VERIFICATION OF WATER-QUALITY MODEL TO SIMULATE EFFECTS OF DISCHARGING TREATED WASTEWATER DURING ICE-COVER CONDITIONS TO THE RED RIVER OF THE NORTH AT FARGO, NORTH DAKOTA, AND MOORHEAD, MINNESOTA

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ABSTRACT

The Red River at Fargo Water-Quality (RRatFGO QW) Model, which used the Enhanced Stream Water Quality Model (QUAL2E) computer program, was calibrated and verified for ice-free conditions. The purpose of this study was to verify the model for ice-cover conditions using the same Red River of the North study reach that was used for ice-free conditions. The study reach begins about 0.1 mile downstream of the 12th Avenue North bridge in Fargo, North Dakota, and extends 30.8 miles downstream to a site 0.8 mile upstream of the confluence of the Buffalo River and the Red River of the North. The study reach receives treated wastewater outflow from municipal wastewater-treatment plants at Fargo, North Dakota, and Moorhead, Minnesota, and inflow from the Sheyenne River. For simulations conducted for ice-cover conditions, the RRatFGO QW Model will be referred to as the Red River at Fargo Ice-Cover Water-Quality (RRatFGOIC QW) Model.

Streamflow measurements were made at 10 sites during February 21-24, 1995, and water-quality samples were collected and field properties were measured at 12 sites during February 23-24, 1995. Properties and constituents analyzed for include specific conductance, water temperature, dissolved oxygen, 5-day carbonaceous biochemical oxygen demand, total nitrite (reported as nitrogen), total nitrite plus nitrate (reported as nitrogen), total ammonia (reported as nitrogen), total organic nitrogen (reported as nitrogen), total phosphorus (reported as phosphorus), chlorophyll a, and algal biomass.

The RRatFGOIC QW Model simulated streamflow, specific conductance, total organic nitrogen, total ammonia, total nitrite, total nitrite plus nitrate, 5-day carbonaceous biochemical oxygen demand, and dissolved oxygen. The model was considered verified for ice-cover conditions for all of the values or concentrations simulated except for the total organic nitrogen concentrations. Based on the results of this study, the QUAL2E Model computer program that was calibrated for ice-free conditions is capable of simulating water quality for both ice-free and ice-cover conditions.

INTRODUCTION

The Clean Water Act requires that all states implement a total maximum daily load (TMDL) process for surface water where current water-quality controls are not adequate to achieve instream standards (U.S. Environmental Protection Agency, Assessment and Watershed Protection Division, 1991). A TMDL process results in an allocation of loads for point and nonpoint sources in order to establish a proper balance of controls between all sources within the watershed. State and Federal agencies have determined that a TMDL process should be developed for a subreach of the Red River of the North (hereinafter referred to as the Red River) at Fargo, N. Dak., and Moorhead, Minn. The timing of this development was prompted by (1) the enlargement and upgrade of the wastewater-treatment plant at Fargo to allow continuous wastewater discharge to the Red River and (2) the recommendation of stricter controls for the wastewater-treatment plant at Moorhead in order to reduce effluent ammonia concentrations. The Moorhead wastewater-treatment plant already continuously discharges wastewater to the Red River.

A work group consisting of local, State, and Federal agency representatives was organized in June 1994 to begin developing the TMDL process for a subreach of the Red River at Fargo and Moorhead. The work group decided that the TMDL process should be implemented in phases. In the first phase, the focus is on attainment of instream standards during critical, low-streamflow conditions when wastewater discharges are the primary loading sources to the river. The water-quality constituents to be addressed during the first phase of the TMDL process are limited to ammonia and dissolved oxygen.

Interest in the water quality of the Red River by State health agencies has at least a 60-year history. In 1931-33, an investigation to define the water quality of the Red River was conducted by the North Dakota and Minnesota State Boards of Health. Wesolowski (1994) discussed the calibration, verification, and use of the Red River at Fargo Water-Quality (RRatFGO QW) Model to simulate the effects of discharging treated wastewater to the Red River during ice-free conditions. The model, which used the Enhanced Stream Water Quality Model (QUAL2E) computer program written by Brown and Barnwell (1987), was used to simulate the effects of loadings of selected water-quality constituents on dissolved-oxygen concentrations in the river.

The purpose of this study was to verify, for ice-cover conditions, the water-quality model that previously was calibrated and verified for ice-free conditions. This report describes the results of the study. Water-quality data needed to verify the model for ice-cover conditions were collected using the same study reach that was used for ice-free conditions. The data were compared to simulated water-quality data for comparative sampling sites in order to determine the effects on dissolved-oxygen concentrations from the continuous discharge of treated wastewater to the river. The study was conducted by the U.S. Geological Survey in cooperation with the North Dakota Department of Health and the Minnesota Pollution Control Agency.

DATA COLLECTION

The study reach begins just downstream of Dam A, which is about 0.1 mile downstream of the 12th Avenue North bridge in Fargo and extends 30.8 miles downstream to a site 0.8 mile upstream of the confluence of the Buffalo and Red Rivers (fig. 1). A network of 13 data-collection sites (fig. 1; table 1) was used to represent the Red River (sites 1, 4, 5, 5.7, 6, 7, 9, 10, 12, and 14), wastewater outflow from municipal wastewater-treatment plants (sites 2 and 5.8), and inflow from the Sheyenne River (site 11). Streamflow measurements were made at 10 of the 13 sites during February 21-24, 1995 (table 2). Water-quality samples were collected and field properties were measured at 6-hour intervals at 12 of the 13 sites during February 23-24, 1995. As explained later, no samples were collected at site 6. Water-quality

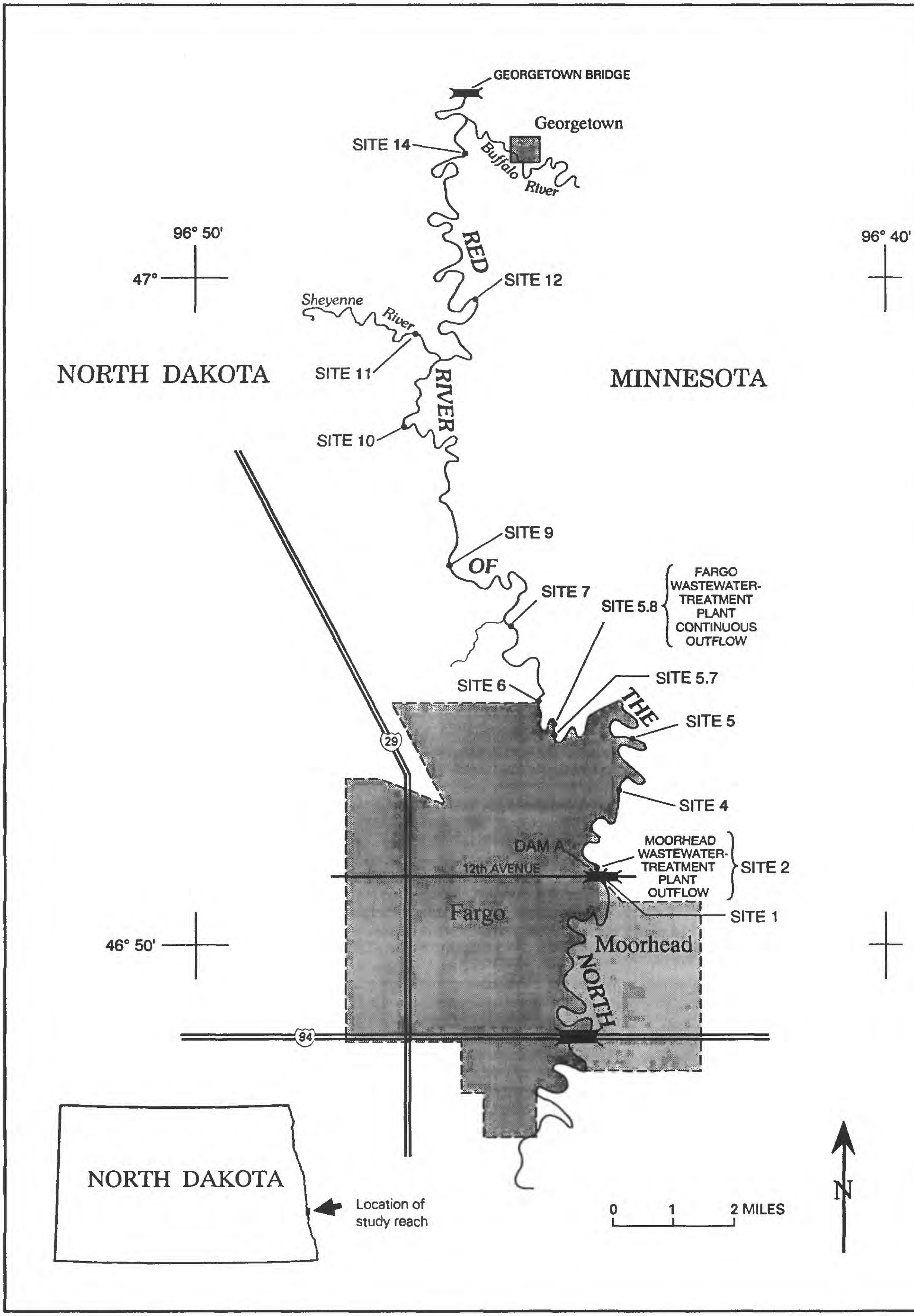

Figure 1. Location of study reach on the Red River of the North and data-collection sites from Fargo, North Dakota, to Georgetown, Minnesota.

