Simulation of Water Quality for Salt Creek in Northeastern Illinois

By Charles S. Melching and T.J. Chang

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer
cubic foot per second (ft^3/s)	0.0283	cubic meter per second
million gallon per day (Mgal/d)	43.81	liters per second
grams per square foot per day (g/ft^2-day)	0.0929	grams per square meter per day
milligrams per square foot per day (mg/ft^2-day)	0.0929	milligrams per square meter per day

Temperatures in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = 5/9(°F - 32)$$

Concentrations are given in milligrams per liter (mg/L), milligrams per kilogram (mg/kg), or micrograms per liter (μg/L). For concentrations reported here, milligrams per liter are equivalent to parts per million and micrograms per liter are equivalent to parts per billion.

SIMULATION OF WATER QUALITY FOR SALT CREEK IN NORTHEASTERN ILLINOIS

by Charles S. Melching and T. J. Chang

ABSTRACT

Water-quality processes in the Salt Creek watershed in northeastern Illinois were simulated with a computer model. Selected waste-load scenarios for 7-day, 10-year low-flow conditions were simulated in the stream system. The model development involved the calibration of the U.S. Environmental Protection Agency QUAL2E model to water-quality constituent concentration data collected by the Illinois Environmental Protection Agency (IEPA) for a diel survey on August 29-30, 1995, and the verification of this model with water-quality constituent concentration data collected by the IEPA for a diel survey on June 27-28, 1995. In-stream measurements of sediment oxygen demand rates and carbonaceous biochemical oxygen demand (CBOD) decay rates by the IEPA and traveltime and reaeration-rate coefficients by the U.S. Geological Survey facilitated the development of a model for simulation of water quality in the Salt Creek watershed. In general, the verification of the calibrated model increased confidence in the utility of the model for water-quality planning in the Salt Creek watershed. However, the model was adjusted to better simulate constituent concentrations measured during the June 27-28, 1995, diel survey.

Two versions of the QUAL2E model were utilized to simulate dissolved oxygen (DO) concentrations in the Salt Creek watershed for selected effluent discharge and concentration scenarios for water-quality planning: (1) the QUAL2E model calibrated to the August 29-30, 1995, diel survey, and (2) the QUAL2E model adjusted to the June 27-28, 1995, diel survey. The results of these simulations indicated that the QUAL2E model adjusted to the June 27-28, 1995, diel survey simulates reliable information for water-quality planning. The results of these simulations also indicated that to maintain DO concentrations greater than 5 milligrams per liter (mg/L) throughout most of Salt Creek for 7-day, 10-year low-flow conditions, the sewage-treatment plants (STP's) must discharge effluent with CBOD and total ammonia as nitrogen concentrations substantially below the permit limits. If the STP's discharge effluent with CBOD and total ammonia as nitrogen concentrations at the permit limits for 7-day, 10-year low-flow conditions, DO concentrations less than 5 mg/L are expected for all of Salt Creek downstream from Fullerton Avenue (river mile 23.1).

INTRODUCTION

To fulfill the requirements of Section 303(d) of the Clean Water Act (CWA), states throughout the country must:

1) identify waters, which will not attain applicable water-quality standards with only technology-based controls, called water-quality limited streams and lakes,

2) establish a priority ranking for such waters, taking into account the severity of pollution and the uses to be made of the waters, and

3) target watersheds for development of Total Maximum Daily Loads (TMDL's) that would be initiated before the next biennial reporting period.

In Illinois, identification of water-quality limited streams and lakes involves a three-stage process. In the first stage, all waters not fully attaining designated uses are identified on the basis of the CWA Section 305(b) report (Illinois Environmental Protection Agency, 1994). In the second stage, all water bodies identified in stage 1 are reviewed and the water bodies for which other requirements or factors can reasonably be expected to result in the attainment or maintenance of applicable water-quality standards are eliminated from consideration for TMDL development. In the third stage, all remaining water bodies are confirmed as water-quality limited and requiring the development of TMDL's. A priority ranking is then developed for the remaining water-quality limited streams and lakes. The rankings are developed on the basis of the severity of pollution, and the uses and resource value of the water body.

Upon completion of the process described above, the Illinois Environmental Protection Agency (IEPA) identified 80 water-quality limited water bodies for 1994. The Salt Creek watershed, a tributary of the Des Plaines River in west suburban Chicago (fig. 1), was targeted by the IEPA for Phase I TMDL development. In Phase I TMDL development, the allocation of loads and the degree of assimilative capacity of the water body to point sources in the watershed are assessed. The assessment of assimilative capacity and allowable loads for biologically and chemically reactive constituents is most often done with computer simulation of the pertinent water-quality processes. Detailed measurements of concentrations of constituents of concern over diel (about 24 hour) periods are needed at wastewater-treatment-plant outfalls and key locations in the stream to develop and verify the computer-simulation model.

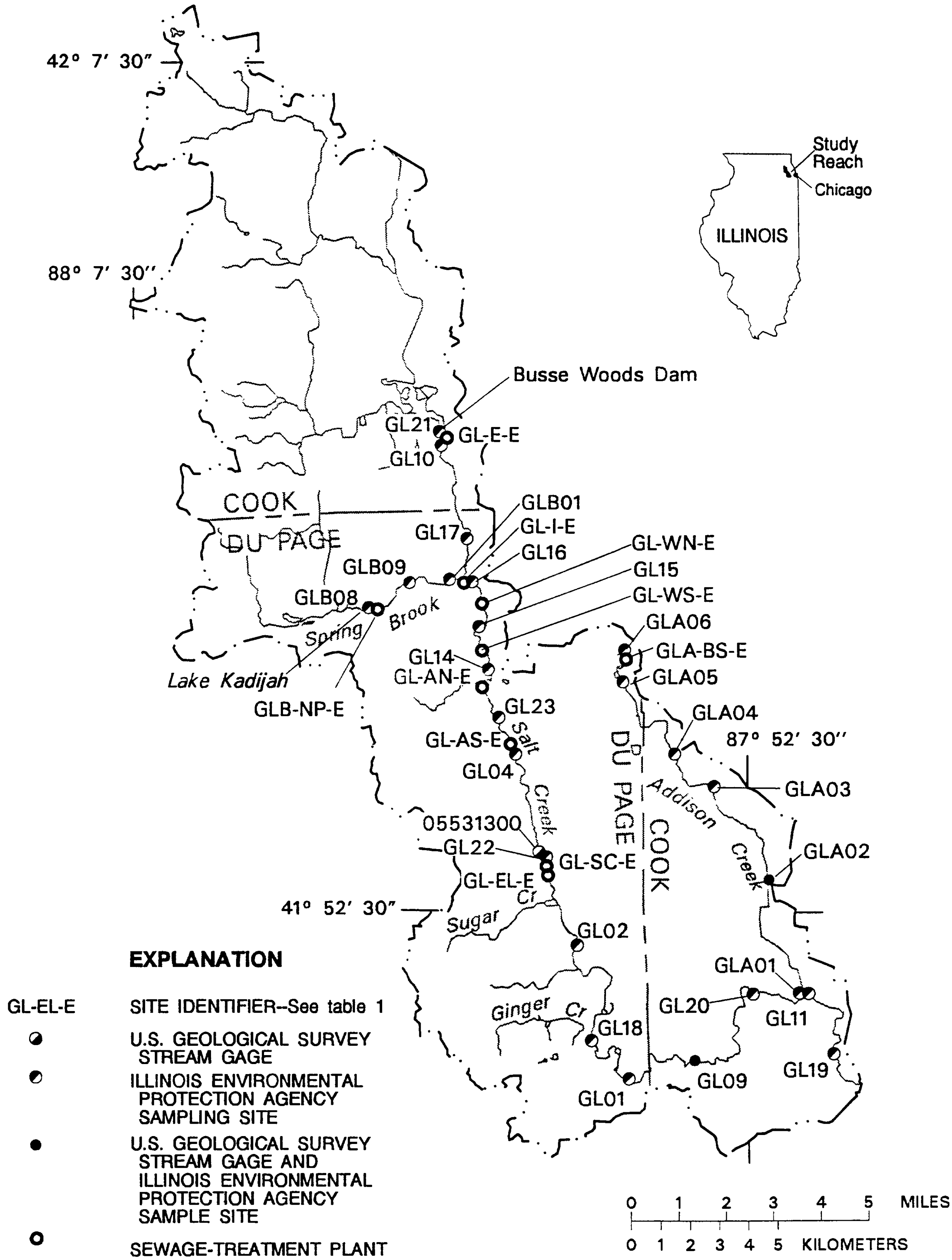

Figure 1. Location of Salt Creek watershed in northeastern Illinois, sewage-treatment plants, water-quality sampling sites, and stream gages in the study reaches.

The U.S. Geological Survey (USGS) and IEPA established a cooperative agreement in 1995 to develop a computer-simulation model of water-quality processes in Salt Creek and its two major tributaries, Spring Brook and Addison Creek (fig. 1). This agreement included three tasks:

1) diel sampling of water-quality constituents for model calibration and verification--IEPA,

2) measurement of traveltimes and reaeration-rate coefficients in selected reaches in the Salt Creek watershed--USGS, and

3) calibration and verification of the water-quality model, and simulation of selected waste-load scenarios for low-flow conditions--USGS with advice and input from IEPA.

The final product of this project is a water-quality model suitable for evaluating waste-load allocation in the Salt Creek watershed.

This study is summarized in a five volume report compiled by the IEPA entitled "Salt Creek: Phase I TMDL," which will be submitted to the U.S. Environmental Protection Agency as the closure report for the study of water quality in the Salt Creek watershed. Volume 1 (Illinois Environmental Protection Agency, 1996a) contains the IEPA's approach to the development of TMDL's, regulatory requirements, selection of the Salt Creek watershed, and a summary of results of the entire study. Volume 2 (Illinois Environmental Protection Agency, 1996b) contains details concerning the Salt Creek watershed and the IEPA water-quality sampling program for the Salt Creek watershed. Volume 3 is the USGS report on the reaeration and traveltime measurements in the Salt Creek watershed (Turner, 1996). Volume 4 is this report summarizing development and application of a water-quality model suitable for waste-load allocation in the Salt Creek watershed. Finally, volume 5 (Illinois Environmental Protection Agency, 1996c) is an inventory of nonpoint sources of pollution in the Salt Creek watershed.

Purpose and Scope

The purpose of this report is to describe the development (calibration and verification) of a computer model for simulation of water-quality processes in Salt Creek and its two major tributaries, Spring Brook and Addison Creek, and to apply the calibrated model to the simulation of selected waste-load scenarios for 7-day, 10-year low-flow conditions in the stream system. The scope of the water-quality model is limited to simulation of concentrations of the constituents that directly affect dissolved oxygen concentration in the stream system for steady-state, low-flow conditions. Specific conductance, a conservative property of the streamflow and treated wastewater, also was simulated to aid in determining the water balance for the low-flow periods utilized for model calibration and verification.

Study Area

Salt Creek drains a 150 mi^2 watershed in Cook and Du Page Counties in suburban Chicago (fig. 1). Salt Creek is 45.9 mi long and its major tributaries, Addison Creek and Spring Brook are 12.5 and 8.5 mi, respectively. The watershed includes 7 USGS stream-gaging stations (4 continuous discharge and 3 continuous stage only) and 19 point-source discharges (sewage-treatment plants). Only 11 point-source discharges varying in design-average flows between 0.5 and 30 Mgal/d (0.77 and 46.4 ft^3/s) are considered in the simulated reaches.

The land use in the Salt Creek watershed is typical of suburban areas in the Midwest. Single family residential areas are mixed with commercial and light industrial areas. The watershed has undergone little development since the early 1970's, and the distribution of residential, commercial, and light industrial areas is well established. In the study area, Salt Creek and Spring Brook flow through greenways composed of golf courses and land owned by the Du Page and Cook County Forest Preserves; whereas Addison Creek flows through commercial and residential areas upstream from river mile 4.9 and through industrial areas (primarily warehouses) in the final 4.9 mi. The greenways protect Salt Creek and Spring Brook from some negative effects of nonpoint-source pollution. All the streams studied are subject to nonpoint-source pollution from storm sewers, and, as described below, Salt Creek and Addison Creek are subject to nonpoint-source pollution from combined-sewer overflows (CSO's).

The most upstream point-source discharge on Salt Creek is the Egan Sewage-Treatment Plant (STP) operated by the Metropolitan Water Reclamation District of Greater Chicago. The outfall from the Egan STP enters Salt Creek at river mile 31.7 (upstream from the confluence of Salt Creek and the Des Plaines River) just downstream from Busse Woods Dam (fig. 1). Therefore, the outlet of Busse Woods Dam forms the upstream boundary of the study area along Salt Creek in this report and the upper 13.2 mi of Salt Creek and 51.9 mi^2 of the Salt Creek watershed are not considered. In addition to the Egan STP, seven other STP's discharge to Salt Creek--Itasca STP at river mile 28.2, Wood Dale North STP at river mile 27.7, Wood Dale South STP at river mile 26, Addison North STP at river mile 25, Addison South STP at river mile 23.3, Salt Creek Sanitary District STP at river mile 20, and Elmhurst STP at river mile 19.7.

The most upstream point-source discharge on Spring Brook is the Roselle STP at river mile 5.7 (upstream from the confluence of Spring Brook and Salt Creek). Lake Kadijah (fig. 1), situated between river miles 2.8 and 3.2 on Spring Brook, has a large storage capacity relative to low flows on Spring Brook. The traveltime through Lake Kadijah is not known, and under low-flow conditions traveltime could be more than a month. Because of the long traveltime for water to pass through the lake, the constituent concentrations at the outlet of the lake may not be strongly related to the discharge at the Roselle STP. This may result from the effects of storm runoff and subsequent nonpoint-source pollution and the long traveltime for wastewater to flow from Roselle STP through the lake. Therefore, the outlet of Lake Kadijah at river mile 2.7 (Rohwling Road) forms the upstream boundary of the study area along Spring Brook and the upper 5.8 miles of Spring Brook are not considered. The Nordic Park STP discharges to Spring Brook at river mile 2.5.

The most upstream point-source discharge on Addison Creek is the Bensenville South STP at river mile 10.4 (upstream from the confluence of Addison Creek and Salt Creek). During low-flow periods, no discharge is present in Addison Creek upstream from the outfall for the Bensenville South STP. Therefore, the outfall for Bensenville South STP forms the upstream boundary for the study area along Addison Creek and the upper 2.1 miles of Addison Creek are not considered. The study area and the locations of the point-source dischargers, USGS continuous-discharge stream gages, and IEPA diel-survey monitoring sites of water quality in the Salt Creek watershed are shown in figure 1 and listed in table 1.

Salt Creek and Addison Creek are not free-flowing streams at low to medium flows (approximately less than 100 ft^3/s at Salt Creek at Western Springs, river mile 8.8; and approximately less than 10 ft^3/s at Addison Creek at Bellwood, river mile 3.2). Three low-head dams on Salt Creek in the study area have been identified (river miles 25.2, 13.5, and 11.6), and the reaeration characteristics of these dams have been studied by Butts and Evans (1978). In addition to the pools behind these dams, numerous natural pools attenuate low flows in Salt Creek. Further, from river mile 15.56 to 18.64, the bed slope of Salt Creek is extremely flat as illustrated in figure 2. Between river mile 6.5 and 9.0, flow in Addison Creek passes through a series of five small ponds, which in total have a large storage capacity in relation to low flows on Addison Creek. The presence of these ponds and the associated long traveltimes make the assumption of steady-state low flows questionable as applied in the model development.

Table 1. Locations and descriptions of sewage-treatment plants, water-quality sampling sites, and stream gages in the Salt Creek watershed in northeastern Illinois

[IEPA, Illinois Environmental Protection Agency; USGS, U.S. Geological Survey]

Site identifier (fig. 1)	River mile	Description
GL21	31.7	IEPA water-quality sampling site on Salt Creek upstream from Egan Sewage-Treatment Plant and downstream of Busse Woods Dam
GL-E-E	31.7	Egan Sewage-Treatment Plant
GL10	31.5	IEPA water-quality sampling site on Salt Creek at Arlington Heights Road
GL17	29.3	IEPA water-quality sampling site on Salt Creek at Thorndale Road
GL-I-E	28.2	Itasca Sewage-Treatment Plant
GL16	28.1	IEPA water-quality sampling site on Salt Creek at Lino and Poli Plumbing
GL-WN-E	27.7	Wood Dale North Sewage-Treatment Plant
GL15	27.1	IEPA water-quality sampling site on Salt Creek off Carter Avenue
GL-WS-E	26.0	Wood Dale South Sewage-Treatment Plant
GL14	25.6	IEPA water-quality sampling site on Salt Creek at Du Page County Country Club, Third Avenue
GL-AN-E	25.0	Addison North Sewage-Treatment Plant
GL23	24.0	IEPA water-quality sampling site on Salt Creek at Wood Dale Avenue
GL-AS-E	23.3	Addison South Sewage-Treatment Plant
GL04	23.1	IEPA water-quality sampling site on Salt Creek at Fullerton Avenue
0551300	20.3	USGS stream gage Salt Creek at Elmhurst, Ill., at State Highway 83
GL22	20.1	IEPA water-quality sampling site on Salt Creek at the Footbridge off Railroad Avenue

Table 1. Locations and descriptions of sewage-treatment plants, water-quality sampling sites, and stream gages in the Salt Creek watershed in northeastern Illinois--Continued

Site identifier (fig. 1)	River mile	Description
GL-SC-E	20.0	Salt Creek Sanitary District Sewage-Treatment Plant
GL-EL-E	19.7	Elmhurst Sewage-Treatment Plant
GL02	17.7	IEPA water-quality sampling site on Salt Creek at Butterfield Road
GL18	13.7	IEPA water-quality sampling site on Salt Creek at 31st Street in Oak Brook, Ill.
GL01	11.5	IEPA water-quality sampling site on Salt Creek at York Road
GL09	8.8	IEPA water-quality sampling site on Salt Creek at Wolf Road and USGS stream gage number 05531500--Salt Creek at Western Springs, Ill.
GL20	4.5	IEPA water-quality sampling site on Salt Creek at Kemman Avenue
GL11	3.2	IEPA water-quality sampling site on Salt Creek at Maple Avenue
GL19	1.1	IEPA water-quality sampling site on Salt Creek at Washington Avenue in Brookfield, Ill.
GLB08	2.7	IEPA water-quality sampling site on Spring Brook at Rohwling Road
GLB-NP-E	2.5	Nordic Park Sewage-Treatment Plant
GLB09	1.4	IEPA water-quality sampling site on Spring Brook at Maple and Line Roads
GLB01	0.3	IEPA water-quality sampling site on Spring Brook at Prospect Avenue
GLA06	10.4	IEPA water-quality sampling site on Addison Creek upstream from Bensenville South Sewage-Treatment Plant
GLA-BS-E	10.3	Bensenville South Sewage-Treatment Plant

Table 1. Locations and descriptions of sewage-treatment plants, water-quality sampling sites, and stream gages in the Salt Creek watershed in northeastern Illinois--Continued

Site identifier (fig. 1)	River mile	Description
GLA05	9.8	IEPA water-quality sampling site on Addison Creek at Diana Court
GLA04	7.1	IEPA water-quality sampling site on Addison Creek at West Palmer Avenue
GLA03	5.9	IEPA water-quality sampling site on Addison Creek at Parkview Drive
GLA02	3.2	IEPA water-quality sampling site on Addison Creek at Washington Boulevard and USGS stream gage number 05532000--Addison Creek at Bellwood, Ill.
GLA01	0.3	IEPA water-quality sampling site on Addison Creek at Cermak Road

An important hydraulic feature of Salt Creek in the study area is a flow diversion structure at river mile 2.2. For flows greater than about 68 ft^3/s, water is diverted over a broad-crested weir into a canal that connects to the Des Plaines River.

An important hydraulic feature of Addison Creek in the study area is that for the first 0.6 mi the flow passes through a sewer pipe around a detention pond that stores flow from Addison Creek during large storm runoff. The pipe system and the detention pond discharge to a stilling basin. Substantial algal growth is always present in the summer in the stilling basin (Howard Essig, Illinois Environmental Protection Agency, personal commun., 1995). Thus, even though the outflow from Bensenville South STP contains no chlorophyll *a*, an initial concentration of chlorophyll *a* is input at the upstream boundary of Addison Creek.

Salt Creek and Addison Creek receive discharge from a number of CSO's, one that is located at St. Charles Road (river mile 20.4) was observed to flow during a dry weather period (John Lesnak, Illinois Environmental Protection Agency, personal commun., 1995). On Salt Creek, four active CSO's are present between river mile 19.7 and 20.4. Also on Salt Creek, five CSO's are present between river mile 6.9 and 9.2 and seven CSO's are present between the outlet of Salt Creek and river mile 2.5. These 12 CSO's were connected to the Chicago Underflow Plan, Tunnel and Reservoir Plan in the late 1980's. On Addison Creek,

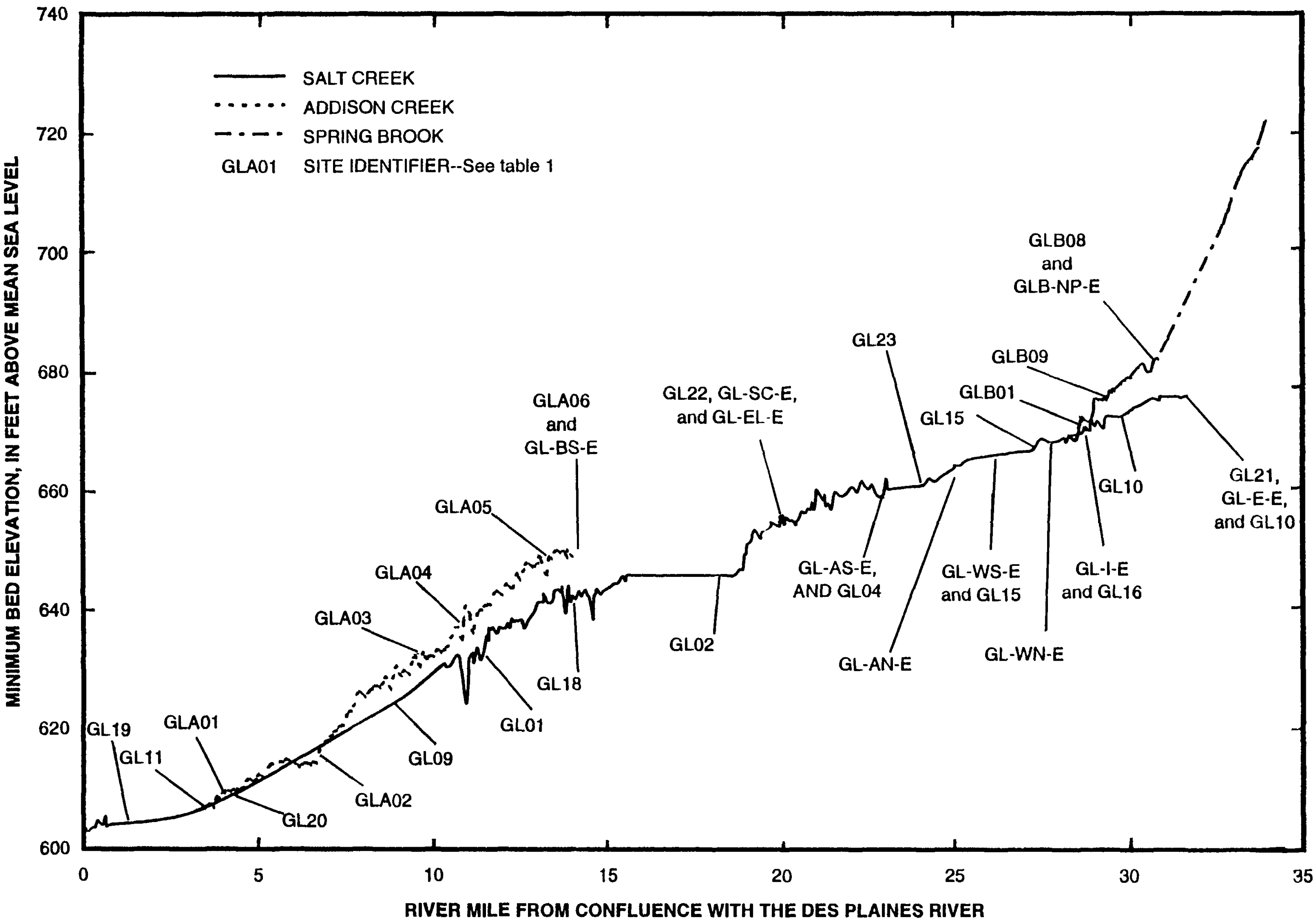

Figure 2. Bed profile and locations of sewage-treatment plants and water-quality sampling points in the study area in the Salt Creek watershed in northeastern Illinois.

eight active CSO's are present between the outlet of Addison Creek and river mile 3.2. The active CSO's result in increased sediment oxygen demand (SOD) levels relative to other areas of Salt Creek and Addison Creek, and leakage from the active CSO's on Salt Creek affected total ammonia as nitrogen and ultimate carbonaceous biochemical oxygen demand ($CBOD_u$) concentrations during the June 27-28, 1995, diel study done by the IEPA.

Water-Quality Sampling

In the study of water quality in the Salt Creek watershed, four water-quality sampling efforts were done by the IEPA and the USGS. The USGS measured traveltime and reaeration-rate coefficients in selected reaches in Salt Creek, Spring Brook, and Addison Creek as described in detail in Turner (1996). The IEPA measured SOD rates at selected locations and performed monthly and diel sampling of 15 water-quality constituents and properties at the locations are listed in table 1. Complete details of the IEPA sampling efforts are given in Illinois Environmental Protection Agency (1996b). However, details of the sampling times for the diel surveys are given below to clarify the type of data utilized to calibrate and verify the QUAL2E model of the Salt Creek watershed.

By definition, a diel water-quality sampling program involves collecting multiple samples of stream-water quality over a 24-hour period. In the IEPA diel-sampling program, the 24-hour period from 8 a.m. on day 1 to 8 a.m. on day 2 was subdivided into four 6-hour sampling rounds (8 a.m. - 2 p.m., 2 p.m. - 8 p.m., 8 p.m. - 2 a.m., and 2 a.m. - 8 a.m.). Water temperature, dissolved oxygen (DO) concentration, specific conductance, and pH were measured twice at each location listed in table 1 during each round of samples. A water-quality sample was collected at each location listed in table 1 during each sampling round and analyzed for concentrations of 5-day CBOD, total ammonia as nitrogen, total Kjeldahl nitrogen, nitrite plus nitrate as nitrogen, total phophorus, total suspended solids, and chloride. Concentrations of chlorophyll *a*, *b*, and *c* were measured for water-quality samples collected at each location listed in table 1 for the first two rounds of samples. Fecal coliform counts were determined from water-quality samples collected at each location listed in table 1 for the first round of samples.

Acknowledgments

Howard Essig and John Lesnak of the IEPA field office in Maywood, Ill., provided valuable input on the physical conditions of the Salt Creek watershed for typical low flows and for the

periods of the IEPA diel sampling. Lalit Sinha of the IEPA, Bureau of Water, in Springfield, Ill., provided valuable advice on the model calibration and selection of load scenarios to be examined by applying the calibrated and verified water-quality model. The input and advice of these individuals is greatly appreciated because it substantially improved the physical basis of the water-quality model for the Salt Creek watershed.

DESCRIPTION OF WATER-QUALITY MODEL

The U.S. Environmental Protection Agency QUAL2E model (Brown and Barnwell, 1987) was applied to simulate water-quality processes in Salt Creek, Spring Brook, and Addison Creek. This section includes a brief summary of the capabilities of and assumptions applied in QUAL2E and the delineation of Salt Creek, Spring Brook, and Addison Creek for simulation of water-quality processes with QUAL2E.

Summary of the QUAL2E Model

In QUAL2E model simulations, the stream is conceptualized as a string of completely mixed reactors that are linked sequentially by advective transport and dispersion. Sequential groups of these reactors are defined as reaches. Each reach is divided into computational elements with identical length, hydrogeometric properties, and biological rate constants. The hydrogeometric properties and biological rate constants may change between reaches. Up to 15 water-quality constituents and properties in any combination selected by the user can be simulated in QUAL2E. Constituents and properties that can be simulated in the model are DO, $CBOD_u$, temperature, algae (phytoplankton) as chlorophyll *a*, components of the nitrogen cycle as nitrogen (organic nitrogen, total ammonia, nitrite, and nitrate), components of the phosphorus cycle as phosphorus (organic and dissolved phosphorus), coliforms, an arbitrary nonconservative constituent, and three arbitrary conservative constituents. The primary application of QUAL2E is simulation of DO concentration in a stream and the interactions between DO and carbonaceous biochemical oxygen demand (CBOD), the nitrogen cycle, algae (dependent on the nitrogen and phosphorus cycles), SOD, and atmospheric reaeration. Details on these interactions as simulated in QUAL2E are presented in Brown and Barnwell (1987). Rate constants describing the interactions among constituents and changes in constituent concentration with time as water parcels move downstream must be determined by calibration with parameter values selected within physically reasonable ranges and confirmed by verification as described in the "Model Development" section.

A number of important biological processes in streams are not simulated in QUAL2E, including the growth of zooplankton, periphyton, and rooted plants. The growth of these forms of aquatic vegetation can have a substantial effect on the concentrations of nitrate, phosphorus, and DO in a stream.

The constituents simulated with QUAL2E in the Salt Creek watershed are DO, $CBOD_u$, organic nitrogen as nitrogen, total ammonia as nitrogen, nitrite as nitrogen, nitrate as nitrogen, organic phosphorus as phosphorus, dissolved phosphorus as phosphorus, and algae (phytoplankton) as chlorophyll *a*. Specific conductance also was simulated with QUAL2E as a conservative constituent to help determine the water balance among discharge sources. Temperature was not simulated with QUAL2E; rather, the daily-mean temperature from measurements in the reach or estimated from adjacent reaches was input as an initial condition for the QUAL2E simulation so that the proper saturation DO concentration and temperature-affected rate constants are utilized. For the August 29-30, 1995, diel survey, the daily-mean temperatures were between 74.4 and 77.4 °F in Salt Creek, 76.0 and 77.4 °F in Addison Creek, and at 77.6 °F in Spring Brook. Whereas for the June 27-28, 1995, diel survey, the daily-mean temperatures were between 69.6 and 74.8 °F in Salt Creek, 70.2 and 73.4 °F in Addison Creek, and at 74.5 °F in Spring Brook.

Delineation of Salt Creek Watershed for QUAL2E Simulation

Salt Creek, Spring Brook, and Addison Creek were divided into 12, 1, and 4 computational reaches, respectively, as shown in figure 3. The subdivision into reaches was primarily guided by geomorphologic characteristics of the stream system, such as stream junctions, changes in slope, and location of ponded areas. The presence of the CSO's between river miles 19.7 and 20.4 of Salt Creek also affected the delineation of reaches. The delineation of reaches also was affected by the maximum number of computational elements allowed in a reach (20). Because 0.2-mi long computational elements were utilized, no reach could be longer than 4 mi even if geomorphologic characteristics were reasonably constant over a greater distance. The upper reaches of Addison Creek are complicated by the presence of the low-flow pipe between river miles 9.8 and 10.4 (Diana Court and Bensenville South STP) and the five ponds between river miles 6.5 and 9.0 (Wolf Road and Grand Avenue). No attempt was made to describe in detail the hydraulic characteristics of these stream features in the QUAL2E model because of the difficulties in describing pond flow in the model. The reaches in upper Addison Creek were defined on the basis of the IEPA sampling locations to achieve a reasonable match of observed changes in constituent

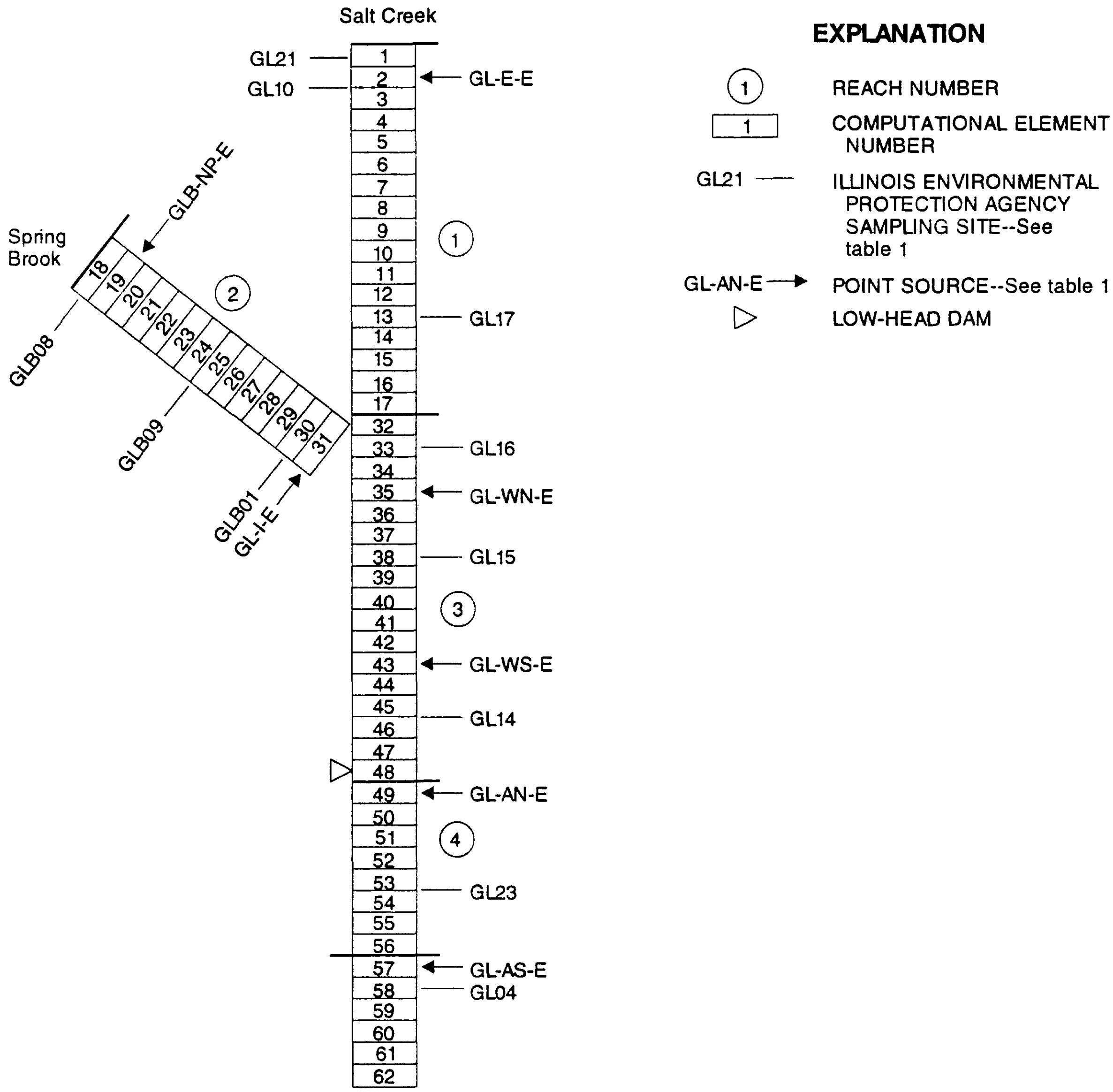

Figure 3. Reaches, computational elements, point sources at sewage-treatment plants, water-quality sampling sites, and low-head dams in the QUAL2E model of Salt Creek watershed in northeastern Illinois.

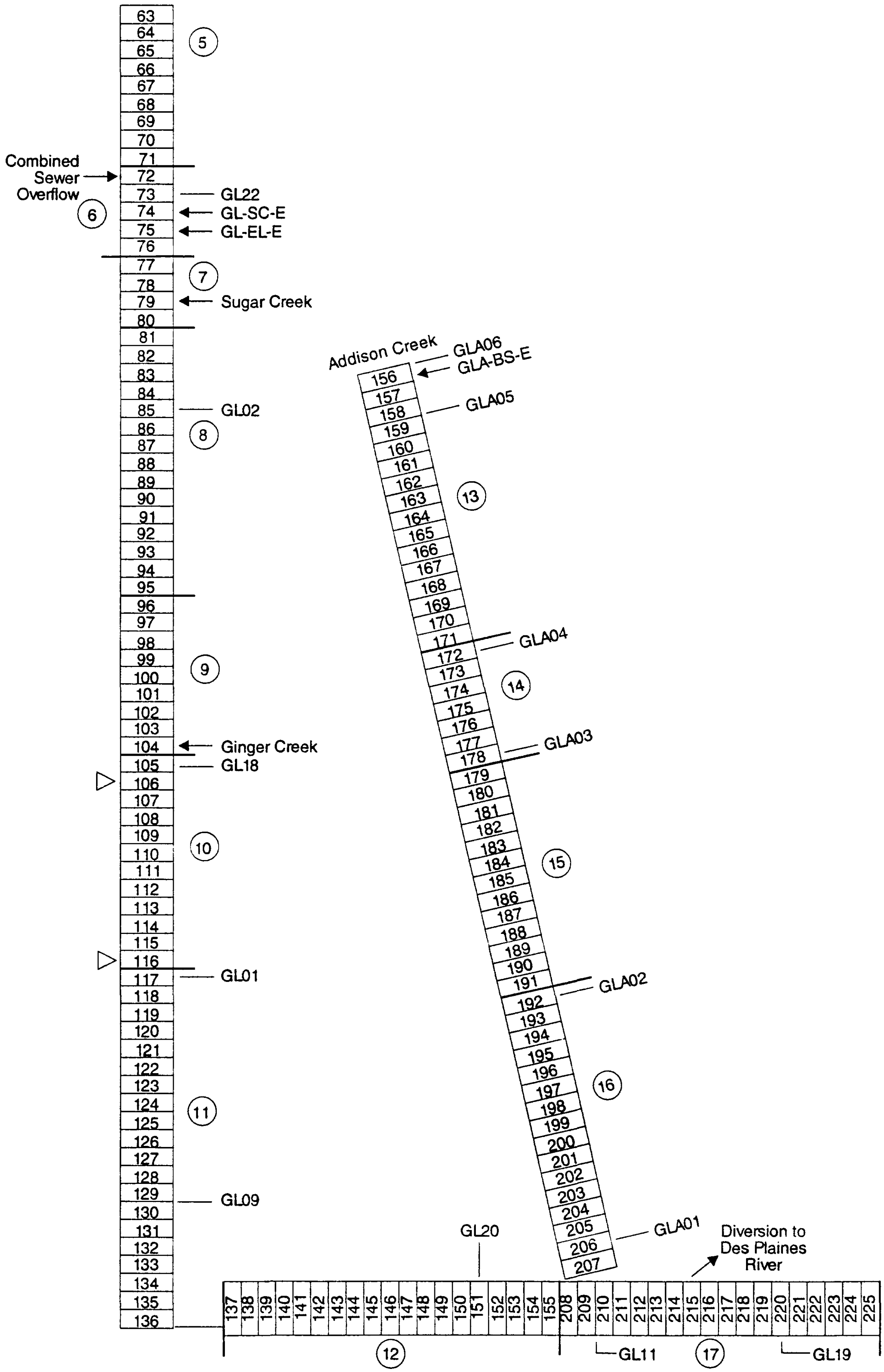

Figure 3. Continued.

concentrations between these sites. The subdivision of Salt Creek and Addison Creek is listed by river mile in table 2.

The STP's are modeled as point sources discharging to the computational element at the appropriate river mile location except for the Egan, Bensenville South, and Itasca STP's. The Bensenville South STP comprises the upstream inflow to Addison Creek. The Egan STP comprises the upstream inflow to Salt Creek for the 7-day, 10-year low-flow conditions simulated in the application of the calibrated QUAL2E model. For simulation of the diel-survey periods, Egan STP is a point-source discharge. The Itasca STP discharges to Salt Creek immediately downstream from the confluence of Salt Creek with Spring Brook (element number 31) (fig. 3). Because computational elements at junctions cannot include a point source in QUAL2E simulation, the Itasca STP was assumed to discharge to the last computational element on Spring Brook. The CSO at river mile 20.4 (St. Charles Road) and Sugar Creek (river mile 18.9) and Ginger Creek (river mile 13.9) are simulated as point sources as described in the "Model Calibration" and "Model Verification" sections.

In the hydraulic simulation of flow, the average, trapezoidal cross-section approximation was applied for each reach. Detailed cross-section data were available on Salt Creek, Spring Brook, and Addison Creek from hydraulic models for flood-plain delineation. The details of the hydraulic models for Salt Creek and Spring Brook and Addison Creek may be obtained from the Du Page County Department of Environmental Concerns and the Illinois Department of Natural Resources, Office of Water Resources, respectively. Cross-section data also were available from the discharge measurements made by the IEPA during the diel surveys and by the USGS during the reaeration-rate coefficient and traveltime measurements. The variation in bottom width and side slopes among cross sections in the reaches is considerable. Thus, the average bottom widths and side slopes are only rough approximations of the actual channel geometry in the reaches.

SIMULATION OF WATER QUALITY

The QUAL2E model was adapted for the purpose of simulating water quality in the Salt Creek watershed. Streamflow and effluent discharge and concentration scenarios were selected and simulated to illustrate important relations between effluent quality and instream water quality. The procedures utilized and results obtained in the simulation of water quality in the Salt Creek watershed are described in the following sections.

