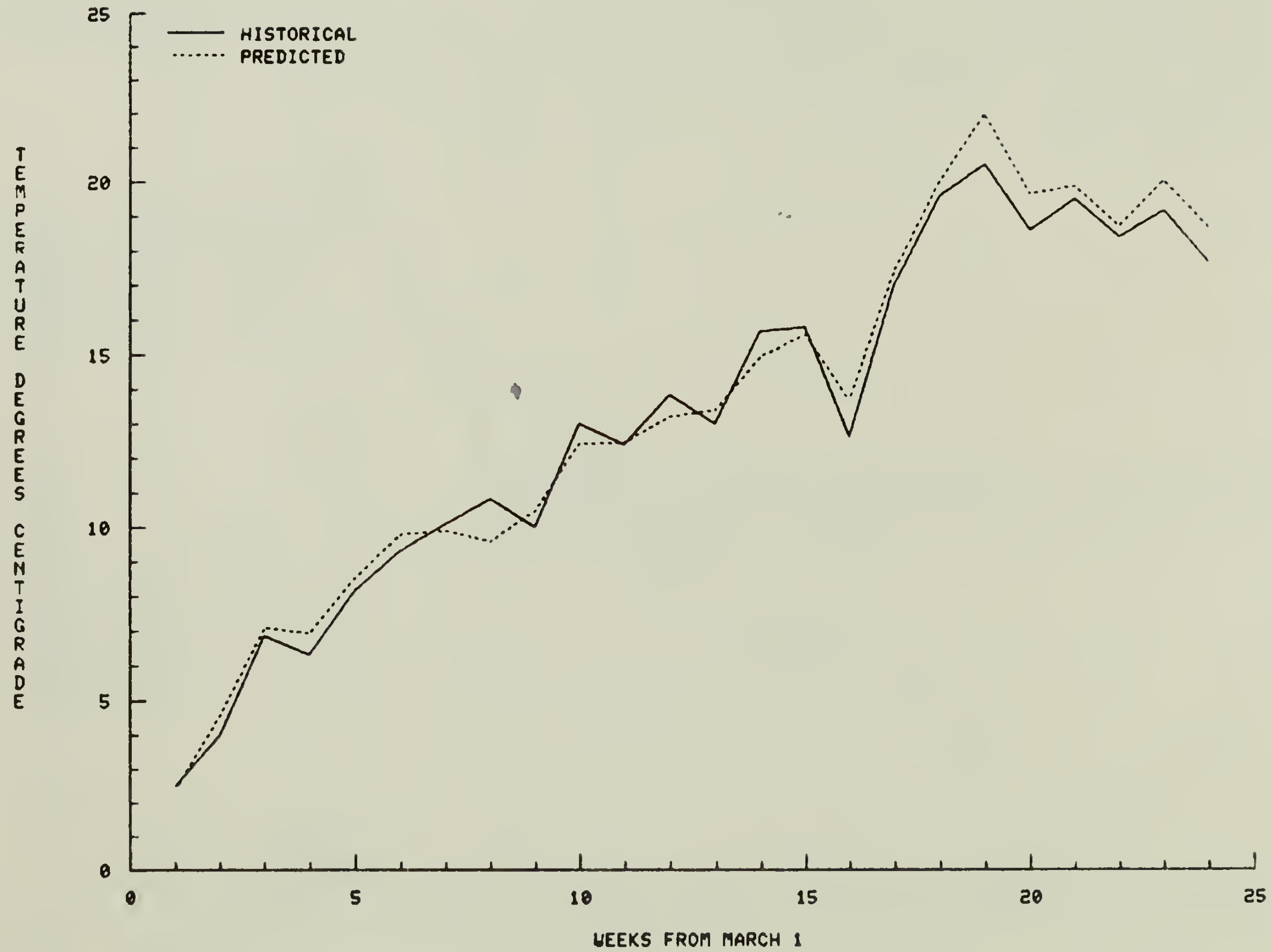
Year	Annual Volume (acre-feet)	Composite Volume (acre-feet)	Surplus Volume (acre-feet)
1975	1,639,300	1,373,800	265,600
1976	120,700	1,116,900	90,100
1977	448,400	445,800	2,626
1981	802,500	776,300	26,200
1982	1,943,100	1,564,400	378,700
1983	2,246,500	1,554,100	692,400

*Composite volume is the summation for the year of daily discharge or simulated daily discharge for the minimum streamflow hydrograph, whichever is less.