Table 1. Site number, description, and location of data-collection sites

Site number	Description	Miles downstream from site 1	Location
1	Synoptic sampling and streamflow measurement of headwater source and comparative Red River site. Defines initial water-quality conditions for model subreach 1.	0	Beginning of study reach. Immediately downstream from Dam A (locally referred to as North Dam), which is about 0.1 mile below 12th Avenue North Bridge.
2	Synoptic sampling of point source.	.1	At Moorhead, Minn., wastewater-treatment plant outflow (buried pipe).
4	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreach 2.	2.3	At intersection of about 25th Avenue North.
5	Synoptic sampling of comparative Red River site. Defines initial water-quality conditions for model subreach 3.	5.2	At intersection of about 35th Avenue North east of Cardinal Muench Seminary.
5.7	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreaches 4 and 5.	8.0	Near west parking lot entrance to Trollwood Park.
5.8	Synoptic sampling of point source.	8.4	At Fargo, N. Dak., wastewater-treatment plant outflow (buried pipe).
6	Streamflow measurement of comparative Red River site.	9.4	At bridge on Cass County, N. Dak., Road No. 20.
7	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreach 6.	11.8	Immediately upstream from previous Fargo, N. Dak., wastewater-treatment plant outflow.
9	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreaches 7 and 8.	15.0	East of Cass County, N. Dak., Road No. 31 and 2.5 miles north of Cass County, N. Dak., Road No. 20.
10	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreach 9.	19.2	East of Cass County, N. Dak., Road No. 31 and about 5 miles north of Cass County, N. Dak., Road No. 20.
11	Synoptic sampling and streamflow measurement of point source.	20.8	At bridge over Sheyenne River on Cass County, N. Dak., Road No. 31.
12	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreach 10.	23.0	At intersection with Clay County, Minn., ditch no. 28, 3.5 miles south of Georgetown, Minn.
14	Synoptic sampling and streamflow measurement of comparative Red River site. Defines initial water-quality conditions for model subreach 11.	30.7	Near end of study reach. About 1 mile west of Georgetown, Minn., and 1.5 miles upstream from Georgetown bridge.

Table 2. Streamflow and cross-section characteristics for sites on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota

Site number	Date	Time	Streamflow (cubic feet per second)	Area of cross section (square feet)	Average velocity in cross section (feet per second)	Width of cross section (feet)	Average effective depth[1] of cross section (feet)
1	2/21/95	1335	372	490	0.76	110	4.4
4	2/23/95	1445	345	381	.91	95	4.0
5.7	2/21/95	1420	342	360	.95	113	3.2
6	2/24/95	1000	370	375	.99	75	5.0
7	2/22/95	0830	349	353	.99	101	3.5
9	2/23/95	1200	352	360	.98	97	3.7
10	2/22/95	1030	361	325	1.11	82	4.0
11	2/22/95	1330	219	222	.99	61	3.6
12	2/23/95	0925	565	335	1.69	102	3.3
14	2/22/95	1535	564	444	1.27	98	4.5

[1]Total depth of the water minus the water column above the bottom of the ice.

samples were collected four times at each of the 12 sites and analyzed for the properties and constituents listed in table 3. Laboratory determinations of property values and constituent concentrations were made by the North Dakota Department of Health.

Table 3. Properties and constituents analyzed for in samples collected during the synoptic sampling period

[Total nitrite, total nitrite plus nitrate, total ammonia, and total ammonia plus organic nitrogen are reported as nitrogen; total phosphorus is reported as phosphorus]

Properties and constituents analyzed for in the field	Properties and constituents analyzed for in the laboratory
Specific conductance	Turbidity
pH	5-day carbonaceous biochemical oxygen demand
Water temperature	Total nitrite
Barometric pressure	Total nitrite plus nitrate
Dissolved oxygen	Total ammonia
	Total ammonia plus organic nitrogen
	Total phosphorus
	Chlorophyll a
	Algal biomass (dry and ash weight)

Depth-integrating hand samplers were used in conjunction with the equal-width-increment method to collect whole-water samples that were analyzed in the laboratory. All samples were collected through the ice except at site 1. Ice thickness in the study reach ranged from about 1 foot to greater than 2 feet. Generally, the ice was thinner in the upstream reaches and thicker in the downstream reaches. Open water was present at and a short distance below site 1. Three portable instruments were used to determine field property values and dissolved-oxygen concentration. Before the synoptic sampling, the barometric-pressure gages were set to the local pressure, and the portable instruments were calibrated. Calibration was checked once or twice during sampling and again after sampling.

Total organic nitrogen concentrations were determined by subtracting total ammonia concentrations from total ammonia plus organic nitrogen concentrations. Because small total organic nitrogen concentrations were undetected in the samples from site 2, only one total organic nitrogen concentration is available for the 24-hour synoptic sampling period. Also, only one dissolved-oxygen concentration is available for the 24-hour synoptic sampling period because the measurement technique used for three dissolved-oxygen measurements made at site 11 was different from the technique used for the first measurement at site 11. Chlorophyll-a concentrations were below the detection limit of 3.0 milligrams per liter (mg/L) in all samples, and algal biomass concentrations were below the detection limit of 1.0 mg/L in all but two samples.

VERIFICATION OF WATER-QUALITY MODEL

The RRatFGO QW Model, which was calibrated and verified for ice-free conditions (Wesolowski, 1994), was used to simulate the effects of loadings of selected water-quality constituents, during ice-cover conditions, on dissolved-oxygen concentrations in the Red River. The input data for the forcing functions that drive the model were changed for the ice-cover conditions. Since the RRatFGO QW Model was calibrated and verified, the outflow site for the Fargo wastewater-treatment plant was moved upstream. At the new site (site 5.8), outflow from the wastewater-treatment plant is continuous, whereas, at the previous site, outflow was intermittent during ice-free conditions. Therefore, the location of the previous outflow site was removed as a point-source load from the stream description in the model input and the location of the new outflow site was added as a point-source load to the stream description in the model input. Hereinafter, the RRatFGO QW Model will be referred to as the Red River at Fargo Ice-Cover Water-Quality (RRatFGOIC QW) Model for simulations conducted for ice-cover conditions.

Model subreaches for the RRatFGOIC QW Model are the same as those used for the RRatFGO QW Model (Wesolowski, 1994, fig. 3) except for one synoptic sampling site that defined the initial water-quality conditions for some model subreaches. Site 6 was eliminated as a synoptic sampling site because the point-source load from site 5.8 would not be uniformly mixed by the time the load reached site 6. The initial water-quality conditions for subreaches 4 and 5 (Wesolowski, 1994, fig. 3) are defined by the water-quality conditions at site 5.7.

The RRatFGOIC QW Model simulates streamflow, specific conductance, total organic nitrogen (reported as nitrogen), total ammonia (reported as nitrogen), total nitrite (reported as nitrogen), total nitrite plus nitrate (reported as nitrogen), total phosphorus (reported as phosphorus), 5-day carbonaceous biochemical oxygen demand (CBOD5), and dissolved oxygen. Hereinafter, total organic nitrogen will be referred to as organic nitrogen, total ammonia will be referred to as ammonia, total nitrite will be referred to as nitrite, total nitrite plus nitrate will be referred to as nitrite plus nitrate, and total phosphorus will be referred to as phosphorus. The RRatFGO QW Model was considered adequately calibrated if simulated values were within one standard deviation of average measured values. The same criterion was used to evaluate simulations in this study.

QUAL2E (Brown and Barnwell, 1987, p. 93) generally simulates ultimate carbonaceous biochemical oxygen demand (CBODu) concentrations. However, an option is available in which CBOD5 concentrations can be used for input and obtained as output. When this option is used, QUAL2E internally converts the CBOD5 concentrations used as input to CBODu concentrations on the basis of a conversion coefficient and then converts the CBODu concentrations back to CBOD5 concentrations for output. During calibration of the RRatFGO QW Model (Wesolowski, 1994), the conversion coefficient was determined to be 0.214 per day, base e. The CBOD5 concentrations determined by the North Dakota Department of Health were input to the RRatFGOIC QW Model and were converted to CBODu concentrations during verification of the model.