Table 2. Reach descriptions and river mile boundaries for the QUAL2E model of water quality in Salt Creek and Addison Creek in northeastern Illinois

Reach[1] (fig. 3)	Description	River mile	
		Upstream	Downstream
	Salt Creek		
1	Busse Woods Dam to confluence with Spring Brook	31.8	28.4
3	Confluence with Spring Brook to Addison North Sewage-Treatment Plant	28.4	25.0
4	Addison North Sewage-Treatment Plant to Addison South Sewage-Treatment Plant	25.0	23.4
5	Addison South Sewage-Treatment Plant to St. Charles Road	23.4	20.4
6	St. Charles Road to Elmhurst Sewage-Treatment Plant (combined-sewer-overflow reach)	20.4	19.4
7	Steep reach (see fig. 2)	19.4	18.6
8	Flat reach (see fig. 2)	18.6	15.6
9	Flat reach to upstream end of Fullersburg Park	15.6	13.8
10	Water ponded behind Fullersburg Dam	13.8	11.6
11	Downstream from Fullersburg Dam	11.6	7.6
12	To confluence with Addison Creek	7.6	3.6
17	Confluence with Addison Creek to confluence with the Des Plaines River	3.6	0.0
	Addison Creek		
13	Bensenville South Sewage-Treatment Plant to West Palmer Avenue; two ponds in this reach	10.4	7.2
14	West Palmer Avenue to Parkview Drive; three ponds in this reach	7.2	5.8
15	Parkview Drive to Washington Boulevard	5.8	3.2
16	Washington Boulevard to confluence with Salt Creek; 8 combined-sewer overflows in this reach	3.2	0.0

[1]The reach numbers correspond to the order of input to QUAL2E.

Model Development

The development of a QUAL2E model suitable for simulation of water-quality conditions during low-flow periods in Salt Creek, Spring Brook, and Addison Creek included three steps. In the first step, the biological and chemical reaction coefficients and constituent source/sink terms were calibrated within physically reasonable ranges so that the constituent concentrations measured in the Salt Creek watershed during the August 29-30, 1995, diel survey could be adequately simulated with the QUAL2E model. In the second step, the calibrated values of the biological and chemical reaction coefficients and constituent source/sink terms for the August diel survey were applied to simulation of the June 27-28, 1995, diel survey. The verification of the calibrated values for August generally increased confidence in the utility of the model for water-quality planning; however, DO concentrations were oversimulated in several segments of Salt Creek and Addison Creek. Thus, in the third step, a limited recalibration was done in these segments to obtain a set of biological and chemical reaction coefficients and constituent source/sink terms corresponding to a "worst case" condition. This "worst case" condition is not a rigorously determined worst case, but rather a condition of somewhat more stressed water-quality processes and resulting DO concentrations that will require higher treatment criteria for the waste-load discharges.

Model Calibration

Model calibration involved adjustment of many biological and chemical reaction coefficients and constituent source/sink terms within physically reasonable ranges to obtain a close simulation of daily-mean constituent concentrations measured in the August 29-30, 1995, diel survey. The constituent concentrations simulated are DO, $CBOD_u$, total ammonia as nitrogen, nitrate as nitrogen, nitrite as nitrogen, dissolved phosphorus as phosphorus, organic phosphorus as phosphorus, and algae as chlorophyll *a*. The model calibration also included determination of the appropriate water balance for the stream system during the diel survey and matching measured traveltimes in the stream system. The streamflow hydraulic, biological, and chemical conditions for the Salt Creek watershed are similar to those for the Du Page River watershed. The Du Page River watershed forms the western boundary of the Salt Creek watershed and is similar in geomorphology, land use, and waste loads to the Salt Creek watershed. Therefore, many of the biological and chemical reaction coefficients utilized in the Salt Creek watershed were transferred from the Du Page River QUAL-II model (an earlier version of QUAL2E developed for the Southeastern Michigan Council of Governments by the National Council of the Paper Industry for Air and Stream Improvement (1982)) developed by Freeman and others (1986). Also, measured values of SOD; the CBOD decay rate, K_1; and the reaeration-rate coefficient, K_2, (Turner, 1996) were utilized where available. The input for QUAL2E corresponding to the calibration to August 29-30, 1995, diel-survey data is listed in appendix A. The assumptions made and results obtained in the calibration of the water balance, traveltime, and constituent concentrations are given in the following sections.

Water Balance--Data presented in tables and charts for computation of daily mean outflows from each STP for the August diel-sampling period were provided by the treatment-plant operators and utilized to estimate daily-mean outflows from each STP. Estimates of STP outflows are uncertain because rigorous quality assurance of flow meters typically is not done and interpretation of strip charts is difficult. Therefore, discharges measured by the IEPA and the mean discharges for the diel-survey period measured at USGS gages were utilized to determine the appropriate discharge values from the STP's and incremental inflows, where necessary. The discharge measurement data available for these adjustments include: single discharge measurements made by the IEPA at the upstream boundaries for Salt Creek, Spring Brook, Addison Creek; at four interior sites on Salt Creek (river miles 29.3, 27.1, 13.7, and 1.1); and one interior site on Spring Brook (river mile 0.3) during the diel survey. In the case of Addison Creek, zero discharge was measured at the upstream end. Discharge values were estimated from two USGS continuous-discharge gages on Salt Creek (river miles 20.3 and 8.8) and one continuous-discharge gage on Addison Creek (river mile 3.2) (fig. 1).

Upstream Boundary of Salt Creek to the Confluence with Spring Brook--The measured discharge value at river mile 29.3 (Thorndale Road) of Salt Creek was 37.8 ft^3/s, whereas the measured discharge upstream from the Egan STP (river mile 31.7) was 9.15 ft^3/s and the daily-mean outflow from the Egan STP (river mile 31.7) was reported at 36.2 ft^3/s. The discharge from the Egan STP to Salt Creek is difficult to estimate because the flows are reported at the outlet of the plant, and from this point the wastewater travels several miles through a pipe to the outfall at Salt Creek. The flows from Salt Creek upstream from Egan STP and from Egan STP were computed to match the measured value at river mile 29.3 with the flow proportions determined with a mass balance of specific conductance.

Spring Brook to the Confluence with Salt Creek--The measured discharge value at river mile 0.3 (Prospect Avenue) of Spring Brook was 4.61 ft^3/s, whereas the measured discharge at river mile 2.7 (Rohwling Road) was 3.18 ft^3/s and the daily-mean outflow from the Nordic Park STP (river mile 2.5) was 0.27 ft^3/s. Thus, an incremental inflow of 1.16 ft^3/s was applied along

Spring Brook. The constituent concentrations applied to this incremental inflow were assumed to be the same as the values for Spring Brook upstream from the Roselle STP at river mile 5.7.

Salt Creek from the Confluence with Spring Brook to the Confluence with Addison Creek--The measured mean discharge for the August diel-survey period at the USGS gage at river mile 20.3 (State Highway 83) of Salt Creek was 50.84 ft^3/s, whereas the flow in Salt Creek upstream from the confluence with Spring Brook (river mile 28.2) was 37.8 ft^3/s and in Spring Brook at its outlet was 4.61 ft^3/s. Therefore, 8.43 ft^3/s entered Salt Creek from river mile 28.2 to 20.3 from the five STP's in this stretch (Itasca, Wood Dale North, Wood Dale South, Addison North, and Addison South). The sum of the reported daily-mean outflows from these STP's was 12.33 ft^3/s. Thus, the reported daily-mean outflows from these STP's were decreased by a factor of 0.684 to maintain the water balance at river mile 20.3.

The measured mean discharge during the August diel-survey period at the USGS gage at river mile 8.8 (Wolf Road) of Salt Creek was 73.95 ft^3/s, whereas the flow in Salt Creek at the USGS gage at river mile 20.3 (State Highway 83) was 50.84 ft^3/s and the daily-mean outflows from the Salt Creek Sanitary District (river mile 20) and Elmhurst (river mile 19.7) STP's were reported at 3.54 and 7.46 ft^3/s, respectively. Thus, a 12.11 ft^3/s shortfall results in Salt Creek between river miles 8.8 and 20.3. Sugar Creek discharges to Salt Creek at river mile 18.9 and Ginger Creek discharges to Salt Creek at river mile 13.9. The 12.11 ft^3/s shortfall was attributed to these streams and divided between these streams in proportion to drainage area. Because no water-quality measurements are available for Sugar Creek and Ginger Creek, constituent concentrations for the inflow from these streams were estimated. The downstream ends of these streams contain many small ponds. Thus, for low-flow periods, it is reasonable to apply the constituent concentrations measured in Spring Brook downstream from Lake Kadijah (river mile 2.7, Rohwling Road) with the exception of $CBOD_u$, which was assigned the concentration for Addison Creek upstream from Bensenville South STP to be conservative in the estimation of $CBOD_u$ load, and total phosphorus (set to a value of 0.8 mg/L). The value of 0.8 mg/L of total phosphorus is greater than 75 percent of the values reported by Terrio (1995) for streams in the upper Illinois River Basin. Thus, this value is slightly high for streams in northeastern Illinois; however, the result is a reasonable simulation of the observed concentration of total phosphorus in Salt Creek.

Addison Creek to the Confluence with Salt Creek--The measured mean discharge for the August diel-survey period at the USGS gage at river mile 3.2 (Washington Boulevard) of Addison Creek was 8.66 ft^3/s, whereas the daily-mean outflow from the

Bensenville South STP (river mile 10.4) was reported at 7.63 ft^3/s. Thus, an incremental inflow of 1.03 ft^3/s was allocated to reaches 13-15 (river miles 10.4 - 3.2) along Addison Creek in proportion to the reach length. The constituent concentrations applied to this incremental inflow were the values for Addison Creek upstream from Bensenville South STP at river mile 10.4 because these values represent ambient water quality in Addison Creek not affected by STP flow.

Salt Creek from the Confluence with Addison Creek to the Confluence with the Des Plaines River--The measured discharge value at river mile 1.1 of Salt Creek was 67.7 ft^3/s, whereas on the basis of USGS gages the flow in Salt Creek upstream from the confluence with Addison Creek (river mile 3.5) was 73.95 ft^3/s. Discharge in Addison Creek at its outlet was 8.66 ft^3/s. Therefore, 14.91 ft^3/s of flow left Salt Creek from river mile 3.6 to 1.1. This loss of flow was assumed to be through the diversion structure at river mile 2.2. These water-balance computations are summarized in table 3.

Traveltime Simulation and Hydraulic Adjustments--Traveltime measurements were made on Salt Creek between river miles 29.3 and 29.9 (reach 1 between Thorndale Road and Devon Avenue) on August 29, 1995; 14.9 and 16.4 (reaches 8 and 9 between 22nd Street at Oakbrook and Drury Lane) on August 30, 1995; 0.3 and 1.1 (reach 17 between Circle Drive and Washington Avenue-Brookfield) on August 31, 1995 (Turner, 1996). Traveltime measurements were made on Spring Brook between river miles 1.5 and 2.0 (reach 2 between Walnut Avenue and Valley Road) on September 1, 1995, and on Addison Creek between river miles 0.06 and 0.5 (reach 16 between 18th Avenue and 19th Avenue at Broadview) on August 28, 1995 (Turner, 1996). For the reaches where traveltime data were available, Manning's n was adjusted to match the measured traveltimes. The calibrated Manning's n values tend to be high compared to values commonly found in hydraulic texts, such as Chow (1959, p. 101-123), reflecting pool and riffle hydraulics and the rough approximation of channel geometry at low flows. Calibrated Manning's n values were applied in neighboring reaches with similar hydraulic characteristics.

Table 3. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the August 29-30, 1995, diel survey of the Salt Creek watershed in northeastern Illinois

[All discharges are in cubic feet per second; a negative discrepancy indicates the sum of estimated upstream discharges is greater than the measured discharge at this site; "measured" refers to discharge measured by the Illinois Environmental Protection Agency or at a U.S. Geological Survey stream gage; "estimated" refers to discharge estimated from sewage-treatment plant data; "adjusted" refers to discharge adjusted to achieve a water balance relative to the measured discharges and measured specific conductance; STP, sewage-treatment plant; USGS, U.S. Geological Survey; --, not applicable]

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Upstream Boundary of Salt Creek to the Confluence with Spring Brook				
Salt Creek headwater	31.7	9.15	--	6.47
Egan STP	31.7	--	36.2	31.33
Sum upstream from Throndale Road	29.3	--	45.35	37.8
Thorndale Road	29.3	37.8	--	--
Discrepancy at Thorndale Road	--	--	-7.55	0.0
Spring Brook to the Confluence with Salt Creek				
Rohlwing Road (Spring Brook headwater)	2.7	3.18	--	3.18
Nordic Park STP	2.5	--	0.27	0.27
Incremental flow	2.7-0	--	--	1.16
Sum upstream from Prospect Avenue	0.3	--	3.45	4.61
Prospect Avenue	0.3	4.61	--	--
Discrepancy at Prospect Avenue	--	--	1.16	0.00

Table 3. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the August 29-30, 1995, diel survey of the Salt Creek watershed in northeastern Illinois--Continued

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Salt Creek from the Confluence with Spring Brook to the Confluence with Addison Creek				
Salt Creek at the Confluence with Spring Brook	28.2	--	--	37.8
Spring Brook at the Confluence with Salt Creek	0.0	--	--	4.61
Itasca STP	28.2	--	3.09	2.11
Wood Dale North STP	27.7	--	1.98	1.35
Wood Dale South STP	26.0	--	0.68	0.46
Addison North STP	25.0	--	4.46	3.06
Addison South STP	23.3	--	2.12	1.45
Sum upstream from State Highway 83	20.3	--	59.91	50.84
State Highway 83 (USGS gage, Salt Creek at Elmhurst)	20.3	50.84	--	--
Discrepancy at State Highway 83	--	--	-9.07	0.00
Salt Creek Sanitary District STP	20.0	--	3.54	3.54
Elmhurst STP	19.7	--	7.46	7.46
Sugar Creek	18.9	--	--	5.23
Ginger Creek	13.9	--	--	6.88
Sum upstream from Wolf Road	8.8	--	61.84	73.95

Table 3. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the August 29-30, 1995, diel survey of the Salt Creek watershed in northeastern Illinois--Continued

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Wolf Road (USGS gage, Salt Creek at Western Springs)	8.8	73.95	--	--
Discrepancy at Wolf Road	--	--	12.11	0.00
Addison Creek to the Confluence with Salt Creek				
Addison Creek headwater	10.4	0.00	--	--
Bensenville South STP	10.3	--	7.63	7.63
Incremental flow	10.3-3.2	--	--	1.03
Sum upstream from Washington Boulevard	3.2	--	7.63	8.66
Washington Boulevard (USGS gage, Addison Creek at Bellwood)	3.2	8.66	--	--
Descrepancy at Washington Boulevard	--	--	1.03	0.00
Salt Creek from the Confluence with Addison Creek to the Confluence with the Des Plaines River				
Salt Creek at the Confluence with Addison Creek	3.6	--	--	73.95
Addison Creek at the Confluence with Salt Creek	0.0	--	--	8.66
Diversion to the Des Plaines River	2.2	--	--	-14.91

Table 3. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the August 29-30, 1995, diel survey of the Salt Creek Watershed in northeastern Illinois--Continued

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Sum upstream from Washington Avenue-Brookfield	1.1	--	82.61	67.7
Washington Avenue-Brookfield	1.1	67.7	--	--
Discrepancy at Washington Avenue-Brookfield	--	--	-14.91	0.00

In reaches 13 and 14 on Addison Creek, the flow passes through a series of five ponds. In reach 1 on Salt Creek, the flow passes through a pool and riffle sequence at low flows. In reach 10 on Salt Creek, the flow passes through the backwater behind Fullersburg Dam. These pools and backwater areas result in substantial traveltimes, which are indicated by large algal growth measured in these reaches. Manning's n was adjusted to lengthen traveltime in these reaches so that the measured algal growth could be simulated. In addition to increasing Manning's n in reach 10, an approximate water-surface slope was applied instead of the bed slope in calculations of depth and velocity in reach 10 with Manning's equation. The water-surface slope behind Fullersburg Dam was approximated from information on the physical characteristics of Fullersburg Dam and the low-head dam at the upstream end of Fullersburg Park described in Butts and Evans (1978) and stream-profile data. The calibrated values of Manning's n for each reach are listed in table 4.

Ultimate Carbonaceous Biochemical Oxygen Demand--In June 1995, the IEPA collected samples at 12 sites on Salt Creek, 1 site on Spring Brook, and 1 site on Addison Creek for determination of $CBOD_u$. The determination of $CBOD_u$ involved monitoring the oxygen demand of the samples over a 21-day period and fitting a linear regression between time and the logarithms of oxygen demand to estimate the $CBOD_u$ decay rate, K_1. Measured mean values of K_1, where available, were utilized in reaches and also in hydraulically and biologically similar reaches where measurements were not available. The mean K_1 value of 0.142 day^{-1} was utilized to convert all measured 5-day CBOD values to $CBOD_u$ values as

$$BOD_u = BOD_5/(1 - \exp(-5K_1)),$$

where BOD_u and BOD_5 are the concentrations of $CBOD_u$ and 5-day CBOD, respectively.

The simulated and measured $CBOD_u$ concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 4-6, respectively. $CBOD_u$ is undersimulated throughout all of Salt Creek (fig. 4) and Spring Brook (fig. 5) and in Addison Creek (fig. 6) downstream from river mile 5.9 (Parkview Drive). Similar results were obtained by the New Jersey Department of Environmental Protection (NJDEP), (1987, p. VI.40-VI.46) in the simulation of 5-day CBOD for the Passaic River in New Jersey. The NJDEP noted that it is known that the algal respiration within a CBOD sample results in incorrect, high estimates of CBOD. No additional sources of $CBOD_u$ are known to be present along Salt Creek, Spring Brook, and Addison Creek, and the undersimulation was attributed to algal respiration in the sample bottles.

Substantial increases in $CBOD_u$ and total ammonia as nitroger concentrations were measured between river miles 7.1 and 9.8 (West Palmer Avenue and Diana Court) on Addison Creek during the August 1995, diel survey (figs. 6 and 12, respectively). Similar increases in 5-day CBOD concentrations were measured between river miles 8.5 and 9.8 (Tri-State Tollway and Diana Court) during a synoptic survey by the IEPA on June 22, 1987. There are two possible sources for these increases. A large pond (in Mount Emblem Cemetary) is present on Addison Creek between river miles 8.5 and 9.8, and this pond is frequently visited by waterfowl. The rise in the $CBOD_u$ concentration could be the result of waterfowl waste. The Du Page County Line Landfill is located along Addison Creek near river mile 9.0 (Grand Avenue). Six wells are located near this landfill to monitor the quality of leachate from the landfill. Ground-water monitoring data collected on February 16, 1995, indicated 5-day CBOD concentrations between 4 and 28 mg/L ($CBOD_u$ between 7.9 and 55 mg/L).

In the application of the calibrated model to simulation of water-quality planning scenarios, the assignment of the proportion of the increase in constituent concentrations to seepage and waterfowl waste could substantially affect simulated constituent concentrations. For 7-day, 10-year low-flow conditions, an incremental outflow will result in Addison Creek (Singh and Ramamurthy, 1993). Thus, the proportion of the increase in constituent concentrations assigned to seepage would not affect the simulation of water-quality planning scenarios; whereas the proportion of the increase in constituent concentrations assigned to waterfowl waste would affect the simulation of water-quality planning scenarios. Because

Table 4. Calibrated values of Manning's n; ultimate carbonaceous biochemical oxygen demand decay rates; algal settling rates; and reaeration-rate coefficients for the August 29-30, 1995, diel survey of the Salt Creek watershed in northeastern Illinois

[n, Manning's n; K_1, ultimate carbonaceous biochemical oxygen demand decay rate; σ_1, algal settling rate; K_2, reaeration-rate coefficient]

Reach	n	K_1 (day^{-1})	σ_1 (feet/day)	K_2 (day^{-1})
		Salt Creek		
1	0.40	[1]0.144	0.0	[1]2.1
3	.11	[1].139	3.3	1.86
4	.11	[1].159	.6	2.0
5	.11	[1].124	1.0	2.0
6	.11	.124	1.0	2.0
7	.05	.140	.6	8.0
8	.06	[1].156	1.5	[1].86
9	.10	.140	.0	[1].86
10	.26	[1].143	.0	.2
11	.052	[1].148	1.3	2.76
12	.052	.140	1.3	2.76
17	.052	[1].113	1.3	[1]2.76
		Spring Brook		
2	.33	[1].140	.6	[1]2.23
		Addison Creek		
13	.20	[1].154	.0	5.2
14	1.20	.150	.0	.6
15	.08	.150	1.25	2.0
16	.08	.150	.0	[1]2.0

[1]Measured value.

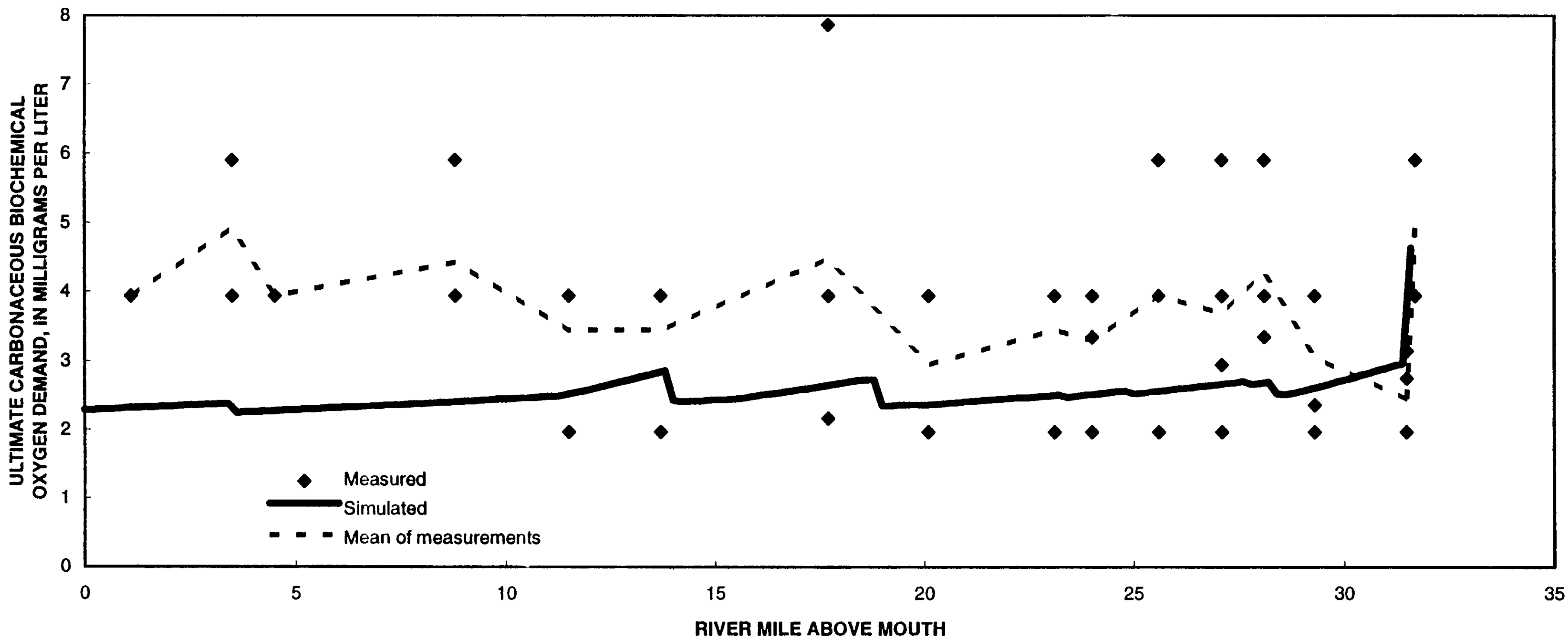

Figure 4. Profiles of simulated and measured ultimate carbonaceous biochemical oxygen demand concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

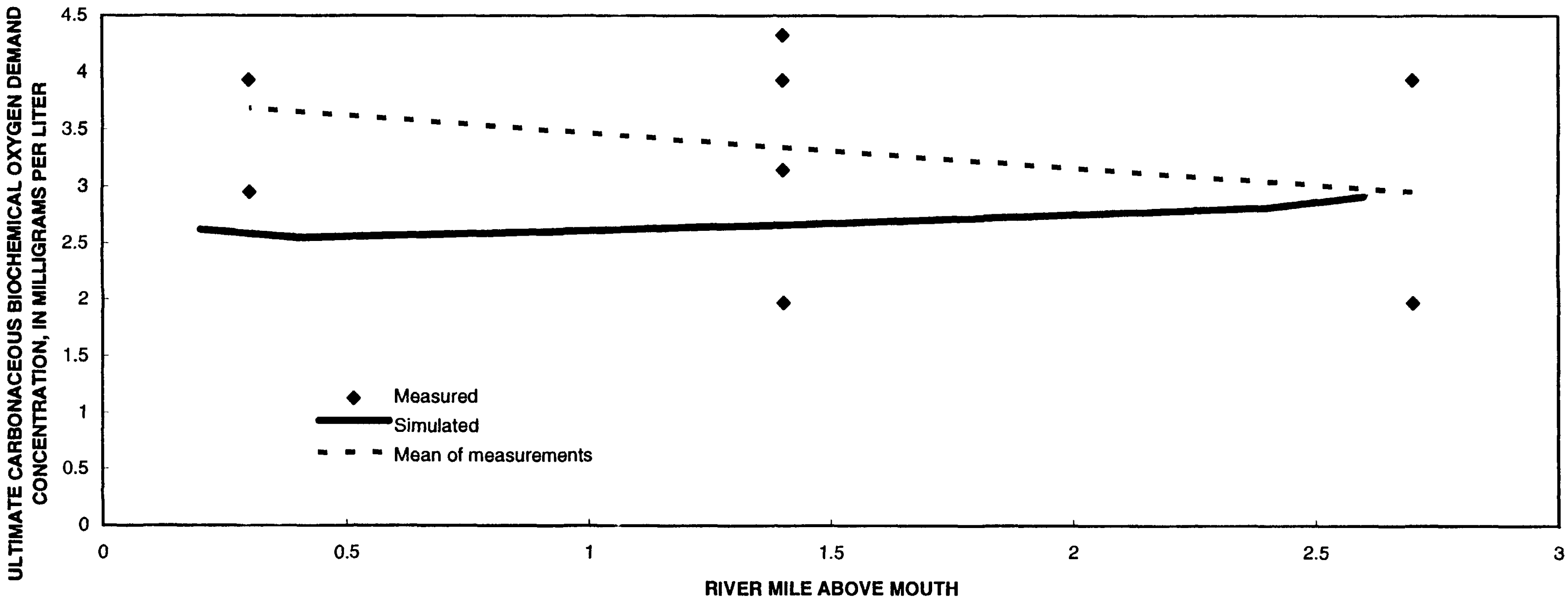

Figure 5. Profiles of simulated and measured ultimate carbonaceous biochemical oxygen demand concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

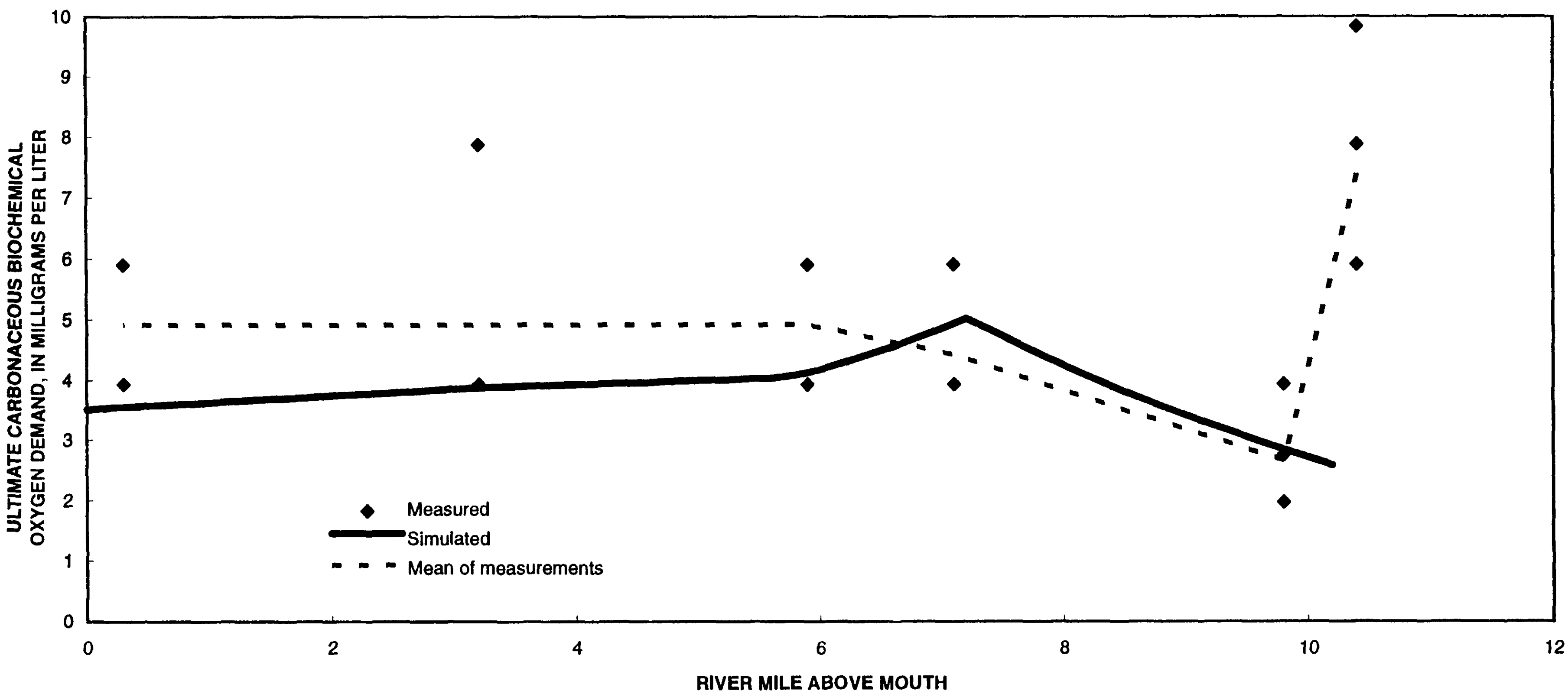

Figure 6. Profiles of simulated and measured ultimate carbonaceous biochemical oxygen demand concentrations in Addison Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

determination of the proportions of the increase in constituent concentrations resulting from seepage from the landfill and waterfowl waste is highly uncertain, a conservative approach was selected to attribute the entire increase to a line source of $CBOD_u$. This line source is simulated based on a negative $CBOD_u$ settling rate of 0.8 day^{-1}.

Organic Nitrogen--Organic nitrogen concentrations are fairly constant throughout Salt Creek, Spring Brook, and Addison Creek (figs. 7-9). Thus, the rate constant for the hydrolysis of organic nitrogen to ammonia (β_3) was set to 0.02 day^{-1}, the lower bound of the reasonable range listed in Brown and Barnwell (1987, p. 56).

A small rise and fall in the organic nitrogen concentration was measured in the first two reaches in Salt Creek (fig. 7). Sediment-quality data throughout Salt Creek indicate elevated concentrations of total Kjeldahl nitrogen (sum of organic nitrogen and total ammonia as nitrogen) greater than 3,200 mg/kg. Thus, because the flow from Egan STP contains little particulate matter and the flow from Busse Woods Dam contains low sediment concentrations, it is reasonable to assume that some erosion of the streambed results in reach 1. The increase in organic nitrogen concentrations in reach 1 may be attributable to bed erosion. After reach 1, some of the eroded sediment settles and organic nitrogen concentrations decrease. The organic nitrogen resuspension and settling processes are simulated with an organic nitrogen settling rate, σ_4, of -0.3 day^{-1} in reach 1 and 0.2 day^{-1} in reach 3. A similar sediment (and organic nitrogen) resuspension process was simulated in Spring Brook based on a σ_4 value of -0.15 day^{-1} in reach 2. In all other reaches in Salt Creek and Addison Creek, a σ_4 value of 0 day^{-1} was utilized.

The simulated and measured organic nitrogen concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 7-9, respectively. The simulated organic nitrogen concentrations are within 15 percent of the mean of the measured concentrations at all sites in the Salt Creek watershed, and the simulated concentration passes through the range of the measured concentrations at all sites in the watershed except for three sites on Salt Creek (fig. 7).

Total Ammonia as Nitrogen--The simulated and measured total ammonia as nitrogen concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 10-12, respectively. Generally, the agreement between the simulated and measured values is good for Spring Brook and Addison Creek and acceptable for Salt Creek.

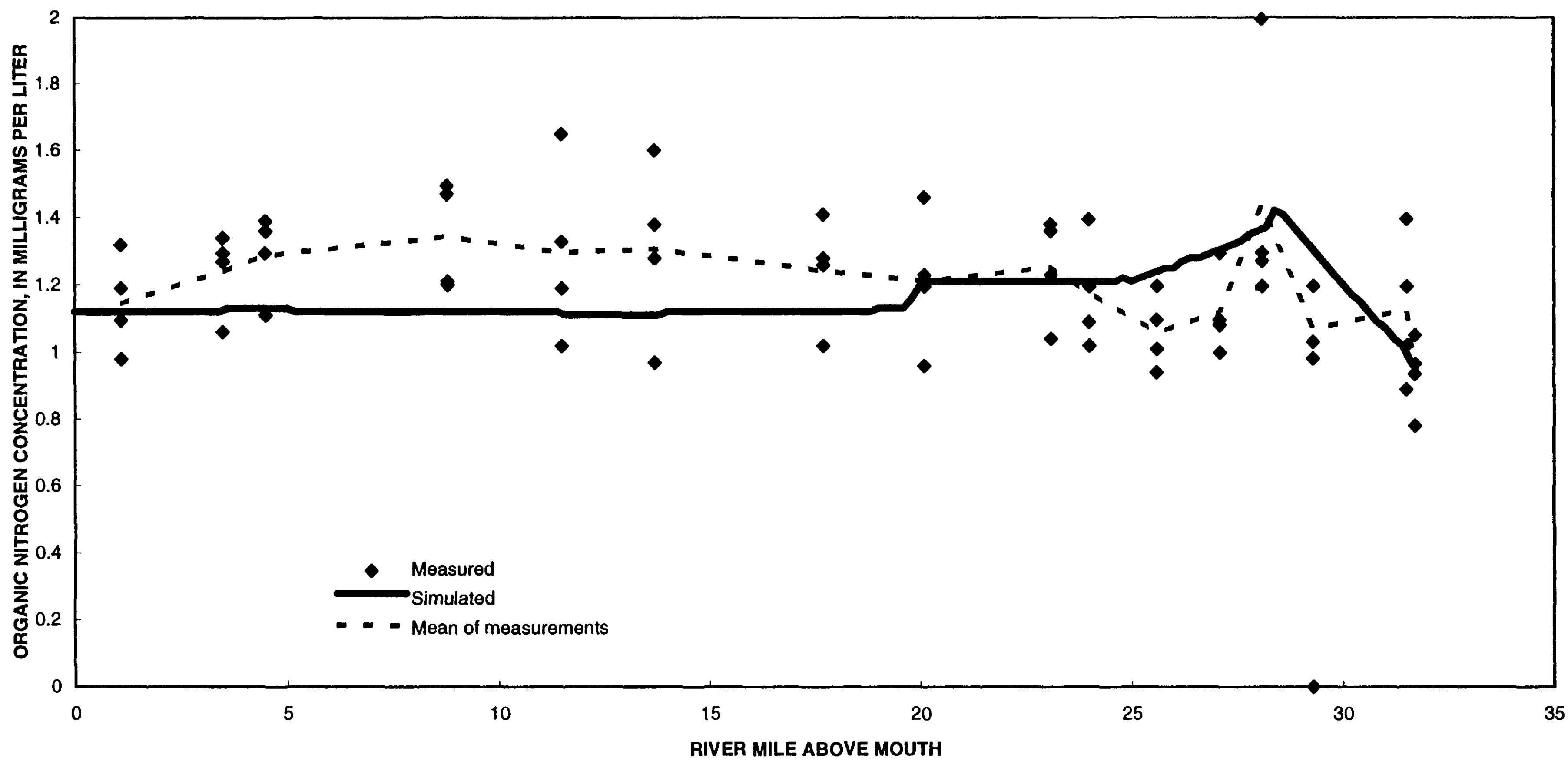

Figure 7. Profiles of simulated and measured organic nitrogen concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

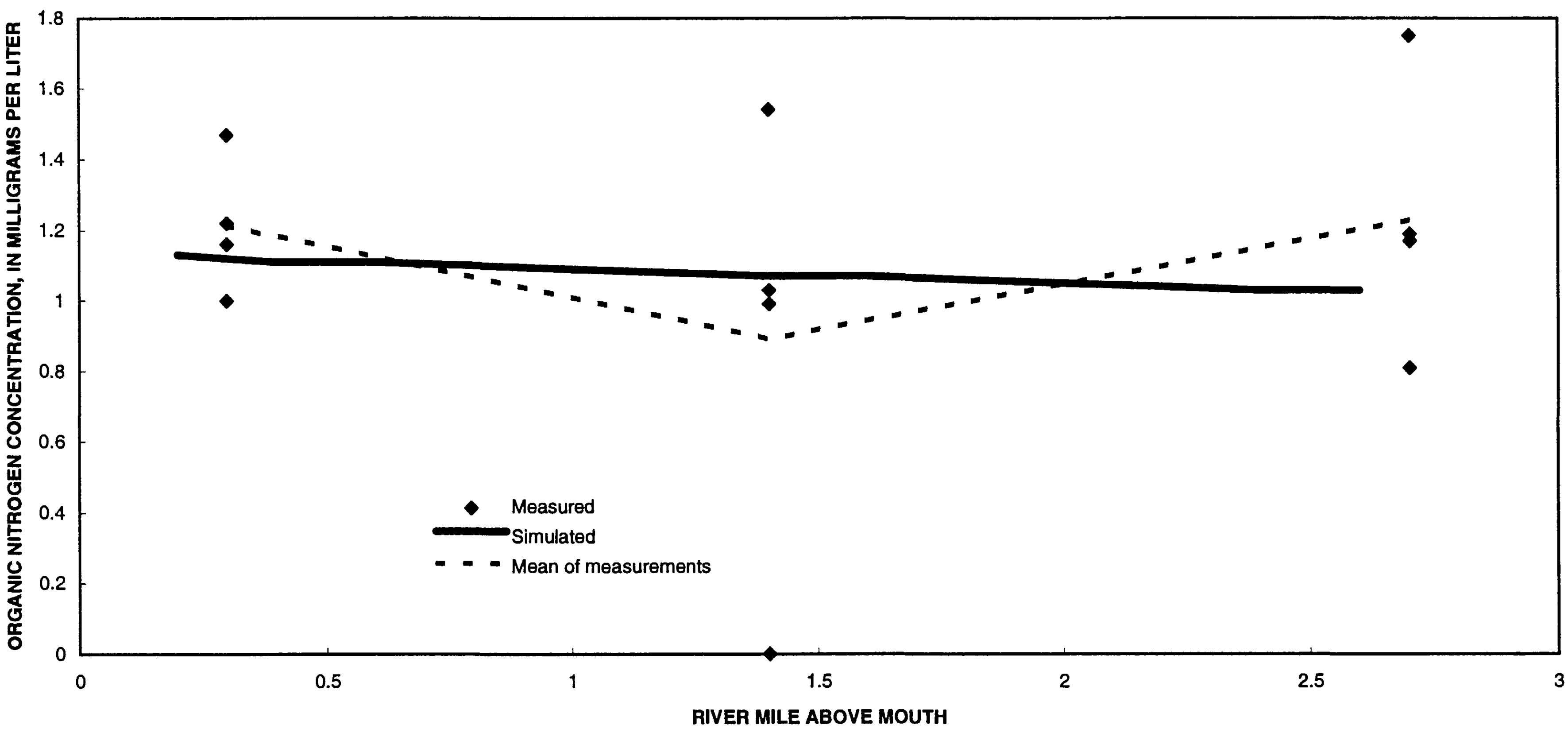

Figure 8. Profiles of simulated and measured organic nitrogen concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

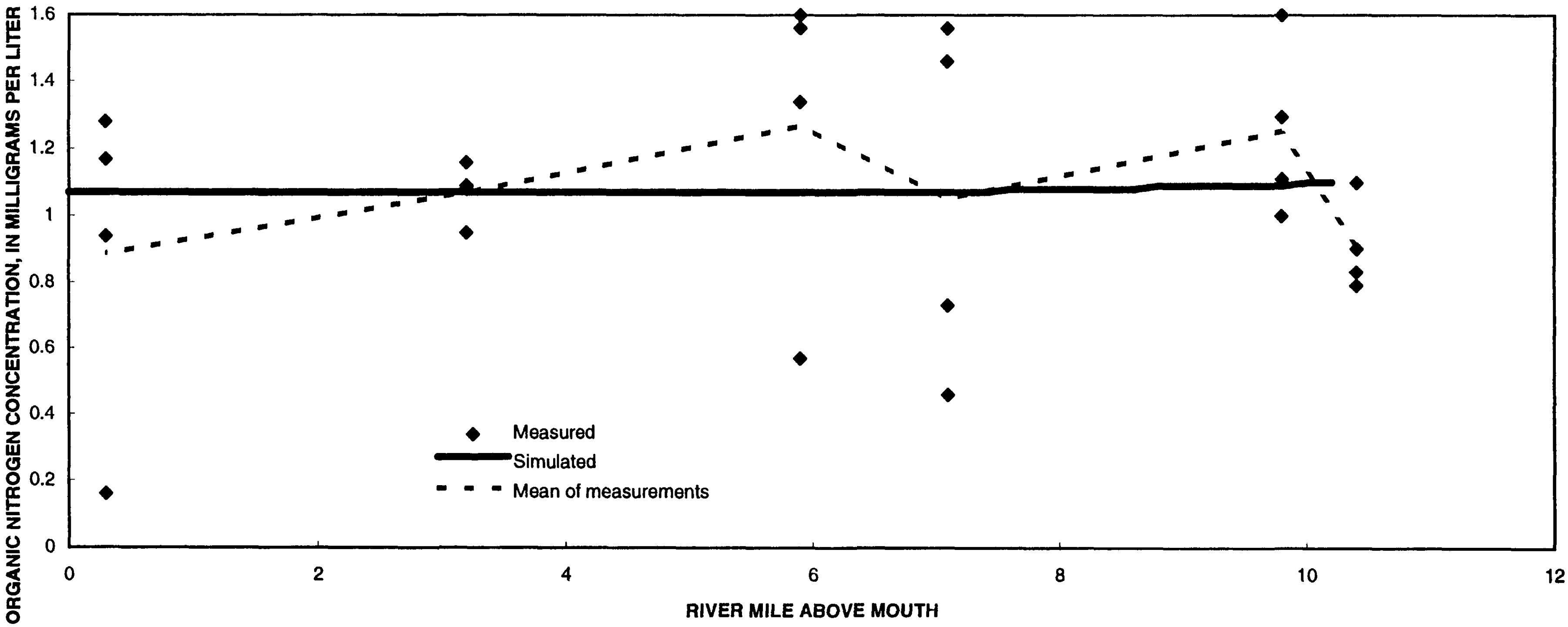

Figure 9. Profiles of simulated and measured organic nitrogen concentrations in Addison Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