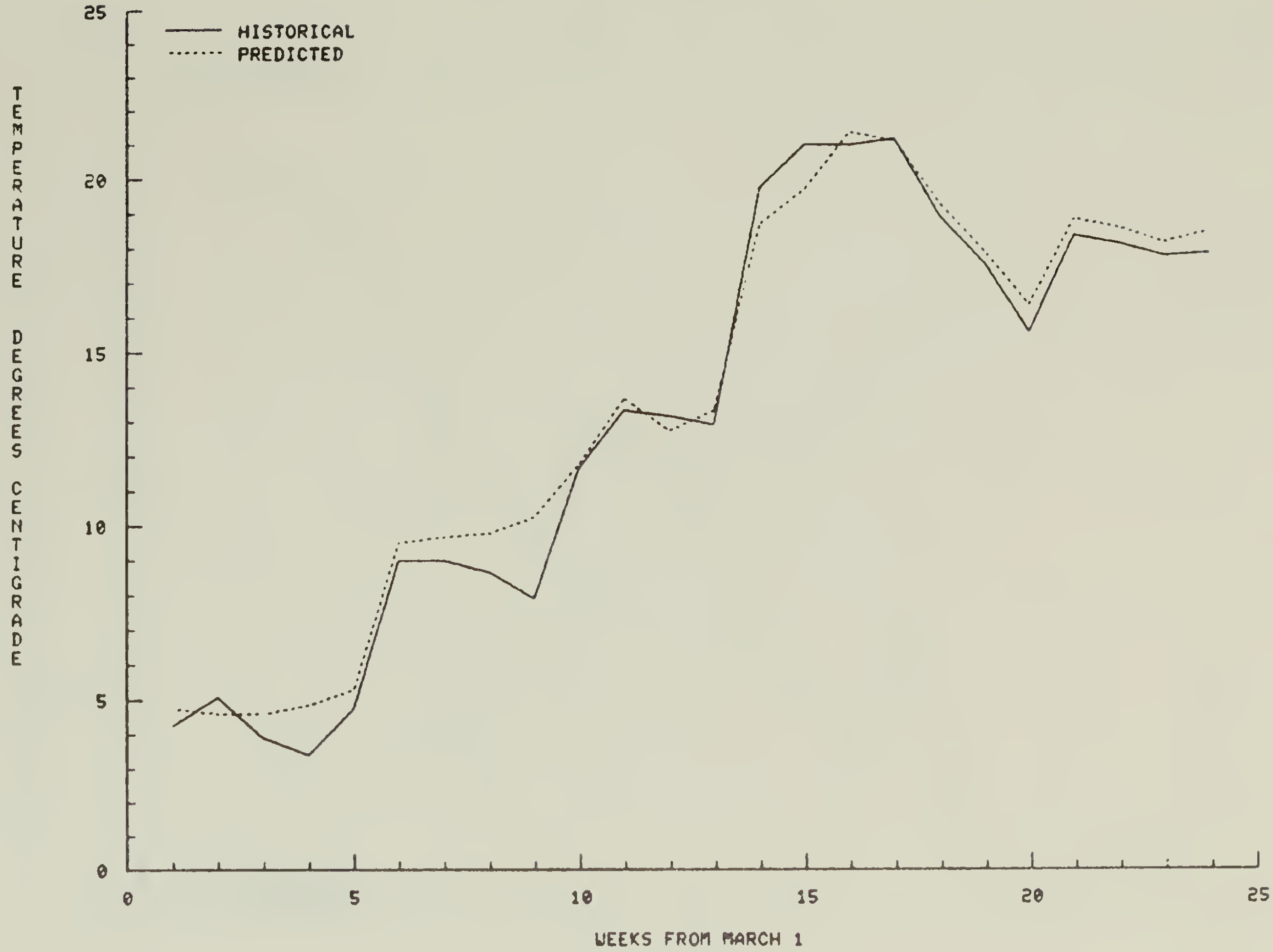
YAMPA RIVER WATER TEMPERATURE CALIBRATION JENSEN GAGE 1975

Figure 8



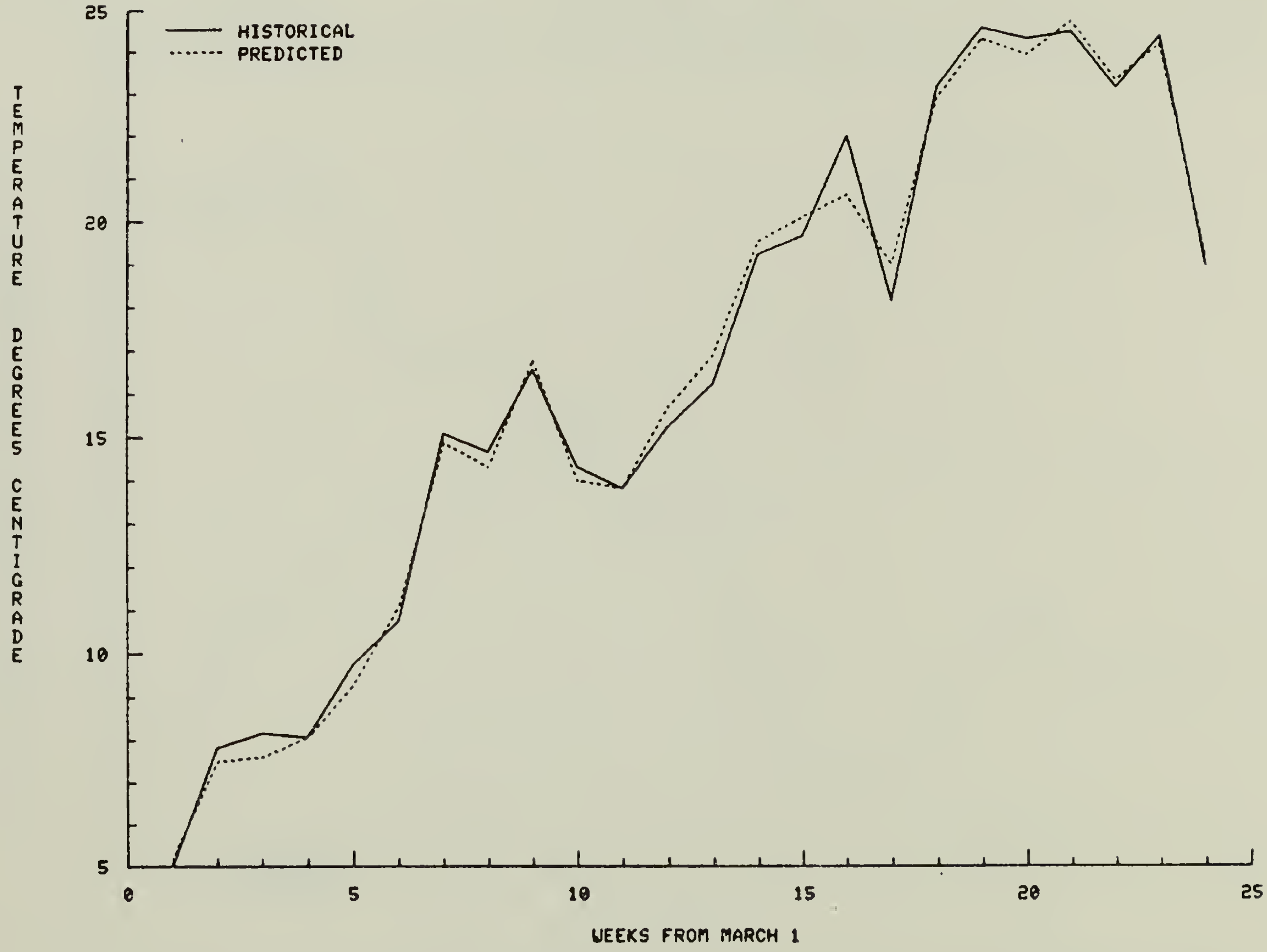
YAMPA RIVER WATER TEMPERATURE CALIBRATION JENSEN GAGE 1976

Figure 9



YAMPA RIVER WATER TEMPERATURE CALIBRATION JENSEN GAGE 1977

Figure 10