The input data for the forcing functions that drive the RRatFGO QW Model were changed to simulate the effects of water-quality constituents during ice-cover conditions. The changes are described in the Boundary Component, Transport Component, and Water-Quality Component sections of this report. Most of the values used in the RRatFGO QW Model and in the RRatFGOIC QW Model for the forcing functions that apply to all model subreaches are listed in table 4. Input data used to verify the RRatFGOIC QW Model for ice-cover conditions are given in supplement 1.

Boundary Component

The boundary component consists of (1) the headwater-source streamflow and water-quality condition at site 1; (2) the point-source streamflow and water-quality conditions at sites 2 and 5.8 and the streamflow and water-quality conditions at site 11; (3) the measured initial water-quality conditions, including temperature, at each model subreach; and (4) the dewpoint and dry bulb air temperatures, windspeed, cloud cover, number of daylight hours, total daily solar radiation, and barometric pressure.

Table 4. Values used in the Red River at Fargo Water-Quality Model and in the Red River at Fargo Ice-Cover Water-Quality Model for selected boundary component forcing functions

Boundary component	Red River at Fargo Water-Quality Model	Red River at Fargo Ice-Cover Water-Quality Model
Headwater-source streamflow (cubic feet per second)	140.0	347.5
Point-source streamflow--Moorhead wastewater effluent (cubic feet per second)	6.0	5.5
Point-source streamflow--Fargo wastewater effluent (cubic feet per second)	14	14
Dewpoint[1] temperature (degrees Fahrenheit)	55.8	19.6
Dry bulb air temperature (degrees Fahrenheit)	61.6	24.4
Windspeed (feet per second)	5.8	6.0
Cloud cover (percent)	55	80
Number of daylight hours	13.3	10.7
Barometric pressure (inches of mercury)	30.98	29.40
Total daily solar radiation (British thermal units per square foot)	[2]1,770	890
Day of year (Julian)	241	54
Initial temperature (degrees Fahrenheit)	70.0	[3]35

[1]The dewpoint temperature is used in place of the wet bulb air temperature that is called for in the QUAL2E manual (Brown and Barnwell, 1987).

[2]Rounded from Wesolowski (1994).

[3]As limited by QUAL2E (Brown and Barnwell, 1987).

The streamflow measurement made at site 1 was considered to be less accurate than the streamflow measurements made at sites 4 and 5 because of unfavorable measuring conditions and streamflow reversal in part of the cross section. Therefore, streamflow at site 1 (table 2) was not used directly to define headwater-source streamflow. Instead, the headwater-source streamflow was calculated by averaging the streamflow for sites 1, 4, and 5.7 and subtracting the point-source streamflow at site 2 from the average. The calculated headwater-source streamflow (347.5 cubic feet per second) was used in the model. During the synoptic sampling period, the average point-source streamflow for the Moorhead wastewater-treatment plant was 5.5 cubic feet per second (oral commun., Robert Zimmerman, Superintendent of the Moorhead wastewater-treatment plant, March 1995), and the average for the Fargo wastewater-treatment plant was 14 cubic feet per second (oral commun., Peter Bilstad, Superintendent of the Fargo wastewater-treatment plant, March 1995).

Property values and constituent concentrations for the four water-quality samples collected at each of 12 sites during the synoptic sampling period were averaged to define water-quality conditions at each of those sites. Samples collected at sites 1, 2, 5.8, and 11 were used to define the boundary water-quality conditions at each of those sites, and samples collected at sites 1, 4, 5, 5.7, 7, 9, 10, 12, and 14 were used to define the initial water-quality conditions at each model subreach (Wesolowski, 1994, fig. 3). Sites 1, 4, 5, 5.7, 7, 9, 10, 12, and 14 also serve as comparative sampling sites as discussed in the Transport Component and Water-Quality Component sections of this report.

The dewpoint and dry bulb air temperatures, windspeed, cloud cover, number of daylight hours, and barometric pressure (table 4) were obtained from the National Weather Service at Fargo, N. Dak. The total daily solar radiation (table 4) was obtained from the North Dakota State Climatologist Office (Chris Brink, oral commun., March 1995).

Transport Component

The transport component consists of the channel geometry, streamflow resistance, and streamflow. The main function of the transport component is to simulate streamflow and traveltime through the study reach. The RRatFGOIC QW Model uses Manning's equation to calculate streamflow. Manning's equation requires cross-section area of the channel as a function of depth, channel slope, channel wetted perimeter, and roughness coefficient.

After the boundary streamflow conditions were updated to simulate ice-cover conditions, simulations of streamflow and specific conductance were made. The relative percent differences between measured and simulated streamflows (the difference between the measured streamflow and the simulated streamflow divided by the sum of the two streamflows at the comparative sampling sites; fig. 2) are within 2.5 percent except at site 1 where the relative percent difference is 3.4.

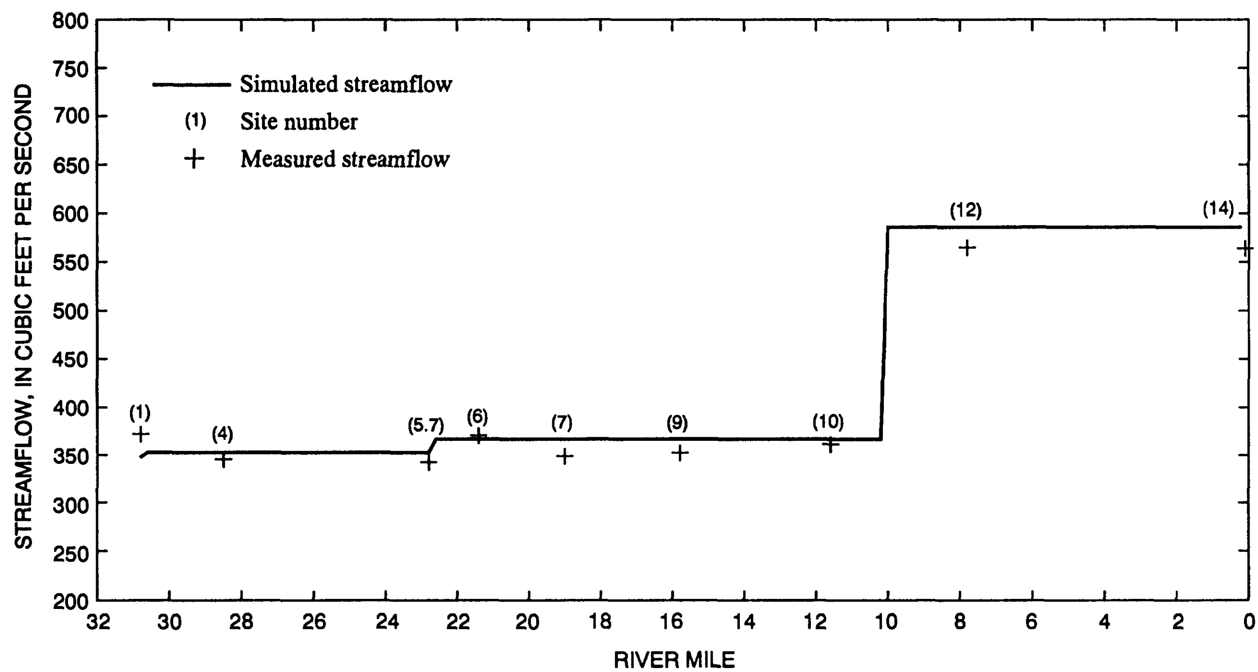

Figure 2. Measured and simulated streamflows for verification data set (February 21-24, 1995) (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

During ice-cover conditions, the backwater caused by the ice thickness results in greater depths than during ice-free conditions at the same streamflow. The RRatFGOIC QW Model calculates depths that generally match the average effective depth (total depth of the water minus the water column above the bottom of the ice) of the model subreaches. The average effective depths of cross sections at the comparative streamflow measurement sites are listed in table 2.