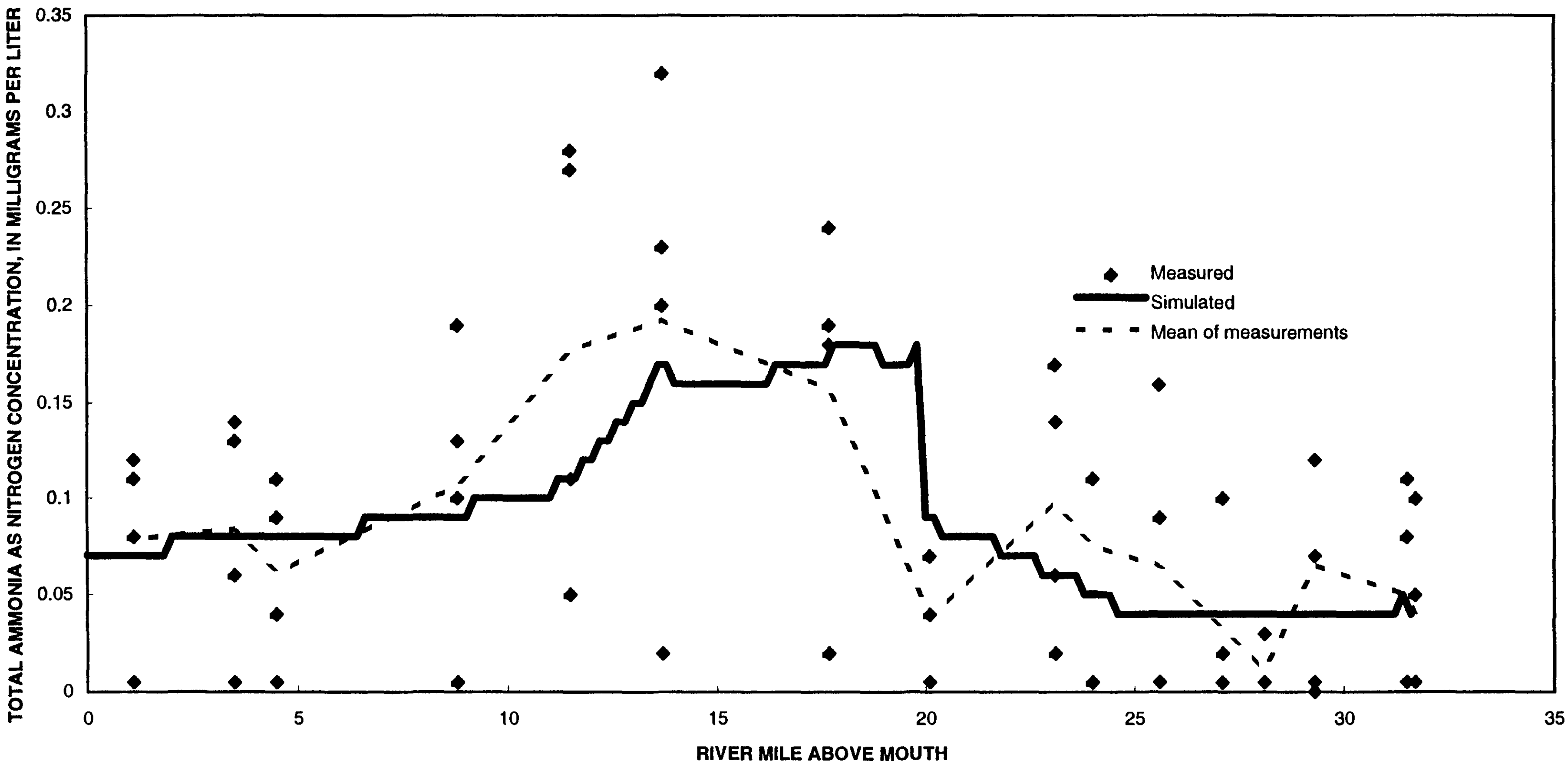

Figure 10. Profiles of simulated and measured total ammonia as nitrogen concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

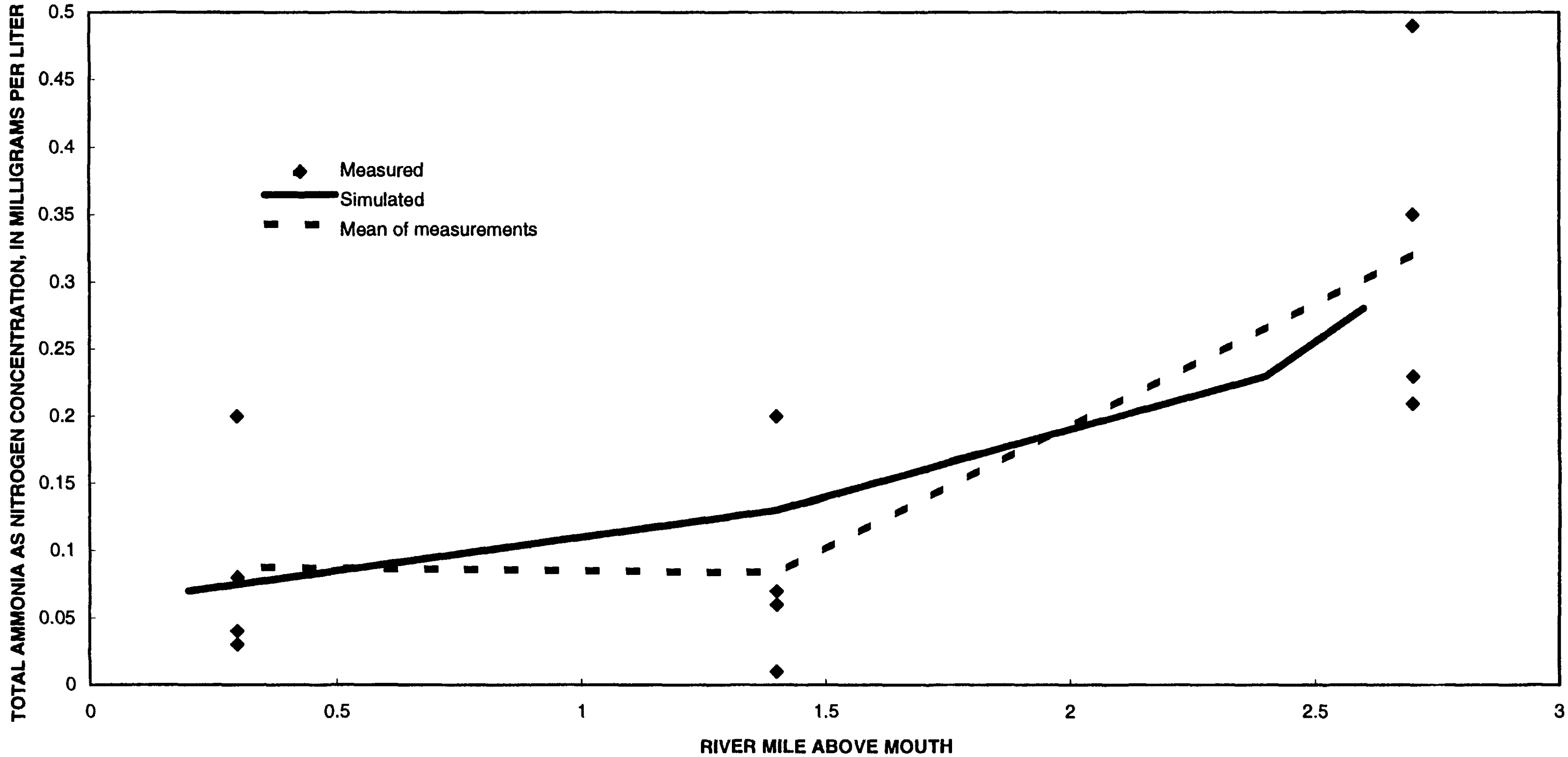

Figure 11. Profiles of simulated and measured total ammonia as nitrogen concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

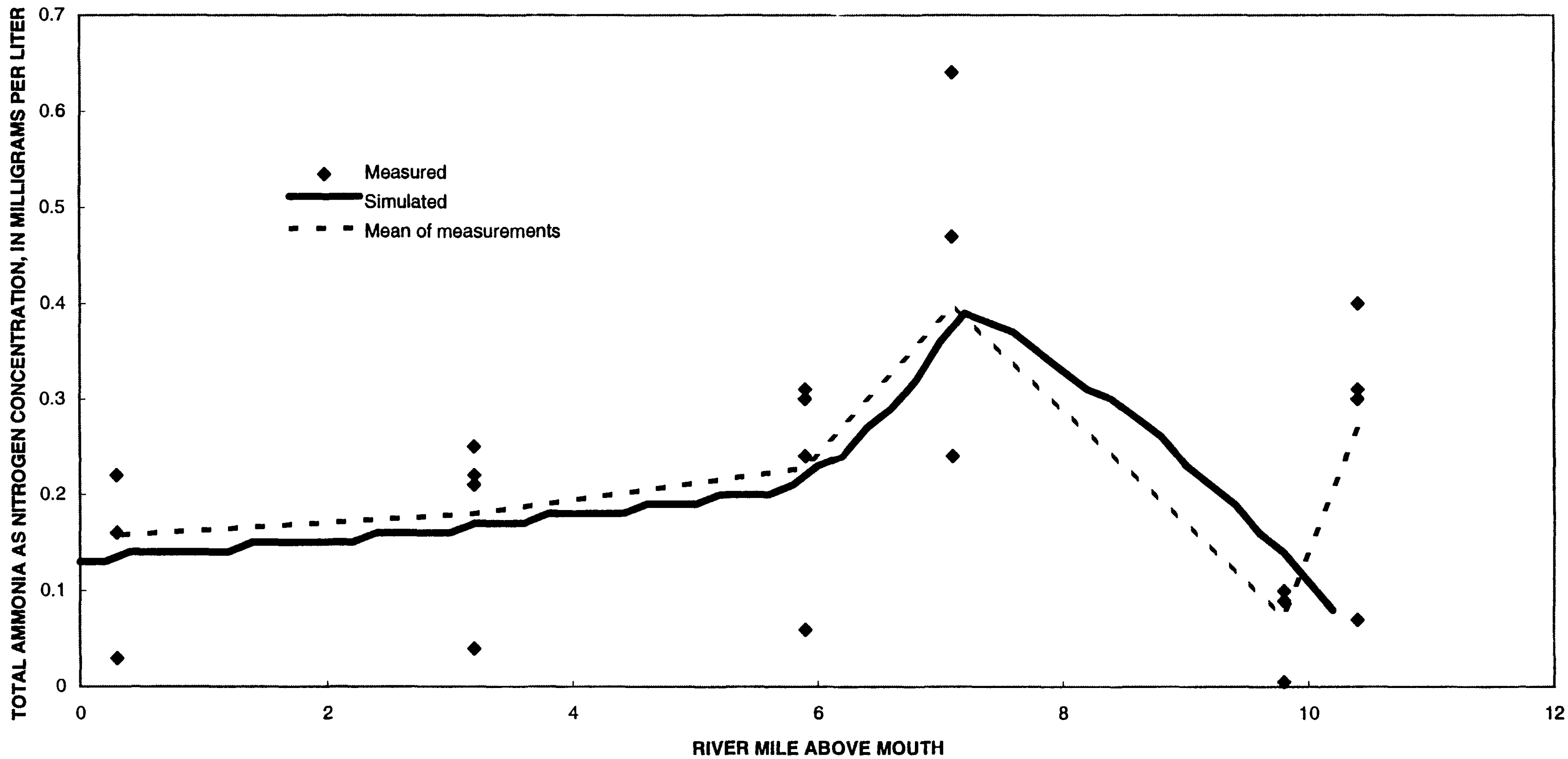

Figure 12. Profiles of simulated and measured total ammonia as nitrogen concentrations in Addison Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

Simulation of total ammonia as nitrogen concentrations along Salt Creek is difficult because of the relatively low concentrations in Salt Creek and the large diel fluctuations in concentrations of total ammonia as nitrogen is taken in by algae during photosynthesis during the daylight hours and given off by algae during respiration at night. At 12 of the 15 IEPA diel-survey sampling sites along Salt Creek, the simulated total ammonia as nitrogen concentration is within 0.030 mg/L of the mean of the measured concentrations, and the maximum difference between the simulated and mean of the measured concentrations is 0.068 mg/L at river mile 11.5 (York Road). The main parameters adjusted in the total ammonia as nitrogen calibration were the rate constant for the biological oxidation of ammonia to nitrite (β_1) and the benthos source rate for total ammonia as nitrogen (σ_3). The range of values for β_1 recommended in Brown and Barnwell (1987, p. 56) is 0.1-1.0 day^{-1}, and a β_1 value of 0.6 day^{-1} was utilized throughout Salt Creek. The measured total ammonia as nitrogen concentrations increase between river miles 17.7 and 20.1 (Butterfield Road and Railroad Avenue) and maintain relatively higher values until river mile 8.8. The increase in total ammonia as nitrogen concentration was simulated by applying a σ_3 value of 5.0 mg/ft^2-day in reaches 4-9 (fig. 3). No physical evidence is available regarding why an increase in total ammonia as nitrogen concentrations results in these reaches of Salt Creek. However, the elevated total ammonia as nitrogen concentrations are observed in both the August 29-30, 1995, and June 27-28, 1995, diel-survey data, and σ_3 is utilized to simulate these elevated concentrations.

The simulation of total ammonia as nitrogen concentrations measured in Spring Brook required setting β_1 to 1.0 day^{-1}, the maximum value of the reasonable range given by Brown and Barnwell (1987, p. 56). No source or sink terms were needed to simulate total ammonia as nitrogen concentrations in Spring Brook.

Substantial increases in $CBOD_u$ and total ammonia as nitrogen concentrations were measured between river miles 7.1 and 9.8 (West Palmer Avenue and Diana Court) on Addison Creek during the August 1995, diel survey (figs. 6 and 12, respectively). There are two possible sources for these increases in concentrations. A large pond (in Mount Emblem Cemetary) is present on Addison Creek between river miles 8.5 and 9.8 (Tri-State Tollway and Diana Court), and this pond is frequently visited by waterfowl. The rise in the total ammonia as nitrogen concentration could be the result of waterfowl waste. The Du Page County Line Landfill is located along Addison Creek near river mile 9.0. Six wells are located near this landfill to monitor the quality of leachate from the landfill. Ground-water-monitoring data collected on February 16, 1995, indicate total ammonia as nitrogen concentrations as high as 2.6 mg/L. Thus, to simulate the combined effects of waterfowl waste and landfill seepage, a σ_3 value of 11.0 mg/ft^2-day was applied in reach 13 to simulate a benthic line source of total ammonia as nitrogen in this reach. A β_1 value of 0.45 day^{-1} was applied throughout Addison Creek.

Nitrite Plus Nitrate as Nitrogen--Measured data were available on the concentration of nitrite plus nitrate as nitrogen and not on the concentrations of the specific constituents. In the QUAL-II model of the Du Page River, Freeman and others (1986) specified the rate constant for the biological oxidation of nitrite to nitrate (β_2) at 10 day^{-1} because nitrite-oxidation rates are typically high and nitrite concentrations are typically low. Freeman and others (1986) noted that the model, with β_2 set to 10 day^{-1}, essentially simulated nitrite plus nitrate as nitrogen concentrations, and the model results could be compared with the measured concentrations of nitrite plus nitrate as nitrogen. This procedure was followed in simulation of nitrite plus nitrate as nitrogen concentrations in Salt Creek, Spring Brook, and Addison Creek. The simulated and measured nitrite plus nitrate as nitrogen concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 13-15, respectively.

Nitrite plus nitrate as nitrogen concentrations are substantially oversimulated throughout Addison Creek (fig. 15). Similar results also were obtained for simulated total phosphorus concentrations (discussed in the "Total Phosphorus" section). It seems likely that nonalgal aquatic vegetation is present in the ponds upstream from river mile 6.5 (Wolf Road), and that this vegetation is consuming the high concentrations of nitrite plus nitrate and phosphorus during the relatively long detention times in the ponds. The effects of nonalgal aquatic vegetation cannot be simulated in QUAL2E. The oversimulation of nitrite plus nitrate as nitrogen concentrations does not substantially affect any other aspect of water-quality simulation in the Salt Creek watershed. The primary interaction between nitrate (the dominant constituent in nitrite plus nitrate as simulated with QUAL2E) and the other water-quality constituents is in simulation of algal growth. Ammonia, nitrate, and dissolved phosphorus are the primary nutrients required for algal growth. If the concentrations of these nutrients are substantially greater than the limiting values, algal growth will be only slightly affected by the exact nutrient concentrations. For example, Thomann and Mueller (1987, p. 427) note that if a nutrient-control program is initiated, but the reduction in input load reduces only the nutrient concentration to a level of two to three times the Michaelis-Menton constant (0.3 mg/L for nitrogen), then there will be no effect on phytoplankton growth. The measured nitrite plus nitrate as nitrogen concentrations throughout the Salt Creek watershed are sufficiently high, such that nitrate will not be a limiting nutrient for algal growth. Thus, the oversimulation of nitrite plus nitrate as nitrogen concentrations in Addison Creek were attributed to nonsimulation of nonalgal aquatic vegetation

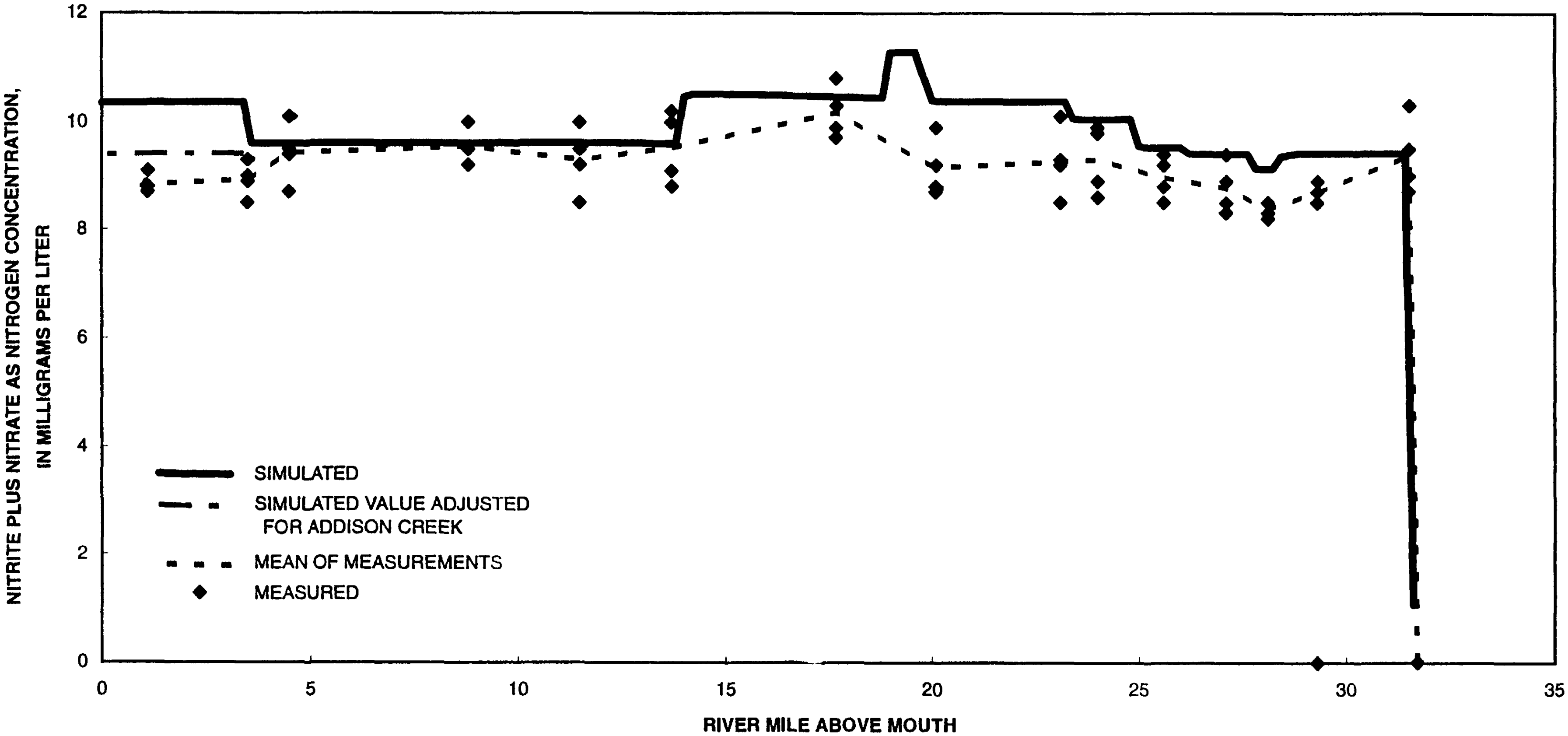

Figure 13. Profiles of simulated and measured nitrite plus nitrate as nitrogen concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

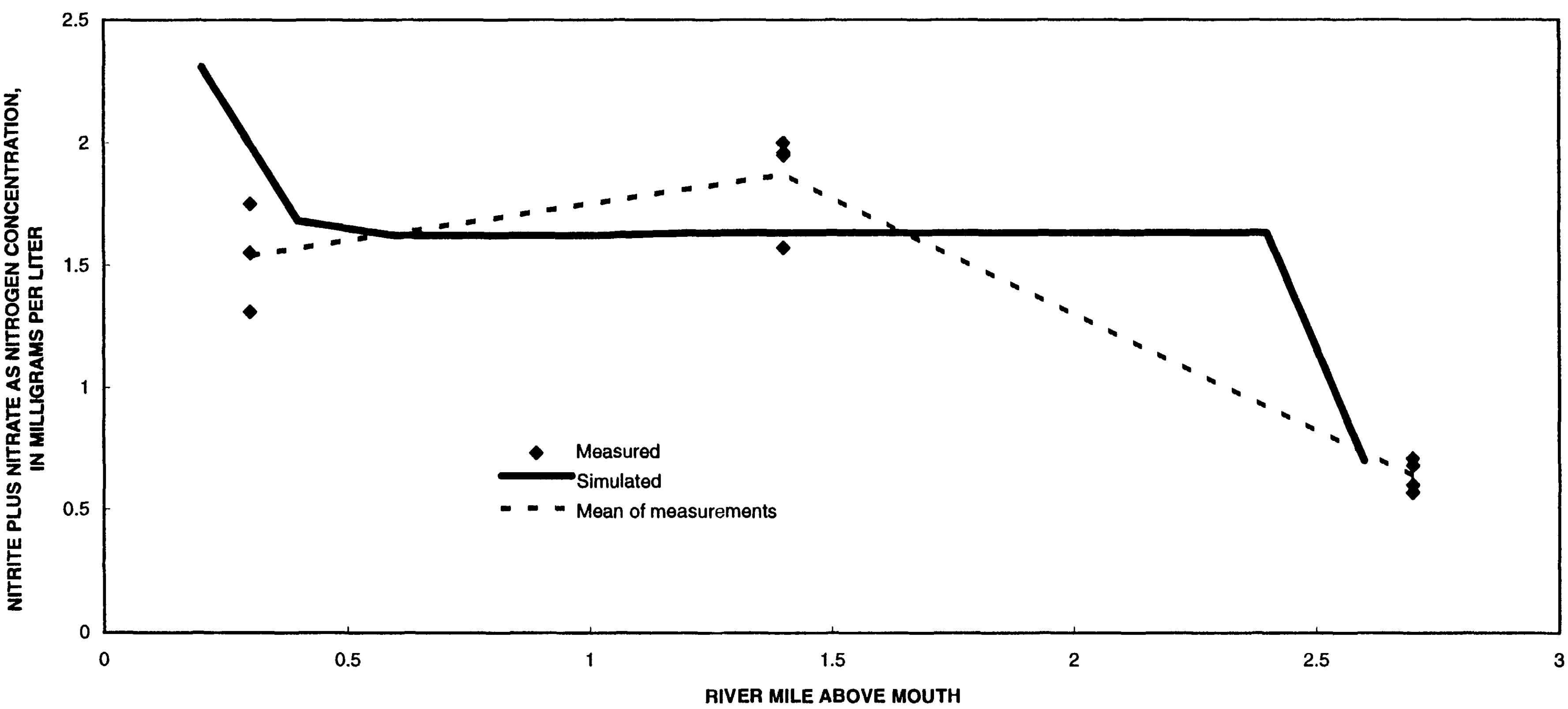

Figure 14. Profiles of simulated and measured nitrite plus nitrate as nitrogen concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

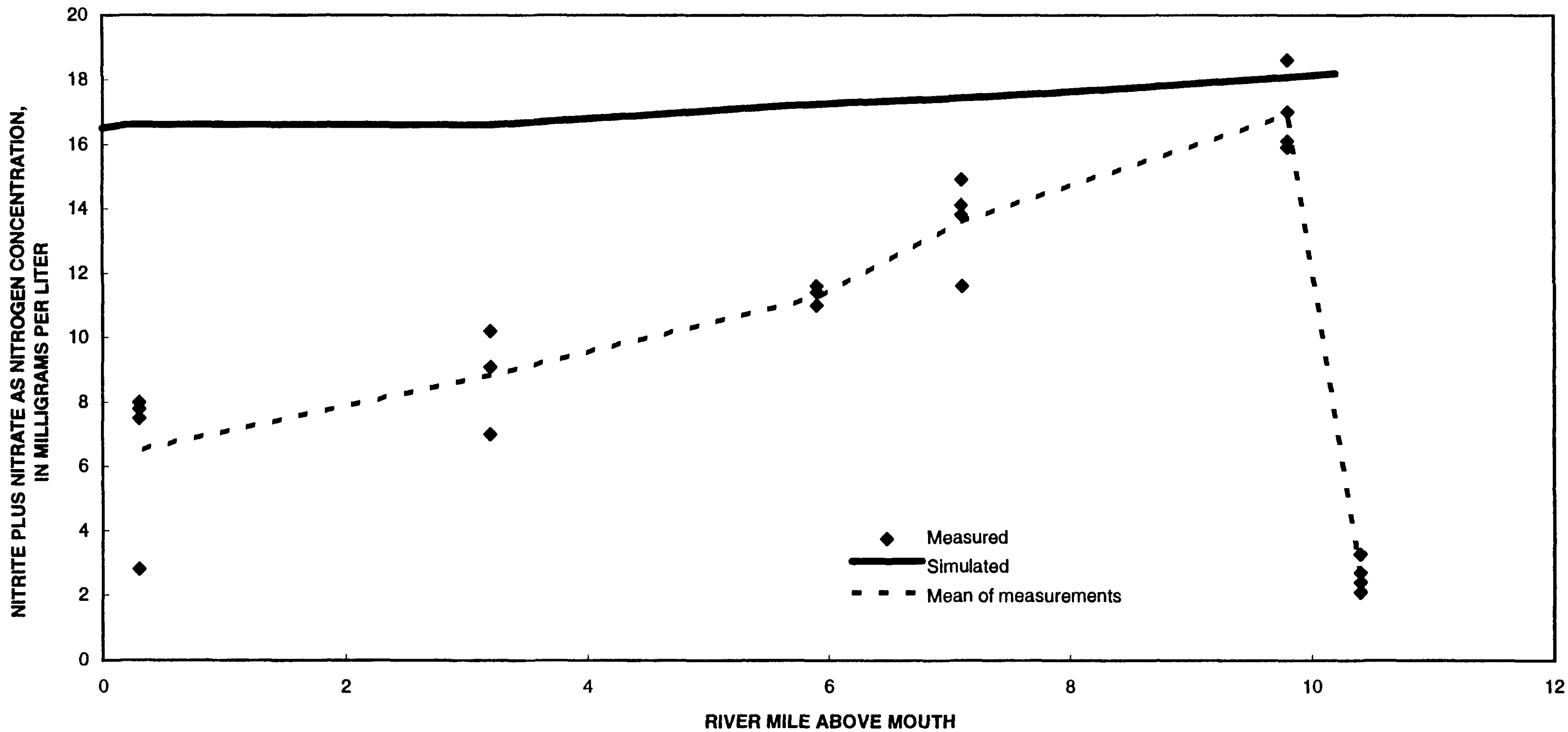

Figure 15. Profiles of simulated and measured nitrite plus nitrate as nitrogen concentrations in Addison Creek in north-eastern Illinois for the calibration to the August 29-30, 1995, diel survey.

and were not considered substantially important in model simulation. Nonalgal aquatic vegetation was assumed to have no net effect on DO concentrations in the stream; that is, for macrophytes and periphyton photosynthesis and respiration have an equal and opposite effect on DO concentrations, and oxygen produced by rooted plants is primarily delivered to the atmosphere.

The simulated nitrite plus nitrate as nitrogen concentrations are within 20 percent of the measured concentrations in Spring Brook (fig. 14). In Salt Creek, however, the simulated nitrite plus nitrate concentrations were higher than measured concentrations for all but the reaches between river miles 3.6 and 13.7 (confluence of Salt Creek and Addison Creek and 31st Street in Oak Brook, Ill.). Outside of the stretch of Salt Creek between river miles 3.6 and 13.7, the simulated concentrations tended to be just slightly higher than the highest measured concentration (fig. 13). Between the confluence of Salt Creek and Addison Creek (river mile 3.6) and the mouth of Salt Creek, the simulated concentrations are high because of the substantial oversimulation of nitrite plus nitrate as nitrogen concentrations in Addison Creek. If the mean of the measured concentrations at river mile 0.3 of Addison Creek was substituted for the simulated value at the mouth of Addison Creek, the result is the curve marked "simulated value adjusted for Addison Creek" in figure 13.

Simulated nitrate as nitrogen concentrations can only be reduced by algal consumption during photosynthesis. The simulated nitrite plus nitrate as nitrogen concentrations could be reduced by decreasing the ratio of chlorophyll *a* to algal biomass (α_1). An α_1 value of 50 micrograms of chlorophyll *a* per milligram of algae was applied in the Salt Creek watershed as done by Freeman and others (1986) in the Du Page River QUAL-II model. If the α_1 value was set to 10 micrograms of chlorophyll *a* per milligram of algae, the lower bound of the recommended range given by Brown and Barnwell (1987, p. 54), then the simulated nitrite plus nitrate as nitrogen concentrations would be closer to the measured concentrations. However, if this α_1 value were utilized, the oxygen production from photosynthesis would be too large and unreasonably high SOD values would be required to accurately simulate DO concentrations. Therefore, the small oversimulation of nitrite plus nitrate concentrations was considered acceptable.

Total Phosphorus--Dissolved and organic phosphorus concentrations are simulated in QUAL2E. In the diel surveys of Salt Creek, only total phosphorus concentrations were measured. The USGS stream gages, Salt Creek at Western Springs, Ill. (river mile 8.8) and Addison Creek at Belwood, Ill. (river mile 3.2), also are sites in the IEPA Ambient Water-Quality-Monitoring

Network (AWQMN). IEPA AWQMN sites are sampled six times a year and measurements made at IEPA AWQMN sites include total phosphorus and dissolved phosphorus concentrations. Data at each site were evaluated for water years[1] 1985-95 (66 measurements) to determine a ratio between dissolved phosphorus and total phosphorus concentrations (DP/TP), suitable for the Salt Creek watershed. For Salt Creek at Western Springs, Ill., the DP/TP ratio for all flows was 0.856 and 0.90 for flows less than 100 ft^3/s. For Addison Creek at Bellwood, Ill., the DP/TP ratio for all flows was 0.807 and 0.845 for flows less than 25 ft^3/s. Thus, a DP/TP ratio of 0.85 was applied to all measured total phosphorus concentrations from the Salt Creek watershed.

The simulated and measured total phosphorus concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 16-18, respectively. The agreement between the measured and simulated concentrations is within 10 percent throughout Spring Brook (fig. 17) and Salt Creek (fig. 16) except for the reach downstream from the confluence with Addison Creek. If the mean of the measured concentrations at river mile 0.3 of Addison Creek is substituted for the simulated value at the mouth of Addison Creek, the result is the curve marked "simulated value adjusted for Addison Creek" in figure 16. An organic phosphorus settling rate, σ_5, of 0 was applied in Spring Brook, and a σ_5 of 1.0 day^{-1} was applied in all reaches of Salt Creek, except reaches 8 and 10. The settling rate of 1.0 day^{-1} exceeds the recommended maximum of 0.1 day^{-1} given in Brown and Barnwell (1987, p. 55), but the value was utilized because it resulted in a good (less than 10 percent at most sampling sites) fit of the measured data and the simulation of total phosphorus does not have a substantial effect on other water-quality constituents. The σ_5 value of 1.0 day^{-1} also was applied in Addison Creek.

Total phosphorus concentrations are substantially oversimulated throughout Addison Creek (fig. 18). Similar results also were obtained for simulated nitrite plus nitrate concentrations as previously discussed. It seems likely that nonalgal aquatic vegetation is present in the ponds upstream from river mile 6.5 (Wolf Road), and that this vegetation is consuming the high concentrations of nitrite plus nitrate and phosphorus during the relatively long detention times in the ponds. The effects of nonalgal aquatic vegetation cannot be simulated in QUAL2E. The oversimulation of total phosphorus concentrations does not substantially affect any other aspect of water-quality simulation in the Salt Creek watershed. The primary interaction between dissolved phosphorus (the dominant constituent in total phosphorus) and the other water-quality constituents is in

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[1]The water year is the 12-month period from October 1 through September 30 and is designated by the calendar year in which it ends and which includes 9 of the 12 months.

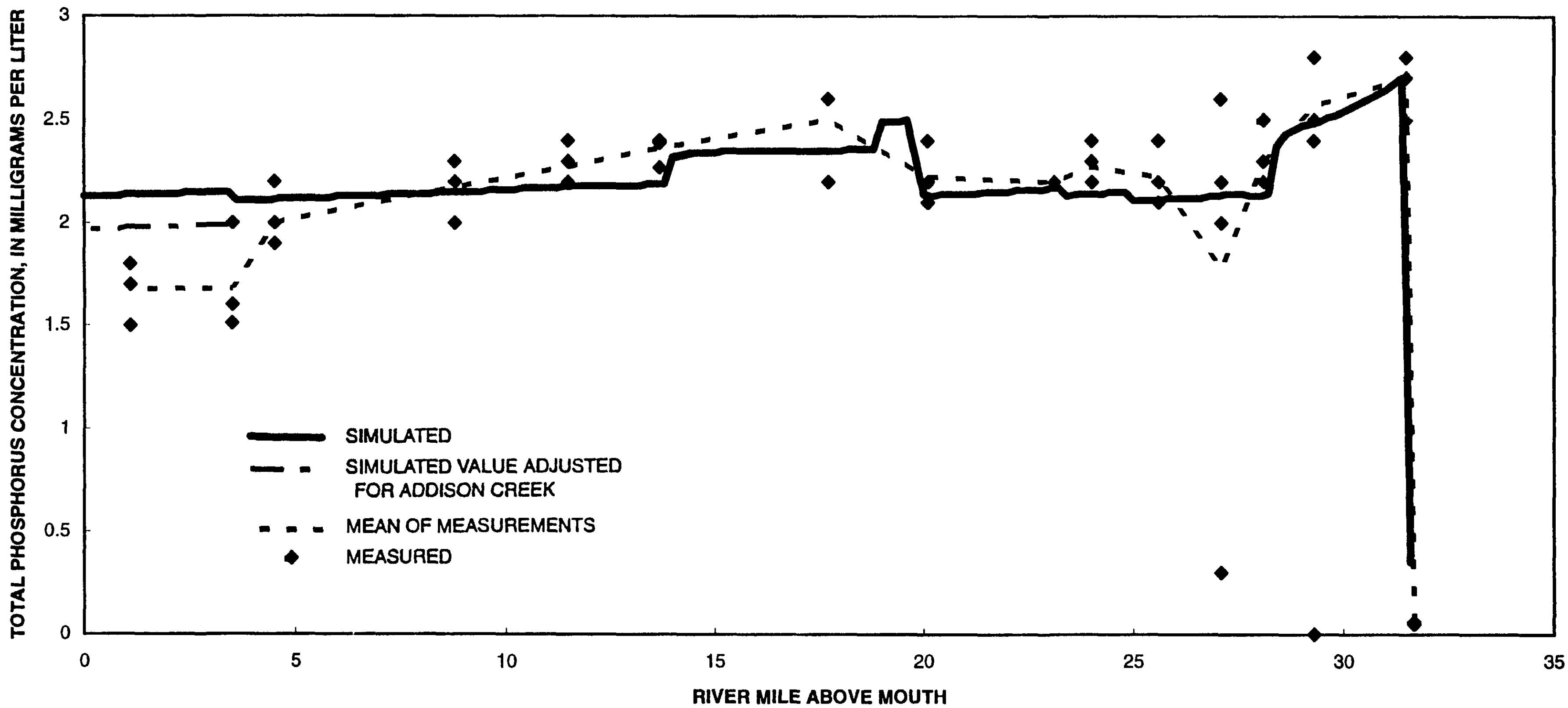

Figure 16. Profiles of simulated and measured total phosphorus concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

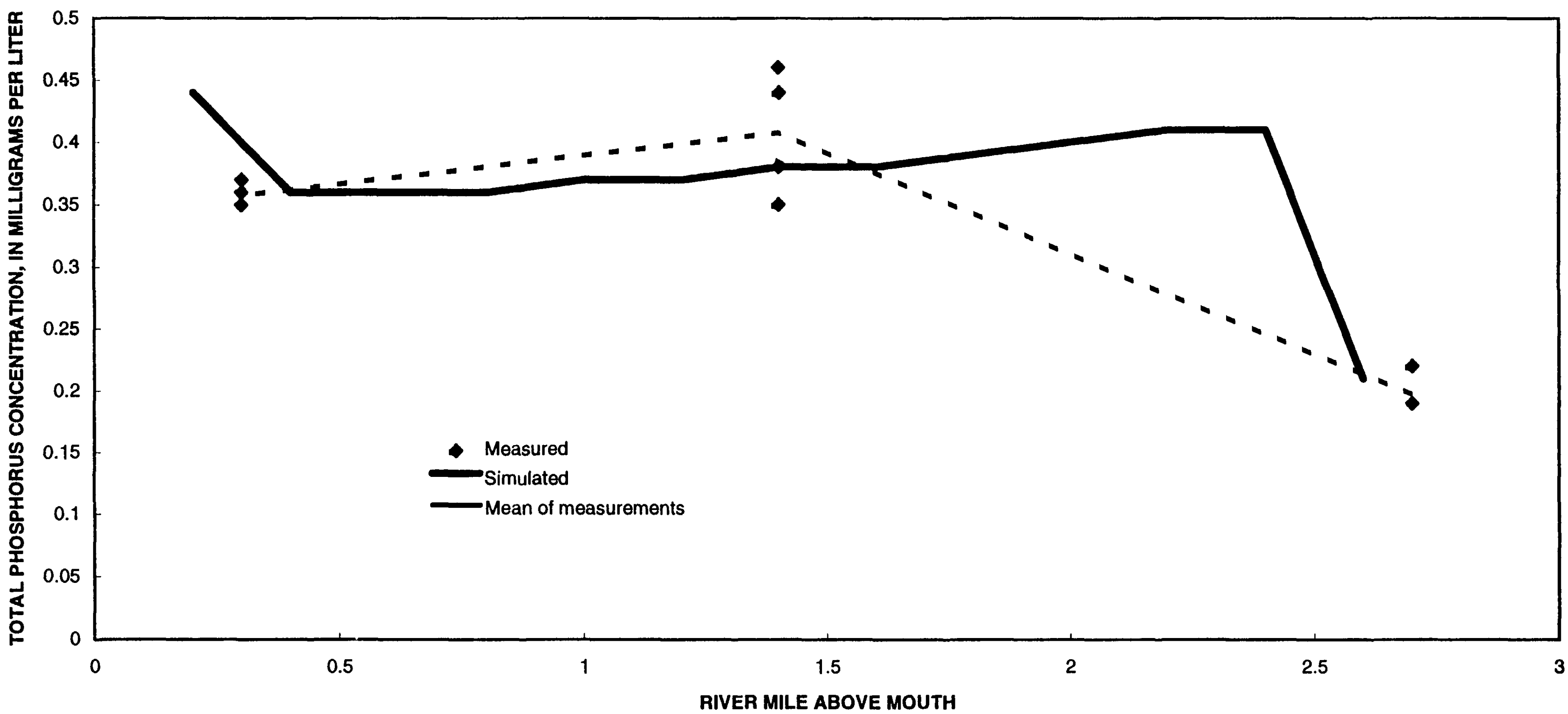

Figure 17. Profiles of simulated and measured total phosphorus concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

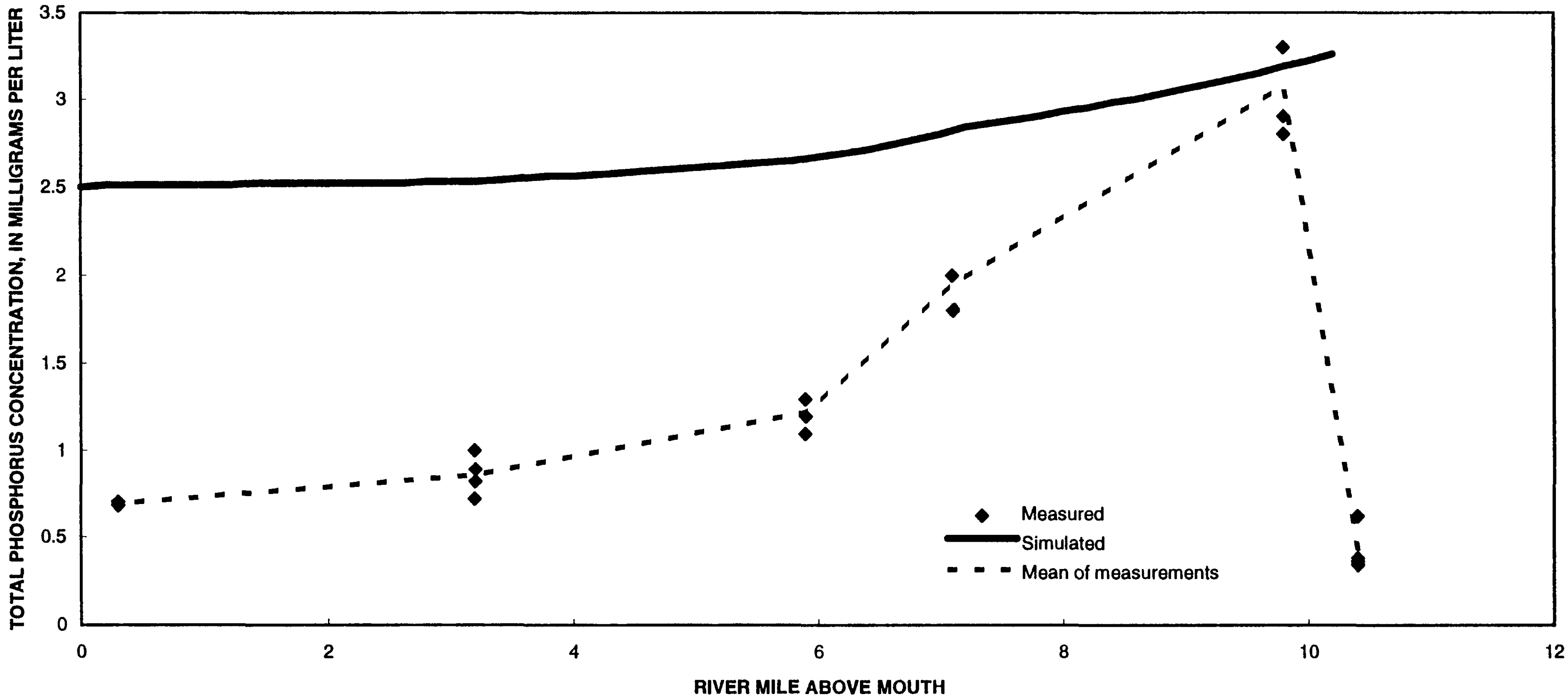

Figure 18. Profiles of simulated and measured total phosphorus concentrations in Addison Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

simulation of algal growth. Ammonia, nitrate, and dissolved phosphorus are the nutrients required for algal growth. If the concentrations of these nutrients are substantially greater than the limiting values, algal growth will be only slightly affected by the exact value of the nutrient concentrations. For example, Thomann and Mueller (1987, p. 427) note that if a nutrient-control program in a watershed is initiated, but the reduction in input load reduces only the nutrient concentration to a level of two to three times the Michaelis-Menton constant (0.04 mg/L for phosphorus), then there will be no effect on phytoplankton growth. The measured total phosphorus and approximated dissolved phosphorus concentrations throughout the Salt Creek watershed are sufficiently high, such that dissolved phosphorus will not be a limiting nutrient for algal growth. Thus, the oversimulation of total phosphorus concentrations in Addison Creek was attributed to nonsimulation of nonalgal aquatic vegetation and was not considered a substantially important flaw in the model. Nonalgal aquatic vegetation was assumed to have no net effect on DO concentrations in the stream; that is, for macrophytes and periphyton photosynthesis and resipiration have an equal and opposite effect on DO concentrations, and oxygen produced by rooted plants is primarily delivered to the atmosphere.