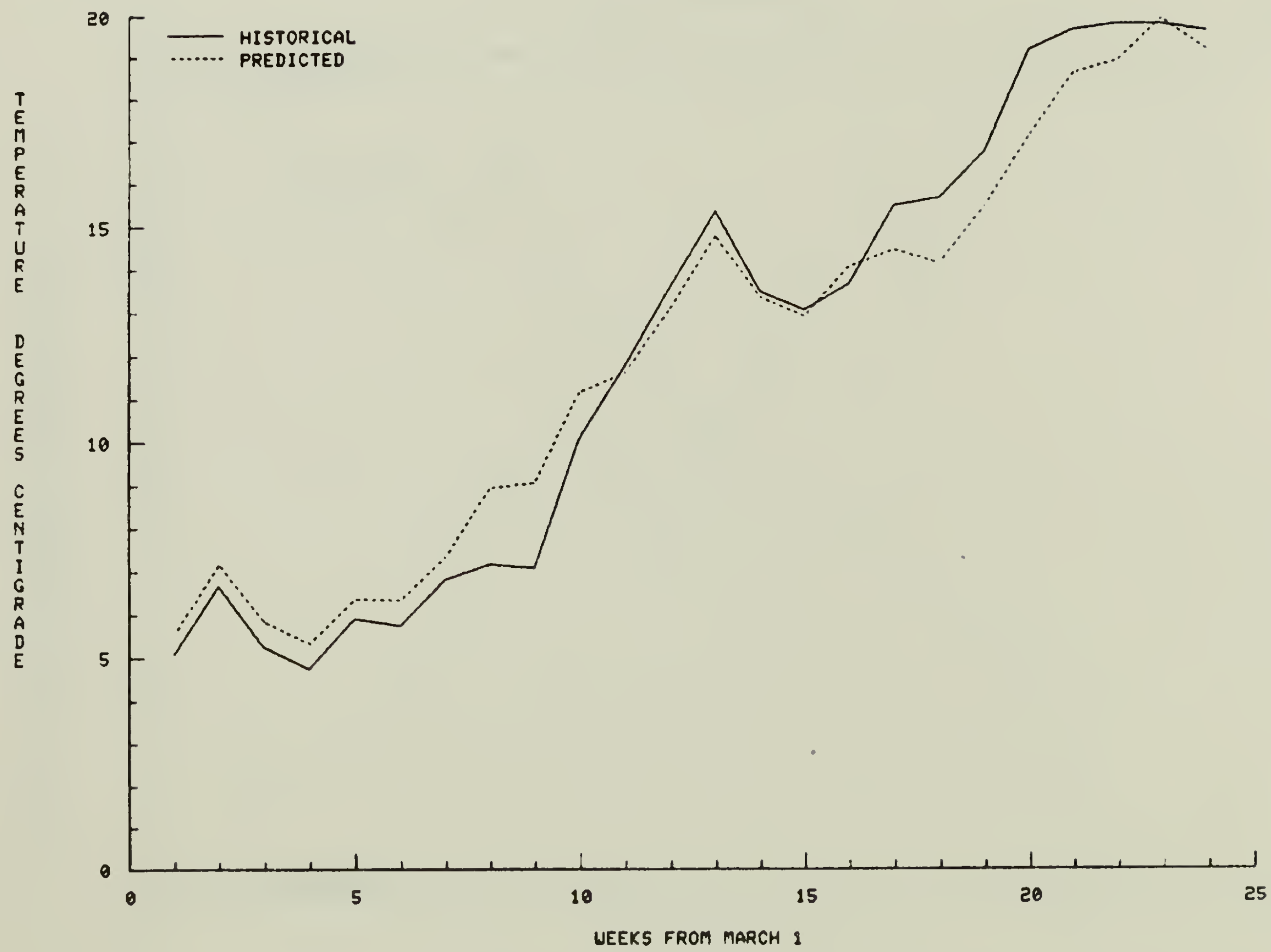


YAMPA RIVER WATER TEMPERATURE CALIBRATION JENSEN GAGE 1981

Figure 11

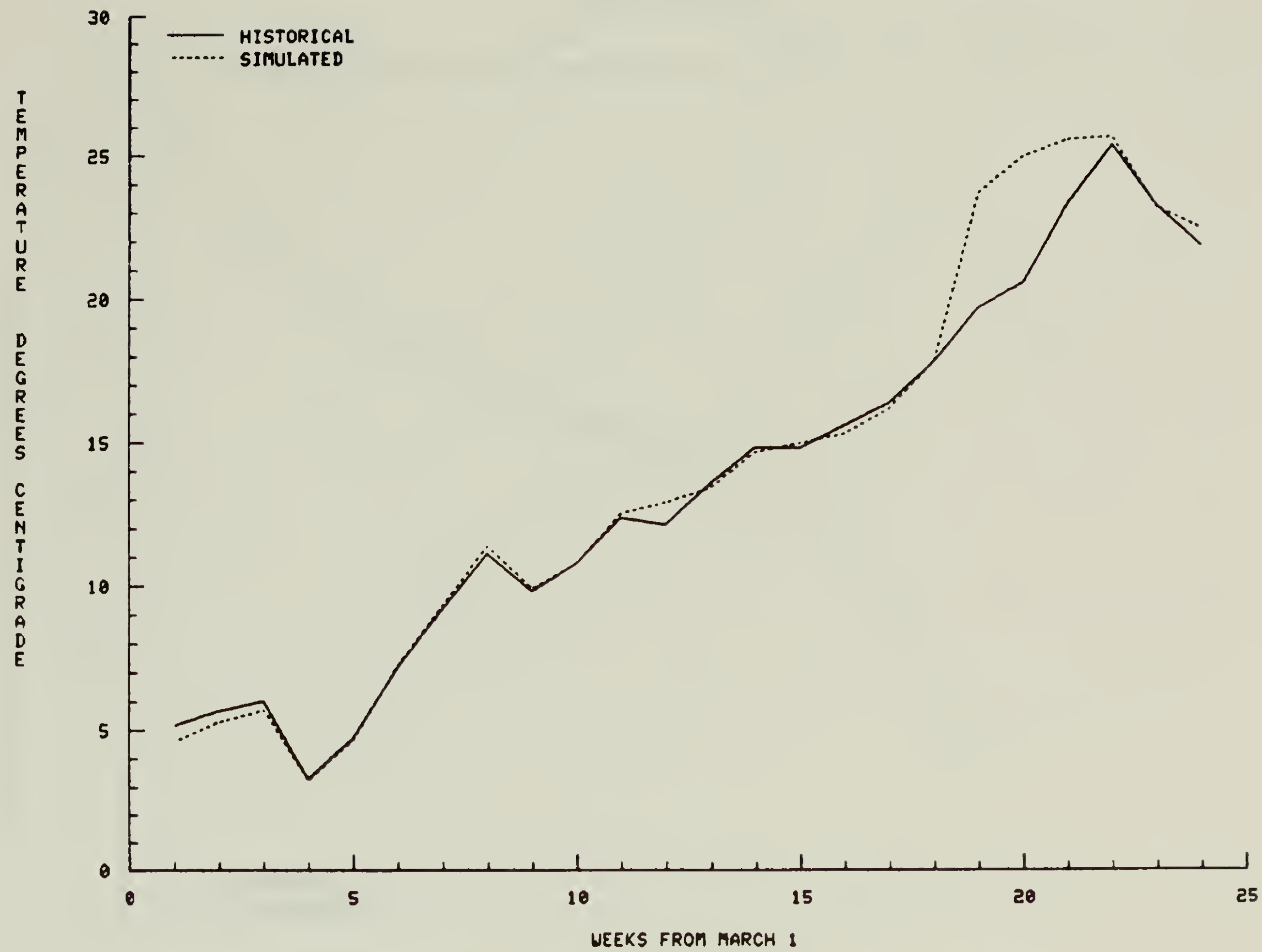
YAMPA RIVER WATER TEMPERATURE CALIBRATION JENSEN GAGE 1982

Figure 12



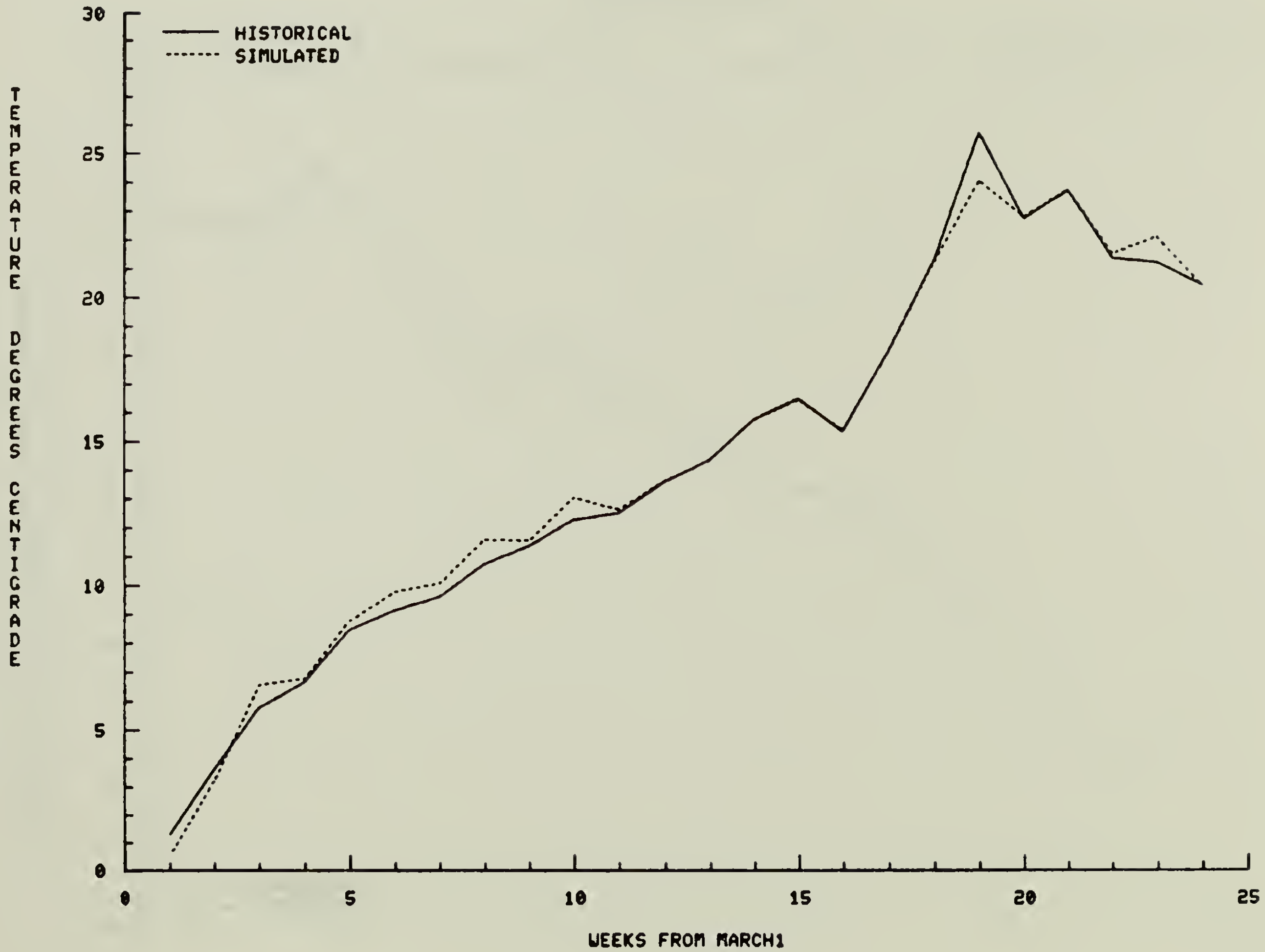
YAMPA RIVER WATER TEMPERATURE CALIBRATION JENSEN GAGE 1983