Specific conductance was simulated to determine how well the model simulates transport velocities because specific conductance is assumed to be a conservative constituent and a change in its value during transport in the study reach is caused only by dilution. Simulated specific-conductance values were compared to average measured values for sites 1, 4, 5, 5.7, 7, 9, 10, 12, and 14 (fig. 3). Simulated values are within one standard deviation, which ranges from 7 to 29 microsiemens per centimeter at 25 degrees

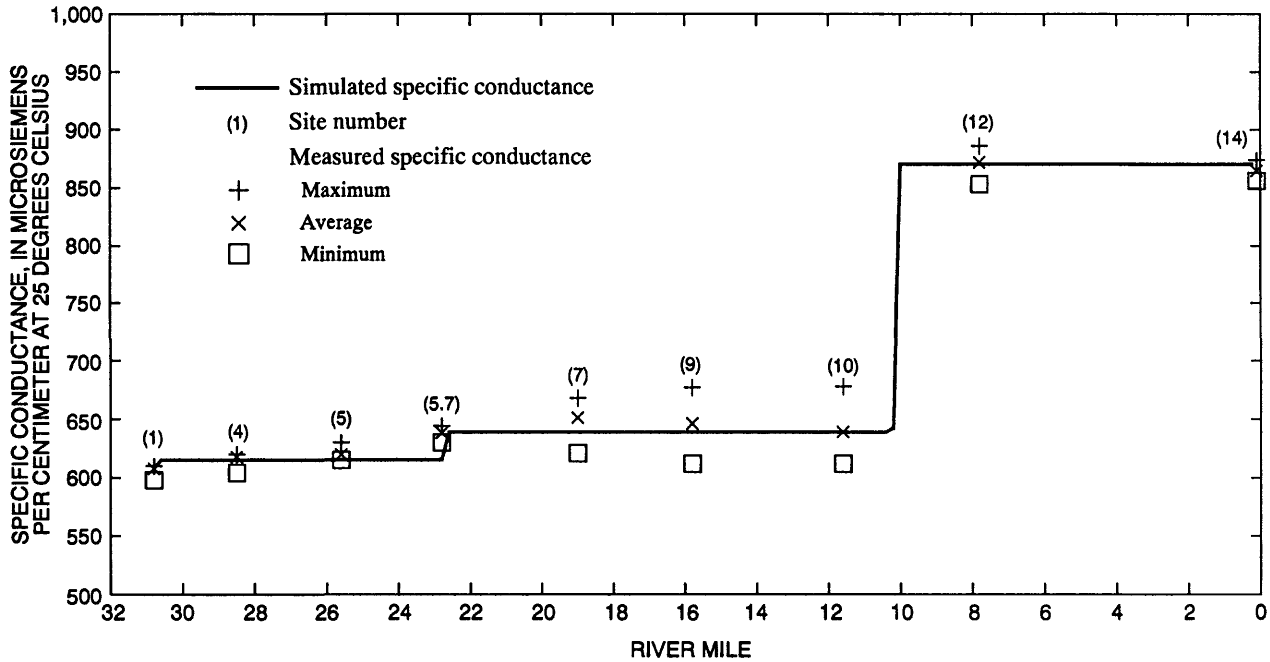

Figure 3. Maximum, average, and minimum measured specific conductance for verification data set (February 23-24, 1995) and simulated specific conductance (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

Celsius, of the corresponding average measured values for all data-collection sites except site 5.7. With the satisfactory simulation of streamflow and specific conductance without any adjustments to the channel geometry or the roughness coefficient, the transport component is considered verified for ice-cover conditions.

Water-Quality Component

The main function of the water-quality component is to simulate water-quality constituents. The water-quality component includes all of the source-sink terms for water-quality properties and constituents and the associated reaction coefficients that are necessary to simulate water-quality properties and constituents. Calibration of the reaction coefficients, which are temperature dependent, is discussed by Wesolowski (1994) for ice-free conditions. Default temperature correction values given by Brown and Barnwell (1987, p. 53) were used in the RRatFGOIC QW Model.

Reaeration-Rate Coefficient

Little or no reaeration occurred during the synoptic sampling period because most of the river was completely ice covered. Open water was present at and a short distance below sites 1, 2, and 5.8. Sites 1 and 2 were open because of upstream water spilling over Dam A and inflow from the Moorhead wastewater-treatment plant. Site 5.8 was open because of inflow from the Fargo wastewater-treatment plant. Reaeration studies that were conducted on the study reach during 1990 (Wesolowski, 1994, p. 38) indicate that the reaeration-rate coefficient is 0.95 per day when open-water streamflow is about 350 cubic feet per second. For this study, a reaeration-rate coefficient of 0.05 per day (Brown and Barnwell, 1987,

p. 48) was used for all model subreaches that had ice cover. About 20 percent of the surface area in model subreaches 1 and 4 was open water, and a reaeration-rate coefficient of 0.20 per day was used for those subreaches.

Simulation of Water-Quality Constituents

Simulated organic nitrogen concentrations are within one standard deviation, which ranges from zero to 0.15 mg/L, of the corresponding average measured concentrations except at sites 9, 10, 12, and 14 (fig. 4). At these sites, the simulations are 0.11 to 0.19 mg/L less than the averaged measured concentrations. The declining trend of the simulated concentrations from below site 5.7 to site 14 (fig. 4) is because the instream reaction rates for hydrolysis of organic nitrogen to ammonia below site 5.7 were larger than the rates upstream from site 5.7 and because of the organic nitrogen settling rate in two model subreaches. In the calibrated RRatFGO QW Model, the hydrolysis rate for organic nitrogen ranges from 0.02 to 0.19 per day. The larger hydrolysis rates and the settling rates are not appropriate for ice-cover conditions.

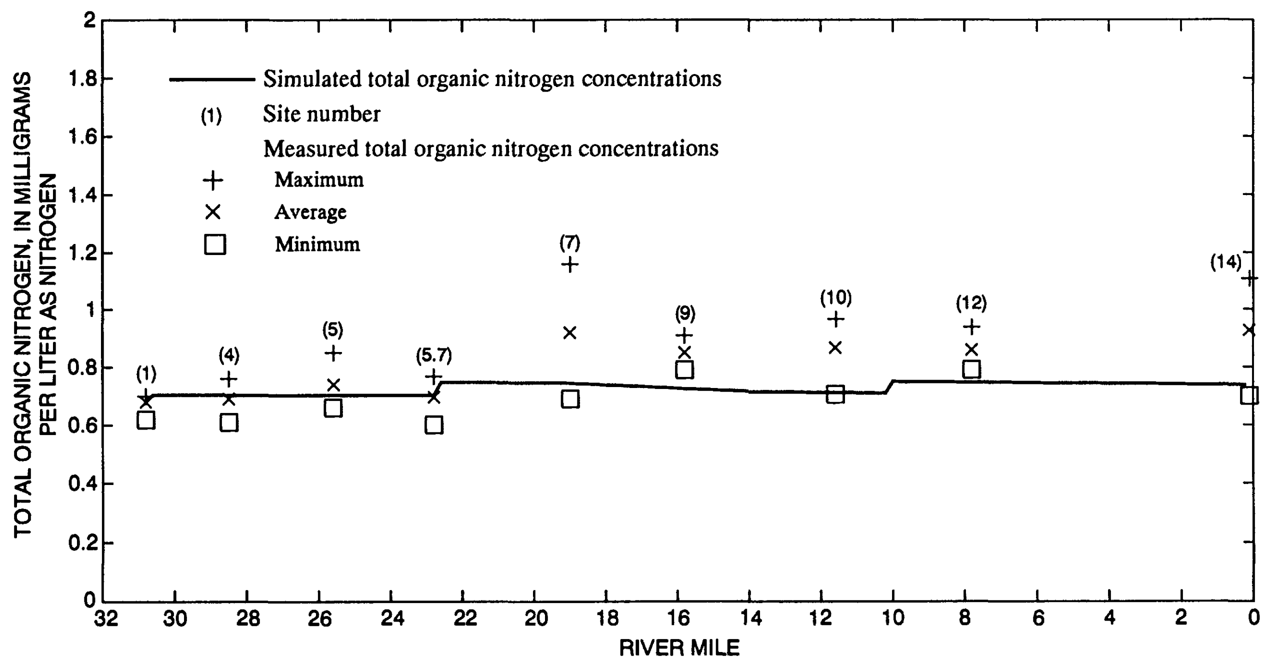

Figure 4. Maximum, average, and minimum measured total organic nitrogen concentrations for verification data set (February 23-24, 1995) and simulated concentrations (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

Although the simulated concentrations are slightly greater, they agree well with the average measured concentrations (fig. 5). Simulated concentrations are within one standard deviation, which is 0.01 mg/L, of the corresponding average measured concentrations except at sites 4, 5, and 14. The simulated concentrations for those three sites are 0.02 to 0.03 mg/L greater than the average measured concentrations.