Chlorophyll *a* --In the simulation of chlorophyll *a* concentrations in the Salt Creek watershed with QUAL2E (Brown and Barnwell, 1987), the two light options and many parameter values were selected to be identical with those applied in the QUAL-II model of the Du Page River (Freeman and others, 1986). A key exception is that the limiting nutrient (option 2 in QUAL2E) algal specific-growth-rate option was applied for Salt Creek with an algal maximum specific-growth rate, (μ_{max}) of 2.6 day^{-1} (recommended range in Brown and Barnwell (1987, p. 54) is 1.0-3.0 day^{-1}). The QUAL-II model utilized for the Du Page River included only one algal specific-growth-rate option, the multiplicative combination of limitation factors for light, nitrogen, and phosphorus (option 1 in QUAL2E). The limiting-nutrient option generally is considered to be most representative of the algal growth process for cases where more than one nutrient is important to growth (Thomann and Mueller, 1987, p. 427). As discussed earlier, the concentrations of nitrogen and phosphorus in the Salt Creek watershed are substantially higher than the limiting values, and, thus, the difference in algal growth resulting from application of algal specific-growth-rate options 1 or 2 in QUAL2E would be small for this watershed.

The limitation factors for nitrogen, phosphorus, and light were computed in the same way as for the Du Page River (Freeman and others, 1986) on the basis of Monod expressions with the Michaelis-Menton half-saturation constant for nitrogen (K_N) equal to 0.3 mg/L, the Michaelis-Menton half-saturation coefficient for phosphorus (K_P) equal to 0.04 mg/L, and the half-saturation coefficient for light (K_L) equal to 0.03 Langleys per minute (light function option 1 in QUAL2E). Algal self shading could not be simulated in the QUAL-II model utilized for the Du Page River. Thus, the linear algal self-shading coefficient (λ_1) and the nonlinear algal self-shading coefficient (λ_2) were set to 0. The nonalgal light-extinction coefficient (λ_0) was set to 0.1 ft^{-1}, whereas λ_0 values varied by reach in the East Branch (0.07-0.9 ft^{-1}) and the West Branch and Main Stem (0.1 - 0.9 ft^{-1}) of the Du Page River (Freeman and others, 1986). The light-averaging option applied was the daylight-average solar-radiation option (option 2 in QUAL2E). The fraction of algal biomass that is nitrogen (α_1), fraction of algal biomass that is phosphorus (α_2), and the algal respiration rate (ρ) were set to the values applied in the Du Page River (Freeman and others, 1986); 0.09 milligrams of nitrogen per milligram of algae, 0.015 milligrams of phosphorus per milligram of algae, and 0.5 day^{-1}, respectively. All of the parameter values listed above are within the ranges recommended in Brown and Barnwell (1987, p. 54-55).

The simulated and measured chlorophyll *a* concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 19-21, respectively. The good agreement between the simulated and measured concentrations wherein the simulated concentrations pass between the measured concentration at all sampling sites was obtained by adjustment of the algal settling rate (σ_1) for each reach and elevated values of Manning's n applied in reaches 1 and 10 in Salt Creek and reach 14 in Addison Creek to lengthen the simulated traveltime to match the algal growth measured in these reaches. The calibrated values of σ_1 for each reach are listed in table 4.

The large drop in the chlorophyll *a* concentration measured between river miles 3.5 and 1.1 (Maple Avenue and Washington Avenue-Brookfield) on Salt Creek is attributed to the diversion of water at river mile 2.2. The diversion structure is a broad-crested weir and water is skimmed off the top of the Salt Creek flow and diverted to the Des Plaines River when flows in Salt Creek exceed about 68 ft^3/s. Because algae primarily grow at the surface of a stream and the water diverted over the weir comes from the surface of Salt Creek, it is assumed that the diverted water contains a higher chlorophyll *a* concentration than the depth-averaged concentration at the diversion location. The drop in simulated chlorophyll *a* concentrations shown in figure 19 results from an assumed chlorophyll *a* concentration of 90 $\mu g/L$ in the diverted water. This concentration is approximately 2.25 times the depth-averaged concentration at the diversion location. The chlorophyll *a* concentrations measured in the June 27-28, 1995, diel survey did not indicate a similar reduction between river miles 3.5 and 1.1. However, as discussed in the "Model Verification" section, water may not have been diverted during

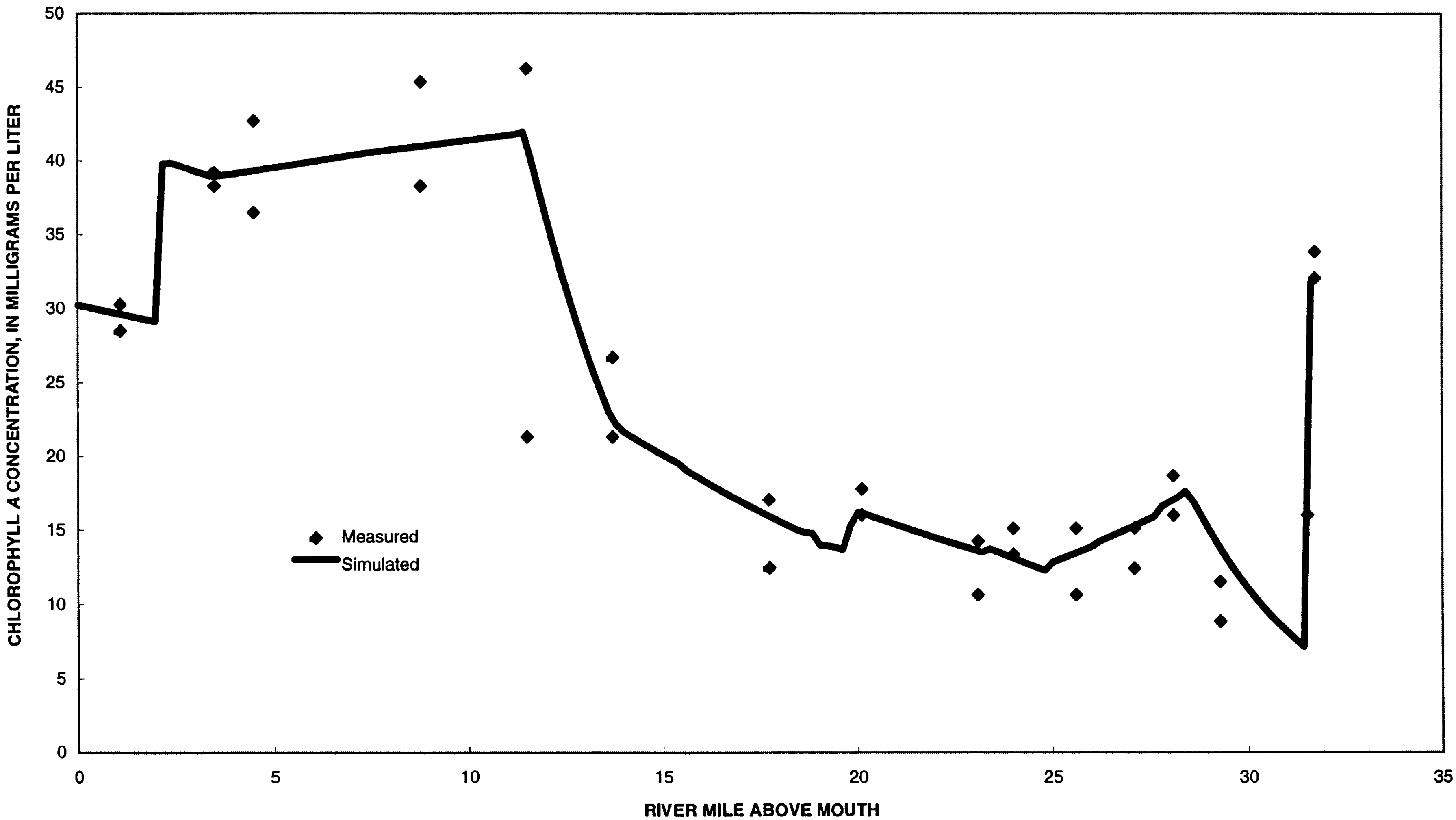

Figure 19. Profiles of simulated and measured chlorophyll *a* concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

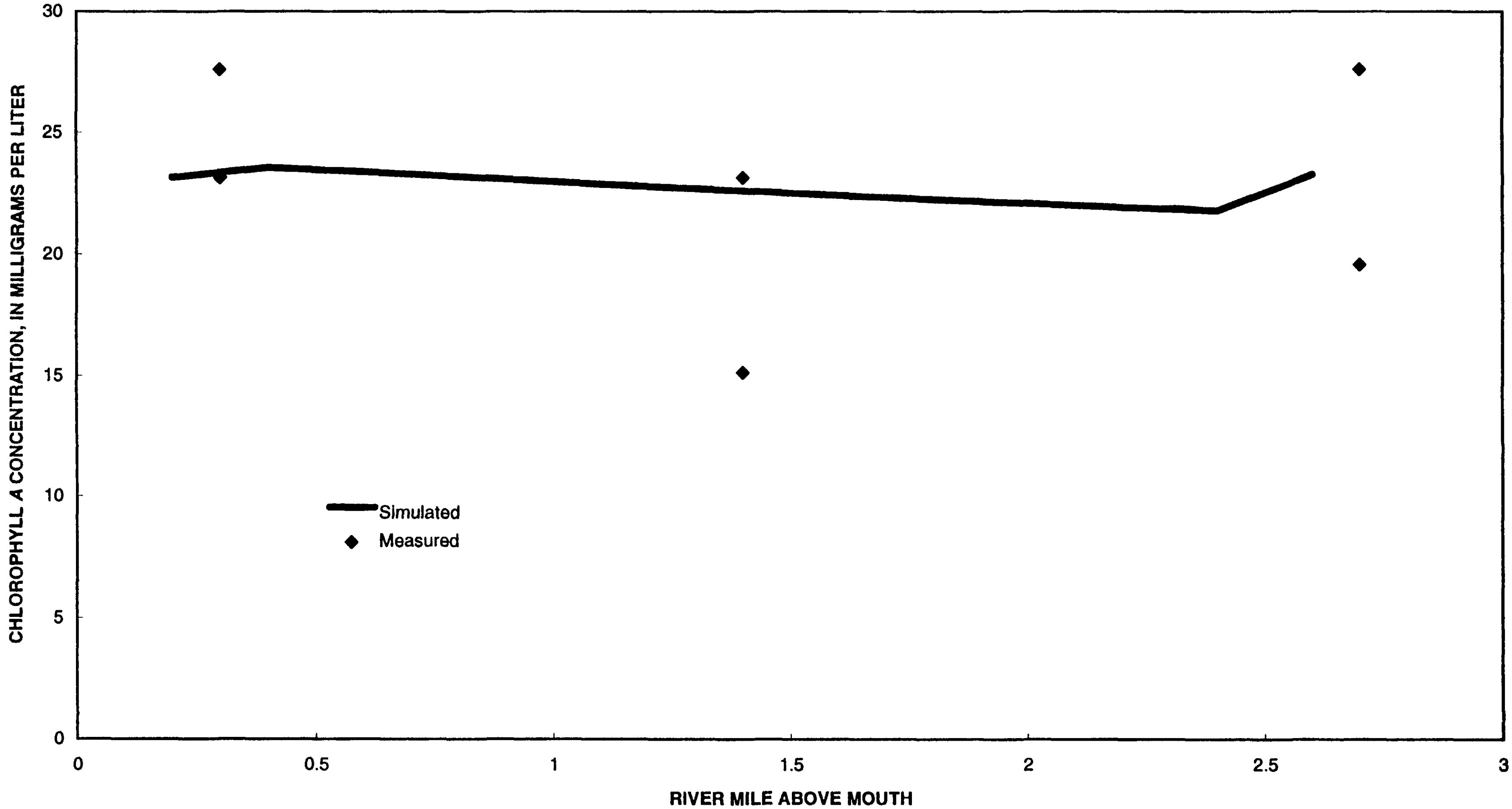

Figure 20. Profiles of simulated and measured chlorophyll *a* concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

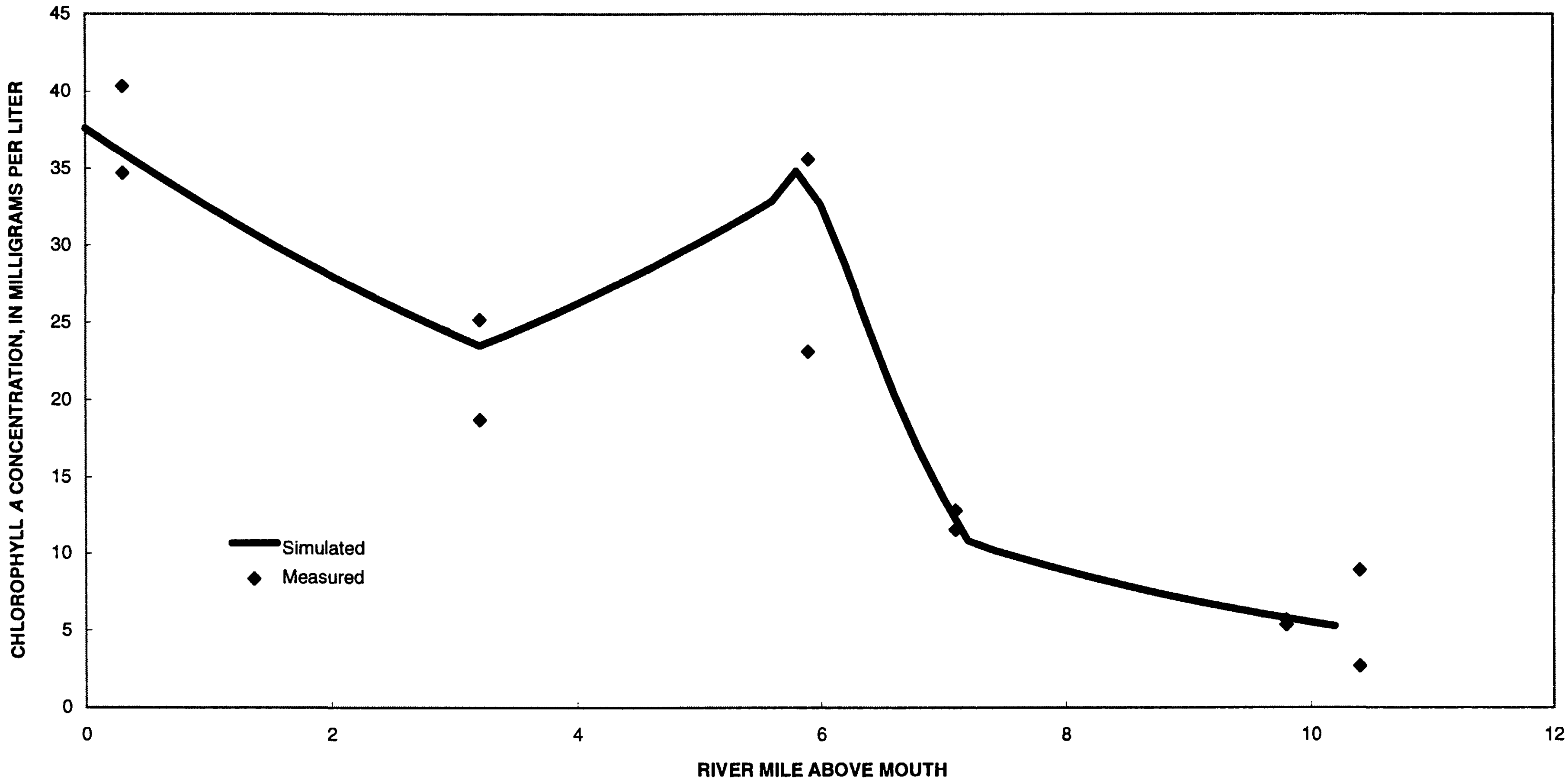

Figure 21. Profiles of simulated and measured chlorophyll *a* concentrations in Addison Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

the June diel survey low-flow period. Thus, the assumption of high chlorophyll *a* concentrations in the diverted water is reasonable.

Dissolved Oxygen--Dissolved oxygen concentrations are affected by many processes including biological oxidation of $CBOD_u$, ammonia, and nitrite; algal photosynthesis and respiration; SOD; and atmospheric reaeration. The rate constants for biological oxidation of $CBOD_u$ were selected on the basis of measured values. The rate constants for biological oxidation of ammonia and nitrite were selected to match measured concentration profiles of these constituents. The oxygen uptake per unit of ammonia oxidation to nitrite (α_5) was set to 3.43 milligrams of oxygen per milligram of ammonia, and the oxygen uptake per unit of nitrite oxidation to nitrate (α_6) was set to 1.14 milligrams of oxygen per milligram of nitrite. These values were selected on the basis of the basic stoichometry of the nitrification process (Viessman and Hammer, 1985, p. 695) and measurements of the processes (Zison and others, 1978). Rates of algal photosynthesis and respiration were set by calibration to the measured concentration profile for chlorophyll *a*. Following the model of the Du Page River (Freeman and others, 1986), the oxygen production per unit of algal growth (α_3) was set to 1.6 milligrams of oxygen per milligram of algae, and the oxygen uptake per unit of algae respired (α_4) was set to 1.95 milligrams of oxygen per milligram of algae. All of the parameter values listed above are within the ranges recommended in Brown and Barnwell (1987, p. 54).

The primary parameters remaining for matching the simulated and measured concentration profiles of dissolved oxygen are the reaeration-rate coefficient (K_2), and SOD rate, which may be set for each reach. Field measurements of K_2 values (Turner, 1996) and SOD rates (Illinois Environmental Protection Agency, 1996b) are available for a limited number of reaches (K_2) and sites (SOD rate) in the Salt Creek watershed. In the calibration of K_2 values and SOD rates, measured values were used in the sampled reaches and hydraulically similar adjacent reaches, wherever possible. Measurements of SOD rates represent values at a single point in a reach, whereas measurements of the K_2 integrate spatial variation of the reaeration process over a reach. Therefore, K_2 values were selected on the basis of measured values, and the SOD rates were varied from the measured values to achieve close simulation of the measured daily-mean DO concentrations.

Reaeration-rate coefficient measurements were made on Salt Creek between river miles 29.3 and 29.9 (reach 1 between Thorndale Road and Devon Avenue) on August 29, 1995; 14.9 and 16.4 (reaches 8 and 9 between 31st Street at Oakbrook and Drury Lane) on August 30, 1995; 0.3 and 1.1 (reach 17 between Circle

Drive and Washington Avenue at Brookfield) on August 31, 1995 (Turner, 1996). Reaeration-rate coefficient measurements were made on Spring Brook between river miles 1.5 and 2.0 (reach 2 between Walnut Avenue and Valley Road) on September 1, 1995 and on Addison Creek between river miles 0.06 and 0.5 (reach 16 between 18th Avenue and 19th Avenue at Broadview) on August 28, 1995 (Turner, 1996). The measured K_2 values were assigned to each of the sampled reaches on Salt Creek. For Addison Creek, a range of K_2 values (1.44-4.06 day^{-1}) was obtained because of a substantial change in flow during the sampling period resulting from storm-sewer flushing. A value within this range, 2.0 day^{-1}, was selected for reach 16. For Spring Brook, the K_2 value measured on September 1, 1995, was 5.23 day^{-1} and the K_2 value measured on October 16, 1995, was 2.23 day^{-1} (Turner, 1996). The K_2 value measured on October 16, 1995, resulted in a more reasonable simulation of DO concentrations in Spring Brook for the August diel survey, and, thus, this value was utilized in the calibrated model.

Initially in the model calibration, K_2 values were set to measured values in the appropriate reaches and the K_2 values for all other reaches were computed on the basis of the O'Connor and Dobbins (1958) equation in QUAL2E. Considering the measured DO concentrations and measured K_2 values, the O'Connor and Dobbins equation yielded reasonable K_2 values for reaches 3-7 on Salt Creek and reach 13 on Addison Creek. The K_2 value for reach 17 on Salt Creek was utilized in the two reaches immediately upstream (11 and 12). The K_2 value for reach 16 of Addison Creek was utilized in the immediate upstream reach (15). Reach 10 on Salt Creek is the reach behind Fullersburg Dam and reach 14 on Addison Creek is the heavily ponded reach. Thus, relatively low (in comparison to the other reaches) K_2 values of 0.2 day^{-1} and 0.6 day^{-1}, respectively, were applied to these reaches to simulate the low reaeration rates resulting from the low-flow velocities in these reaches. The K_2 values applied for each reach are listed in table 4.

A major assumption in the application of the QUAL2E model of the Salt Creek watershed is that the calibrated K_2 values may be directly applied to the June diel-survey conditions and the simulation of selected waste-load scenarios for 7-day, 10-year low-flow conditions in the stream system. Typically, K_2 values are related to hydraulic conditions in the stream, such as flow depth, velocity, and (or) discharge, so that changes in reaeration rates resulting from changing flow conditions may be estimated. The discharge in Salt Creek, Spring Brook, and Addison Creek for (1) the June diel survey (prior to a rainstorm at 1:05 p.m.) and the 7-day, 10-year low flow with the STP's discharging, (2) design-average flows, or (3) average low flow (described in detail in the "Application of Water-Quality Model to Planning Scenarios" section) are not substantially different from the discharge during the August diel survey. For example, if the O'Connor and Dobbins (1958) equation was applied to estimate K_2 throughout the Salt Creek watershed, the changes in the K_2 values relative to the August diel survey for flow conditions 1, 2, and 3 would be from 10 to 15 percent. Thus, the changes in K_2 values likely to result from flow changes are smaller than the estimation error in the typical K_2 estimation equation. Application of the K_2 values from calibration to the August diel-survey data for flow conditions 1, 2, and 3 is reasonable because this results in an error in the K_2 values less than or equal to the error from utilizing a typical K_2 estimation equation. For the case of 7-day, 10-year low stream and STP flow, the discharge and K_2 values in the Salt Creek watershed would be substantially different from the conditions for the August diel survey. However, for consistency and for lack of better information, the same K_2 values were applied for all planning scenarios considered in this report.

From June 20 through July 3, 1995, SOD rates were measured at 10 sites in the Salt Creek watershed (9 sites in the study area). Two SOD measurements were made at each site. The mean value of the measured SOD rate for each site is listed by reach in table 5. Initially, the measured SOD rates were applied in the appropriate reaches and extended to neighboring reaches. The SOD rates were then adjusted so that the simulated DO concentration profile agreed with the measured DO concentration profile. The simulated and measured DO concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 22-24, respectively. The calibrated SOD rates are listed in table 5. The measured SOD rates are values for a single location in a reach. Thus, it is expected that the calibrated values for reaches 1, 6, and 17 on Salt Creek are considerably higher than the measured values. Reach 1 receives wastewater from the largest STP discharging to Salt Creek, reach 6 receives discharge from 4 active CSO's, and reach 17 formerly received discharge from 7 CSO's (the effects of which may not be completely removed because of backwater effects from the Des Plaines River during high-flow periods). Therefore, these reaches could have relatively high SOD rates in comparison to the remainder of Salt Creek considered in this study. The excellent agreement between the measured and simulated profiles of DO concentration (differences less than 5 percent) throughout Salt Creek, Spring Brook, and Addison Creek (figs. 22-24) and the reasonable selection of K_2 values and SOD rates indicate that a good calibration of DO concentrations has been obtained.

Table 5. Calibrated and measured sediment oxygen demand rates for the August 29-30, 1995, and June 27-28, 1995, diel surveys of the Salt Creek watershed in northeastern Illinois

[All values are in grams per square foot per day; --, no data]

Reach (fig. 3)	Calibrated		Measured
	August 1995	June 1995	
	Salt Creek		
1	0.18	0.20	0.115
3	.135	.15	.135
4	.30	.30	--
5	.30	.45	.126
6	.30	.45	--
7	.12	.12	--
8	.12	.12	.157
9	.12	.12	--
10	.04	.04	--
11	.15	.23	.228
12	.15	.15	--
17	.40	.45	.148
	Spring Brook		
2	.148	.148	.148
	Addison Creek		
13	.22	.22	.218
14	.05	.05	--
15	.10	.10	.135
16	.20	.35	--

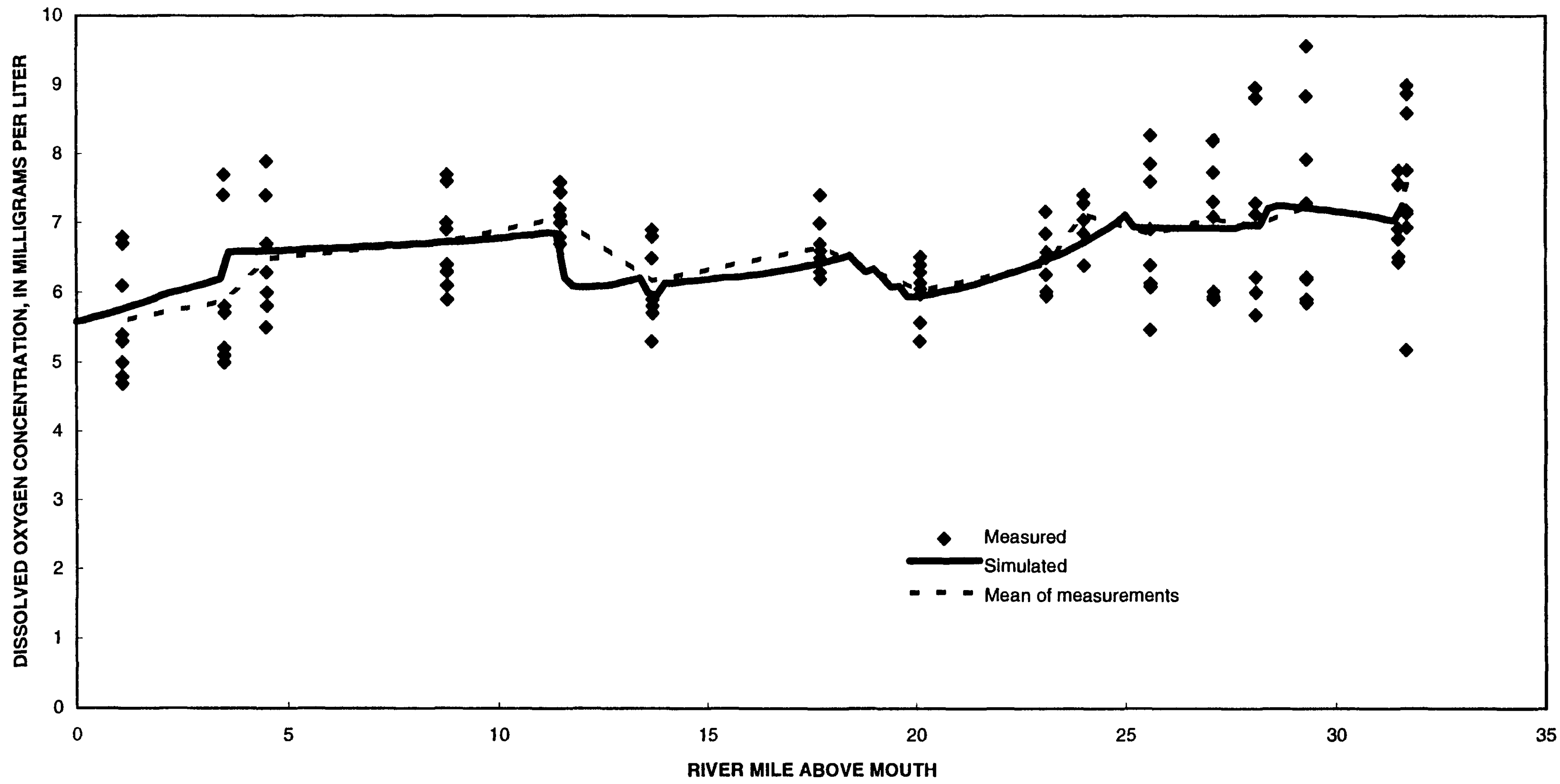

Figure 22. Profiles of simulated and measured dissolved oxygen concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

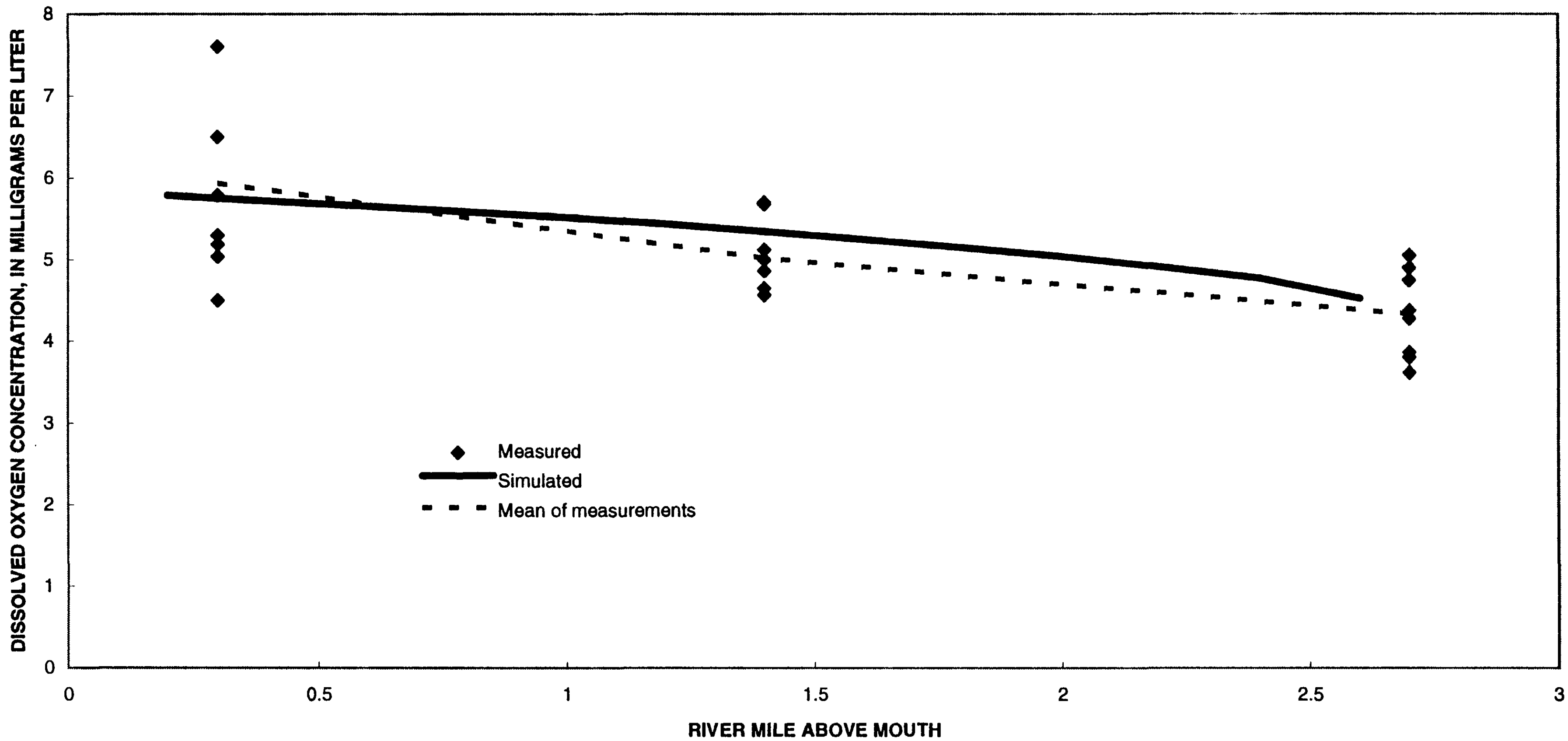

Figure 23. Profiles of simulated and measured dissolved oxygen concentrations in Spring Brook in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

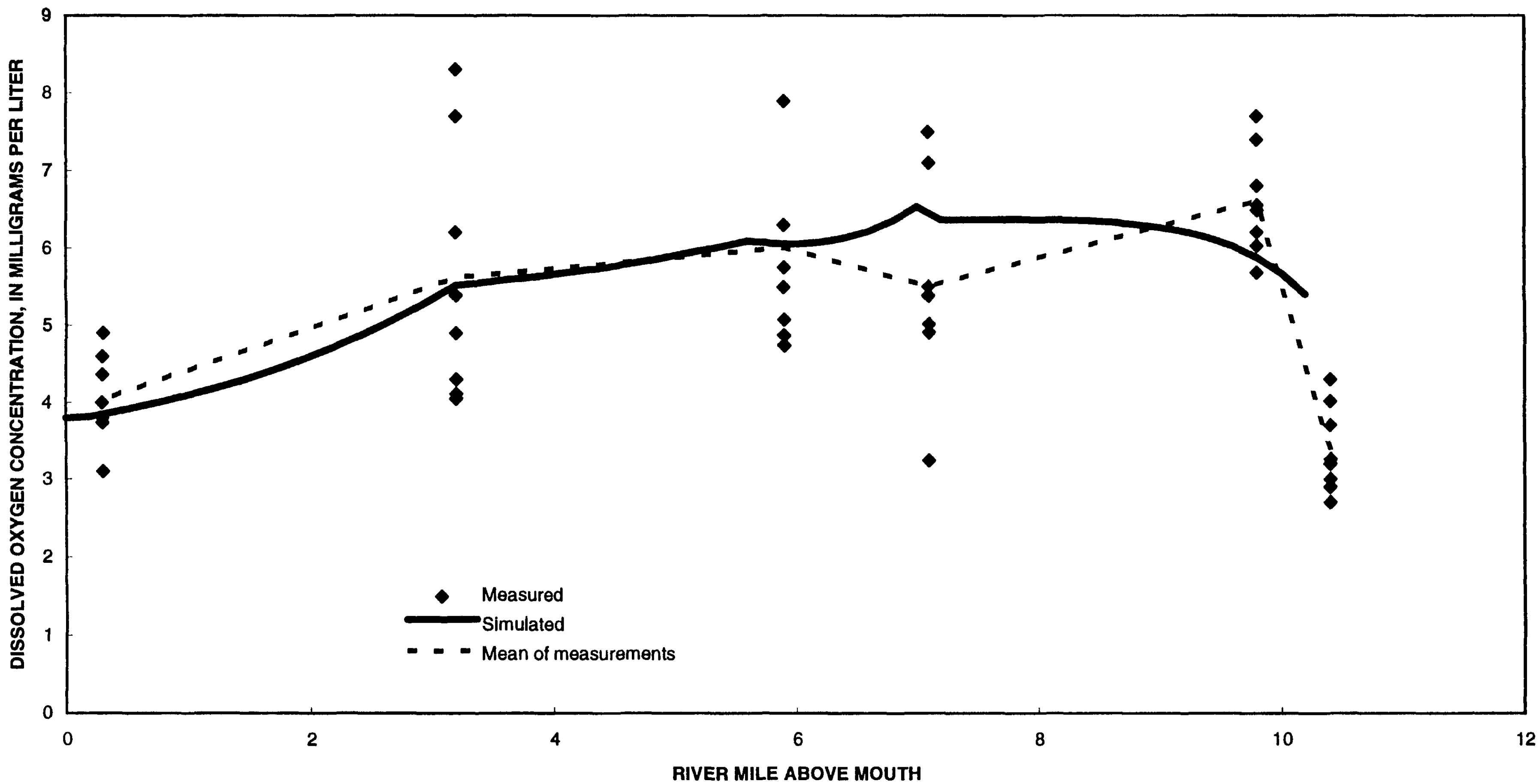

Figure 24. Profiles of simulated and measured dissolved oxygen concentrations in Addison Creek in northeastern Illinois for the calibration to the August 29-30, 1995, diel survey.

Model Verification

Model verification involves subsequent testing of a calibrated model to additional field data, preferably under different external conditions (such as river flow or external load) to further examine model validity (Thomann, 1982). In practical application of QUAL2E to waste-load allocation, the goal of model verification is to demonstrate that the model can be applied to reliably simulate constituent concentrations for a range of water-quality conditions in the stream suitable for evaluating the effects of varying waste-load scenarios. The goal of verification is not to rigorously prove the validity of the approximation of actual physical processes applied in the model, but rather to demonstrate that the model may be applied for water-quality planning. Thomann (1982) recommended that the verification data set should represent water quality under a sufficiently perturbed condition (high flows, decreased temperature, and (or) changed waste input) relative to the calibration data set to provide an adequate test of the model and, thus, illustrate the range of applicability of the model for water-quality planning.

For simulation with a steady-state stream water-quality model, such as QUAL2E, the assumption of steady-state conditions has a great effect on model verification. In the calibrated QUAL2E model obtained for the August 29-30, 1995, diel survey, it is assumed that the constituent concentrations in the downstream reaches are directly related to the wastewater discharges and loads in the upstream reaches. In streams with long traveltimes between upstream and downstream reaches, such as Salt Creek and Addison Creek, the result is that discharges, loads, and meteorological conditions (radiation and daylight hours for algal growth) are assumed to be constant for a period of a week or more. Nearly constant conditions for a week or more are unlikely in nature. Thus, simulation errors resulting from this assumption are incorporated (absorbed) in the parameters determined by calibration. Also, the assumed constant conditions for the calibration period are probably different from those for the verification period. Therefore, the effects of the absorbed errors may be magnified in the comparison of the simulated and measured constituent-concentration profiles for the verification period. As a result, differences between simulated and measured constituent-concentration profiles are likely to be substantial at some locations in the verification of QUAL2E for the Salt Creek watershed.