Figure 13



TEMPERATURE AT MATHERS HOLE 1975

Figure 14

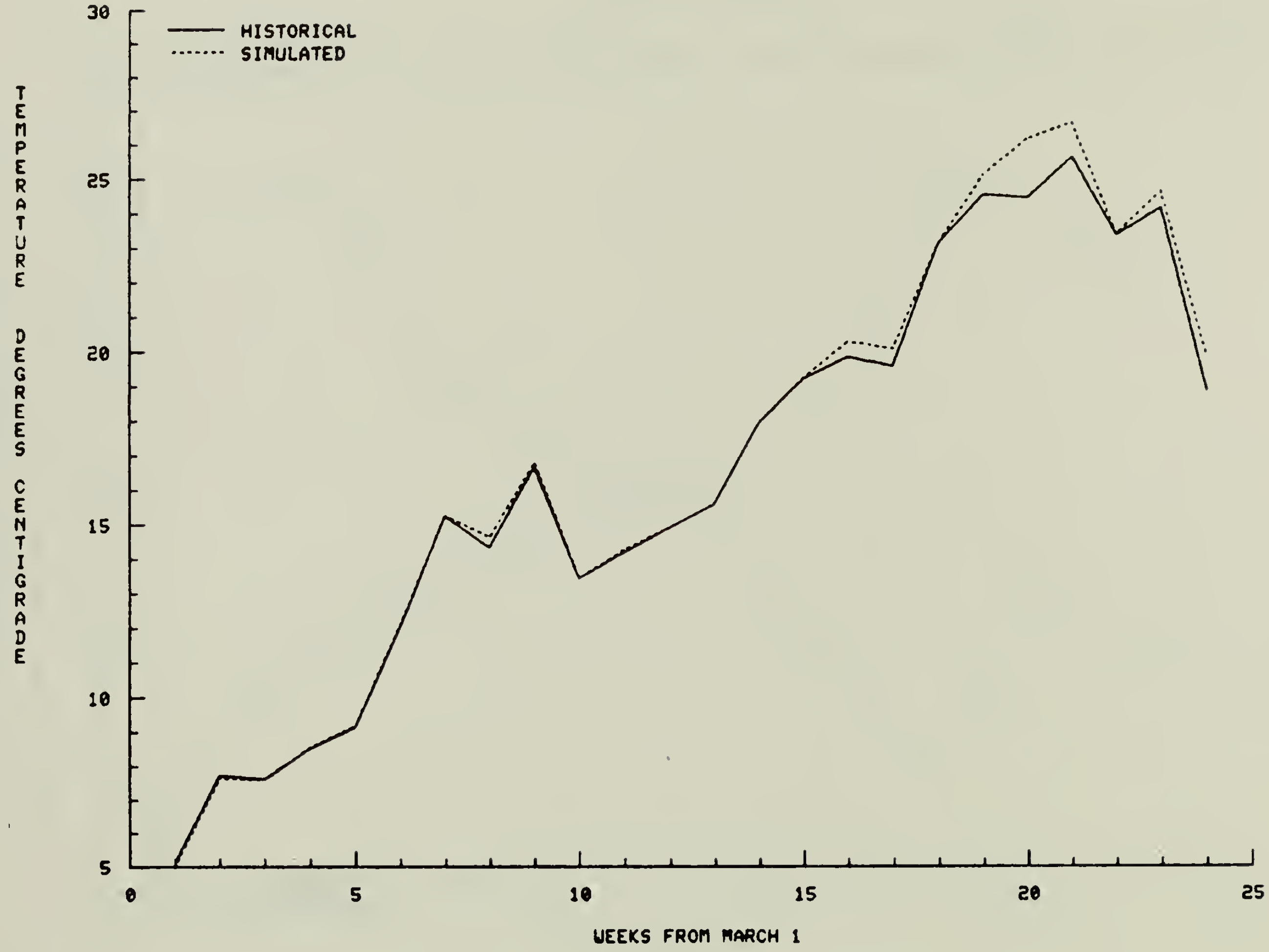


TEMPERATURE AT MATHERS HOLE 1976

Figure 15

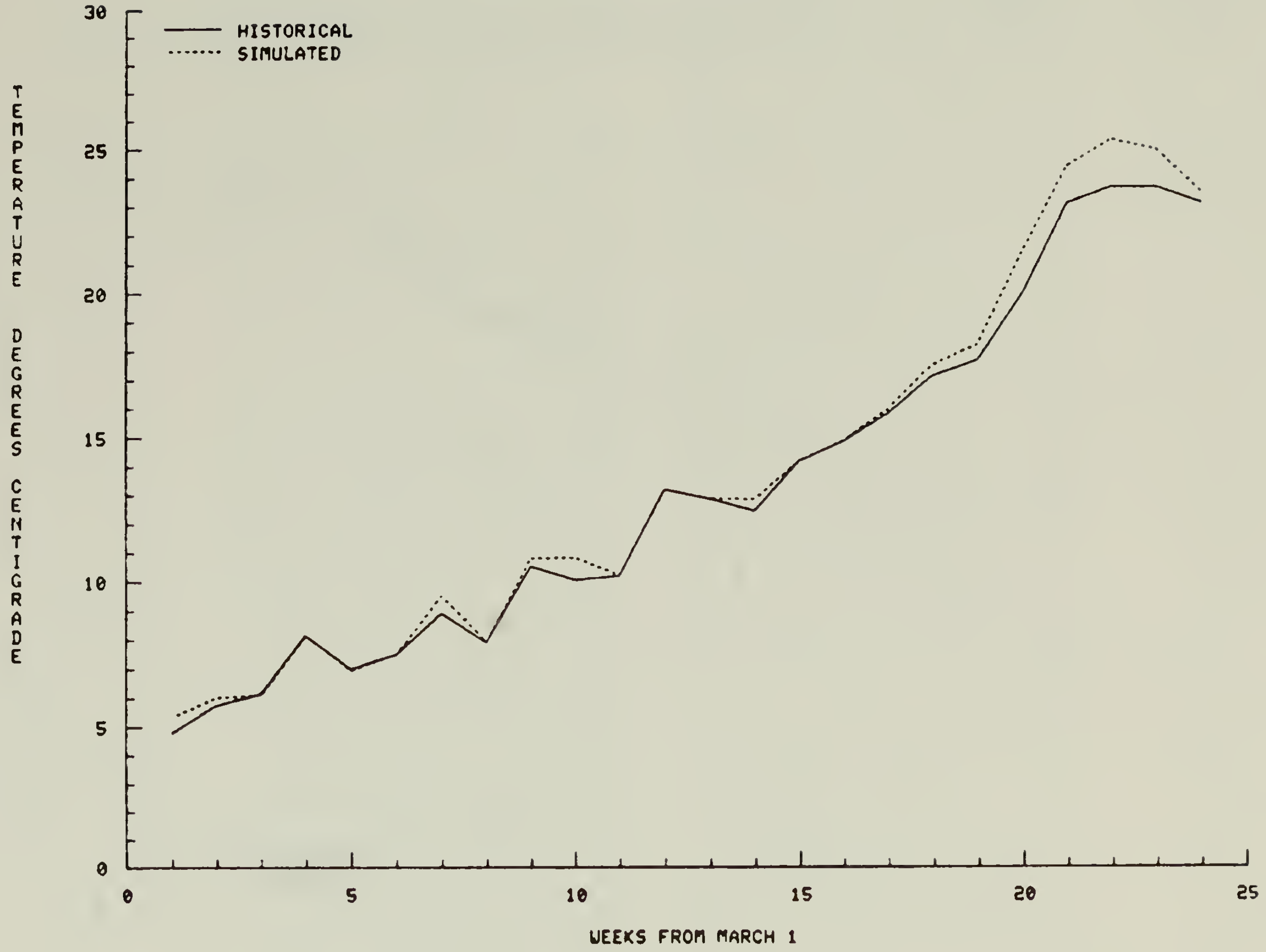
TEMPERATURE AT MATHERS HOLE 1977

Figure 16



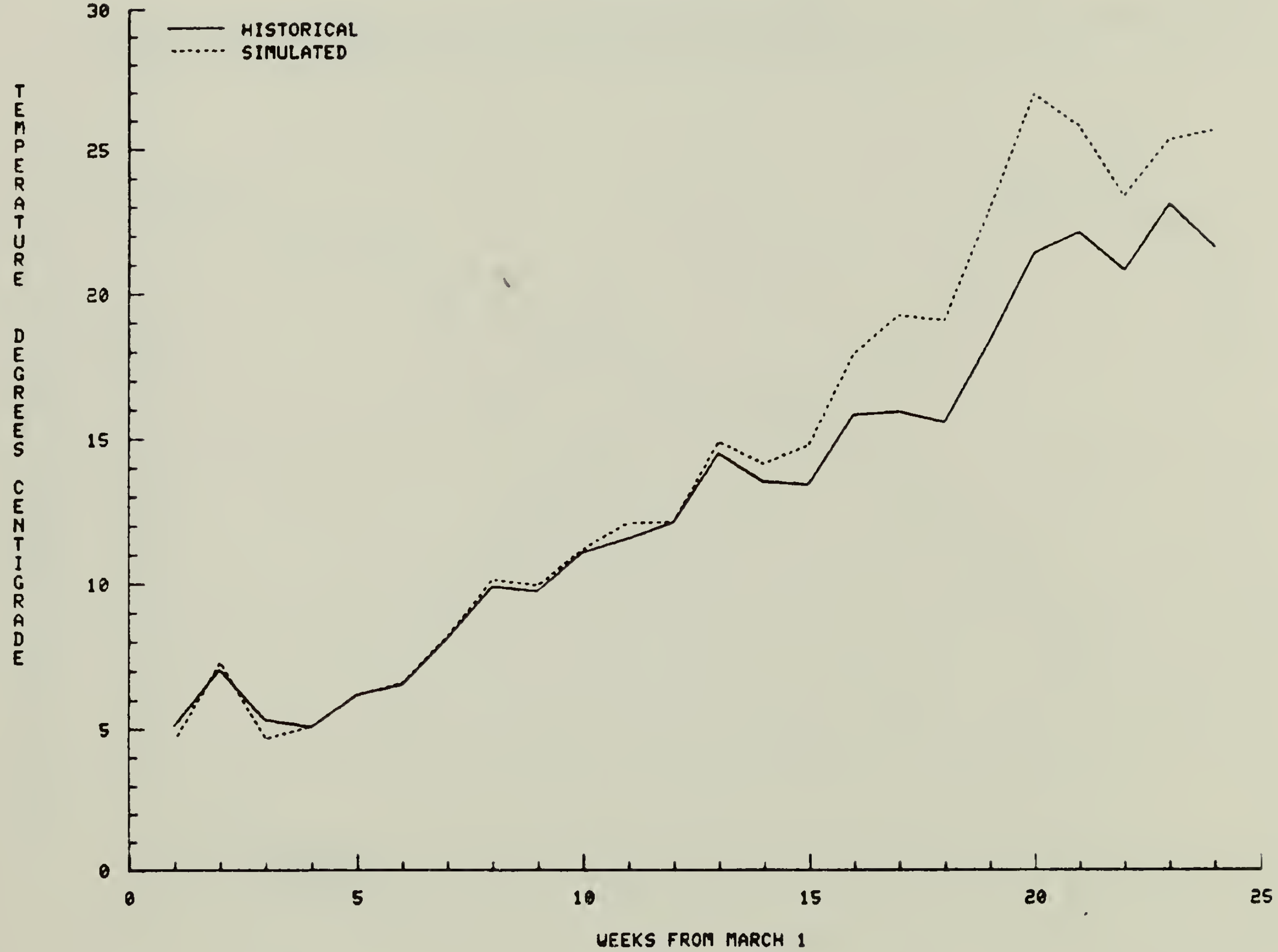
WATER TEMPERATURE AT MATHERS HOLE 1981

Figure 17