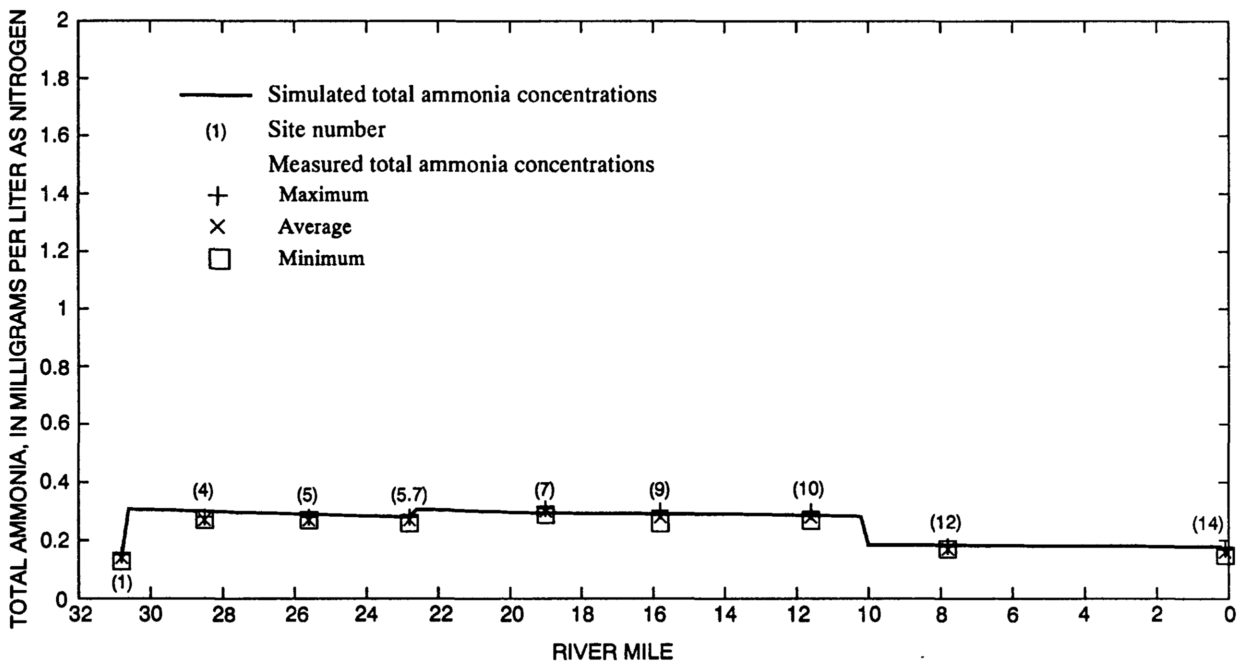

Figure 5. Maximum, average, and minimum measured total ammonia concentrations for verification data set (February 23-24, 1995) and simulated concentrations (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, MInnesota).

The simulated nitrite concentrations generally agree well with the average measured concentrations (fig. 6). Simulated concentrations are within one standard deviation, which ranges from less than 0.01 to 0.01 mg/L, of the corresponding average measured concentrations except at sites 5 and 5.7. The simulated concentrations for those two sites are about 0.01 mg/L greater than the average measured concentrations.

The simulated nitrite plus nitrate concentrations generally agree well with the average measured concentrations (fig. 7). Simulated concentrations are within one standard deviation, which ranges from less than 0.01 to 0.15 mg/L, of the corresponding average measured concentrations except at sites 5 and 7. The simulated concentration for site 5 is 0.02 mg/L less than the average measured concentration, and the simulated concentration for site 7 is 0.21 mg/L greater than the average measured concentration.

The simulated CBOD5 concentrations generally agree well with the average measured concentrations (fig. 8). Simulated concentrations are within one standard deviation, which ranges from 0.11 to 0.59 mg/L, of the corresponding average measured concentrations except at sites 4 and 5.7. The simulated concentration for site 4 is 0.3 mg/L less than the average measured concentration, and the simulated concentration for site 5.7 is 0.4 mg/L less than the average measured concentration.

Although the RRatFGOIC QW Model simulates phosphorus, the simulations were not included in this report because the low phosphorus concentrations have only a minor effect on the dissolved-oxygen budget in the river. During ice-free conditions, instream phosphorus concentrations are affected by inflow sources to the Red River, by uptake and release through algal photosynthesis and respiration, and by settling to and re-entrainment from the streambed. During ice-cover conditions, changes in instream phosphorus concentrations are caused mostly by inflows because algal activity is reduced and because settling and re-entrainment are reduced by relatively steady flows. During the synoptic sampling period,

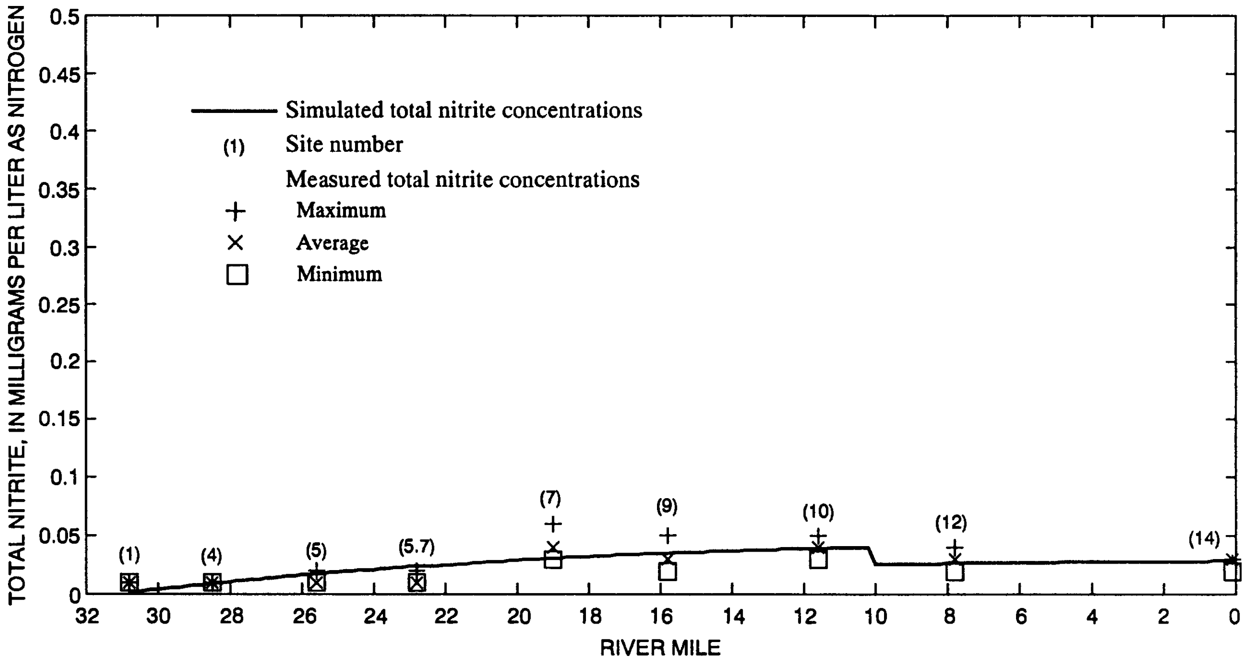

Figure 6. Maximum, average, and minimum measured total nitrite concentrations for verification data set (February 23-24, 1995) and simulated concentrations (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

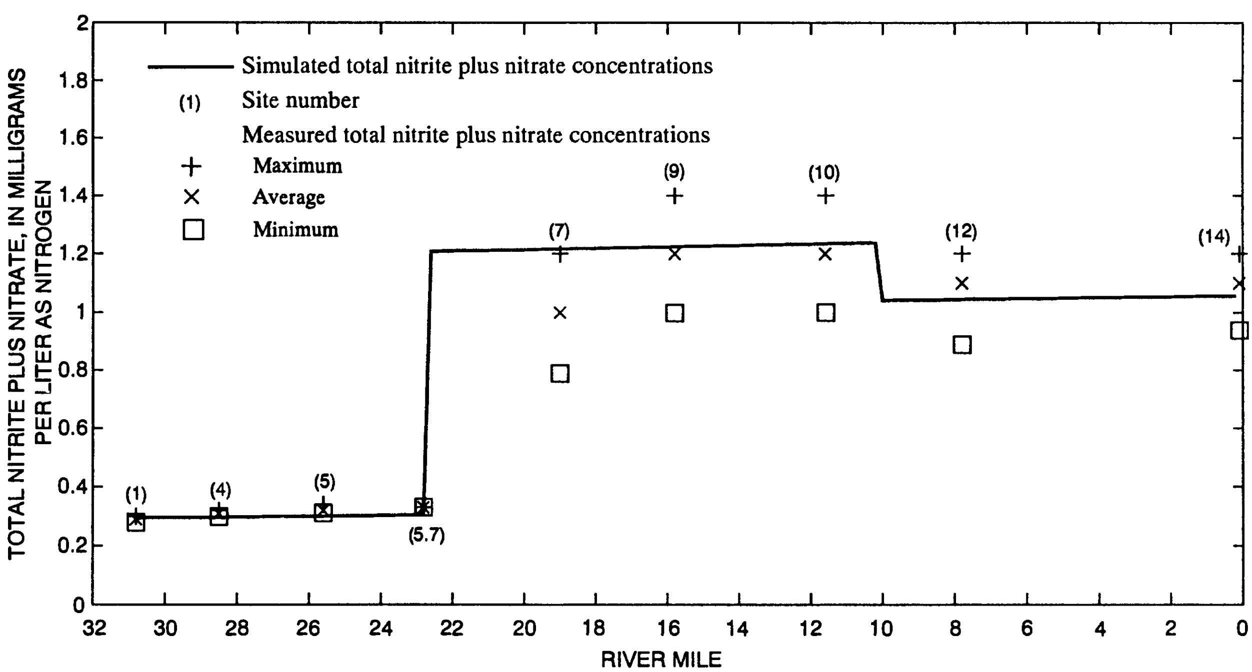

Figure 7. Maximum, average, and minimum measured total nitrite plus nitrate concentrations for verification data set (February 23-24, 1995) and simulated concentrations (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