The verification data set for the QUAL2E model for the Salt Creek watershed represents, in part, an overly perturbed condition for verification. The verification data set is complicated in that from 1:05 to 3:15 p.m. (1305 - 1515) on June 27, 1995, 0.22 in. of rain was measured at the USGS rain gage at Elmhurst. This relatively small rainfall resulted in a near doubling of the discharge at the USGS gages Salt Creek at Elmhurst (river mile 20.3), Salt Creek at Western Springs (river mile 8.8), and Addison Creek at Bellwood (river mile 3.2) during the diel-sampling period as shown in figure 25. The storm runoff resulted in increases in $CBOD_u$ and total ammonia as nitrogen concentrations at many sites and decreases in DO concentrations at nearly all sites. The high $CBOD_u$ and total ammonia as nitrogen loads and possibly low DO concentrations in the runoff reduced in-stream DO concentrations by nearly 50 percent at many sites. Therefore, in the simulation for model verification only, data from the first round (8 a.m. to 2 p.m.) of constituent sampling was utilized. The implications and results of this are discussed below for the specific constituents where appropriate. The mean constituent concentrations in the discharges from the STP's were based on only the first round of samples to be consistent with the stream data. This mean was not substantially different from the mean constituent concentrations determined on the basis of constituent concentrations in the STP discharges for the entire diel-sampling period.

Water Balance--Data presented in tables and charts for computation of daily-mean outflows from each STP for the June diel-sampling period were provided by the treatment-plant operators. Estimates of STP outflows are uncertain because rigorous quality assurance of flow meters is typically not done and interpretation of strip charts is difficult. Therefore, discharges measured by the IEPA and the mean discharges for the diel-survey period prior to rainfall (indicated by the start of hydrograph rise in fig. 25) measured at USGS gages were utilized to determine the appropriate discharge values from the STP's, and incremental inflows where necessary. In the case of Salt Creek and Addison Creek, zero discharge was measured at the upstream ends.

Upstream Boundary of Salt Creek to the Confluence with Spring Brook--The measured discharge value at river mile 29.3 (Thorndale Road) of Salt Creek was 25.5 ft^3/s, whereas the measured discharge upstream from the Egan STP (river mile 31.7) was 0.0 ft^3/s and the daily-mean outflow from the Egan STP (river mile 31.7) was reported at 38.7 ft^3/s. The discharge from the Egan STP to Salt Creek is difficult to estimate because the flows are reported at the outlet of the plant, and from this point the wastewater travels several miles through a pipe to the outfall at Salt Creek. Stage data from the USGS continuous-recording stage gage at Busse Woods Dam (fig. 1) (river mile 31.8) indicate that water was flowing over the dam on the morning of June 27, 1995. Thus, the zero discharge measurement was not representative of the flow in Salt Creek during sampling round 1 (8 a.m. to 2 p.m.) on June 27, 1995. The flow from the Egan STP was set to 25.5 ft^3/s, and the flow upstream from the Egan STP along

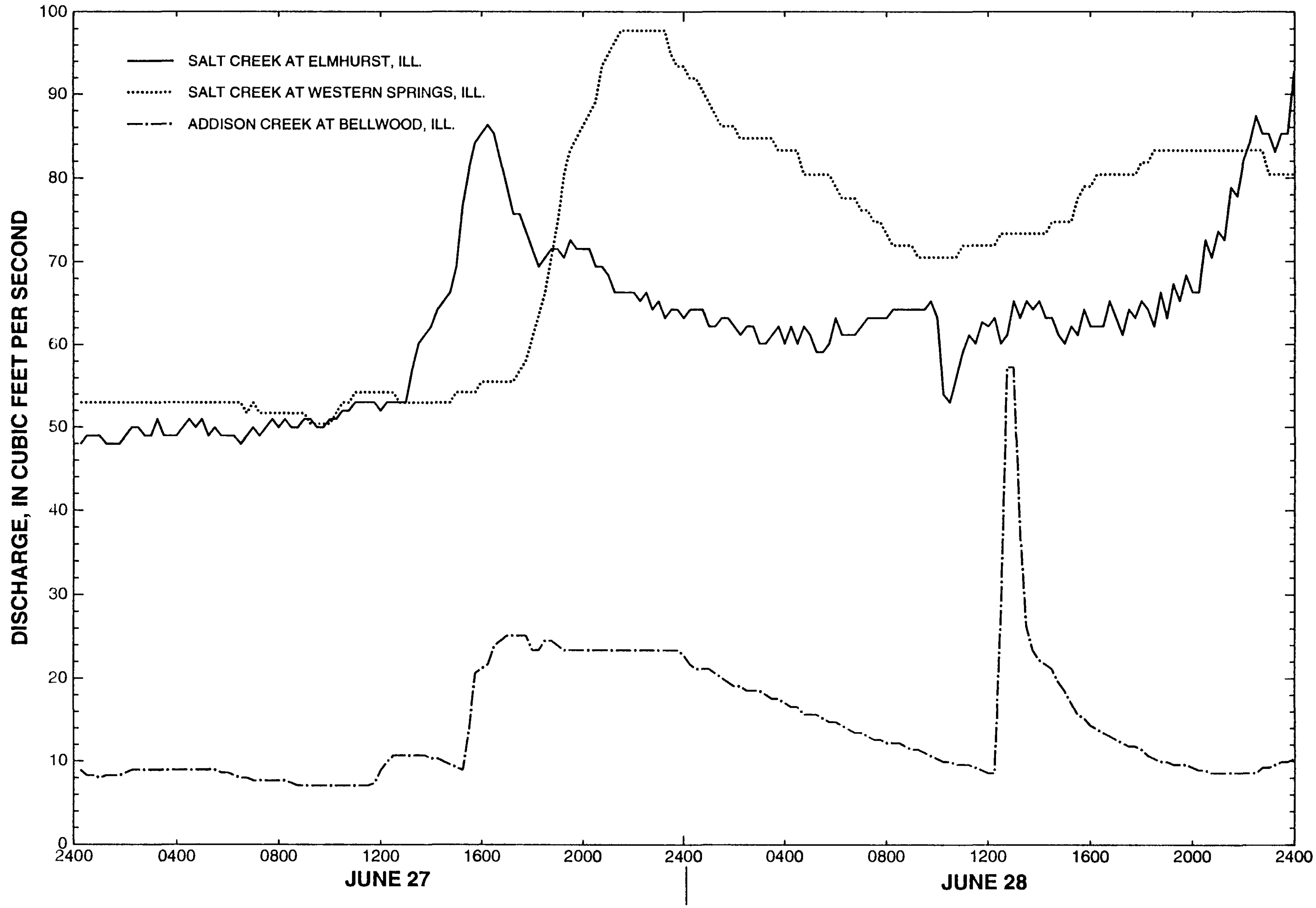

Figure 25. Discharge at the U.S. Geological Survey stream gages in the study area in the Salt Creek watershed in northeastern Illinois for June 27-28, 1995.

Salt Creek was computed as 3.38 ft^3/s to match the specific conductance at river mile 29.3 and the discrepancy in flows at river mile 27.1 (Carter Avenue).

Spring Brook to the Confluence with Salt Creek--The measured discharge value at river mile 0.3 (Prospect Avenue) of Spring Brook was 4.84 ft^3/s, whereas the measured discharge at river mile 2.7 (Rohwling Road) was 3.64 ft^3/s and the daily-mean outflow from the Nordic Park STP (river mile 2.5) was 0.23 ft^3/s. Thus, an incremental inflow of 0.97 ft^3/s was applied along Spring Brook. The constituent concentrations applied to this incremental inflow were the values for Spring Brook upstream from the Roselle STP at river mile 5.7.

Salt Creek from the Confluence with Spring Brook to the Confluence with Addison Creek--The measured mean discharge for the June diel-survey period prior to rainfall at the USGS gage at river mile 20.3 (State Highway 83) of Salt Creek was 49.59 ft^3/s, whereas the flow in Salt Creek upstream from the confluence with Spring Brook (river mile 28.2) was 28.88 ft^3/s and in Spring Brook at its outlet was 4.84 ft^3/s. Therefore, 15.87 ft^3/s entered Salt Creek from river mile 28.2 to 20.3 primarily from the five STP's in this region (Itasca, Wood Dale North, Wood Dale South, Addison North, and Addison South). The sum of the reported daily-mean outflows from these STP's was 14.42 ft^3/s. Thus, a shortfall of 1.45 ft^3/s resulted in this stretch of Salt Creek. Substantial increases in total ammonia as nitrogen and $CBOD_u$ concentrations in the vicinity of the CSO's (at river mile 20.4) were measured. The increase in measured total ammonia as nitrogen and $CBOD_u$ concentrations could result from CSO leakage because of light rainfall the previous night (0.03 in. were measured at the USGS rain gage at Elmhurst). On July 19, 1995, the CSO at St. Charles Road (river mile 20.4) was observed to be discharging during a dry-weather period and a sample of the CSO flow was collected and analyzed. Utilizing the total ammonia as nitrogen and $CBOD_u$ concentrations from the CSO sample and a simple mass balance of total ammonia as nitrogen and $CBOD_u$ concentrations upstream and downstream from St. Charles Road, a CSO discharge of 0.51 ft^3/s was estimated. The CSO discharge at St. Charles Road was added to the QUAL2E model as a point source for the simulation of the June 27-28, 1995, diel survey. No incremental flows were added between river miles 20.3 and 28.2.

The measured mean discharge during the June diel-survey period prior to rainfall at the USGS gage at river mile 8.8 (Wolf Road) of Salt Creek was 52.78 ft^3/s, whereas the flow in Salt Creek at the USGS gage at river mile 20.3 (State Highway 83) was 49.59 ft^3/s and the daily-mean outflows from the Salt Creek Sanitary District (river mile 20) and Elmhurst (river mile 19.7) STP's were reported as 3.09 and 8.92 ft^3/s, respectively. An 8.82 ft^3/s oversupply results in Salt Creek between river miles

8.8 and 20.3. The flow from the Salt Creek Sanitary District and Elmhurst STP's must travel more than 10 mi to reach the USGS gage at river mile 8.8. Thus, part of the increase in streamflow recorded at the USGS gage at river mile 8.8 could result from the 8.82 ft^3/s oversupply of flow, but the storm runoff obscured the increase in discharge at river mile 8.8 resulting from the higher wastewater flows. Therefore, the full daily-mean flows from the Salt Creek Sanitary District and Elmhurst STP's were utilized in the simulation of the June diel-survey period. Sugar Creek and Ginger Creek were assumed to have zero flow during the June 27-28, 1995, diel survey because of the small difference in measured discharge between river miles 20.3 and 8.8.

Addison Creek to the Confluence with Salt Creek--The measured mean discharge for the June diel-survey period prior to rainfall at the USGS gage at river mile 3.2 (Washington Boulevard) of Addison Creek was 8.32 ft^3/s, whereas the daily-mean outflow from the Bensenville South STP was reported as 6.77 ft^3/s. Thus, an incremental inflow of 1.55 ft^3/s was allocated to reaches 13-15 along Addison Creek (fig. 3) in proportion to the reach length. The constituent concentrations applied to this incremental inflow were the values for Addison Creek upstream from Bensenville South STP at river mile 10.4 because these values represent ambient water quality in Addison Creek not affected by STP flow.

Salt Creek from the Confluence with Addison Creek to the Confluence with Des Plaines River--The measured discharge value at river mile 1.1 (Washington Avenue-Brookfield) of Salt Creek was 61.1 ft^3/s, whereas on the basis of the USGS gages, the measured flow in Salt Creek upstream from the confluence with Addison Creek (river mile 3.5) was 52.78 ft^3/s and in Addison Creek at its outlet was 8.32 ft^3/s. Therefore, the sum of the measured discharge upstream from the confluence of Salt Creek and Addison Creek equaled the discharge measured at river mile 1.1, and the diversion at river mile 2.2 was not operating. The simulated discharge in Salt Creek upstream from the confluence with Addison Creek (river mile 3.5) was 60.66 ft^3/s and in Addison Creek at its outlet was 8.32 ft^3/s. Thus, the sum of the simulated discharge in the final reach of Salt Creek is 68.98 ft^3/s. An actual discharge of 68.98 ft^3/s would probably result in about 1 ft^3/s being diverted to the Des Plaines River. This diversion was not included in the simulation of the June 27-28, 1995, diel survey. These water-balance computations are summarized in table 6.

Table 6. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the June 27-28, 1995, diel survey of the Salt Creek watershed in northeastern Illinois

[All discharges are in cubic feet per second; a negative discrepancy indicates the sum of estimated upstream discharges is greater than the measured discharge at this site; "measured" refers to discharge measured by the Illinois Environmental Protection Agency or at a U.S. Geological Survey stream gage; "estimated" refers to discharge estimated from sewage-treatment plant data; "adjusted" refers to discharge adjusted to achieve a water balance relative to the measured discharges and measured specific conductance; larger discrepancies are allowed in this water balance because of the effect of storm runoff and traveltime between sites on the water-balance evaluation; STP, sewage-treatment plant; USGS, U.S. Geological Survey; --, not applicable]

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Upstream Boundary of Salt Creek to the Confluence with Spring Brook				
Salt Creek headwater	31.7	0.00	--	3.38
Egan STP	31.7	--	38.7	25.5
Sum upstream from Thorndale Road	29.3	--	38.7	28.88
Thorndale Road	29.3	25.5	--	--
Discrepancy at Thorndale Road	--	--	-13.2	-3.38
Spring Brook to the Confluence with Salt Creek				
Rohlwing Road (Spring Brook headwater)	2.7	3.64	--	3.64
Nordic Park STP	2.5	--	0.23	0.23
Incremental flow	2.7-0	--	--	0.97
Sum upstream from Prospect Avenue	0.3	--	3.87	4.84
Prospect Avenue	0.3	4.84	--	--

Table 6. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the June 27-28, 1995, diel survey of the Salt Creek watershed in northeastern Illinois--Continued

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Discrepancy at Prospect Avenue	--	--	0.97	0.00
Salt Creek from the Confluence with Spring Brook to the Confluence with Addison Creek				
Salt Creek at the Confluence with Spring Brook	28.2	--	--	28.88
Spring Brook at the Confluence with Salt Creek	0.0	--	--	4.84
Itasca STP	28.2	--	3.40	3.40
Wood Dale North STP	27.7	--	1.96	1.96
Sum upstream from Carter Avenue	27.1	--	39.08	39.08
Carter Avenue	27.1	39.08	--	--
Discrepancy at Carter Avenue	--	--	0.00	0.00
Wood Dale South STP	26.0	--	0.33	0.33
Addison North STP	25.0	--	5.10	5.10
Addison South STP	23.3	--	3.63	3.63
St. Charles Road combined-sewer overflow	20.4	--	--	0.51
Sum upstream from State Highway 83	20.3	--	48.14	48.65
State Highway 83 (USGS gage, Salt Creek at Elmhurst)	20.3	49.59	--	--
Discrepancy at State Highway 83	--	--	1.45	0.94

Table 6. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the June 27-28, 1995, diel survey of the Salt Creek watershed in northeastern Illinois--Continued

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Salt Creek Sanitary District STP	20.0	--	3.09	3.09
Elmhurst STP	19.7	--	8.92	8.92
Sum upstream from Wolf Road	8.8	--	60.15	60.66
Wolf Road (USGS gage, Salt Creek at Western Springs)	8.8	52.78	--	--
Discrepancy at Wolf Road	--	--	-7.37	-7.88
Addison Creek to the Confluence with Salt Creek				
Addison Creek headwater	10.4	0.00	--	--
Bensenville South STP	10.3	--	6.77	6.77
Incremental flow	10.3-3.2	--	--	1.55
Sum upstream from Washington Boulevard	3.2	--	6.77	8.32
Washington Boulevard (USGS gage, Addison Creek at Bellwood)	3.2	8.32	--	--
Discrepancy at Washington Boulevard	--	--	1.55	0.00
Salt Creek from the Confluence with Addison Creek to the Confluence with the Des Plaines River				
Salt Creek at the Confluence with Addison Creek	3.6	--	--	60.66

Table 6. Measured, estimated, and adjusted headwater and sewage-treatment plant flows for the water balance for the June 27-28, 1995, diel survey of the Salt Creek watershed in northeastern Illinois--Continued

Site description	River mile	Discharge		
		Measured	Estimated	Adjusted
Addison Creek at the Confluence with Salt Creek	0.0	--	--	8.32
Diversion to the Des Plaines River	2.2	--	--	0.00
Sum upstream from Washington Avenue-Brookfield	1.1	--	68.98	68.98
Washington Avenue-Brookfield	1.1	61.2	--	--
Discrepancy at Washington Avenue-Brookfield	--	--	-7.78	-7.78

Ultimate Carbonaceous Biochemical Oxygen Demand--The simulated and measured $CBOD_u$ concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 26-28, respectively. The agreement between the simulated and measured concentrations is good (within 5 percent at nearly all sampling sites) throughout all streams. However, the simulated values reflect modifications to the calibrated parameter set for the August 29-30, 1995, diel survey on Addison Creek and Salt Creek.

For Salt Creek, the modification involved utilizing high $CBOD_u$ decay rates in the immediate vicinity of the CSO discharge. The K_1 values measured in the Salt Creek watershed and utilized in the calibration to the August 29-30, 1995, diel-survey data reflect the decay of $CBOD_u$, which has undergone considerable biological activity (consumption) in the STP's and is to some extent biologically inert. The $CBOD_u$ leaking from the CSO's is raw, untreated waste with high biological decay rates (consumption rates). Therefore, a K_1 value of 1.6 day^{-1} was applied in the immediate vicinity of the CSO's (reaches 6 and 7, river miles 18.6 - 20.4). This K_1 value was determined by calibration, and it is within the range of values (0.5-2.5 day^{-1}) for streams with moderate velocities reported by Chadderton and

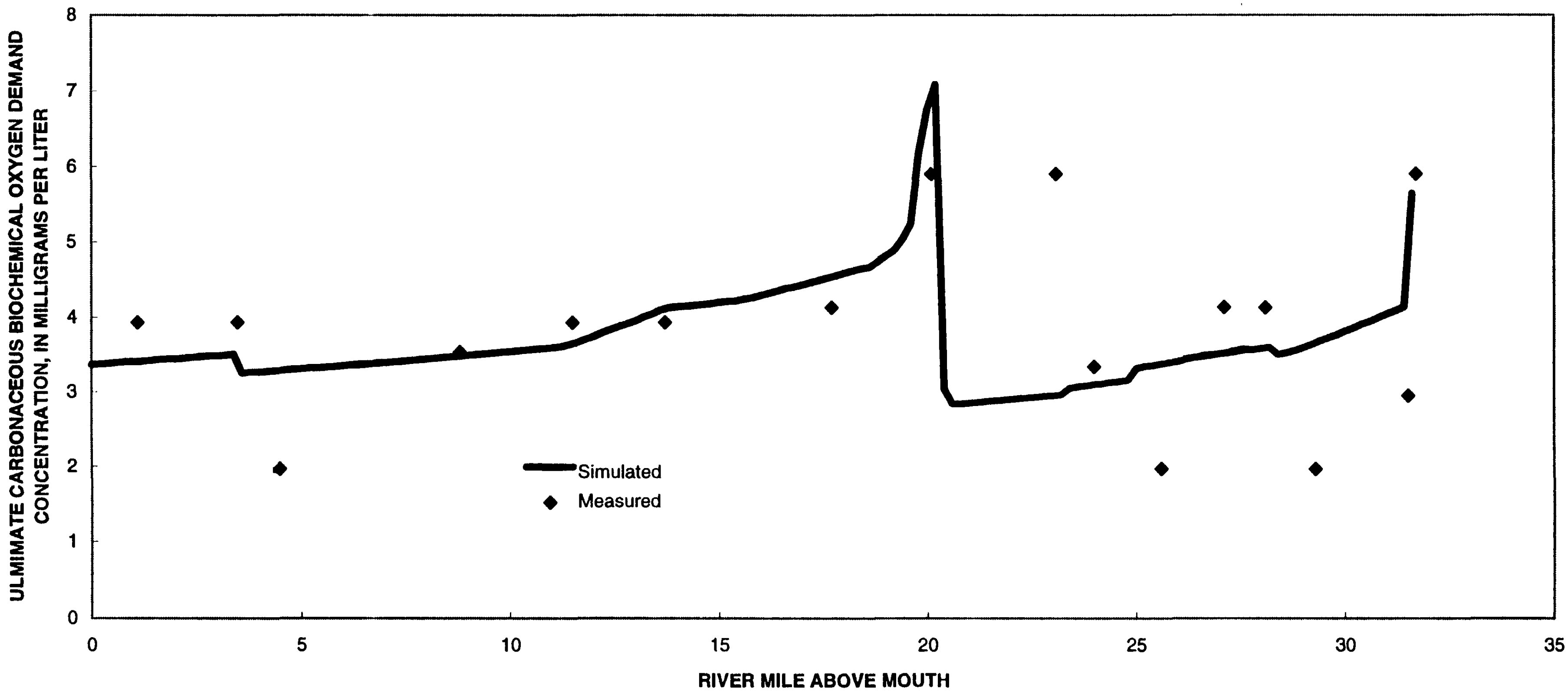

Figure 26. Profiles of simulated and measured ultimate carbonaceous biochemical oxygen demand concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

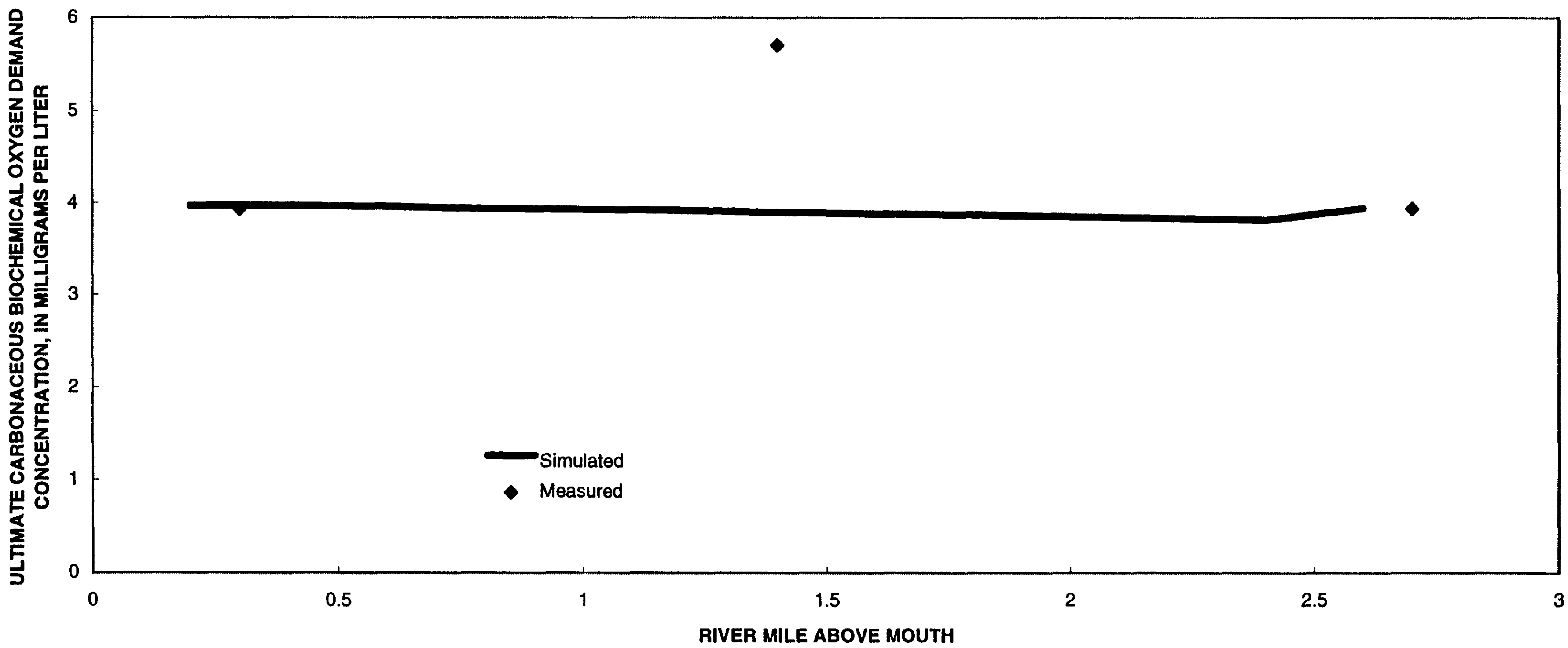

Figure 27. Profiles of simulated and measured ultimate carbonaceous biochemical oxygen demand concentrations in Spring Brook in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

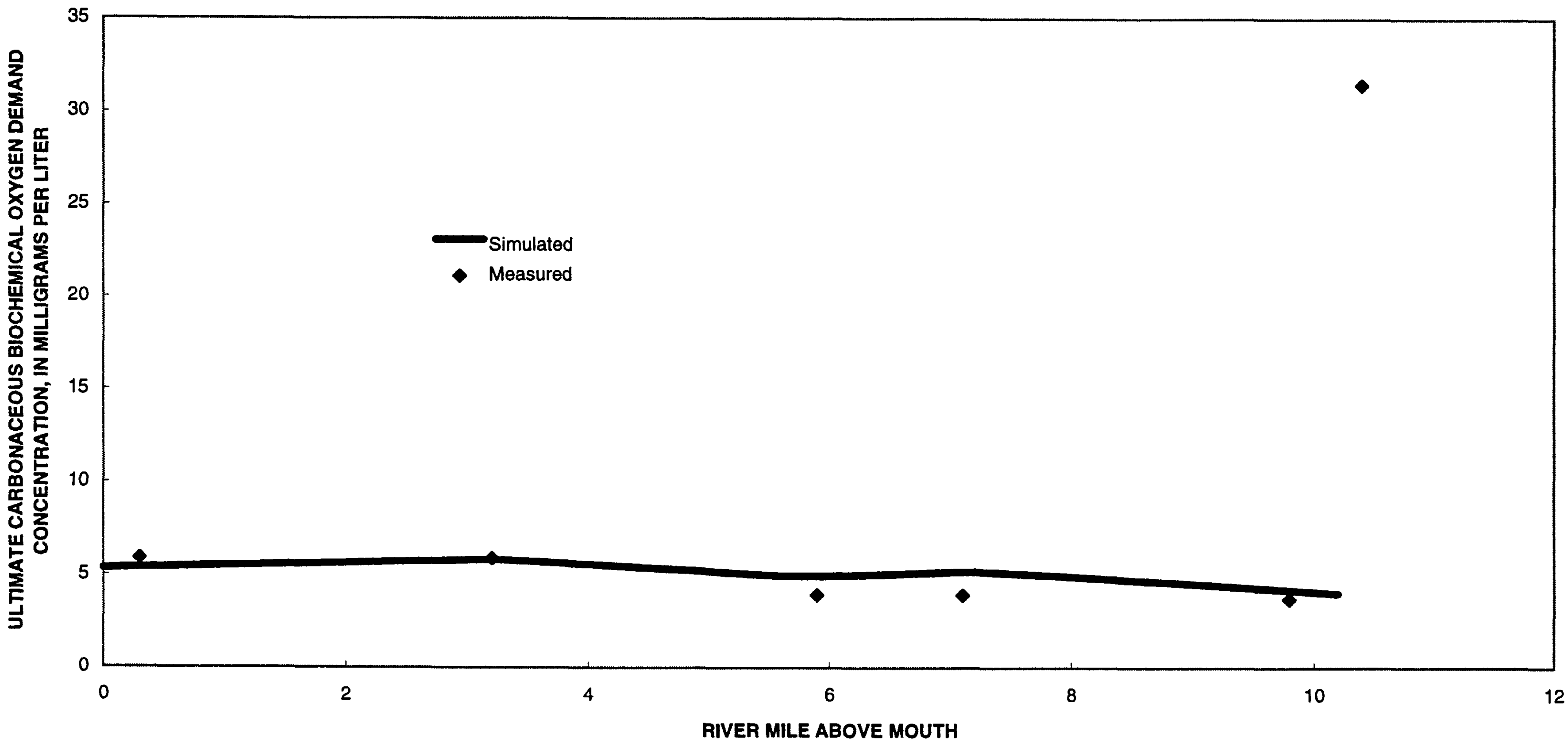

Figure 28. Profiles of simulated and measured ultimate carbonaceous biochemical oxygen demand concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

others (1982). The K_1 values applied in the calibration to the August 29-30, 1995, diel-survey data were utilized for all other reaches on the Salt Creek watershed.

For Addison Creek, no substantial increase in $CBOD_u$ and total ammonia as nitrogen concentrations were measured between river miles 7.1 and 9.8 (West Palmer Avenue and Diana Court) during the June 27-28, 1995, diel survey. Therefore, the line sources of $CBOD_u$ and total ammonia as nitrogen were deleted from the parameter set for the verification to the June 27-28, 1995, diel-survey data. The results illustrated in figure 28 indicate that this was an appropriate modification.

The results illustrated in figures 26-28 represent a verification of the calibration to the August 29-30, 1995, diel-survey data, which has been fine tuned to reflect physical considerations for the June 27-28, 1995, diel survey. Thus, the results of the simulations for $CBOD_u$ concentrations for the June 27-28, 1995, diel survey increased confidence in the utility of the model for water-quality planning in the Salt Creek watershed.

Organic Nitrogen--The simulated and measured organic nitrogen concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 29-31, respectively. Other than a small oversimulation of the organic nitrogen concentration around river miles 3.2, 4.5, 28.1, and 29.3 on Salt Creek and river mile 0.3 on Addison Creek, the agreement between the measured and simulated values is within 10 percent at almost all sites in the Salt Creek watershed. Thus, the results of the simulations for organic nitrogen concentrations for the June 27-28, 1995, diel survey increased confidence in the utility of the model for water-quality planning in the Salt Creek watershed.

Total Ammonia as Nitrogen--The simulated and measured total ammonia as nitrogen concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 32-34, respectively. The verification for simulation of total ammonia as nitrogen concentrations in Salt Creek and Spring Brook is poor (errors greater than 20 percent at many sites). Whereas for Addison Creek, the results of the simulations for total ammonia as nitrogen concentrations for the June 27-28, 1995, diel survey increased confidence in the utility of the model for water-quality planning. However, the simulation for Addison Creek includes a modification to the calibrated parameter set for the August 29-30, 1995, diel survey.

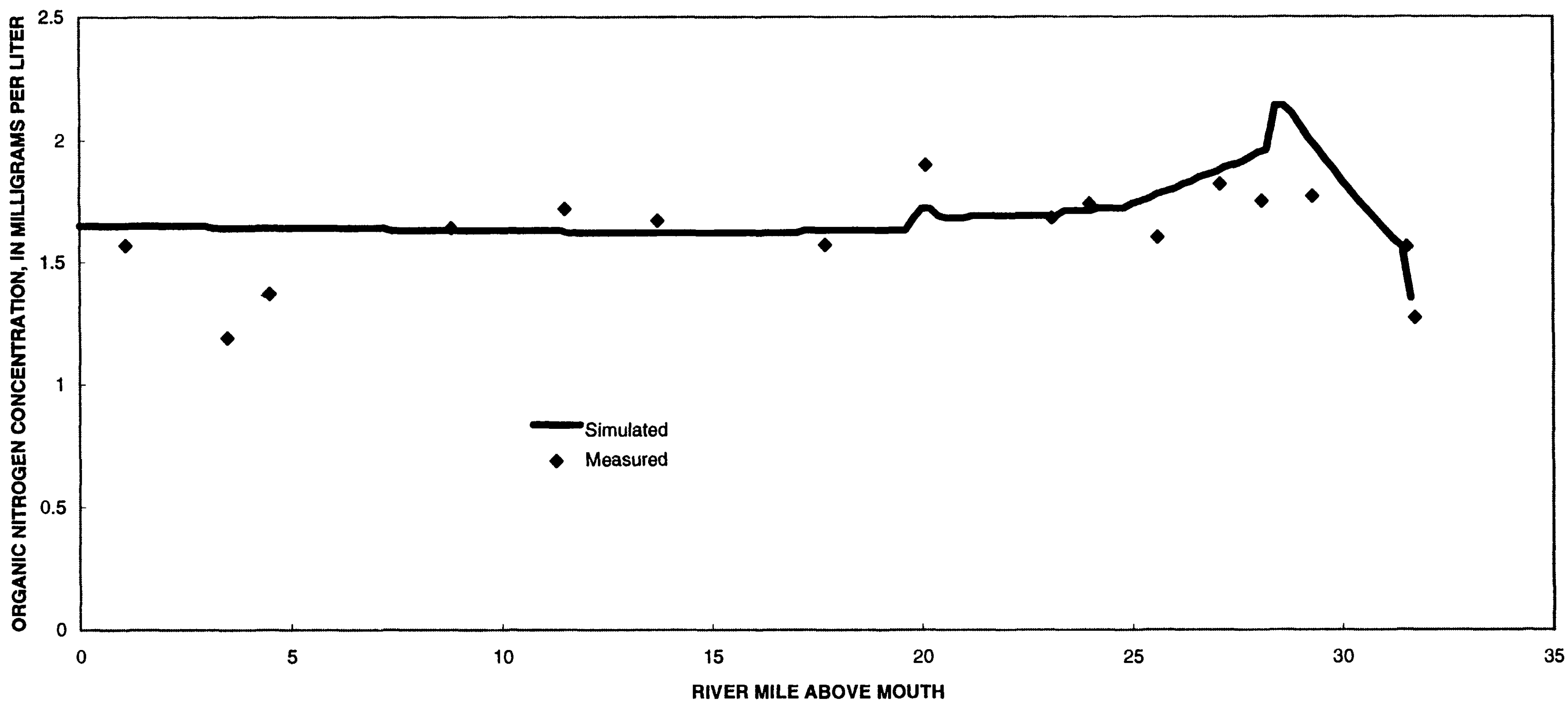

Figure 29. Profiles of simulated and measured organic nitrogen concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

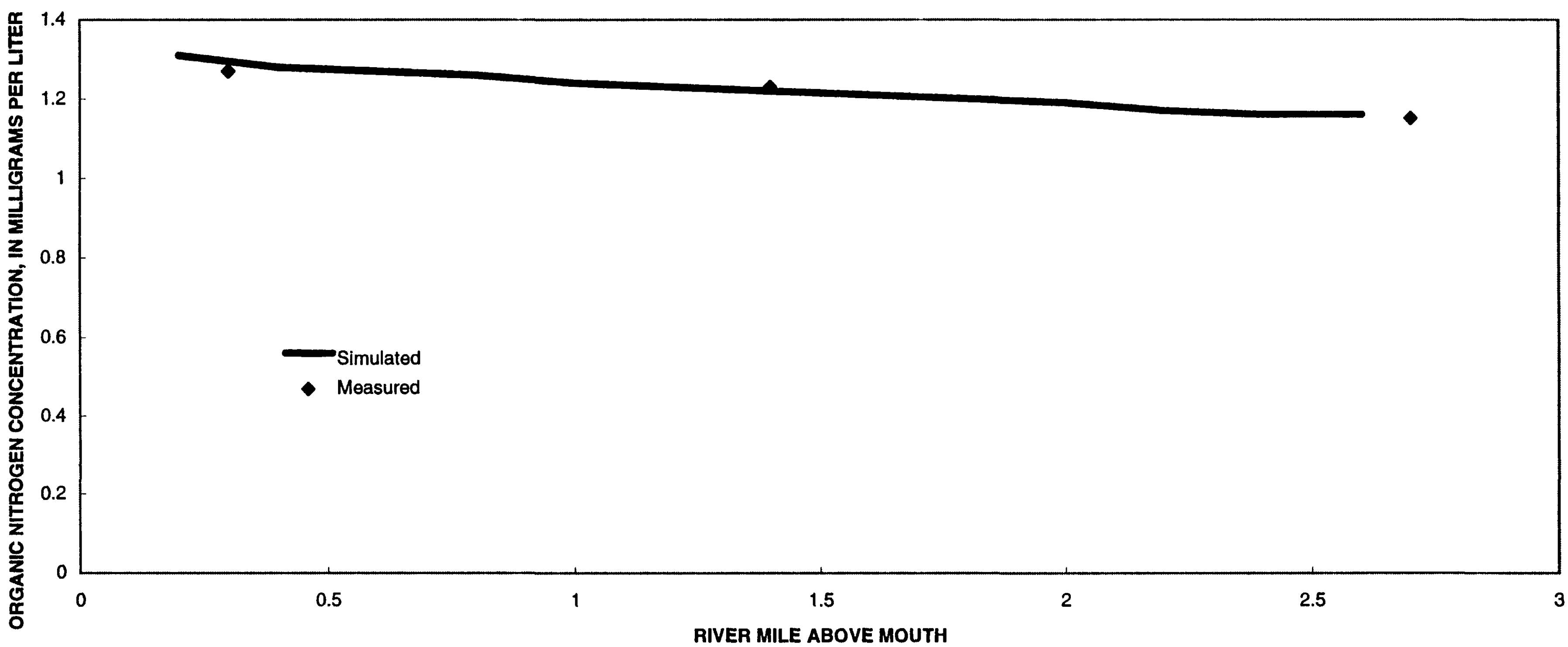

Figure 30. Profiles of simulated and measured organic nitrogen concentrations in Spring Brook in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

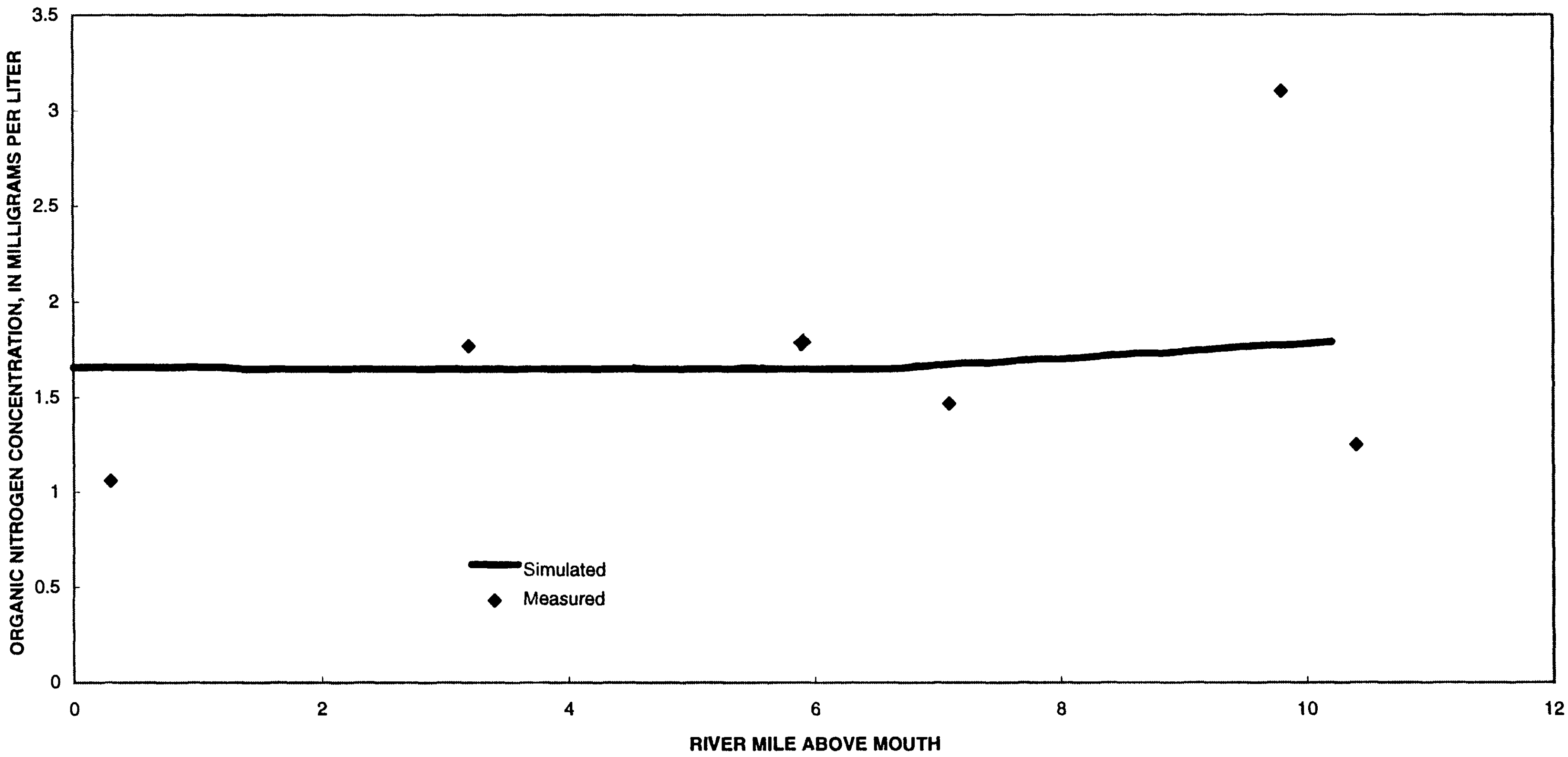

Figure 31. Profiles of simulated and measured organic nitrogen concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