WATER TEMPERATURE AT MATHERS HOLE 1982

Figure 18



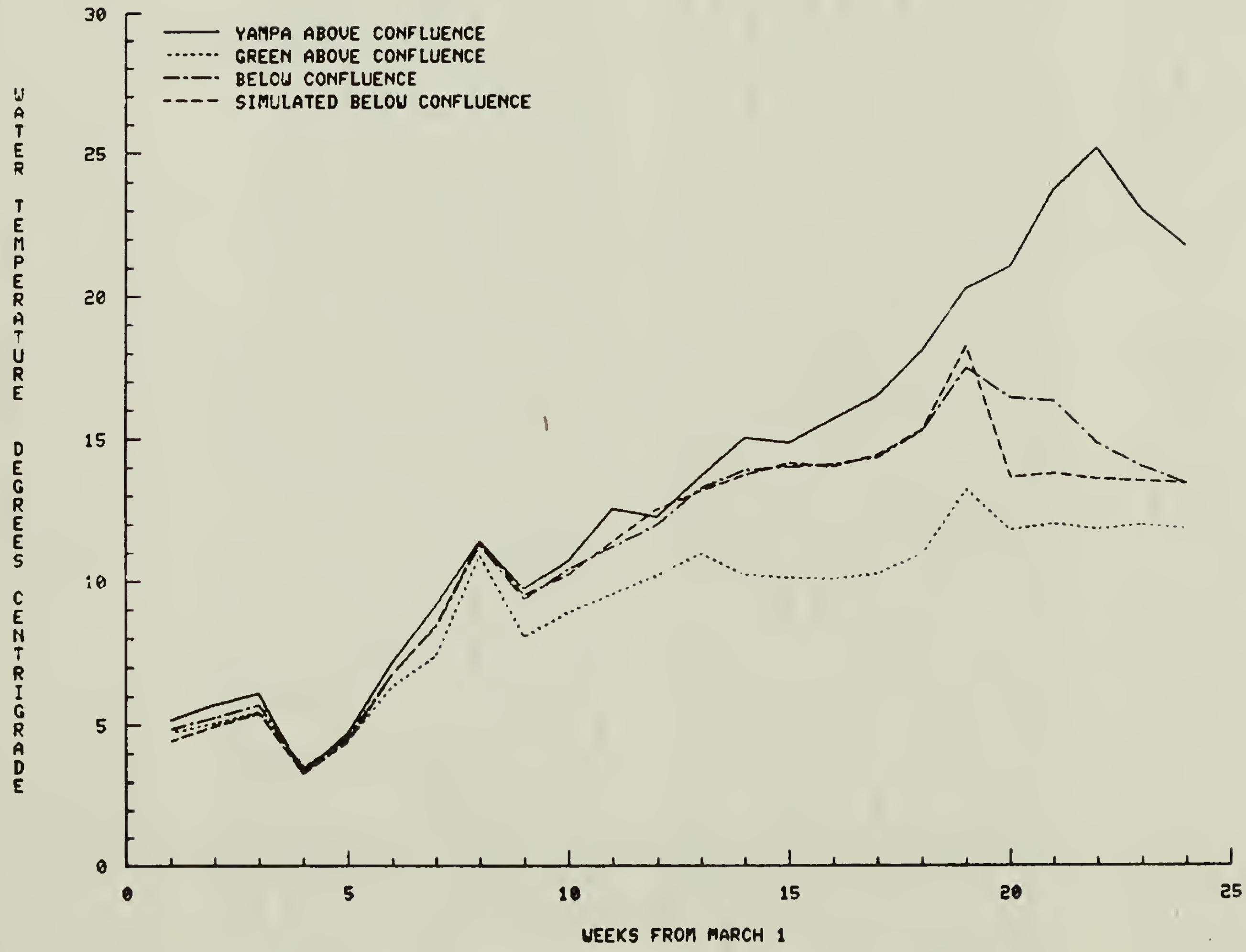
YAMPA RIVER WATER TEMPERATURE AT MATHERS HOLE 1983

Figure 19

historically occurred. Since the resultant composite hydrographs do not deviate significantly from the shape of the historical hydrographs, the water temperatures are not adversely affected. The warmer water temperatures in July and August combined with composite hydrograph might have a beneficial effect in initiating and lengthening the postulated spawning period of the Colorado squawfish. The minimum streamflow hydrograph requested by the Park Service is suitable for continued utilization of the Yampa River in the canyon by the Colorado squawfish. In contrast, a reduction of the upstream water temperatures with the corresponding reduction in water discharge would decrease the water temperature at Mathers Hole, adversely impacting the spawning habitat in the cobble reach.