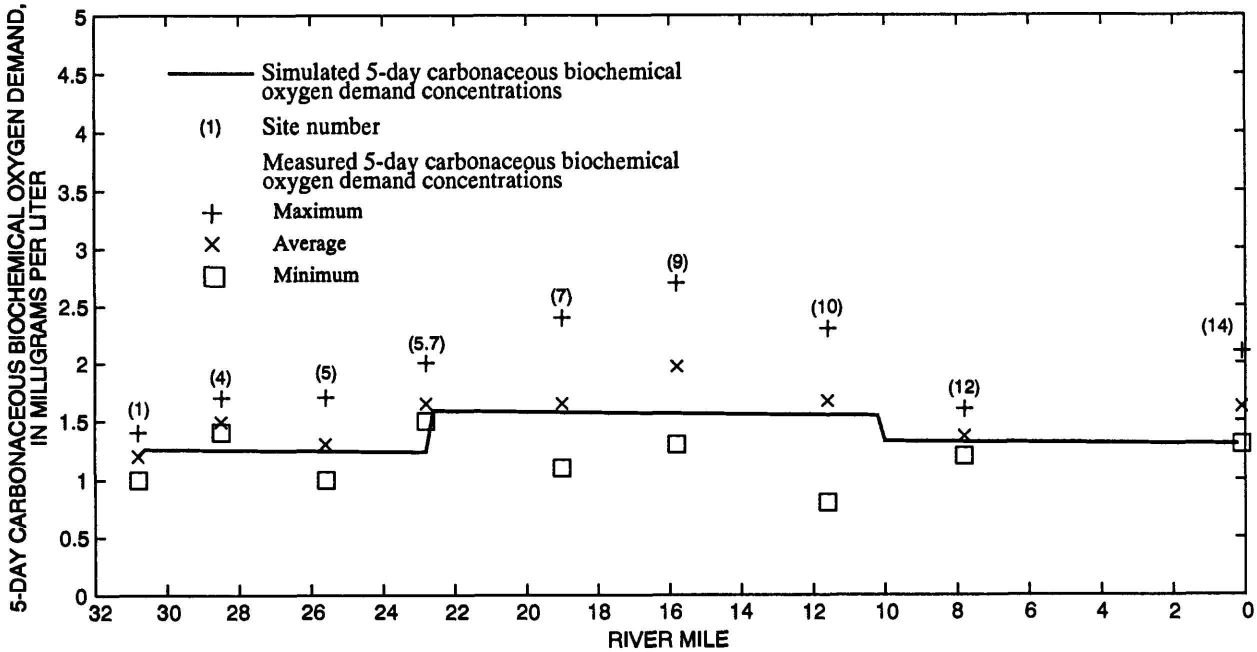

Figure 8. Maximum, average, and minimum measured 5-day carbonaceous biochemical oxygen demand concentrations for verification data set (February 23-24, 1995) and simulated concentrations (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

the phosphorus concentration at site 1 was 0.03 mg/L, and the concentration from point sources (sites 2, 5.8, and 11) ranged from 0.12 to 2.65 mg/L. The point-source contributions increased the instream phosphorus concentration at site 14 to 0.10 mg/L.

Generally, the simulated dissolved-oxygen concentrations agree well with the average measured concentrations except at the lower end of the study reach (fig. 9). The similar trend of the measured and simulated concentrations from site 1 through site 7 indicates the model simulates dissolved-oxygen use at the same rate as instream processes use dissolved oxygen. Downstream from site 9, the model simulates dissolved-oxygen use at a greater rate than instream processes use dissolved oxygen. Simulated concentrations are within one standard deviation, which ranges from 0.1 to 0.6 mg/L, of the corresponding average measured concentrations except at sites 12 and 14. The simulated concentration for site 12 is 1.3 mg/L less than the average measured concentration, and the simulated concentration for site 14 is 1.7 mg/L less than the average measured concentration.

The average measured dissolved-oxygen concentration at site 12 is 13.8 mg/L, and the average measured concentration at site 14 is 14.1 mg/L. These concentrations, which are approaching saturation, are larger than the concentration at site 1 and were unexpected under the present instream conditions. At both sites, the measured dissolved-oxygen concentrations appear to be outliers. However, given the available data and information, the concentrations cannot be discounted because of sampling or instrument error nor can they be attributed to some known processes in the river because the conditions needed to simulate the concentrations at these two sites did not exist during the synoptic sampling period.

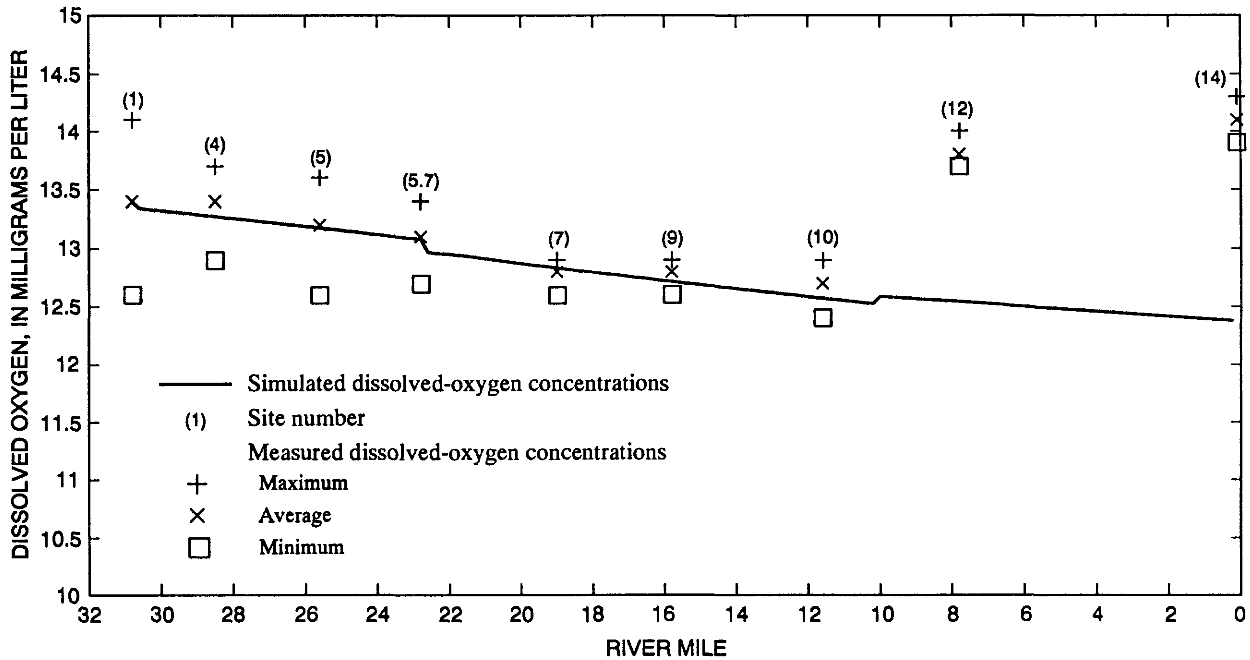

Figure 9. Maximum, average, and minimum measured dissolved-oxygen concentrations for verification data set (February 23-24, 1995) and simulated concentrations (mile zero is downstream end of study reach, which is on the Red River of the North at Fargo, North Dakota, and Moorhead, Minnesota).

SUMMARY AND CONCLUSIONS

The Red River at Fargo Water-Quality (RRatFGO QW) Model, which used the Enhanced Stream Water Quality Model (QUAL2E) computer program, was calibrated and verified for ice-free conditions. The purpose of this study was to verify the model for ice-cover conditions using the same Red River of the North study reach that was used for ice-free conditions. The study reach begins about 0.1 mile downstream of the 12th Avenue North bridge in Fargo, North Dakota, and extends 30.8 miles downstream to a site 0.8 mile upstream of the confluence of the Buffalo River and the Red River of the North. The study reach receives treated wastewater outflow from municipal wastewater-treatment plants at Fargo, North Dakota, and Moorhead, Minnesota, and inflow from the Sheyenne River.