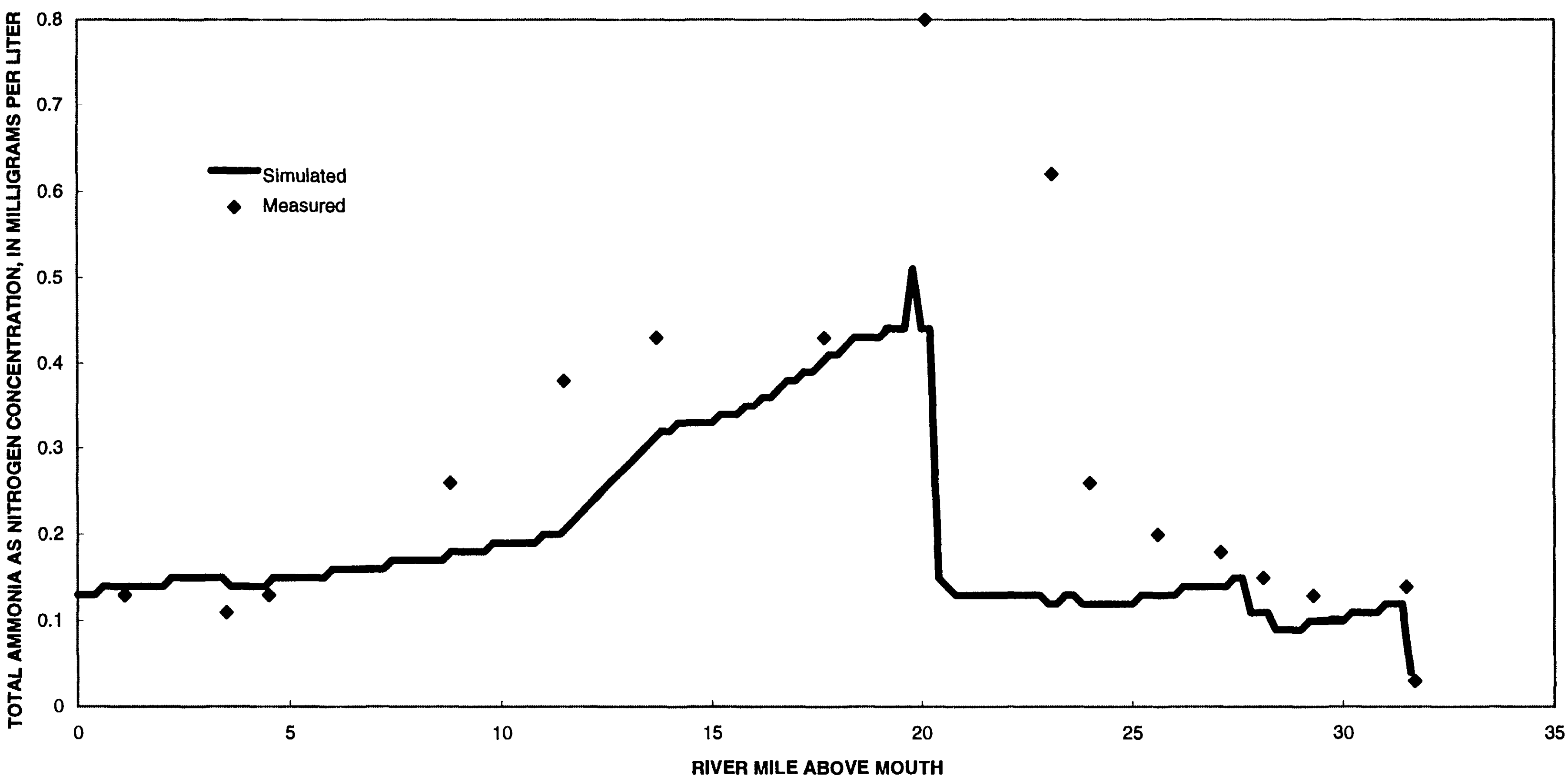

Figure 32. Profiles of simulated and measured total ammonia as nitrogen concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

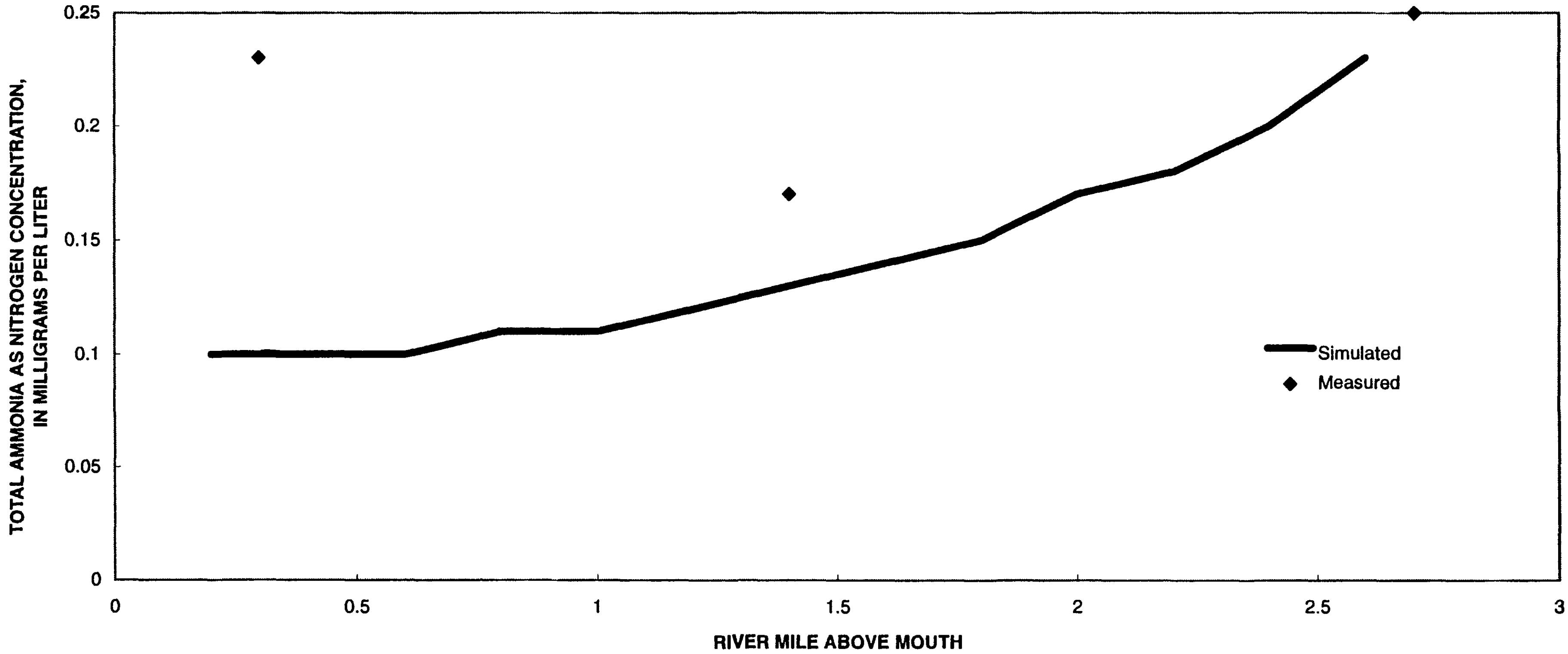

Figure 33. Profiles of simulated and measured total ammonia as nitrogen concentrations in Spring Brook in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

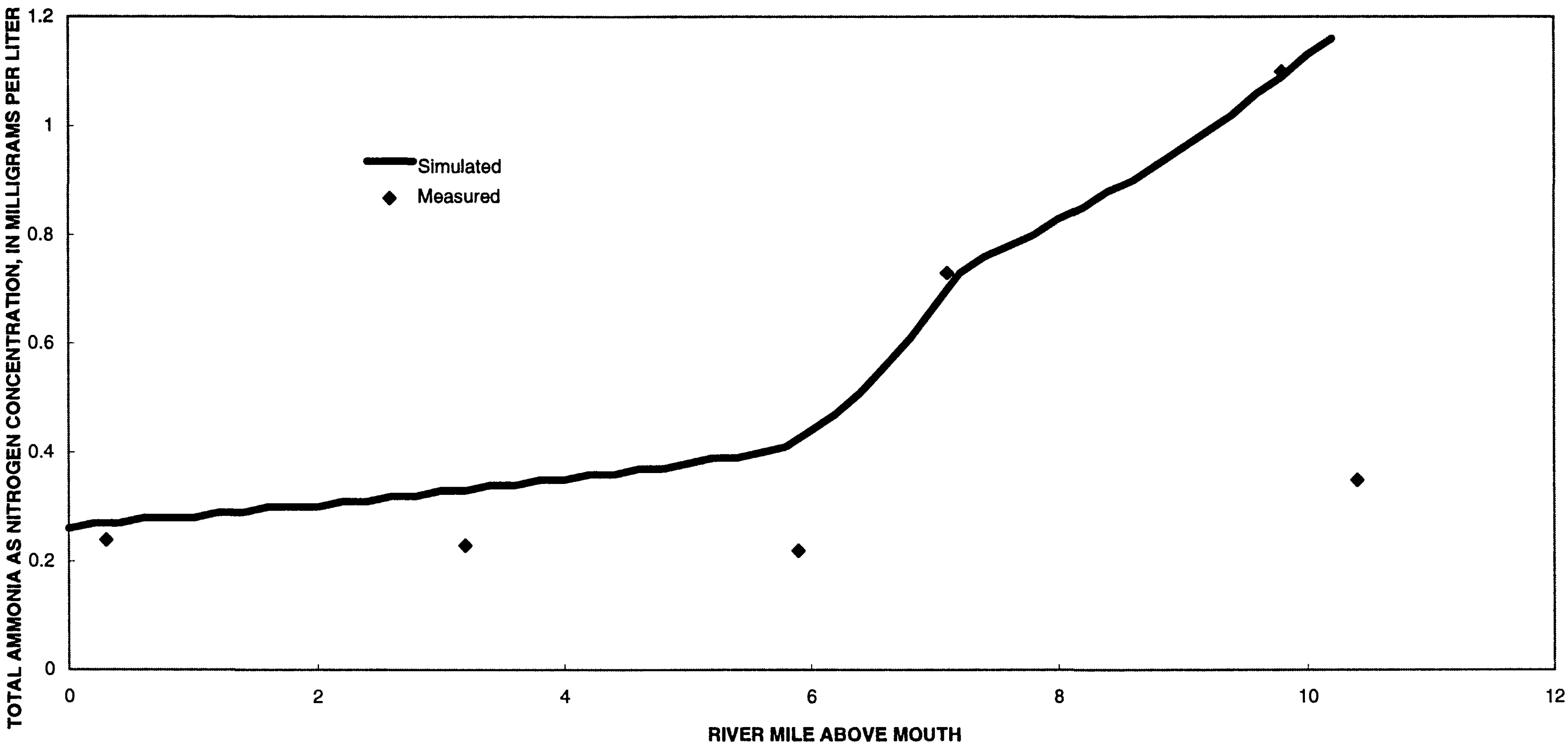

Figure 34. Profiles of simulated and measured total ammonia as nitrogen concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

The measured total ammonia as nitrogen concentrations in Salt Creek are substantially undersimulated from river mile 8.8 to 27.1 (Wolf Road to Carter Avenue). Thus, the strength of the benthic line source of total ammonia as nitrogen utilized in the calibration to the August 29-30, 1995, diel survey seems to be underestimated for the June 27-28, 1995, diel survey. The verification of simulation of total ammonia as nitrogen concentrations for Salt Creek is considered unacceptable and modifications of the calibrated parameters are needed to adequately simulate total ammonia as nitrogen concentrations for the June 27-28, 1995, diel survey as discussed in the "Parameter Adjustments for the June 1995, Diel Survey" section.

The measured total ammonia as nitrogen concentrations are undersimulated at downstream sites on Spring Brook. The rise in total ammonia as nitrogen concentration between river mile 1.4 and 0.3 (Maple and Line Roads and Prospect Avenue) of Spring Brook indicates that the measured concentrations at these locations might be affected by runoff from the rainfall on the previous night. Thus, the results of the simulations for total ammonia as nitrogen concentrations for the June 27-28, 1995, diel survey increased confidence in the utility of the model for water-quality planning in Spring Brook.

The simulated values (fig. 34) reflect modifications to the calibrated parameter set for the August 29-30, 1995, diel survey on Addison Creek. No substantial increase in $CBOD_u$ and total ammonia as nitrogen concentrations were measured between river miles 7.1 and 9.8 (West Palmer Avenue and Diana Court) during the June 27-28, 1995, diel survey for Addison Creek. Therefore, the line sources of $CBOD_u$ and total ammonia as nitrogen were deleted from the parameter set for the verification to the June 27-28, 1995, diel-survey data. The results illustrated in figure 34 indicate that this was a reasonable modification.

Nitrite plus Nitrate as Nitrogen--The simulated and measured nitrite plus nitrate as nitrogen concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 35-37, respectively. Nitrite plus nitrate as nitrogen concentrations are oversimulated by about 15 percent throughout Salt Creek. Nitrite plus nitrate as nitrogen concentrations are substantially oversimulated at river mile 0.3 (Prospect Avenue) of Spring Brook. This oversimulation results in part because of dispersion of the high nitrite plus nitrate as nitrogen concentrations discharged by the Itasca STP, which is input to the last computational element of Spring Brook. Nitrite plus nitrate as nitrogen concentrations are greatly oversimulated throughout Addison Creek (fig. 37). The verification results on Addison Creek are identical to the calibration results in that the measured decreases in nitrite plus nitrate as nitrogen concentrations because of the effects of long traveltimes and nonalgal aquatic vegetation in the ponded reaches upstream from

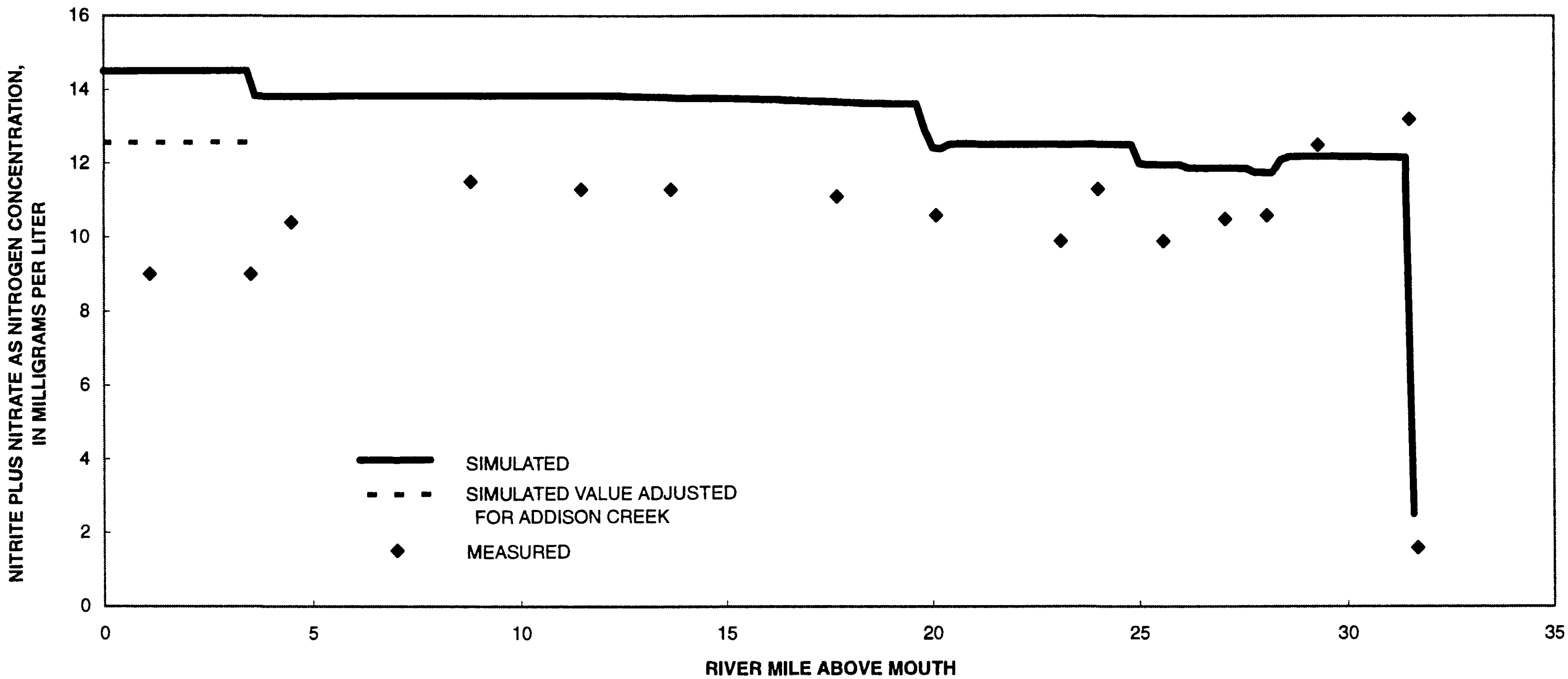

Figure 35. Profiles of simulated and measured nitrite plus nitrate as nitrogen concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

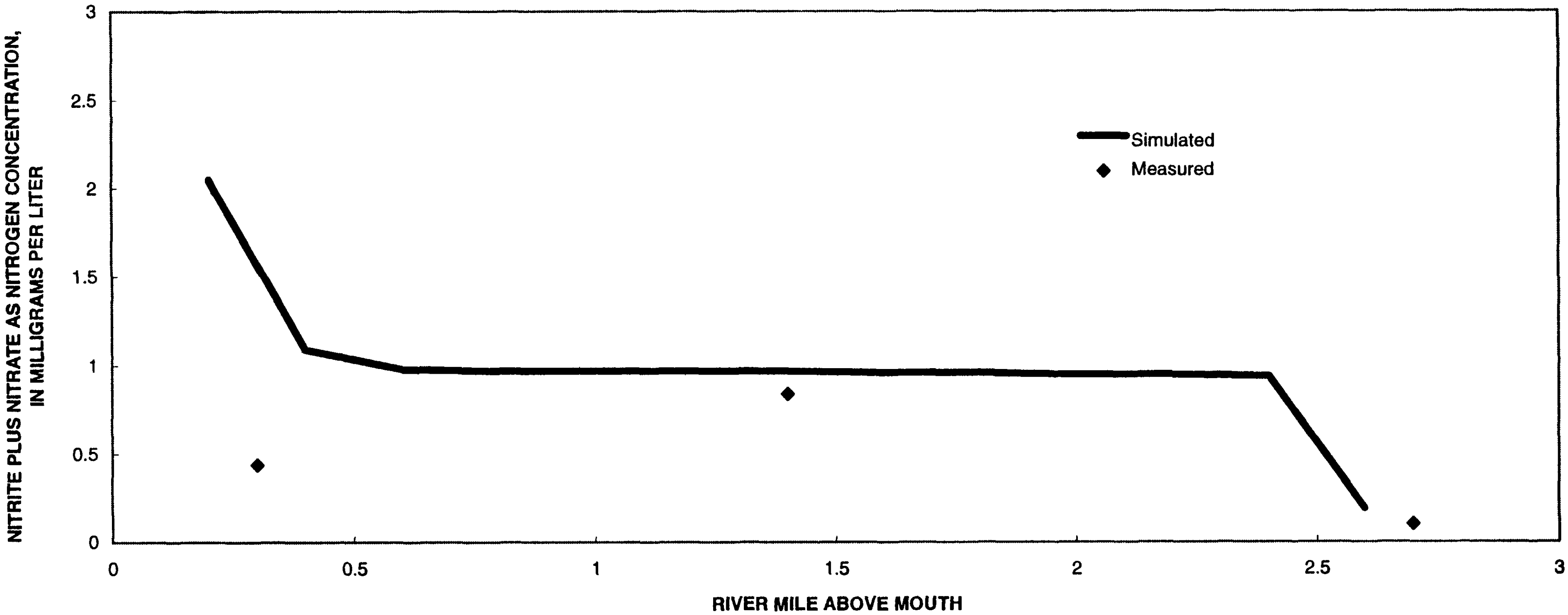

Figure 36. Profiles of simulated and measured nitrite plus nitrate as nitrogen concentrations in Spring Brook in north-eastern Illinois for the verification to the June 27-28, 1995, diel survey.

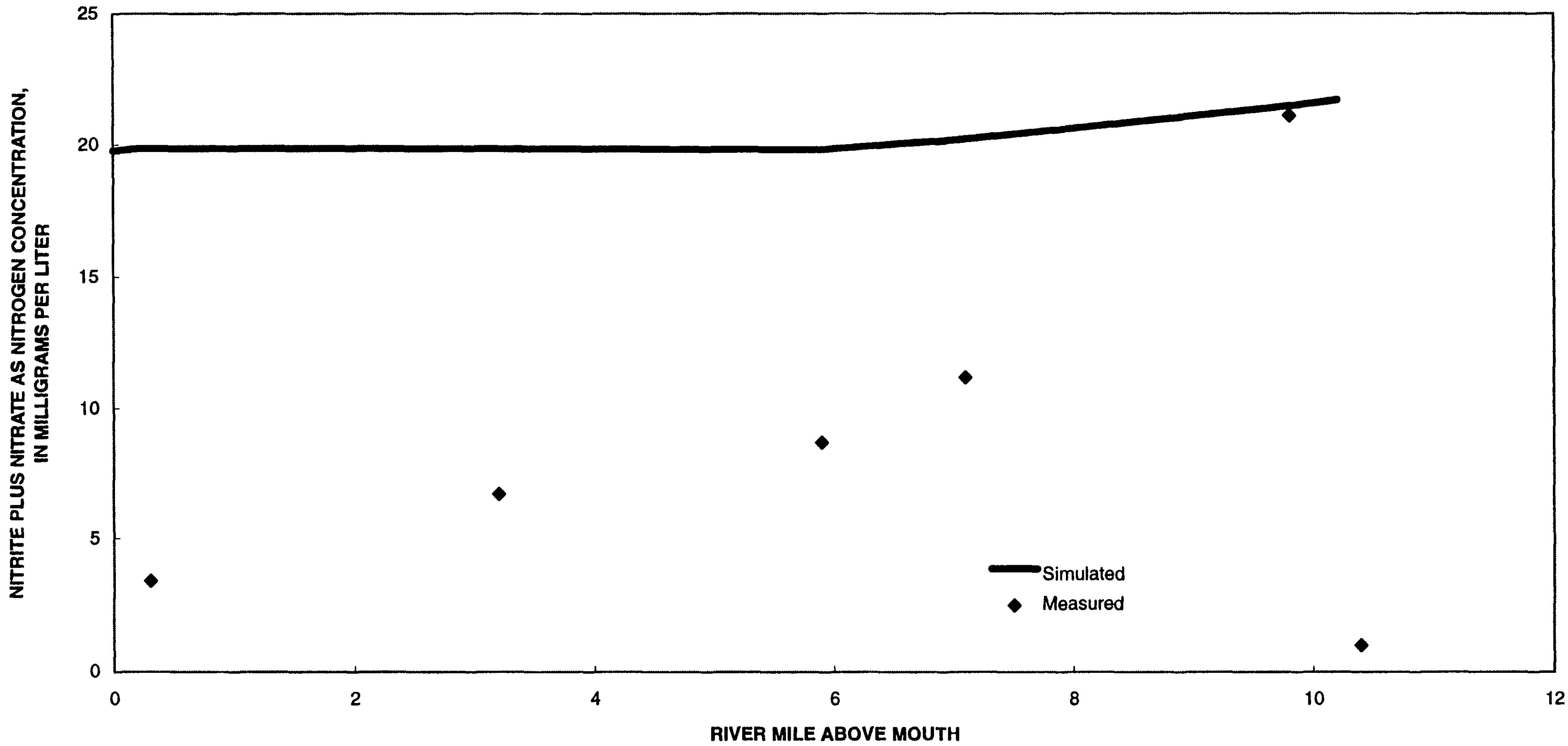

Figure 37. Profiles of simulated and measured nitrite plus nitrate as nitrogen concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

Addison Creek are not simulated in QUAL2E. Because of the limited effects of oversimulation of nitrite plus nitrate as nitrogen concentrations on the simulation of other constituents in QUAL2E, the results of the simulations for nitrite plus nitrate as nitrogen concentrations for the June 27-28, 1995, diel survey supported the utility of the model for water-quality planning in the Salt Creek watershed.

Total Phosphorus--The simulated and measured total phosphorus concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 38-40, respectively. Total phosphorus concentrations are undersimulated by about 20 percent upstream from river mile 20.1 (Railroad Avenue) and oversimulated by 10-20 percent downstream from river mile 20.1 on Salt Creek (fig. 38). Total phosphorus concentrations are well simulated (within 5 percent) in Spring Brook (fig. 39). Total phosphorus concentrations are greatly oversimulated throughout Addison Creek (fig. 40). The verification results on Addison Creek are identical to the calibration results in that the measured decreases in total phosphorus concentrations because of the effects of long traveltimes and nonalgal aquatic vegetation in the ponded reaches upstream from Addison Creek are not simulated in QUAL2E. Because of the limited effects oversimulation of total phosphorus concentrations have on the simulation of other constituents in QUAL2E, the results of the simulations for total phosphorus concentrations for the June 27-28, 1995, diel survey supported the utility of the model for water-quality planning in the Salt Creek watershed. The undersimulated total phosphorus concentrations in Salt Creek are sufficiently high that phosphorus is not a limiting nutrient in Salt Creek upstream from river mile 20.1.

Chlorophyll *a*--The simulated and measured chlorophyll *a* concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 41-43, respectively. Concentrations measured after the start of rainfall are included in the comparison because the chlorophyll *a* concentrations were less affected by runoff than the concentrations of the other constituents. Therefore, a more reliable comparison of simulated and in-stream chlorophyll *a* concentrations is obtained by ignoring the relatively small dilution effects resulting from storm runoff.

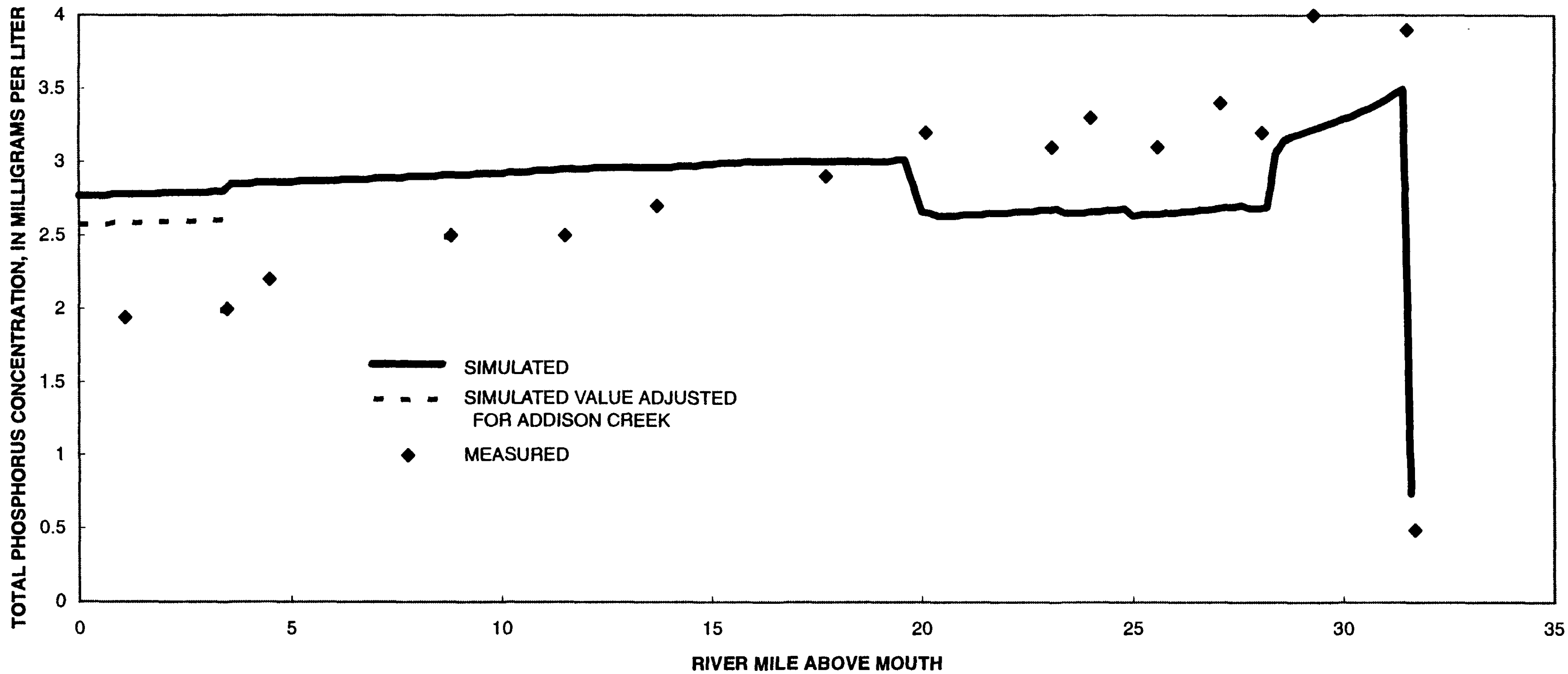

Figure 38. Profiles of simulated and measured total phosphorus concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

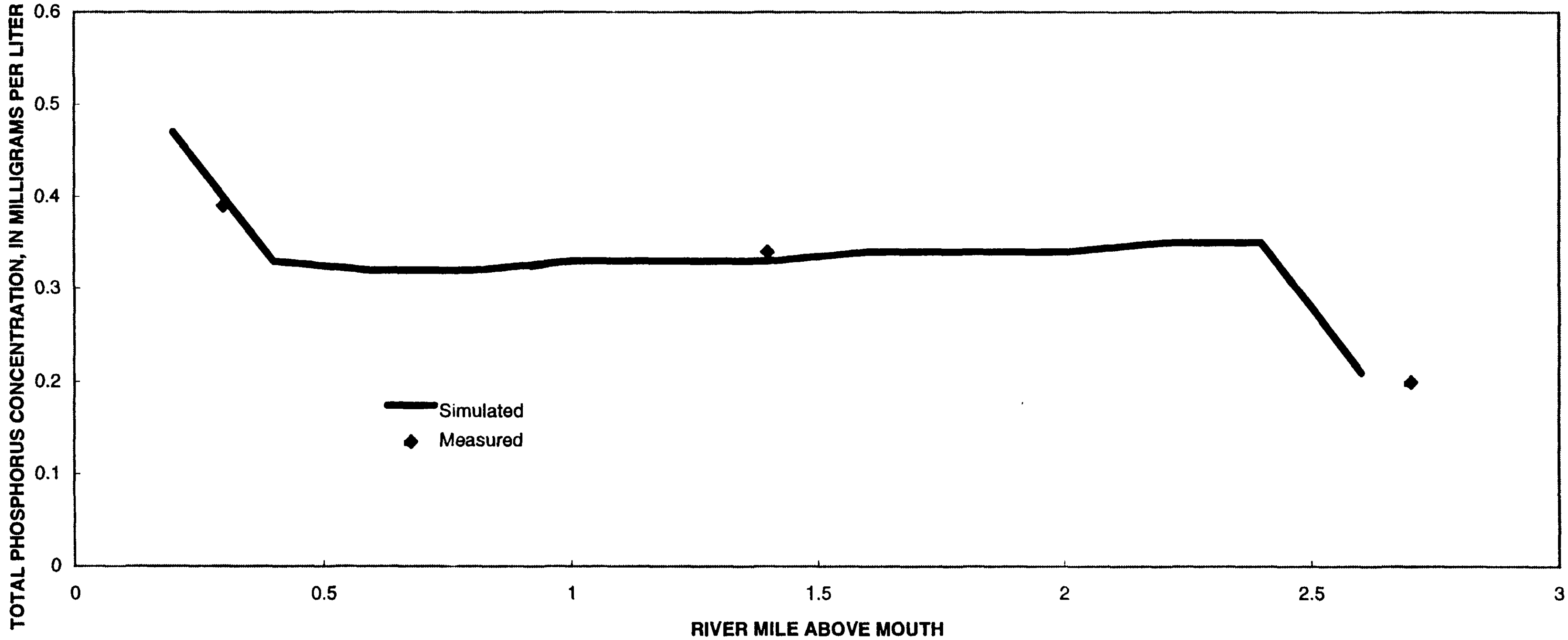

Figure 39. Profiles of simulated and measured total phosphorus concentrations in Spring Brook in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

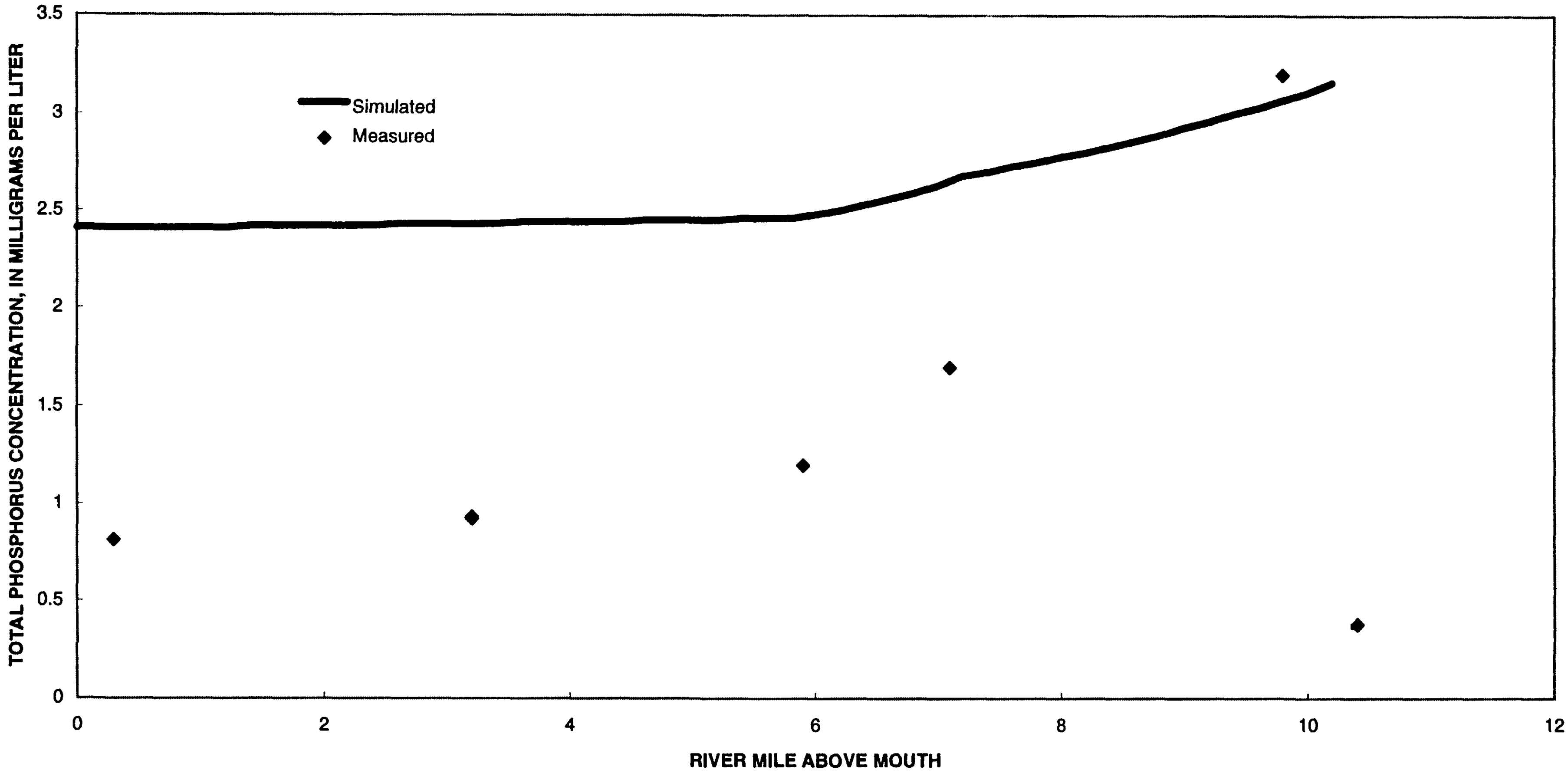

Figure 40. Profiles of simulated and measured total phosphorus concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

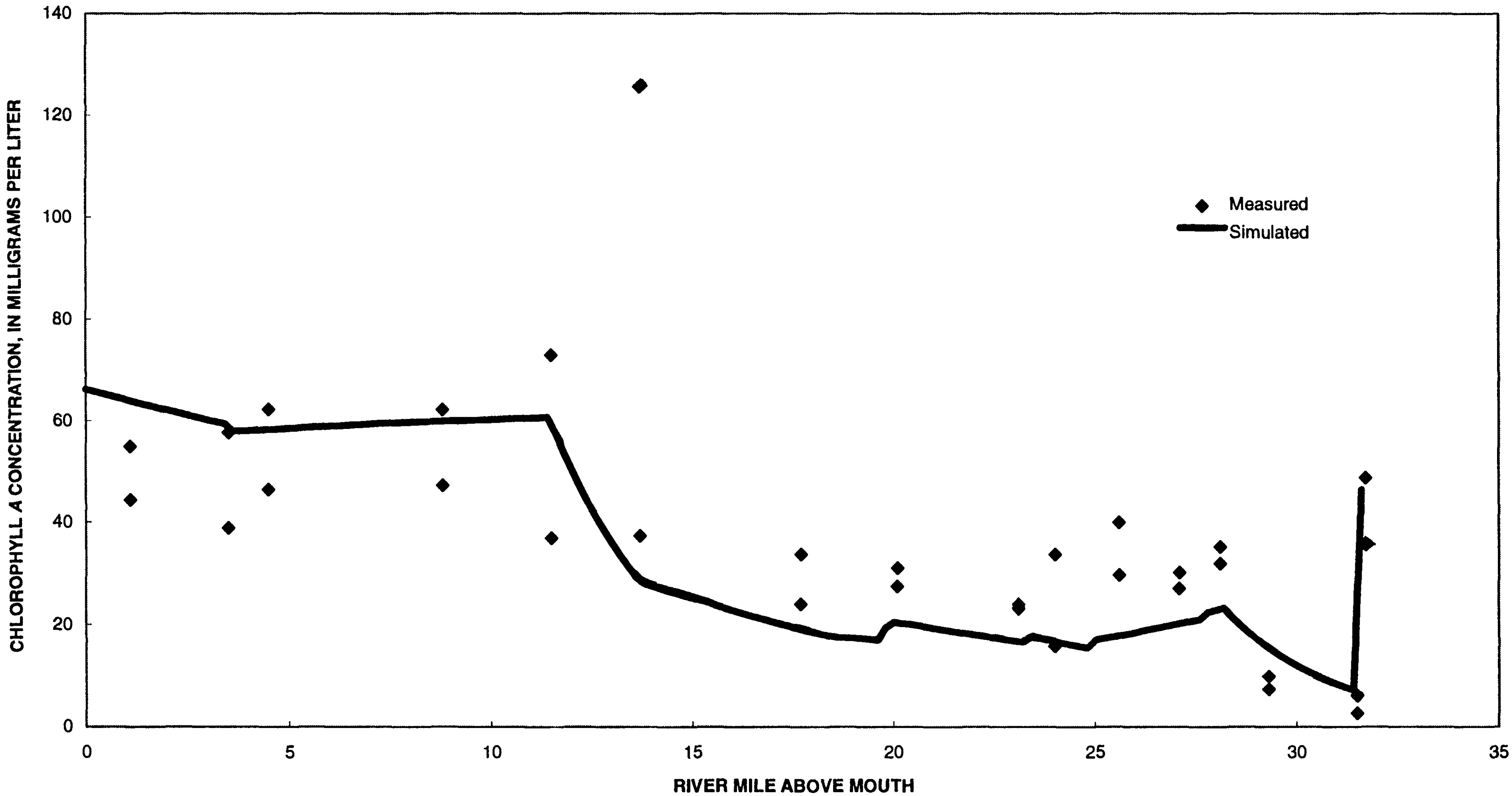

Figure 41. Profiles of simulated and measured chlorophyll *a* concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

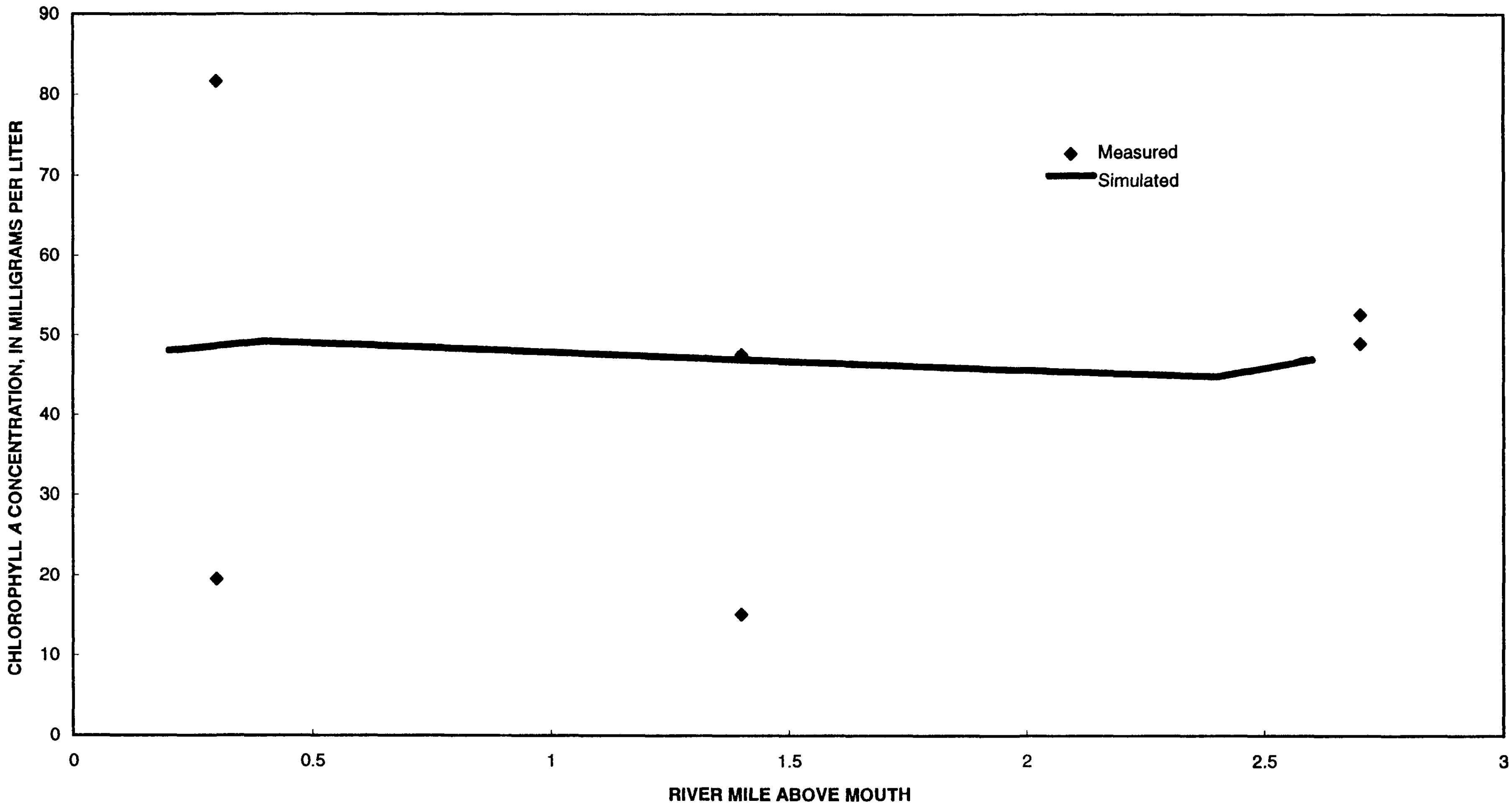

Figure 42. Profiles of simulated and measured chlorophyll *a* concentrations in Spring Brook in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

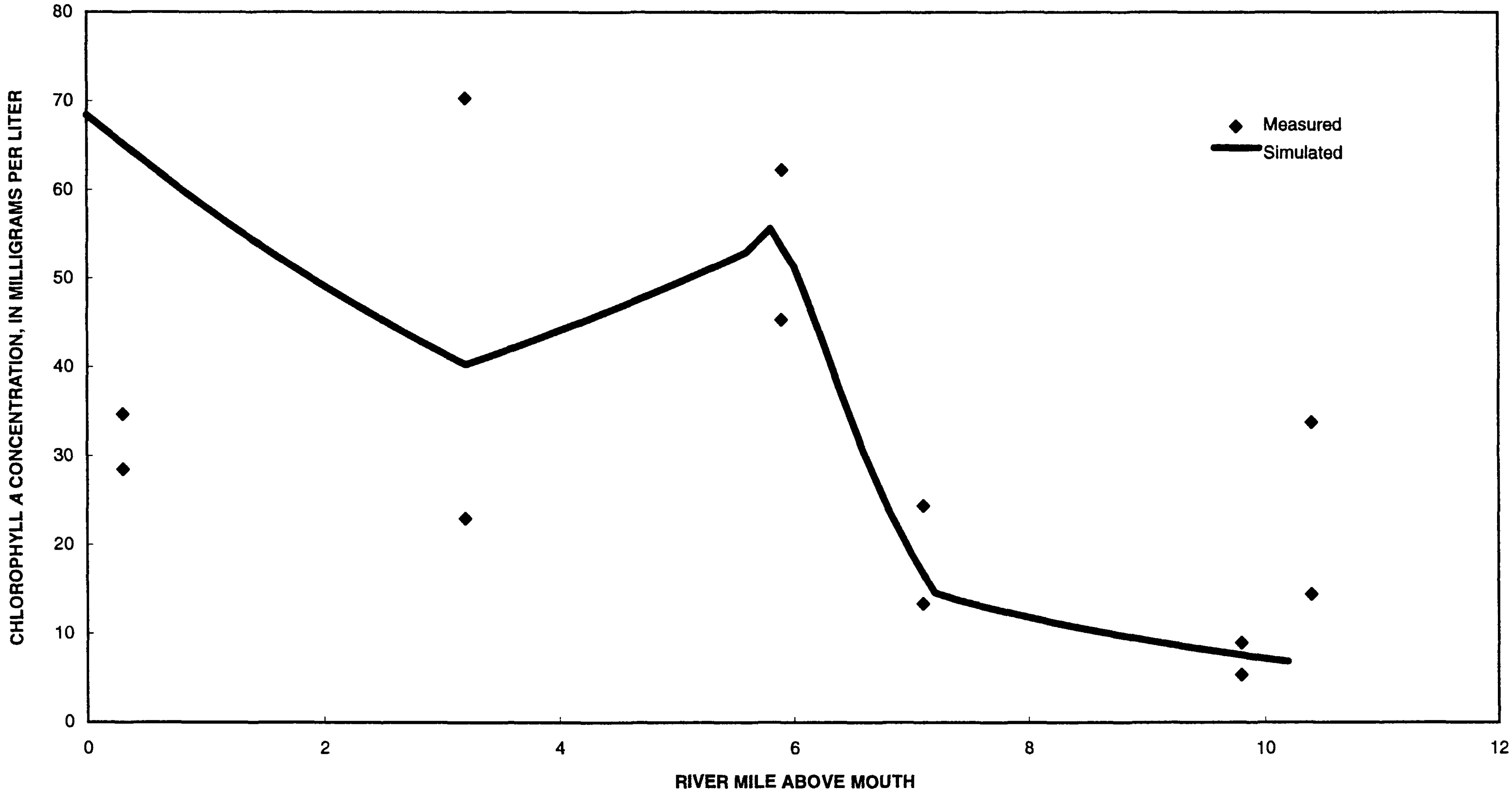

Figure 43. Profiles of simulated and measured chlorophyll *a* concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

The simulated chlorophyll *a* concentrations pass between the measured chlorophyll *a* concentrations in Spring Brook (fig. 42) and in Addison Creek between river miles 3.2 and 10.4 (Washington Boulevard and Bensenville South STP) (fig. 43), and compare reasonably well in Salt Creek between river miles 3.2 and 11.5 (Maple Avenue and York Road) (fig. 40). Chlorophyll *a* concentrations are substantially undersimulated between river miles 13.7 and 28.1 (31st Street in Oak Brook and Lino and Poli Plumbing) of Salt Creek (fig. 40), and substantially oversimulated at river mile 0.3 (Cermak Road) in Addison Creek (fig. 42). The verification of simulation of chlorophyll *a* concentrations for Salt Creek and the downstream end of Addison Creek is considered unacceptable and modifications of the calibrated parameters are needed to adequately simulate chlorophyll *a* concentrations for the June 27-28, 1995, diel survey as discussed in the "Parameter Adjustment for the June 1995, Diel Survey" section.