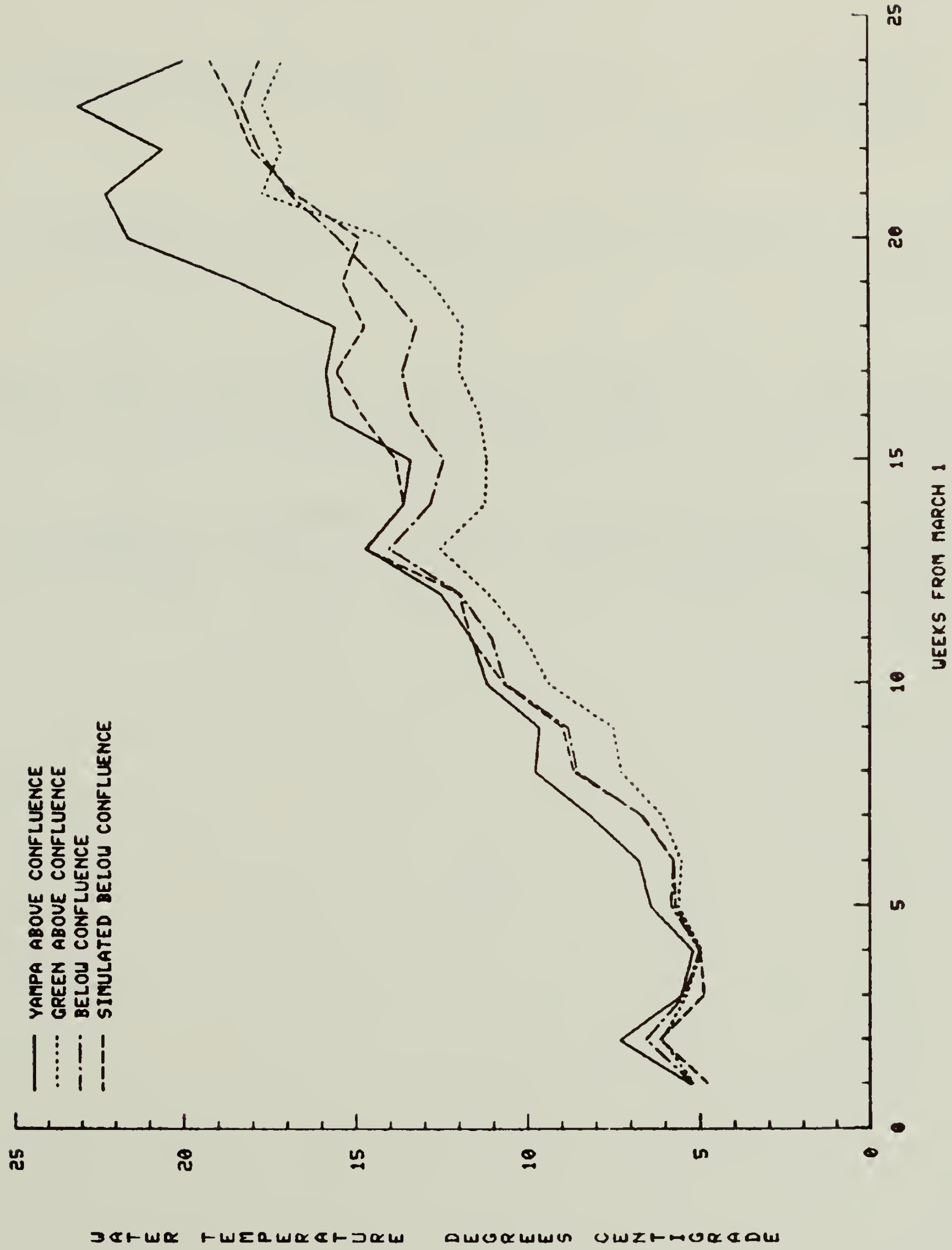
At the confluence of the Yampa and the Green Rivers, the water temperature response to reduced discharges in the Yampa River is complex and difficult to predict. Figure 20 shows that 1975 water temperatures just downstream of the confluence would be decreased by a maximum of almost 4°C. This would represent a water temperature reduction shock of almost 13°C between the two rivers for one specific time increment in the late summer. In 1983, however, the warmer water temperatures in the Yampa are a greater influence in warming the Green River than the discharge loss from the Yampa is in decreasing the water temperatures. The resulting water temperatures in the Green downstream of the confluence are warmer with the reduction of discharge in the Yampa. The warmer water temperature releases from Flaming Gorge Dam on the Green River decreased the water temperature difference between the Yampa and Green Rivers at confluence in 1983 compared to 1975.

August 15 was designated as the end of the study period in this investigation based on the NPS minimum streamflow hydrograph. Following this date, the flows requested by NPS return to the base flows of 367 cfs. Based on Figures 20 and 21, it is recommended that this analysis be extended into the months of September and October when the larval Colorado squawfish enter the nursury stage following the downstream drift cycle of its lifestage. The possible water temperature difference shock late in the summer at the confluence may be detrimental to larval fish. Further, this analysis for the baseflow should be extended to the Jensen-Ouray area where the young-of-the-year seek nursury habitat. A constant baseflow of 367 cfs for the Yampa River should be reviewed for its possible adverse effects on the young-of-the-year lifestage of the Colorado squawfish in the lower Green River.



1975 WATER TEMPERATURES YAMPA & GREEN RIVERS CONFLUENCE

Figure 20



1983 WATER TEMPERATURES YAMPA & GREEN RIVERS CONFLUENCE

Figure 21

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