A network of 13 data-collection sites was used to represent the Red River of the North, wastewater outflow from municipal wastewater-treatment plants, and inflow from the Sheyenne River. Streamflow measurements were made at 10 of the sites during February 21-24, 1995, and water-quality samples were collected and field properties were measured at 6-hour intervals at 12 of the sites during February 23-24, 1995. Water-quality samples were collected four times at each of the 12 sites. Properties and constituents analyzed for in the field included specific conductance, pH, water temperature, barometric pressure, and dissolved oxygen. Properties and constituents analyzed for in the laboratory included turbidity, 5-day carbonaceous biochemical oxygen demand, total nitrite (reported as nitrogen), total nitrite plus nitrate (reported as nitrogen), total ammonia (reported as nitrogen), total ammonia plus organic nitrogen (reported as nitrogen), total phosphorus (reported as phosphorus), chlorophyll a, and algal biomass.

The input data for the forcing functions that drive the model were changed for the ice-cover conditions. Since the RRatFGO QW Model was calibrated and verified, the outflow site for the Fargo wastewater-treatment plant was moved upstream and the outflow has become continuous. Samples collected at sites 1, 2, 5.8, and 11 were used to define the boundary water-quality conditions at each of those sites, and samples collected at sites 1, 4, 5, 5.7, 7, 9, 10, 12, and 14 were used to define the initial water-quality conditions at each model subreach. Sites 1, 4, 5, 5.7, 7, 9, 10, 12, and 14 also serve as comparative sampling sites.

The Red River at Fargo Ice-Cover Water-Quality (RRatFGOIC QW) Model simulated streamflow, specific conductance, total organic nitrogen (reported as nitrogen), total ammonia, total nitrite, total nitrite plus nitrate, 5-day carbonaceous biochemical oxygen demand (CBOD5), and dissolved oxygen. The model was considered verified if simulated values were within one standard deviation of average measured values. The relative percent differences between measured and simulated streamflows are within 2.5 percent except at site 1 where the relative percent difference is 3.4. Simulated specific-conductance values are within one standard deviation of the average measured values for all data-collection sites except site 5.7. With the satisfactory simulation of streamflow and specific conductance, the transport component is considered verified for ice-cover conditions.

The simulated concentrations for total ammonia, total nitrite, total nitrite plus nitrate, and CBOD5 are within one standard deviation of the average measured concentrations at most of the comparative sampling sites. Therefore, the calibrated reaction coefficients are appropriate for ice-cover conditions and the model is considered verified for simulation of these constituents. Total organic nitrogen concentrations are underpredicted by more than one standard deviation at four of the comparative sampling sites because the calibrated hydrolysis rates and settling rates that were used in the model subreaches associated with these sampling sites do not seem appropriate for ice-cover conditions. Therefore, the RRatFGOIC QW Model is considered not verified for simulation of total organic nitrogen. Generally, the simulated dissolved-oxygen concentrations agree well with the average measured concentrations except at the lower end of the study reach. Simulated concentrations are within one standard deviation of the average measured concentrations except at sites 12 and 14 where the measured values appear to be outliers but cannot be discounted on the basis of available information. Thus, the water-quality component is considered verified for ice-cover conditions with the exception of the simulation of total organic nitrogen.

With the verification of both the transport component and the water-quality component, except for the simulation of total organic nitrogen, the RRatFGOIC QW Model is considered verified for ice-cover conditions. Based on the results of this study, the QUAL2E Model computer program that was calibrated for ice-free conditions is capable of simulating water quality for both ice-free and ice-cover conditions.

References

Brown, L.C., and Barnwell, T.O., Jr., 1987, The enhanced stream water quality models QUAL2E and QUAL2E-UNCAS--Documentation and user manual: Athens, Georgia, U.S. Environmental Protection Agency, Environmental Research Laboratory, EPA/600/3-87/007, 189 p.

U.S. Environmental Protection Agency, Assessment and Watershed Protection Division, 1991, Guidance for water-quality-based decision: The TMDL process: EPA440/4-91-002, April 1991, 50 p.

Wesolowski, E.A., 1994, Calibration, verification, and use of a water-quality model to simulate effects of discharging treated wastewater to the Red River of the North at Fargo, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 94-4058, 143 p.