Dissolved Oxygen--The simulated and measured DO concentrations throughout Salt Creek, Spring Brook, and Addison Creek are shown in figures 44-46, respectively. The simulated DO concentrations in Salt Creek generally are higher than the measured values. Measured DO concentrations vary widely throughout a diel period because of the effects of algal photosynthesis and respiration. The measured DO concentrations in figures 44-46 were measured between 8 a.m. and 2 p.m., whereas the calibrated QUAL2E model was adjusted to simulate daily-mean DO concentrations for the August 29-30, 1995, diel survey. The simulated DO concentration profile in Salt Creek for the calibration to the August 29-30, 1995, diel survey and the DO concentrations measured in Salt Creek between 8 a.m. and 2 p.m. on August 29, 1995, are shown in figure 47. Comparison of figures 44 and 47 indicates that the agreement between simulated and measured DO concentrations for verification is substantially different from that for calibration only at river mile 20.1 (Railroad Avenue) and in the reach immediately downstream from Fullersburg Dam (river mile 11.5). River mile 20.1 is in the center of the reach of active CSO's, and these CSO's were probably discharging during the sampling period. Thus, it is reasonable that the SOD rate could be much higher than estimated for the August 29-30, 1995, diel survey. Further, the SOD rate measured at river mile 8.8 on June 20, 1995, was 0.228 g/ft^2-day, whereas the value utilized for calibration to the August 29-30, 1995, diel-survey data in this reach was 0.15 g/ft^2-day. Thus, application of a higher SOD rate for simulation of the June 27-28, 1995, diel survey is reasonable.

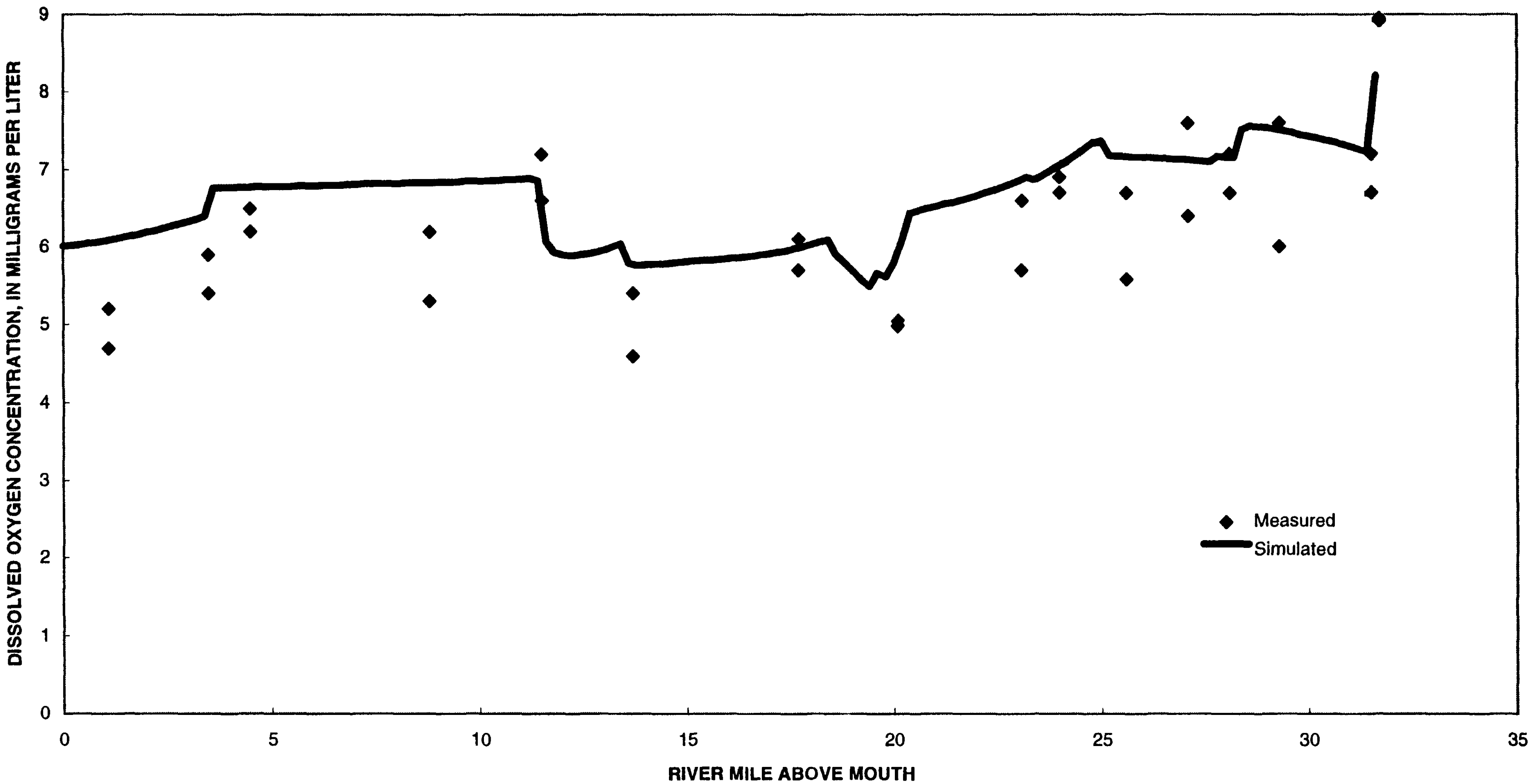

Figure 44. Profiles of simulated and measured dissolved oxygen concentrations in Salt Creek in northeastern Illinois for the verification to the June 27-28, 1995 diel survey.

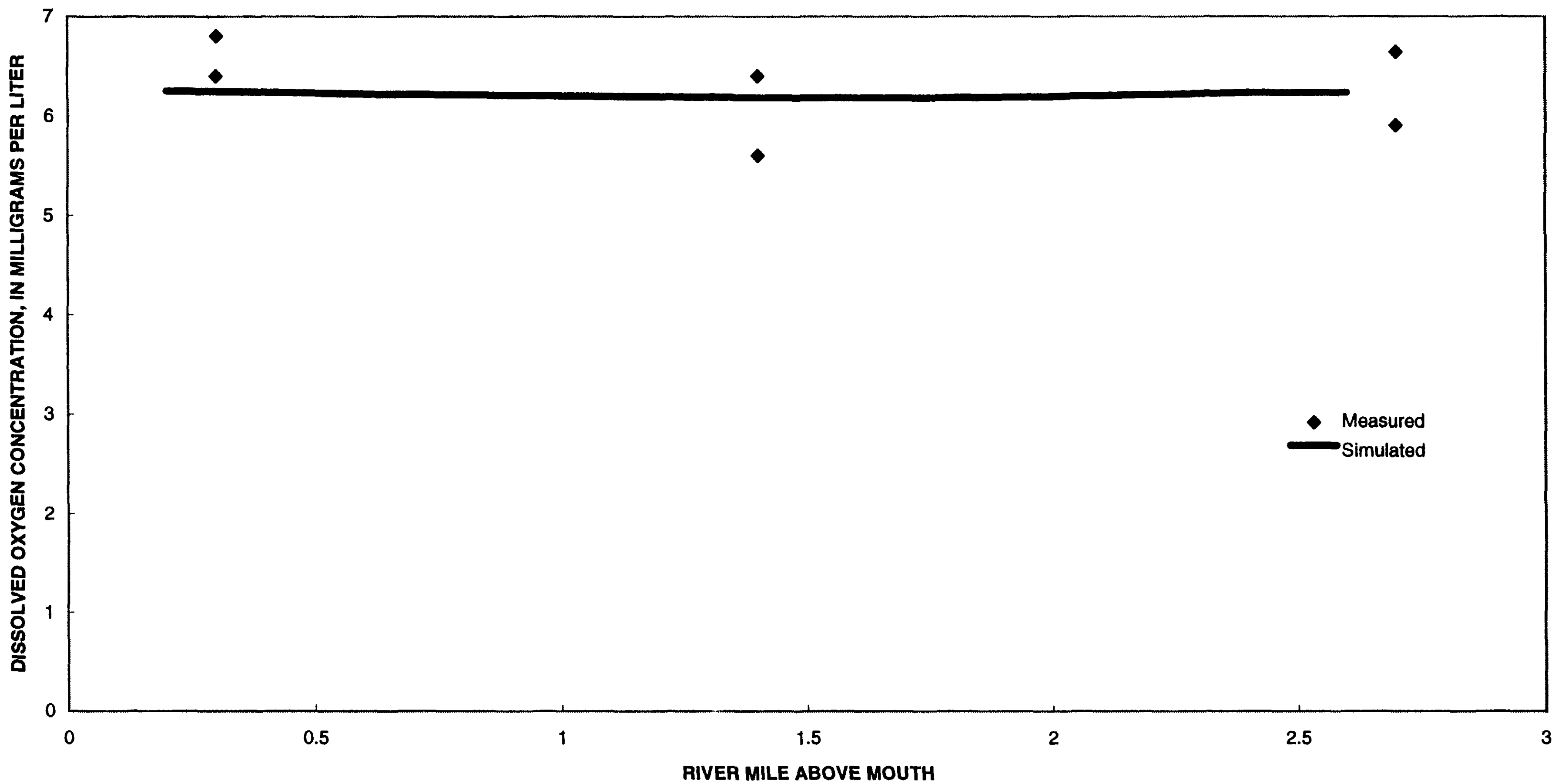

Figure 45. Profiles of simulated and measured dissolved oxygen concentrations in Spring Brook in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

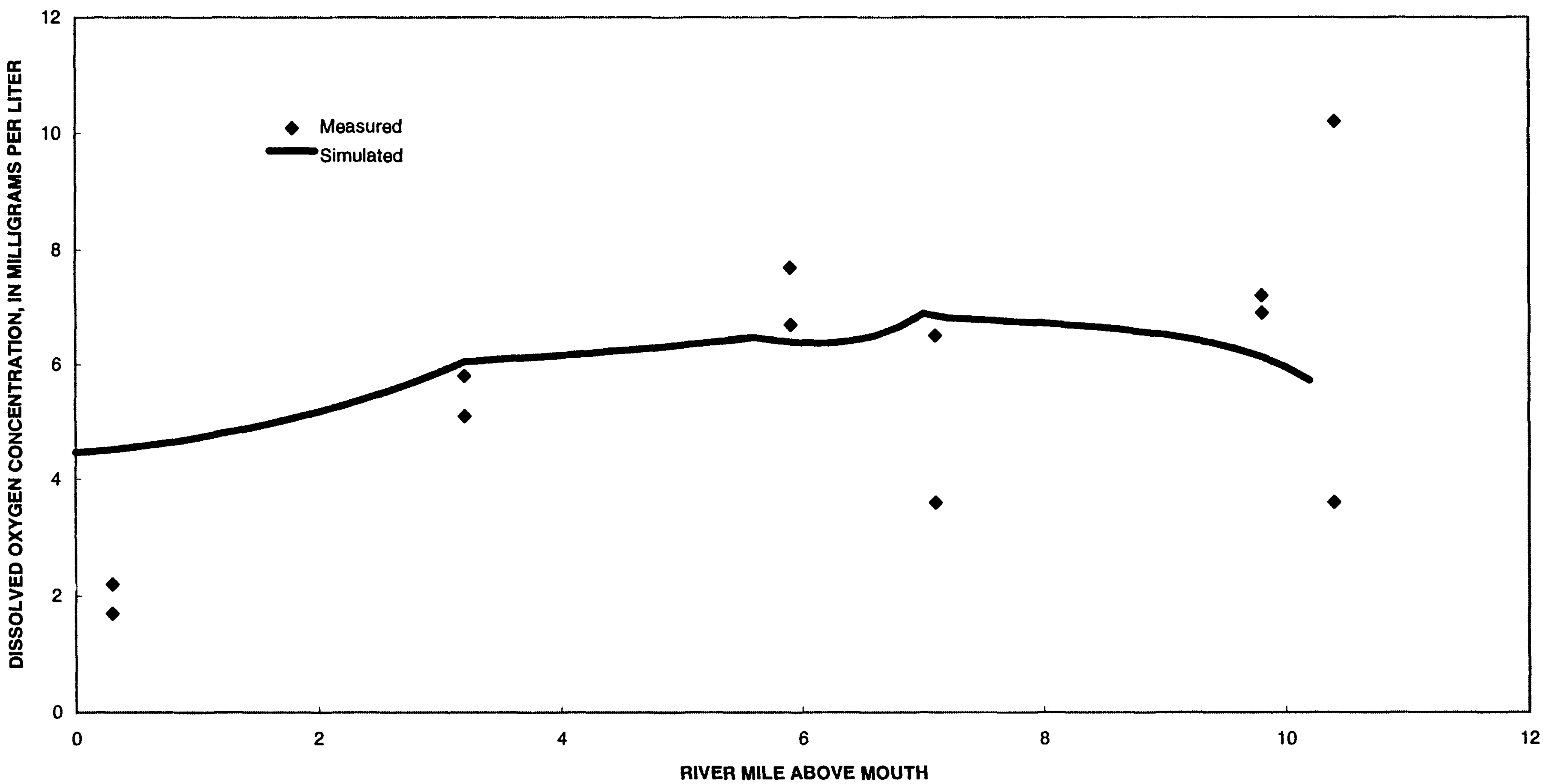

Figure 46. Profiles of simulated and measured dissolved oxygen concentrations in Addison Creek in northeastern Illinois for the verification to the June 27-28, 1995, diel survey.

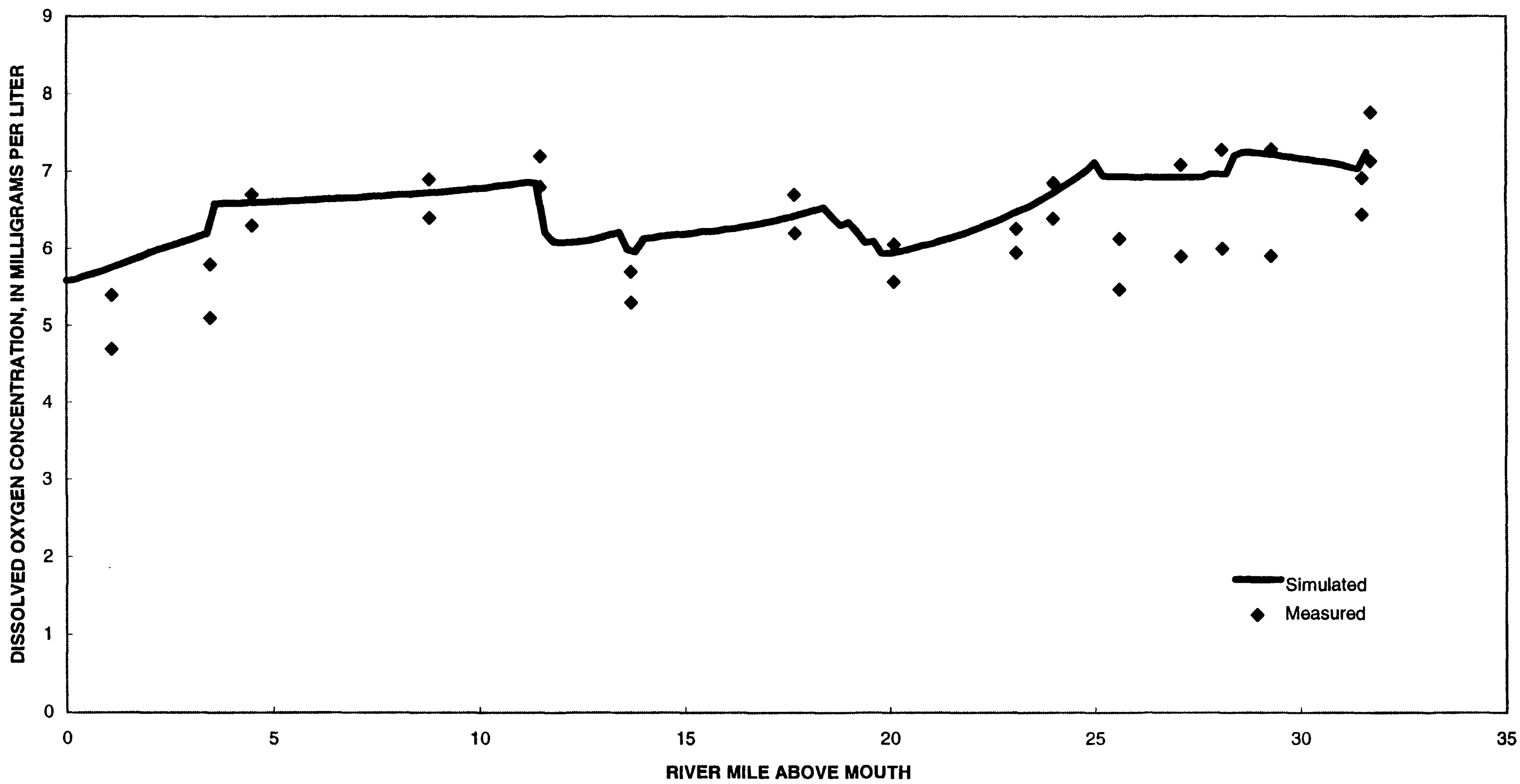

Figure 47. Profiles of simulated and measured (between 8 a.m. and 2 p.m.) dissolved oxygen concentrations in Salt Creek in northeastern Illinois for the calibration to the August 29-30, 1995 diel survey.

The agreement between the measured and simulated DO concentrations is good (simulated DO concentrations within 5 percent of the measured concentrations) in Spring Brook (fig. 45) and in Addison Creek between river miles 3.2 and 10.4 (Washington Boulevard and Bensenville South STP) (fig. 46). The substantial oversimulation of DO concentration at river mile 0.3 (Cermak Road) of Addison Creek results from the oversimulation of chlorophyll *a* at this location and from an underestimation of the SOD rate in reach 16 of Addison Creek. Reach 16 of Addison Creek includes seven active CSO's; therefore, an increased SOD rate during the June 27-28, 1995, diel-survey period is reasonable.

Parameter Adjustments for the June 1995, Diel Survey

The results of the simulations for DO concentrations for the June 27-28, 1995, diel survey increased confidence in the utility of the model for water-quality planning in many reaches in the Salt Creek watershed, and in several reaches the poor verification results can be attributed to CSO operation and other physical factors. Thus, overall, water-quality processes are fairly well simulated with the QUAL2E model. However, further adjustment of the parameters affecting total ammonia as nitrogen concentrations in Salt Creek and chlorophyll *a* and DO concentrations in Salt Creek and Addison Creek provides a "worst-case" stream condition for application to water-quality planning in the Salt Creek watershed. This "worst-case" condition is not a rigorously determined worst case, but rather a condition of somewhat more stressed water-quality processes and resulting DO concentrations that may affect treatment criteria on the waste-load discharges. The adjustments made to improve chlorophyll *a* simulation necessitated a small adjustment in organic nitrogen simulation. No parameter adjustments were applied to improve the simulation of any of the other constituents for the June 27-28, 1995, diel survey.

In total, only 17 parameter values were changed (2 Manning's n values, 2 organic nitrogen settling rates, 2 algal settling rates, 5 benthos source rates for total ammonia as nitrogen, and 6 SOD rates). The values of all other reach-varying parameters and the system-wide parameters remained as calibrated for the August 29-30, 1995, diel survey. The relatively small number of changes required to accurately simulate the measured values for the June 27-28, 1995, diel survey supports the validity of the QUAL2E model for simulation of water quality in the Salt Creek watershed for planning purposes. Simulation of the August 29-30, 1995, diel survey with the parameters adjusted for the June 27-28, 1995, diel survey results in undersimulation of DO concentrations and oversimulations of total ammonia as nitrogen and chlorophyll *a* concentrations in Salt Creek. The magnitudes of these undersimulation and oversimulations are similar to the oversimulation of DO concentrations, undersimulations of total ammonia as nitrogen, and chlorophyll *a* concentrations in Salt Creek in the verification illustrated in figures 44, 32, and 41, respectively. The results of this simulation are not included here. The input for QUAL2E corresponding to the adjustment to the June 27-28, 1995, diel-survey data is listed in appendix B.

Organic Nitrogen--The parameter adjustments utilized to increase chlorophyll *a* concentrations in the upstream reaches of Salt Creek resulted in increased organic nitrogen concentrations. To maintain a good simulation of organic nitrogen in Salt Creek, the resuspension rate of organic nitrogen (negative organic nitrogen settling rate) was changed from -0.3 to -0.15 day^{-1} in reach 1 (fig. 3), and the organic nitrogen settling rate was changed from 0.2 to 0.0 day^{-1} in reach 3.

Total Ammonia as Nitrogen--The strength of the benethic line source of total ammonia as nitrogen applied in reaches 4-9 was increased from 5 to 10 mg/ft^2-day to reduce the undersimulation of the measured total ammonia as nitrogen concentrations in Salt Creek between river miles 8.8 and 27.1 (Wolf Road and Carter Avenue) for the June 27-28, 1995, diel survey. The simulated and measured total ammonia as nitrogen concentrations throughout Salt Creek are shown in figure 48. The measured total ammonia as nitrogen concentrations are still substantially undersimulated between river miles 20.1 and 24 (Railroad Avenue and Wood Dale Avenue), but the measured total ammonia as nitrogen concentrations are well simulated (within 0.1 mg/L) throughout the rest of Salt Creek. Simulation of the large measured increase in total ammonia as nitrogen concentrations between river miles 20.1 and 24 would require a very large line source of total ammonia as nitrogen or an additional point source of total ammonia as nitrogen. Neither of these is justified in this part of Salt Creek. The results of the adjusted simulations for organic nitrogen concentrations for the June 27-28, 1995, diel survey increased confidence in the utility of the model for water-quality planning in the Salt Creek watershed.

Chlorophyll *a*--The simulated and measured chlorophyll *a* concentrations throughout Salt Creek and Addison Creek are shown in figures 49 and 50, respectively. By increasing the algal settling rate in reach 16 from 0 to 1.1 ft/d, the simulated chlorophyll *a* concentrations in Addison Creek matched the concentrations measured for the June 27-28, 1995, diel survey (fig. 50). The match between the simulated and measured concentrations in Salt Creek for the June 27-28, 1995, diel survey was obtained by increasing Manning's n for reach 1 from 0.4 to 0.56, decreasing Manning's n for reach 10 from 0.26 to 0.07, and increasing the algal settling rate for reach 17 from 1.3 to 1.8 ft/d. The changes in Manning's n increased the

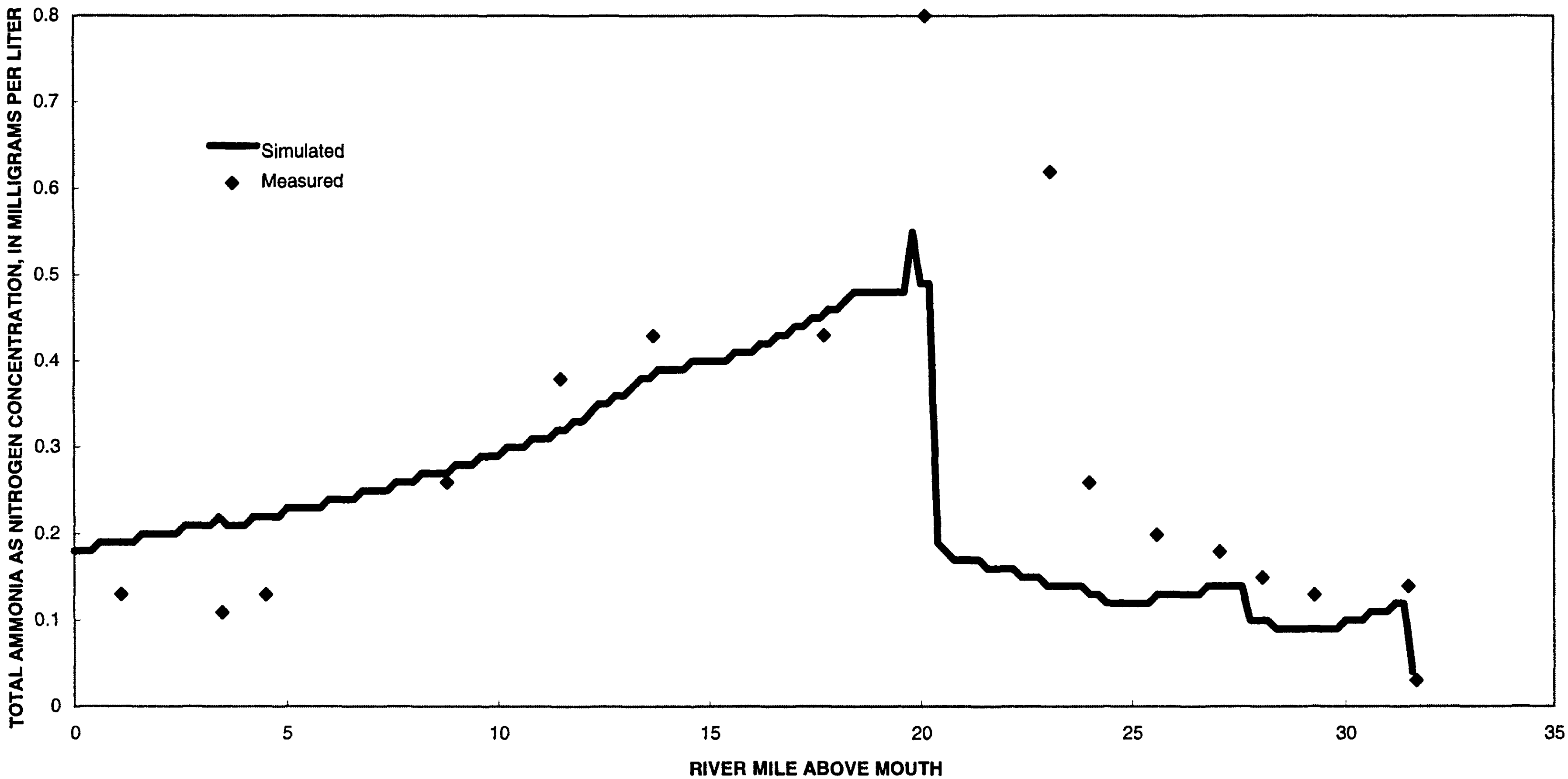

Figure 48. Profiles of simulated and measured total ammonia as nitrogen concentrations in Salt Creek in northeastern Illinois for the calibration to the June 27-28, 1995, diel survey.

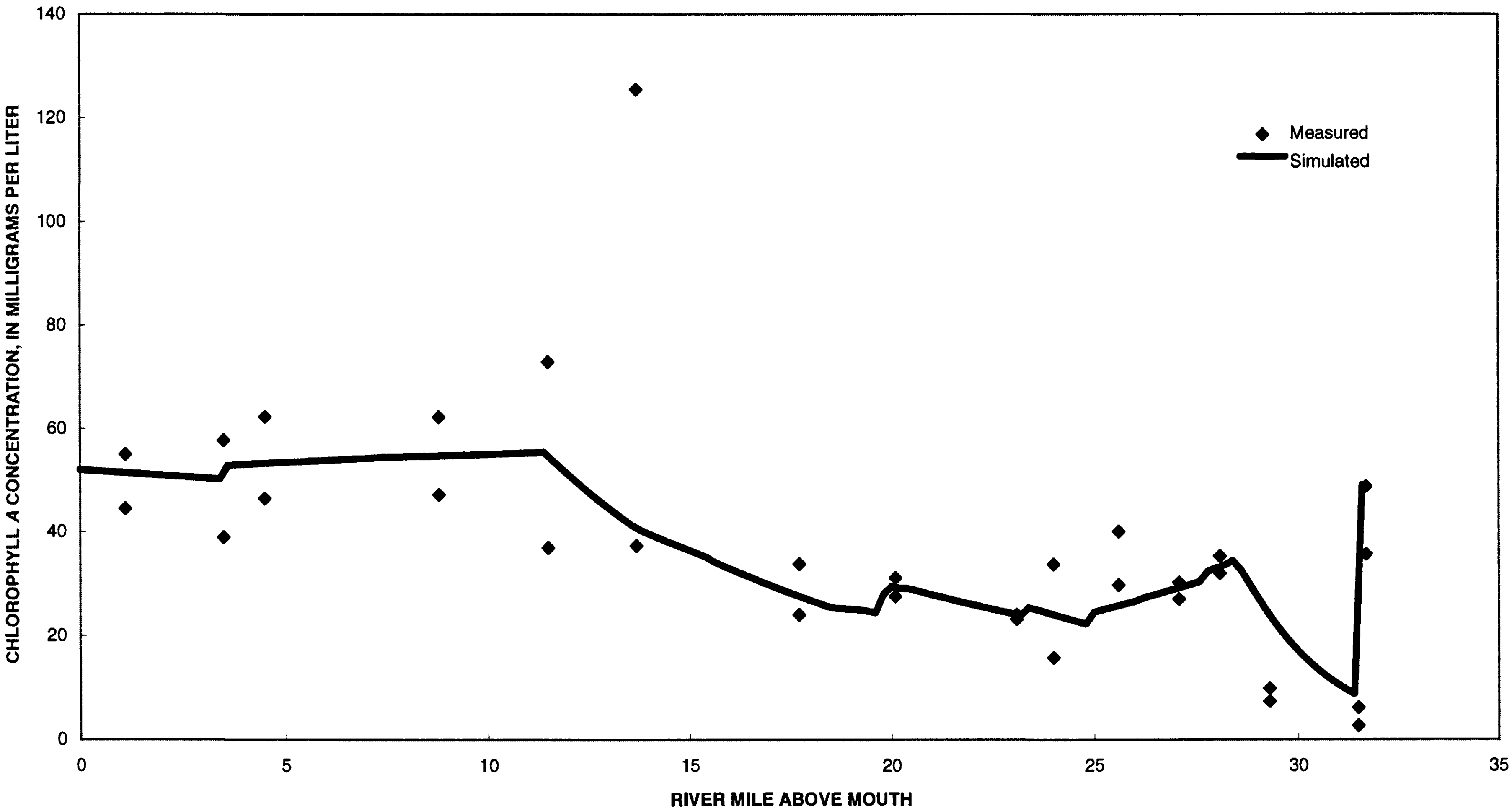

Figure 49. Profiles of simulated and measured chlorophyll *a* concentrations in Salt Creek in northeastern Illinois for the calibration to the June 27-28, 1995, diel survey.

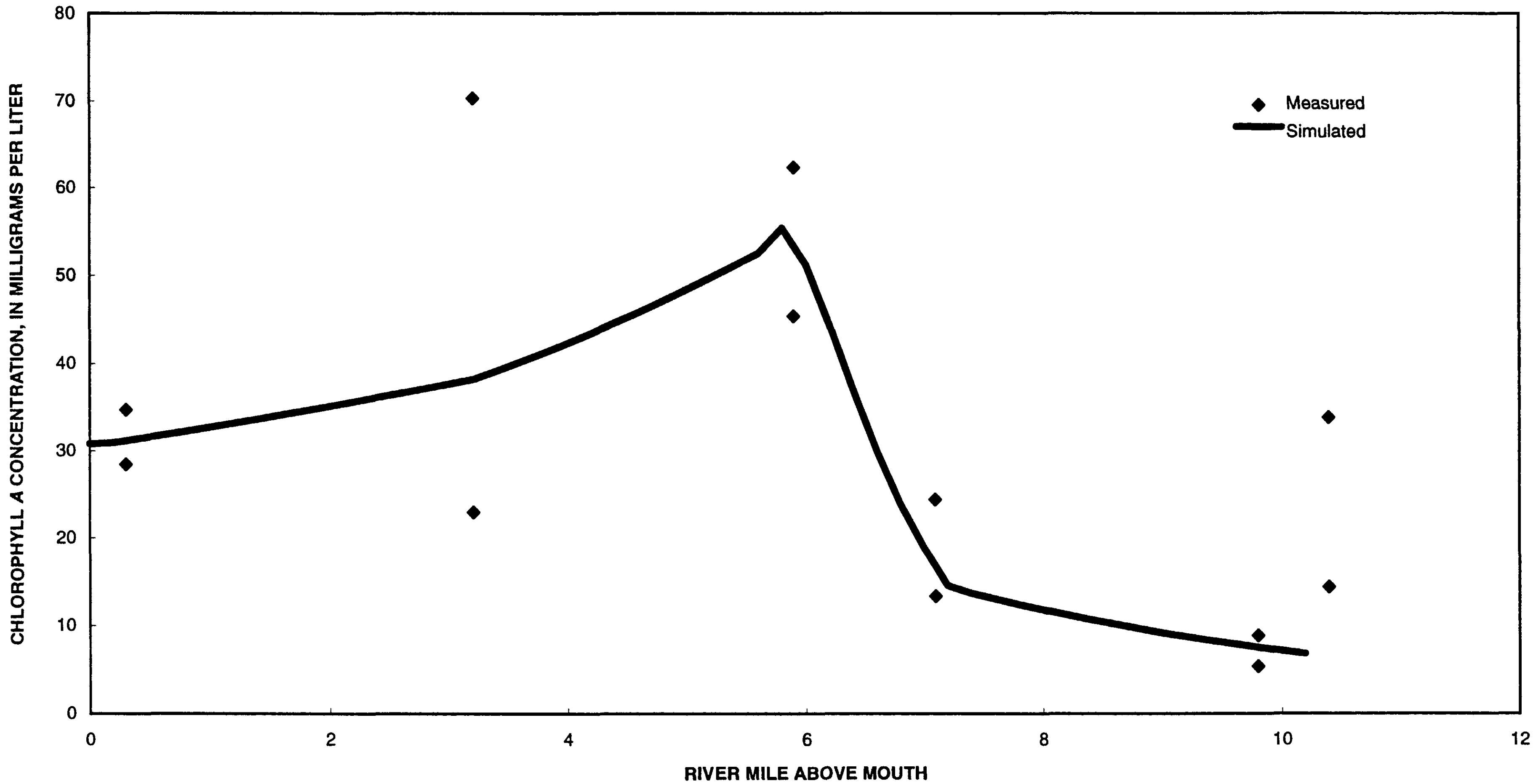

Figure 50. Profiles of simulated and measured chlorophyll *a* concentrations in Addison Creek in northeastern Illinois for the calibration to the June 27-28, 1995, diel survey.

traveltime (algal growth time) in reach 1 such that the simulated chlorophyll *a* concentrations could increase to the values measured at river mile 28.1 (Lino and Poli Plumbing), and decreased the traveltime in reach 10 such that the gradual increase in chlorophyll *a* concentrations measured in this reach could be simulated.

Dissolved Oxygen--The simulated and measured DO concentrations throughout Salt Creek and Addison Creek are shown in figures 51 and 52, respectively. The match between measured and simulated DO concentrations for the June 27-28, 1995, diel survey was obtained by changing the SOD rates in six reaches in Salt Creek and one reach in Addison Creek as listed in table 5. In the verification to the June 27-28, 1995, diel survey, the simulated DO concentrations was within the range of the measured concentrations in reaches 1 and 3 on Salt Creek. However, because of the increased chlorophyll *a* concentrations for the adjusted simulation, it was necessary to increase the SOD rates in these reaches by about 10 percent. It also was necessary to increase the SOD rate in reach 17 by about 10 percent to obtain good agreement between the measured and simulated concentrations. Much larger increases in the SOD rate were applied in reaches 5, 6, and 11 on Salt Creek and reach 16 on Addison Creek. Reach 6 on Salt Creek and reach 16 on Addison Creek include active CSO's, and light rain fell on the night of June 26, 1995. Thus, increased SOD rates resulting from recent CSO discharges seem reasonable for the June 27-28, 1995, diel survey. The SOD rate measured in reach 11 on Salt Creek on June 20, 1995, was 0.228 g/ft^2-day, and a value of 0.23 g/ft^2-day was utilized for the June 27-28, 1995, diel survey. In summary, the good agreement between measured and simulated DO concentrations illustrated in figures 51 and 52 results from small increases in SOD rates in three reaches and larger, physically justified increases in SOD rate in four other reaches. This result further supports the physical justification of the calibrated and adjusted QUAL2E model for application to water-quality planning in the Salt Creek watershed.