SUPPLEMENT 1. INPUT DATA USED FOR MODEL VERIFICATION FOR ICE-COVER CONDITIONS

```
TITLE01        STREAM QUALITY MODEL--QUAL2E/NCASI VERSION--STEADY STATE
TITLE02        CALIBRATION: February 23-24, 1995   RED RIVER NR FARGO, ND
TITLE03 YES     CONSERVATIVE MINERAL  I  SPCN   USCM
TITLE04 YES     CONSERVATIVE MINERAL  II  TURB   NTU
TITLE05 NO      CONSERVATIVE MINERAL III
TITLE06 NO      TEMPERATURE
TITLE07 YES     5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08 NO      ALGAE AS CHL-A IN UG/L
TITLE09 YES     PHOSPHORUS CYCLE AS P IN MG/L
TITLE10        (ORGANIC-P; DISSOLVED-P)
TITLE11 YES     NITROGEN CYCLE AS N IN MG/L
TITLE12        (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13 YES     DISSOLVED OXYGEN IN MG/L
TITLE14 NO      FECAL COLIFORM IN NO./100 ML
TITLE15 NO      FECAL STREP IN NO./100 ML  FCSP   100M
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NOFLOW AUGMENTATION
STEADY STATE
TRAPEZOIDAL CHANNELS
PRINT LCD/SOLAR DATA
PLOT DO AND BOD
FIXED DNSTM CONC (YES=1)=      0.      5D-ULT BOD CONV K COEF =      .21
INPUT ENGLISH          =     0.     OUTPUT ENGLISH        =     0.
NUMBER OF REACHES      =     11.      NUMBER OF JUNCTIONS    =     0.
NUM OF HEADWATERS      =     1.      NUMBER OF POINT LOADS  =     4.
TIME STEP (HOURS)      =     1.      LNTH. COMP. ELEMENT (MI)=      .2
MAXIMUM ROUTE TIME (HRS)=    30.      TIME INC. FOR RPT2 (HRS)=     0.
LATITUDE OF BASIN (DEG) =   47.00      LONGITUDE OF BASIN     =   96.75
STANDARD MERIDIAN (DEG) =    98.      DAY OF YEAR STAT TIME  =      54
EVAP. COEFF. (AE)      =  .00068      EVAP. COEFF. (BE)      =  .00027
ELEV. OF BASIN (ELEV.) =    900.      DUST ATTENUATION COEFF. =     .05
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)=  3.43  O UPTAKE BY NO2 OXID(MG 0/MG N)=  1.14
O PROD BY ALGAE (MG O/MG A)    =   1.6  O UPTAKE BY ALGAE (MG O/MG A)  =   2.
N CONTENT OF ALGAE (MG N/MG A) =  .080  P CONTNET OF ALGAE (MG P/MG A) =  .011
ALG MAX SPEC GROWTH RATE(1/DAY)=   1.6  ALGAE RESPIRATION RATE(1/DAY)  =  .12
N HALF SATURATION CONST (MG/L) =   .03  P HALF SATURATION CONST (MG/L) =  .04
LIN ALG SHADE CO(1/FT-UGCHA/L) = .0027  NLIN SHADE(1/FT-(UGCHA/L)**2/3)= .0165
LIGHT FUNCTION OPTION (LFNOPT) =     1  LIGHT SATURATION COEF (BTU/MIN)= .1105
DAILY AVERAGING OPTION (LAVOPT)=     2  LIGHT AVERAGING FACTOR (AFAACT)=  1.0
NUMBER OF DAYLIGHT HOURS (DLH) =  10.7  TOTAL DAILY SOLAR RADTN (INT)  = 890.0
ALGY GROWTH CALC OPTION(LGROPT)=     2  ALGAL PREF FOR NH3-N (PREFN)   =   .9
ALG/TEMP SOLR RAD FACTOR(TFACT)=   1.0  NITRICATION INHIBITION COEF    = 10.0
ENDATA1A
ENDATA1B
STREAM REACH    1. RCH=SITE NO 1       FROM      30.8   TO       28.6
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STREAM REACH   2. RCH=SITE NO 4        FROM    28.6  TO    25.6
STREAM REACH   3. RCH=SITE NO 5-7.4    FROM    25.6  TO    23.4
STREAM REACH   4. RCH=MI:7.4-9.4       FROM    23.4  TO    21.4
STREAM REACH   5. RCH=SITE NO 6        FROM    21.4  TO    19.0
STREAM REACH   6. RCH=SITE NO 7        FROM    19.0  TO    15.8
STREAM REACH   7. RCH=SITE NO 9        FROM    15.8  TO    13.8
STREAM REACH   8. RCH=MI:17.0-19.2     FROM    13.8  T0    11.6
STREAM REACH   9. RCH=SITE NO 10       FROM    11.6  TO     7.8
STREAM REACH  10. RCH=SITE NO 12       FROM     7.8  TO     3.8
STREAM REACH  11. RCH=SITE NO 13       FROM     3.8  TO     0.0
ENDATA2
FLOW AUGMT SOURCES  RCH=  1.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  2.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  3.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  4.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  5.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  6.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  7.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  8.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH=  9.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH= 10.   0.   0.  0.  0.  0.  0.  0.  0.
FLOW AUGMT SOURCES  RCH= 11.   0.   0.  0.  0.  0.  0.  0.  0.
ENDATA3
FLAG FIELD RCH=  1.   11.   1.6.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  2.   15.   2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  3.   11.   2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  4.   10.   2.2.2.2.6.2.2.2.2.2.
FLAG FIELD RCH=  5.   12.   2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  6.   16.   6.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  7.   10.   2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  8.   11.   2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  9.   19    2.2.2.2.2.2.2.2.6.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH= 10.   20    2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH= 11.   19    2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.5.
ENDATA4
HYDRAULICS RCH=  1.   30.   6.94   6.15   77.30  .0001136   .030
HYDRAULICS RCH=  2.   30.   6.33   2.03   68.95  .0001136   .033
HYDRAULICS RCH=  3.   30.   6.13   1.96   64.43  .0001136   .037
HYDRAULICS RCH=  4.   30.   3.53   3.21   77.38  .0001136   .037
HYDRAULICS RCH=  5.   30.   6.36   5.52   73.57  .0001136   .037
HYDRAULICS RCH=  6.   50.   5.16   5.10   69.28  .0001136   .033
HYDRAULICS RCH=  7.   50.   5.80   5.00   60.00  .0001136   .030
HYDRAULICS RCH=  8.   50.   5.78   4.31   76.70  .0001136   .028
HYDRAULICS RCH=  9.   50.   4.19   4.76   62.19  .0000943   .028
HYDRAULICS RCH= 10.   50.   4.10   6.00   76.00  .0001136   .028
HYDRAULICS RCH= 11.   50.   3.04   6.66   71.69  .0001136   .028
ENDATA5
REACT COEF RCH=  1.   .05  0.03  .100  1  0.20   .0001136
REACT COEF RCH=  2.   .05  0.03  .100  1   .05   .0001136
REACT COEF RCH=  3.   .05  0.03  .100  1   .05   .0001136
REACT COEF RCH=  4.   .05  0.03  .100  1   .20   .0001136
REACT COEF RCH=  5.   .05  0.03  .100  1   .05   .0001136
REACT COEF RCH=  6.   .05  0.03  .100  1   .05   .0001136
REACT COEF RCH=  7.   .05  0.03  .100  1   .05   .0001136
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REACT COEF RCH= 8.   .05  0.03  .100  1   .05      .0001136
REACT COEF RCH= 9.   .05  0.03  .100  1   .05      .0000943
REACT COEF RCH= 10.  .05  0.03  .100  1   .065     .0001136
REACT COEF RCH= 11.  .05  0.03  .100  1   .065     .0001136
ENDATA6
N AND P COEF  RCH= 1.  .02  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 2.  .02  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 3.  .02  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 4.  .02  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 5.  .02  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 6.  .19  .1  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 7.  .19  .1  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 8.  .09  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 9.  .09  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 10.  .09  .0  1.07  .0  3.08  .21  .0  .0
N AND P COEF  RCH= 11.  .09  .0  1.07  .0  3.08  .21  .0  .0
ENDATA6A
ALG/OTHER COEF RCH= 1.  10.  1.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 2.  10.  1.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 3.  10.  4.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 4.  10.  4.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 5.  10.  2.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 6.  10.  2.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 7.  10.  2.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 8.  10.  2.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 9.  10.  2.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 10.  10.  2.0  .5  .8  .8  .0  .0
ALG/OTHER COEF RCH= 11.  10.  2.0  .5  .8  .8  .0  .0
ENDATA6B
INITIAL COND-1 RCH=  1.  35.0 13.40  1.20  608.  12.00  0.00   00  0000
INITIAL COND-1 RCH=  2.  35.0 13.40  1.50  613.  12.00  0.00  000  0000
INITIAL COND-1 RCH=  3.  35.0 13.20  1.30  620.  14.00  0.00  000  0000
INITIAL COND-1 RCH=  4.  35.0 13.10  1.60  638.  13.00  0.00  000  0000
INITIAL COND-1 RCH=  5.  35.0 13.10  1.60  638.  13.00  0.00  000  0000
INITIAL COND-1 RCH=  6.  35.0 12.80  1.60  651.  14.00  0.00  000  0000
INITIAL COND-1 RCH=  7.  35.0 12.80  2.00  646.  16.00  0.00  000  0000
INITIAL COND-1 RCH=  8.  35.0 12.80  2.00  646.  16.00  0.00  000  0000
INITIAL COND-1 RCH=  9.  35.0 12.70  1.70  639.  14.00  0.00  000  0000
INITIAL COND-1 RCH= 10.  35.0 13.80  1.40  872.  14.00  0.00  000  0000
INITIAL COND-1 RCH= 11.  35.0 14.10  1.60  865.  13.00  0.00  000  0000
ENDATA7
INITIAL COND-2 RCH=  1. 00.00  0.68  .14  .001   .29  .01  .03
INITIAL COND-2 RCH=  2. 00.00  0.69  .27  .001   .31  .01  .07
INITIAL COND-2 RCH=  3. 00.00  0.74  .27  .001   .32  .01  .08
INITIAL COND-2 RCH=  4. 00.00  0.70  .27  .001   .33  .01  .08
INITIAL COND-2 RCH=  5. 00.00  0.70  .27  .001   .33  .01  .08
INITIAL COND-2 RCH=  6. 00.00  0.92  .30  .001  1.00  .01  .10
INITIAL COND-2 RCH=  7.  0.00  0.85  .28  .001  1.20  .01  .11
INITIAL COND-2 RCH=  8.  0.00  0.85  .28  .001  1.20  .01  .11
INITIAL COND-2 RCH=  9. 00.00  0.87  .28  .001  1.20  .01  .11
INITIAL COND-2 RCH= 10. 00.00  0.86  .17  .001  1.10  .01  .11
INITIAL COND-2 RCH= 11.  0.00  0.93  .16  .001  1.10  .01  .11
ENDATA7A
INCR INFLOW-1  RCH=  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.
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INCR INFLOW-1  RCH=  2.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  3.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  4.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  5.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  6.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  7.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  8.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH=  9.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH= 10.   0.   0.  0.  0.  0.  0.  0.  0.  0.
INCR INFLOW-1  RCH= 11.   0.   0.  0.  0.  0.  0.  0.  0.  0.
ENDATA8
INCR INFLOW-2  RCH=  1.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  2.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  3.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  4.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  5.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  6.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  7.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  8.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH=  9.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH= 10.   0.   0.   0.   0.   0.   0.   0.
INCR INFLOW-2  RCH= 11.   0.   0.   0.   0.   0.   0.   0.
ENDATA8A
ENDATA9
HEADWTR-1 HDW=  1.RED RIVER        347.5 32.5 13.4  1.2 608.   12
ENDATA10
HEADWTR-2  HDW=  1.   0   0   0  .68  .14  .001  .29  .01  .03
ENDATA10A
POINTLD-1 PTL=  1.MOREHEAD STP      5.5 42.4 10.5  5.1 1070   10
POINTLD-1 PTL=  2.FARGO STP       14.0 54.7 10.2 10.5 1240   15
POINTLD-1 PTL=  3.TRIB NO 1        .0   .0   .0   .0    0    0
POINTLD-1 PTL=  4.SHEYENNE R.     219.0 32.5 12.7  .96 1260   15
ENDATA11
POINTLD-2 PTL   1.   0   0   0  2.3   11  .001  0.7  .01  2.6
POINTLD-2 PTL   2.   0   0   0  1.9  1.0  .001   24  .01  .98
POINTLD-2 PTL   3.   0   0  .0   .0   .0  .000   .0  .00  .00
POINTLD-2 PTL   4.   0   0   0  .82  .02  .001  .71  .01  .12
ENDATA11A
ENDATA12
DOWNSTREAM BOUNDARY-1    32.5  13.8  1.62  872   13   0   0
ENDATA13
DOWNSTREAM BOUNDARY-2     0  .93  .16  .001  1.1  .01  .10
ENDATA13A
LOCAL CLIMATOLOGY02 23 95 0600          .80   24.4   19.6   29.40   6.0
BEGIN  RCH   1
PLOT  RCH   1  2  3  4  5  6  7  8  9  10  11
```