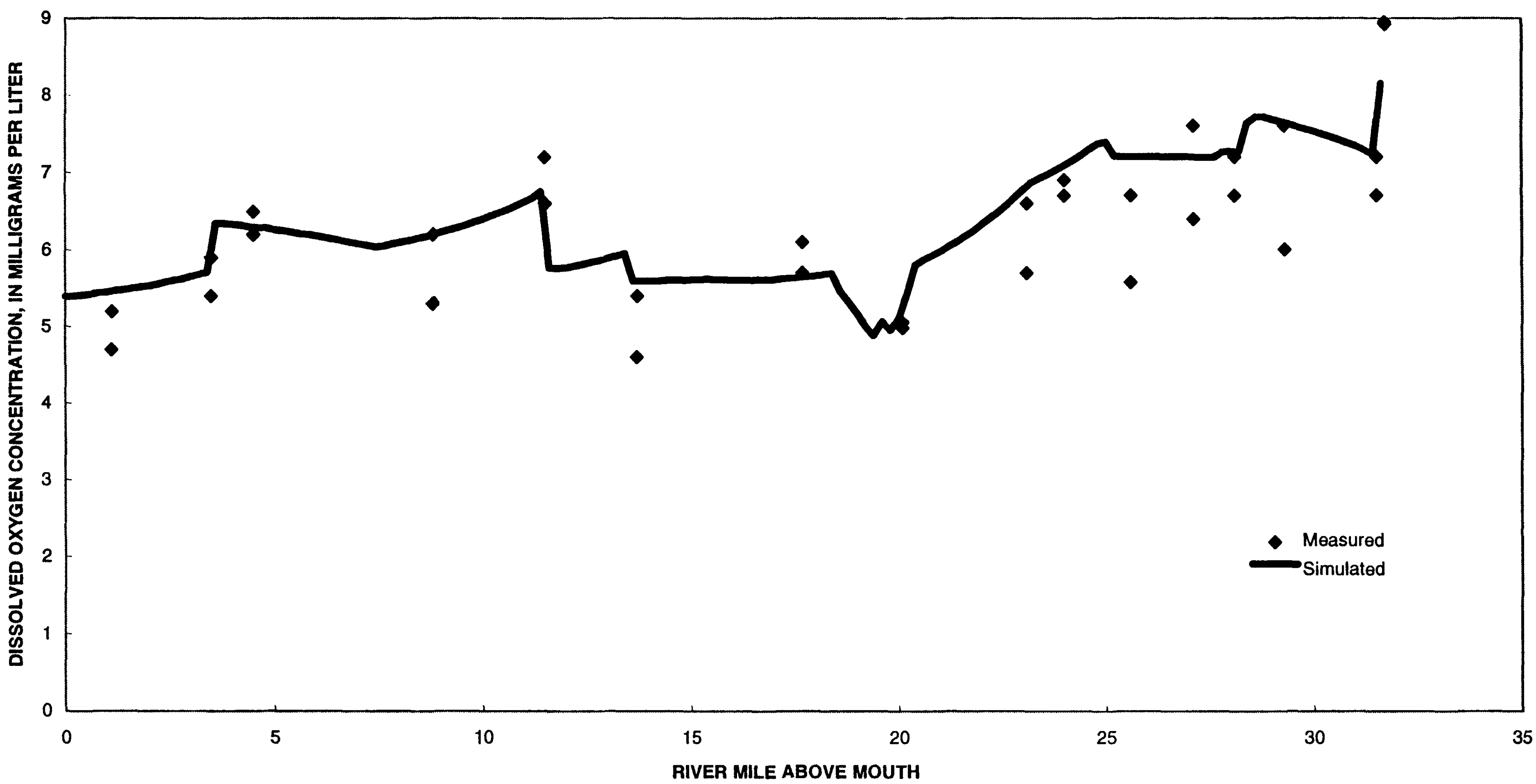

Figure 51. Profiles of simulated and measured dissolved oxygen concentrations in Salt Creek in northeastern Illinois for the calibration to the June 27-28, 1995 diel survey.

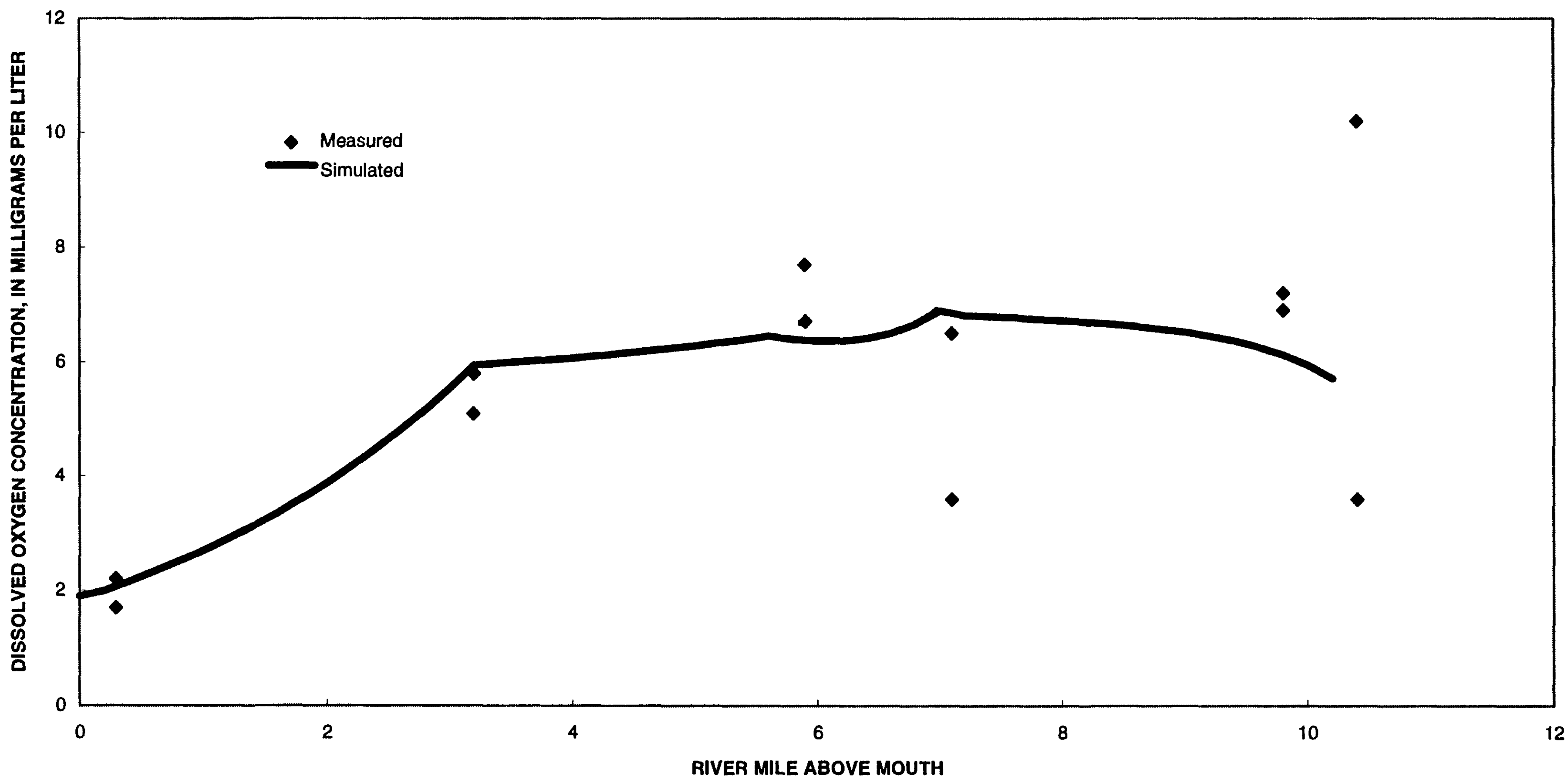

Figure 52. Profiles of simulated and measured dissolved oxygen concentrations in Addison Creek in northeastern Illinois for the calibration to the June 27-28, 1995 diel survey.

Application of Water-Quality Model to Planning Scenarios

The purpose of developing a water-quality simulation model in most studies is to evaluate water quality in a stream for streamflow and sewage-treatment plant discharge scenarios for which measurements of constituent concentrations are not available. The QUAL2E model of water quality in the Salt Creek watershed was applied to the 7-day, 10-year low flow (Singh and Ramamurthy, 1993) with 11 effluent constituent-concentration scenarios for three levels of STP discharges: (1) 7-day, 10-year low flow from the STP (Singh and Ramamurthy, 1993), (2) average of the three lowest monthly flow values for each STP for the period from January 1991 through October 1995, and (3) STP design-average flow. The STP flow levels are listed in table 7; scenarios for effluent constituent concentrations are listed in table 8; and the permit limits for 5-day CBOD and total ammonia as nitrogen for each STP are listed in table 9. This set of 33 effluent discharge and constituent-concentration scenarios was simulated with the QUAL2E model calibrated to the August 29-30, 1995, diel survey and the QUAL2E model adjusted to the June 27-28, 1995, diel survey. These simulations provide a range of DO concentrations in the Salt Creek watershed corresponding to potentially critical low-flow and effluent-load conditions.

The DO concentrations at the IEPA water-quality sampling locations and upstream from Fullersburg Dam simulated with the QUAL2E model calibrated to the August 29-30, 1995, diel-survey data for STP flow levels 1-3 are listed in tables 10-12, respectively. The DO concentrations at the IEPA water-quality sampling locations and upstream from Fullersburg Dam simulated with the QUAL2E model adjusted to the June 27-28, 1995, diel-survey data for STP flow levels 1-3 are listed in tables 13-15, respectively. The simulated DO concentration profiles for five effluent concentration scenarios for the 7-day, 10-year low stream and STP flow for the August 29-30, 1995, and June 27-28, 1995, diel-survey conditions are shown in figures 53 and 54, respectively. These five scenarios were selected to illustrate a range of DO concentration profiles resulting from (1) current loads, (2) allowable maximum loads, and (3) intermediate cases between 1 and 2. The simulated DO concentration profiles for effluent concentration scenario 2 for the 7-day, 10-year low stream and STP flow for the August 29-30, 1995, and June 27-28, 1995, diel-survey conditions are shown in figure 55. Many inferences regarding the relations between DO concentrations in the Salt Creek watershed and STP discharge levels and effluent concentrations may be made from the information presented in tables 10-15 and figures 53-55. Major conclusions, drawn from this information for DO concentrations in Salt Creek, are discussed in the following.

Table 7. Sewage-treament plant flows for the water-quality planning scenarios simulated in the Salt Creek watershed in northeastern Illinois

[All flows are in cubic feet per second]

Sewage-Treatment Plant	7-day, 10-year low flow	Average 3-month low flow, January 1991 - October 1995	Design average flow
Egan	24.60	30.01	46.41
Nordic Park	.25	.26	.77
Itasca	2.00	2.65	4.02
Wood Dale North	1.70	1.56	3.05
Wood Dale South	.45	.31	1.75
Addison North	3.30	3.91	8.20
Addison South	2.60	1.77	4.95
Salt Creek Sanitary District	2.00	2.58	5.11
Elmhurst	6.50	8.04	12.38
Bensenville South	3.00	4.53	7.27

Table 8. Sewage-treatment plant effluent constituent concentrations for the water-quality planning scenarios simulated in the Salt Creek watershed in northeastern Illinois

[mg/L, milligrams per liter]

Effluent scenario	Description
1	Constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
2	Five-day carbonaceous biochemical oxygen demand concentrations set to permitted monthly average limits; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
3	Five-day carbonaceous biochemical oxygen demand concentrations set to permitted monthly average limits and total ammonia as nitrogen concentrations set to permitted summer (May-October) monthly average limits; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
4	Five-day carbonaceous biochemical oxygen demand concentrations set to permitted monthly average limits; total ammonia as nitrogen concentrations set to permitted summer (May-October) monthly average limits; and dissolved oxygen concentrations set to 6 mg/L at sewage-treatment plants where concentrations are less than 6 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
5	Five-day carbonaceous biochemical oxygen demand concentrations set to permitted monthly average limits; total ammonia as nitrogen concentrations set to permitted summer (May-October) monthly average limits; and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey

Table 8. Sewage-treatment plant effluent constituent concentrations for the water-quality planning scenarios simulated in the Salt Creek watershed in northeastern Illinois--Continued

Effluent scenario	Description
6	Five-day carbonaceous biochemical oxygen demand concentrations set to 10 mg/L and total ammonia as nitrogen concentrations set to 1.5 mg/L for each sewage-treatment plant, and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
7	Five-day carbonaceous biochemical oxygen demand concentrations set to 5 mg/L and total ammonia as nitrogen concentrations set to 1.5 mg/L for each sewage-treatment plant, and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
8	Five-day carbonaceous biochemical oxygen demand concentrations set to 10 mg/L and total ammonia as nitrogen concentrations set to 1.0 mg/L for each sewage-treatment plant, and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
9	Five-day carbonaceous biochemical oxygen demand concentrations set to 10 mg/L and total ammonia as nitrogen concentrations set to 0.5 mg/L for each sewage-treatment plant, and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey
10	Five-day carbonaceous biochemical oxygen demand concentrations set to 5 mg/L and total ammonia as nitrogen concentrations set to 1.0 mg/L for each sewage-treatment plant, and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey

Table 8. Sewage-treatment plant effluent constituent concentrations for the water-quality planning scenarios simulated in the Salt Creek watershed in northeastern Illinois--Continued

Effluent scenario	Description
11	Five-day carbonaceous biochemical oxygen demand concentrations set to 5 mg/L and total ammonia as nitrogen concentrations set to 0.5 mg/L for each sewage-treatment plant, and dissolved oxygen concentrations set to 8 mg/L; all other constituent concentrations in the sewage-treatment plant effluent at the levels measured during the appropriate diel survey

Table 9. Permit limits for monthly average effluent 5-day carbonaceous biochemical oxygen demand and total ammonia as nitrogen concentrations for sewage-treatment plants in the Salt Creek watershed in northeastern Illinois

Sewage-Treatment Plant	5-day carbonaceous biochemical oxygen demand concentration (milligrams per liter)	Total ammonia as nitrogen concentration (milligrams per liter)
Egan	10	1.5
Nordic Park	10	1.5
Itasca	20	1.5
Wood Dale North	20	1.5
Wood Dale South	20	1.5
Addison North	20	1.5
Addison South	20	1.5
Salt Creek Sanitary District	10	1.5
Elmhurst	10	2.3
Bensenville South	10	[1]1.5

[1]For Bensenville South Sewage-Treatment Plant, the permit limit for ammonia of 1.5 milligrams per liter for May through October is a daily maximum value rather than a monthly average value. The permit limit changes to 3.3 milligrams per liter on a monthly average basis for November through April.

Table 10. Dissolved oxygen concentrations at selected locations in the Salt Creek watershed in northeastern Illinois for 7-day, 10-year low stream and sewage-treatment plant flow for selected effluent concentration scenarios for the August 29-30, 1995, diel-survey conditions

[Scenarios are described in table 8; all concentrations are in milligrams per liter]

River mile	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
					Salt Creek						
31.7	7.02	6.83	6.54	6.54	7.37	7.37	7.48	7.47	7.57	7.58	7.68
31.5	7.02	6.75	6.34	6.34	7.1	7.1	7.26	7.24	7.38	7.4	7.54
29.3	7.06	6.08	4.9	4.9	5.02	5.02	5.58	5.42	5.84	5.99	6.4
28.1	6.74	5.9	5.06	5.08	5.26	5.29	5.76	5.58	5.88	6.04	6.34
27.1	6.66	5.77	4.95	4.99	5.19	5.26	5.74	5.55	5.84	6.02	6.3
25.6	6.66	5.69	4.88	4.91	5.04	5.17	5.66	5.44	5.72	5.94	6.21
24	6.37	5.43	4.77	4.78	4.91	5.1	5.55	5.32	5.55	5.77	6
23.1	6.1	5.14	4.51	4.52	4.68	4.89	5.33	5.11	5.32	5.54	5.76
20.1	5.46	4.42	3.8	3.8	3.86	4.15	4.6	4.37	4.58	4.8	5.02
17.7	6.28	5.3	4.67	4.67	4.76	5.1	5.52	5.3	5.5	5.72	5.93
13.7	5.8	4.06	3.08	3.08	3.13	3.74	4.52	4.05	4.36	4.82	5.13
[1]11.5	6.32	4.06	3.08	3.08	3.1	3.86	4.86	4.17	4.48	5.17	5.48
[2]11.5	6.68	4.48	4.07	4.07	4.09	4.7	5.51	4.94	5.18	5.76	6
8.8	6.26	5.01	4.55	4.55	4.56	4.96	5.52	5.11	5.25	5.66	5.8
4.5	5.86	5.07	4.86	4.86	4.86	5.1	5.45	5.16	5.23	5.52	5.58
3.5	5.46	4.68	4.51	4.51	4.52	4.72	5.07	4.78	4.84	5.13	5.18
1.1	4.49	3.86	3.74	3.74	3.74	3.9	4.18	3.93	3.96	4.22	4.26
					Spring Brook						
2.7	4.45	4.45	4.44	4.44	4.45	4.45	4.45	4.45	4.45	4.45	4.45
1.4	5.05	4.99	4.87	4.87	4.92	4.92	4.95	4.96	5	5	5.04
.3	5.37	5.28	5.16	5.16	5.2	5.21	5.26	5.26	5.3	5.3	5.34
					Addison Creek						
10.4	5.12	4.93	4.73	5.39	6.75	6.75	6.86	6.82	6.89	6.93	7
9.8	5.18	4.74	4.31	4.62	5.25	5.25	5.5	5.4	5.54	5.65	5.79
7.1	5.06	3.39	2.98	2.98	3	3	3.93	3.13	3.28	4.08	4.22
5.9	5.13	0	0	0	0	0	1.44	0	0	1.78	2.12
3.2	2.95	0	0	0	0	0	1.08	0	0	1.22	1.35
.3	0	0	0	0	0	0	0	0	0	0	0

[1]Upstream from Fullersburg Dam.

[2]Downstream from Fullersburg Dam.

Table 11. Dissolved oxygen concentrations at selected locations in the Salt Creek watershed in northeastern Illinois for 7-day, 10-year low streamflow and average 3-month low flow (January 1991–October 1995) from sewage-treatment plants for selected effluent concentration scenarios for the August 29–30, 1995, diel-survey conditions

[Scenarios are described in table 8; all concentrations are in milligrams per liter]

River mile	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
					Salt Creek						
31.7	7.03	6.85	6.58	6.58	7.41	7.41	7.52	7.51	7.6	7.61	7.71
31.5	7.04	6.78	6.39	6.39	7.16	7.16	7.32	7.3	7.44	7.44	7.58
29.3	7.14	6.18	4.98	4.98	5.11	5.11	5.67	5.52	5.94	6.08	6.5
28.1	6.82	5.98	5.09	5.12	5.32	5.36	5.82	5.66	5.96	6.13	6.44
27.1	6.77	5.86	4.98	5.02	5.22	5.3	5.79	5.6	5.91	6.09	6.39
25.6	6.77	5.78	4.92	4.94	5.08	5.21	5.71	5.5	5.79	6.01	6.3
24	6.54	5.58	4.89	4.9	5.03	5.21	5.67	5.45	5.69	5.91	6.15
23.1	6.27	5.28	4.6	4.62	4.75	4.96	5.42	5.2	5.42	5.66	5.88
20.1	5.68	4.66	4.01	4.01	4.08	4.34	4.78	4.56	4.78	5.01	5.23
17.7	6.42	5.46	4.82	4.82	4.92	5.22	5.66	5.43	5.64	5.86	6.08
13.7	5.99	4.28	3.29	3.29	3.34	3.92	4.68	4.23	4.55	5	5.32
[1]11.5	6.48	4.3	3.28	3.28	3.32	4.01	5	4.33	4.65	5.32	5.64
[2]11.5	6.81	5.02	4.23	4.23	4.25	4.81	5.63	5.06	5.32	5.88	6.13
8.8	6.46	5.21	4.71	4.71	4.73	5.11	5.68	5.26	5.42	5.83	5.99
4.5	6.12	5.31	5.07	5.07	5.08	5.3	5.67	5.38	5.45	5.74	5.82
3.5	5.77	4.96	4.76	4.76	4.76	4.96	5.34	5.03	5.1	5.4	5.48
1.1	4.94	4.27	4.13	4.13	4.13	4.28	4.6	4.32	4.37	4.64	4.7
					Spring Brook						
2.7	4.45	4.45	4.44	4.44	4.45	4.45	4.45	4.45	4.45	4.45	4.45
1.4	5.06	5	4.87	4.87	4.92	4.92	4.96	4.97	5.01	5	5.04
.3	5.38	5.29	5.15	5.16	5.21	5.22	5.26	5.26	5.31	5.31	5.36
					Addison Creek						
10.4	5.29	5.12	4.95	5.64	7.07	7.07	7.16	7.13	7.19	7.22	7.28
9.8	5.58	5.18	4.79	5.14	5.87	5.87	6.1	6.01	6.14	6.24	6.37
7.1	5.77	4.34	3.88	3.88	3.89	3.89	4.7	4.05	4.21	4.86	5.02
5.9	5.58	.36	0	0	0	0	2.22	0	.05	2.6	3
3.2	4.32	1.12	.57	.57	.57	.57	2.4	.76	.95	2.59	2.78
.3	1.3	0	0	0	0	0	.16	0	0	.26	0.34

[1]Upstream from Fullersburg Dam.

[2]Downstream from Fullersburg Dam.

Table 12. Dissolved oxygen concentrations at selected locations in the Salt Creek watershed in northeastern Illinois for 7-day, 10-year low streamflow and design-average flow from sewage-treatment plants for selected effluent concentration scenarious for the August 29-30, 1995, diel-survey conditions
[Scenarios are described in table 8; all concentrations are in milligrams per liter]

River mile	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
					Salt Creek						
31.7	7.06	6.89	6.65	6.65	7.5	7.5	7.59	7.58	7.67	7.68	7.76
31.5	7.08	6.84	6.48	6.48	7.28	7.28	7.42	7.4	7.52	7.54	7.66
29.3	7.3	6.34	5.12	5.12	5.29	5.29	5.84	5.71	6.14	6.26	6.68
28.1	7	6.13	5.15	5.18	5.42	5.46	5.94	5.8	6.14	6.28	6.61
27.1	6.94	6.02	5.05	5.09	5.35	5.44	5.92	5.76	6.1	6.26	6.59
25.6	6.98	5.96	5	5.03	5.22	5.36	5.88	5.69	6.02	6.21	6.53
24	6.87	5.88	5.1	5.11	5.3	5.5	5.97	5.77	6.04	6.23	6.5
23.1	6.69	5.68	4.92	4.93	5.14	5.37	5.83	5.64	5.9	6.09	6.36
20.1	6.3	5.18	4.38	4.38	4.48	4.8	5.28	5.08	5.36	5.56	5.82
17.7	6.74	5.7	4.96	4.96	5.08	5.44	5.9	5.69	5.94	6.14	6.39
13.7	6.42	4.59	3.46	3.46	3.54	4.2	4.99	4.57	4.94	5.36	5.74
[1]11.5	6.8	4.5	3.35	3.35	3.4	4.2	5.19	4.58	4.96	5.57	5.95
[2]11.5	7.07	5.16	4.22	4.22	4.26	4.92	5.74	5.22	5.53	6.05	6.36
8.8	6.87	5.43	4.79	4.79	4.81	5.3	5.92	5.51	5.72	6.13	6.35
4.5	6.68	5.68	5.32	5.32	5.33	5.66	6.09	5.78	5.89	6.21	6.33
3.5	6.46	5.48	5.16	5.16	5.16	5.45	5.89	5.56	5.66	6	6.1
1.1	5.9	4.86	4.56	4.56	4.57	4.85	5.32	4.94	5.04	5.42	5.52
					Spring Brook						
2.7	4.46	4.46	4.44	4.44	4.47	4.47	4.47	4.47	4.48	4.47	4.48
1.4	5.24	5.1	4.78	4.78	4.92	4.92	5	5.03	5.13	5.1	5.21
.3	5.56	5.36	5.03	5.04	5.13	5.14	5.24	5.25	5.36	5.36	5.46
					Addison Creek						
10.4	5.4	5.25	5.1	5.1	7.33	7.33	7.41	7.38	7.43	7.46	7.51
9.8	5.86	5.51	5.15	5.15	6.4	6.4	6.6	6.52	6.65	6.73	6.85
7.1	6.38	5.14	4.6	4.6	4.63	4.63	5.34	4.82	5	5.52	5.7
5.9	6.08	1.78	.52	.52	.52	.52	2.98	.96	1.4	3.42	3.86
3.2	5.36	2.4	1.68	1.68	1.68	1.68	3.37	1.93	2.18	3.62	3.87
.3	3.21	1.14	.74	.74	.74	.74	1.92	.88	1.02	2.06	2.2

[1]Upstream from Fullersburg Dam.
[2]Downstream from Fullersburg Dam.

Table 13. Dissolved oxygen concentrations at selected locations in the Salt Creek watershed in northeastern Illinois for 7-day, 10-year low stream and sewage-treatment plant flow for selected effluent concentration scenarios for the June 27–28, diel-survey conditions
[Scenarios are described in table 8; all concentrations are in milligrams per liter]

River mile	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
Salt Creek											
31.7	7.17	6.98	6.71	6.71	7.45	7.45	7.57	7.55	7.65	7.67	7.77
31.5	7.2	6.93	6.55	6.55	7.22	7.22	7.39	7.36	7.5	7.54	7.68
29.3	7.63	6.76	5.83	5.83	5.9	5.9	6.44	6.25	6.6	6.79	7.14
28.1	7.33	6.54	5.85	5.92	6.1	6.14	6.61	6.4	6.66	6.86	7.12
27.1	7.18	6.34	5.66	5.72	5.94	6.03	6.5	6.28	6.54	6.76	7
25.6	7.1	6.17	5.52	5.56	5.7	5.85	6.34	6.1	6.35	6.59	6.84
24	6.86	5.93	5.4	5.41	5.48	5.68	6.13	5.9	6.11	6.34	6.56
23.1	6.5	5.56	5.04	5.06	5.12	5.34	5.78	5.55	5.76	5.98	6.19
20.1	5.12	4.1	3.55	3.55	3.58	3.88	4.32	4.1	4.31	4.54	4.75
17.7	6.32	5.34	4.78	4.78	4.86	5.2	5.62	5.4	5.6	5.82	6.02
13.7	6.17	4.42	3.52	3.52	3.56	4.18	4.94	4.5	4.8	5.25	5.56
[1]11.5	6.71	4.97	4.14	4.14	4.17	4.78	5.54	5.06	5.35	5.82	6.1
[2]11.5	6.98	5.58	4.93	4.93	4.95	5.44	6.04	5.66	5.89	6.27	6.49
8.8	6.01	4.93	4.47	4.47	4.48	4.85	5.32	5.01	5.16	5.48	5.63
4.5	5.86	5.06	4.8	4.8	4.8	5.06	5.41	5.15	5.24	5.5	5.6
3.5	5.4	4.63	4.4	4.4	4.4	4.64	4.98	4.72	4.8	5	5.14
1.1	4.38	3.76	3.59	3.59	3.6	3.78	4.06	3.84	3.9	4.12	4.18
Spring Brook											
2.7	5.93	5.93	5.92	5.92	5.93	5.93	5.93	5.93	5.93	6.93	5.94
1.4	5.39	5.25	4.99	4.99	5.04	5.04	5.11	5.13	5.22	5.2	5.29
.3	5.3	5.12	4.9	4.92	4.96	4.96	5.06	5.04	5.12	5.13	5.2
Addison Creek											
10.4	5.51	5.36	5.33	5.75	7.14	7.14	7.23	7.2	7.25	7.29	7.34
9.8	5.62	5.31	5.24	5.44	6.12	6.12	6.31	6.24	6.36	6.43	6.55
7.1	6.12	5.63	5.54	5.54	5.55	5.55	5.85	5.7	5.84	6	6.14
5.9	7.87	6.17	5.94	5.94	5.94	5.94	7	6.33	6.71	7.39	7.78
3.2	4.85	3.89	3.78	3.78	3.79	3.79	4.39	3.96	4.13	4.56	4.73
.3	0	0	0	0	0	0	0	0	0	0	0

[1]Upstream from Fullersburg Dam.

[2]Downstream from Fullersburg Dam.

Table 14. Dissolved oxygen concentrations at selected locations in the Salt Creek watershed in northeastern Illinois for 7-day, 10-year low streamflow and average 3-month low flow (January 1991–October 1995) from sewage-treatment plants for selected effluent concentration scenarios for the June 27–28, 1995, diel-survey conditions

[Scenarios are described in table 8; all concentrations are in milligrams per liter]

River mile	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
Salt Creek											
31.7	7.18	7	6.74	6.74	7.49	7.49	7.6	7.58	7.68	7.7	7.79
31.5	7.22	6.96	6.6	6.6	7.28	7.28	7.44	7.41	7.54	7.58	7.7
29.3	7.68	6.82	5.86	5.86	5.95	5.95	6.49	6.3	6.66	6.84	7.2
28.1	7.36	6.58	5.84	5.92	6.14	6.18	6.65	6.45	6.72	6.92	7.18
27.1	7.26	6.4	5.68	5.74	5.97	6.06	6.54	6.33	6.6	6.8	7.08
25.6	7.21	6.26	5.56	5.6	5.75	5.89	6.39	6.16	6.43	6.66	6.93
24	7.02	6.09	5.52	5.54	5.61	5.81	6.26	6.03	6.25	6.48	6.71
23.1	6.68	5.72	5.14	5.16	5.22	5.44	5.9	5.67	5.89	6.12	6.34
20.1	5.44	4.42	3.86	3.86	3.9	4.17	4.63	4.4	4.62	4.84	5.06
17.7	6.5	5.53	4.97	4.97	5.06	5.38	5.8	5.58	5.78	6	6.21
13.7	6.38	4.68	3.77	3.77	3.82	4.4	5.15	4.72	5.03	5.46	5.78
[1]11.5	6.89	5.22	4.38	4.38	4.41	4.98	5.72	5.26	5.56	6.02	6.3
[2]11.5	7.14	5.8	5.14	5.14	5.16	5.61	6.21	5.84	6.07	6.44	6.67
8.8	6.31	5.24	4.76	4.76	4.78	5.13	5.6	5.29	5.45	5.77	5.93
4.5	6.18	5.36	5.07	5.07	5.08	5.33	5.7	5.43	5.53	5.8	5.9
3.5	5.76	5	4.74	4.74	4.74	4.97	5.32	5.06	5.15	5.41	5.5
1.1	4.9	4.28	4.08	4.08	4.08	4.26	4.55	4.34	4.41	4.62	4.7
Spring Brook											
2.7	5.93	5.93	5.92	5.92	5.93	5.93	5.93	5.93	5.93	5.93	5.94
1.4	5.41	5.26	4.99	4.99	5.04	5.04	5.12	5.13	5.22	5.21	5.3
.3	5.32	5.14	4.9	4.92	4.96	4.97	5.06	5.05	5.12	5.14	5.22
Addison Creek											
10.4	5.65	5.52	5.49	5.93	7.39	7.39	7.47	7.43	7.48	7.51	7.56
9.8	5.95	5.66	5.59	5.83	6.6	6.6	6.78	6.71	6.82	6.89	7
7.1	6.55	6.06	5.96	5.96	5.98	5.98	6.28	6.13	6.29	6.44	6.6
5.9	7.1	5.42	5.16	5.17	5.17	5.17	6.22	5.6	6.02	6.64	7.07
3.2	5.68	4.61	4.47	4.48	4.48	4.48	5.14	4.7	4.92	5.37	5.59
.3	0	0	0	0	0	0	0	0	0	0	0

[1]Upstream from Fullersburg Dam.

[2]Downstream from Fullersburg Dam.

Table 15. Dissolved oxygen concentrations at selected locations in the Salt Creek watershed in northeastern Illinois for 7-day, 10-year low streamflow and design-average flow from sewage-treatment plants for selected effluent concentration scenarios for the June 27–28, 1995, diel-survey conditions
[Scenarios are described in table 8; all concentrations are in milligrams per liter]

River mile	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
					Salt Creek						
31.7	7.2	7.03	6.8	6.8	7.56	7.56	7.66	7.65	7.73	7.75	7.84
31.5	7.24	7	6.68	6.68	7.38	7.38	7.52	7.5	7.62	7.64	7.77
29.3	7.78	6.93	5.94	5.94	6.05	6.05	6.58	6.42	6.78	6.94	7.31
28.1	7.45	6.65	5.85	5.94	6.18	6.22	6.7	6.52	6.82	7	7.29
27.1	7.36	6.49	5.72	5.79	6.06	6.16	6.63	6.44	6.74	6.92	7.22
25.6	7.36	6.4	5.64	5.69	5.88	6.04	6.54	6.33	6.62	6.83	7.13
24	7.33	6.39	5.75	5.77	5.88	6.09	6.54	6.34	6.58	6.78	7.03
23.1	7.12	6.16	5.53	5.55	5.64	5.88	6.32	6.12	6.36	6.56	6.8
20.1	6.29	5.19	4.51	4.52	4.56	4.9	5.36	5.16	5.42	5.62	5.88
17.7	6.9	5.87	5.23	5.23	5.34	5.7	6.14	5.93	6.16	6.37	6.61
13.7	6.81	5.01	4	4	4.07	4.72	5.48	5.08	5.44	5.84	6.2
[1]11.5	7.22	5.49	4.58	4.58	4.62	5.24	5.98	5.58	5.9	6.31	6.64
[2]11.5	7.45	6.05	5.32	5.32	5.35	5.85	6.44	6.11	6.38	6.71	6.97
8.8	6.92	5.73	5.16	5.16	5.18	5.6	6.1	5.8	6.01	6.31	6.51
4.5	6.82	5.86	5.47	5.47	5.47	5.8	6.21	5.94	6.08	6.36	6.5
3.5	6.56	5.64	5.28	5.28	5.3	5.6	5.98	5.72	5.86	6.12	6.26
1.1	6.01	5.04	4.68	4.68	4.68	5	5.42	5.14	5.27	5.56	5.7
					Spring Brook						
2.7	5.96	5.95	5.94	5.94	5.95	5.95	5.96	5.96	5.96	5.96	5.97
1.4	5.83	5.53	4.92	4.92	5.04	5.04	5.2	5.25	5.45	5.41	5.61
.3	5.78	5.4	4.86	4.87	4.94	4.96	5.16	5.14	5.33	5.34	5.53
					Addison Creek						
10.4	5.73	5.62	5.59	6.05	7.58	7.58	7.65	7.62	7.66	7.69	7.73
9.8	6.17	5.91	5.85	6.12	7.01	7.01	7.17	7.11	7.21	7.27	7.37
7.1	6.92	6.41	6.3	6.32	6.34	6.34	6.66	6.51	6.68	6.82	7
5.9	6.78	5.14	4.86	4.86	4.88	4.88	5.9	5.33	5.78	6.36	6.81
3.2	6.18	5.02	4.86	4.86	4.86	4.86	5.59	5.14	5.42	5.86	6.14
.3	1.48	.66	.56	.56	.56	.56	1.07	.72	.88	1.23	1.4

[1]Upstream from Fullersburg Dam.

[2]Downstream from Fullersburg Dam.

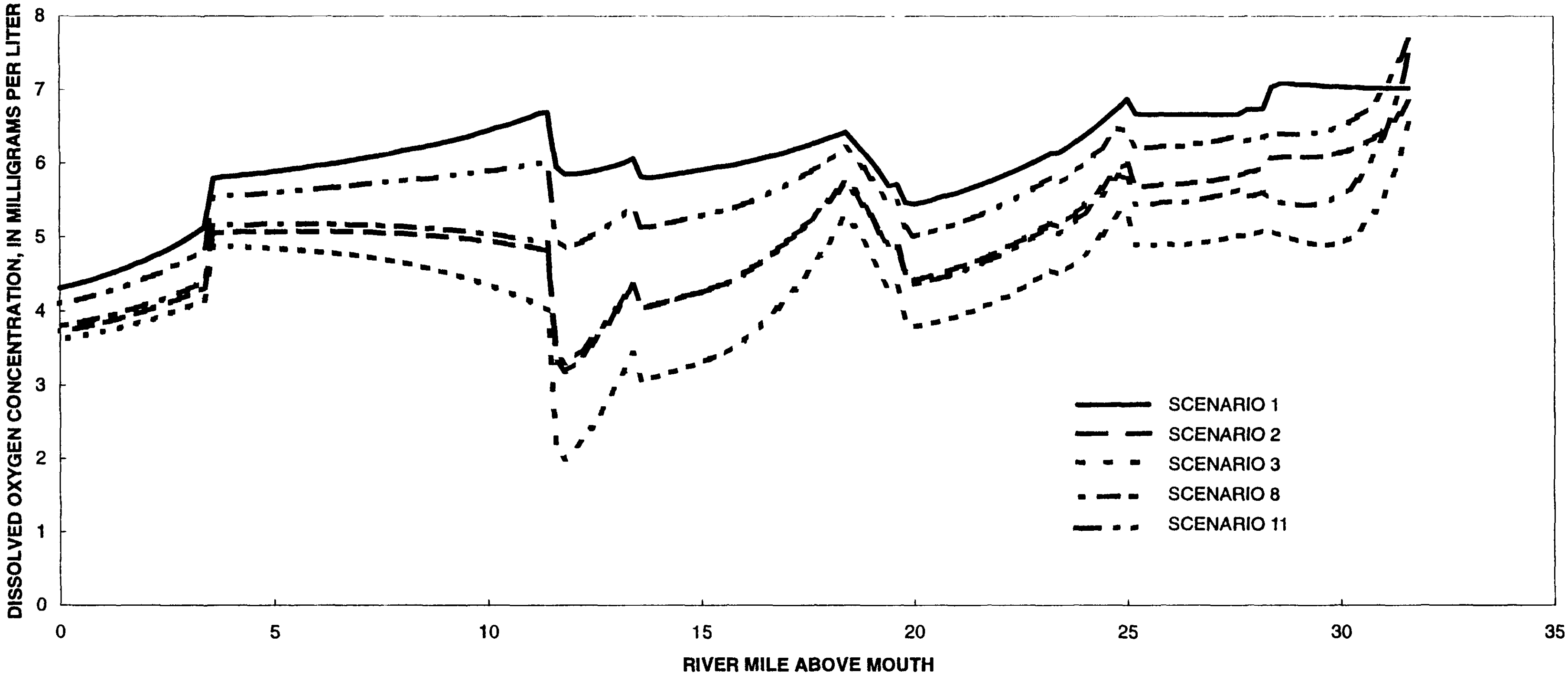

Figure 53. Profiles of simulated dissolved oxygen concentrations in Salt Creek in northeastern Illinois for selected effluent concentration scenarios for 7-day, 10-year low stream and sewage-treatment plant flow for the August 29-30, 1995, diel-survey conditions.

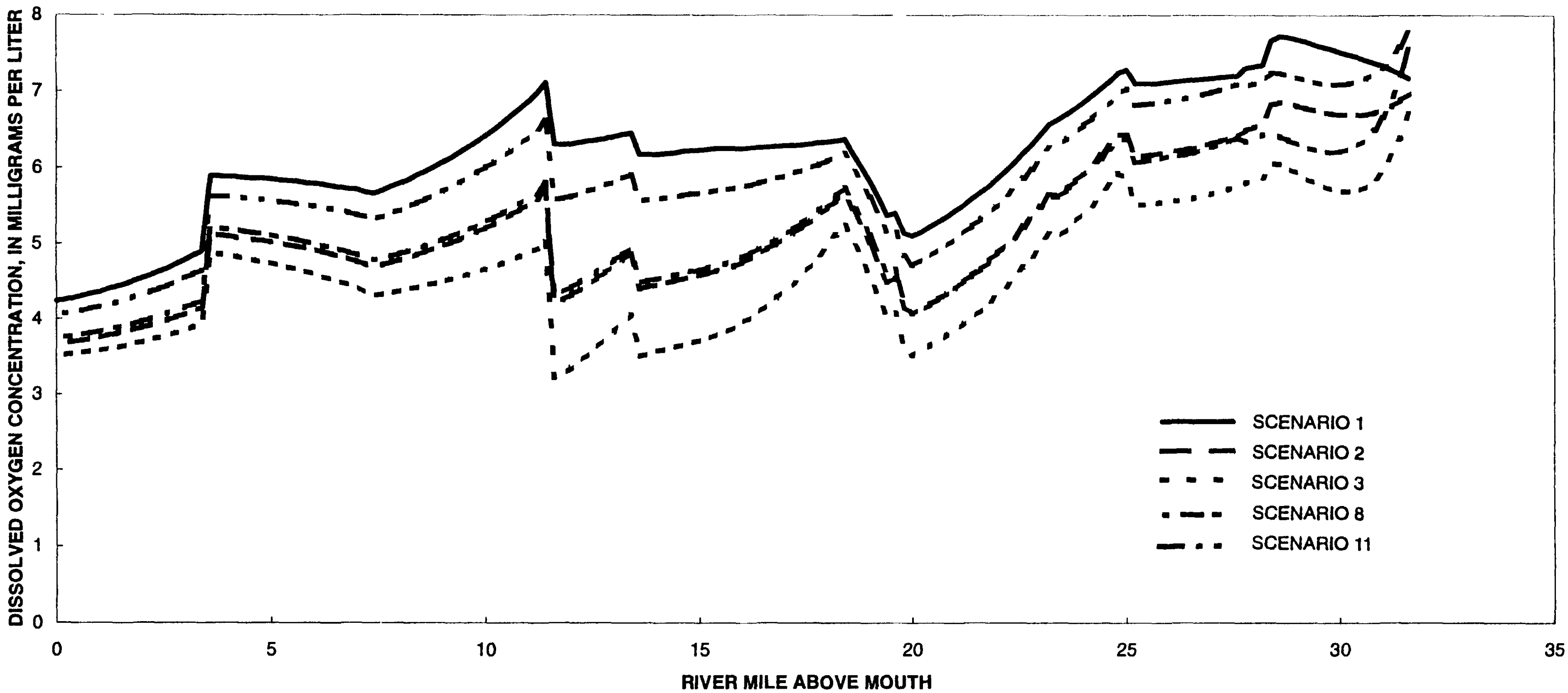

Figure 54. Profiles of simulated dissolved oxygen concentrations in Salt Creek in northeastern Illinois for selected effluent concentration scenarios for 7-day, 10-year low stream and sewage-treatment plant flow for the June 27-28, 1995, diel-survey conditions.

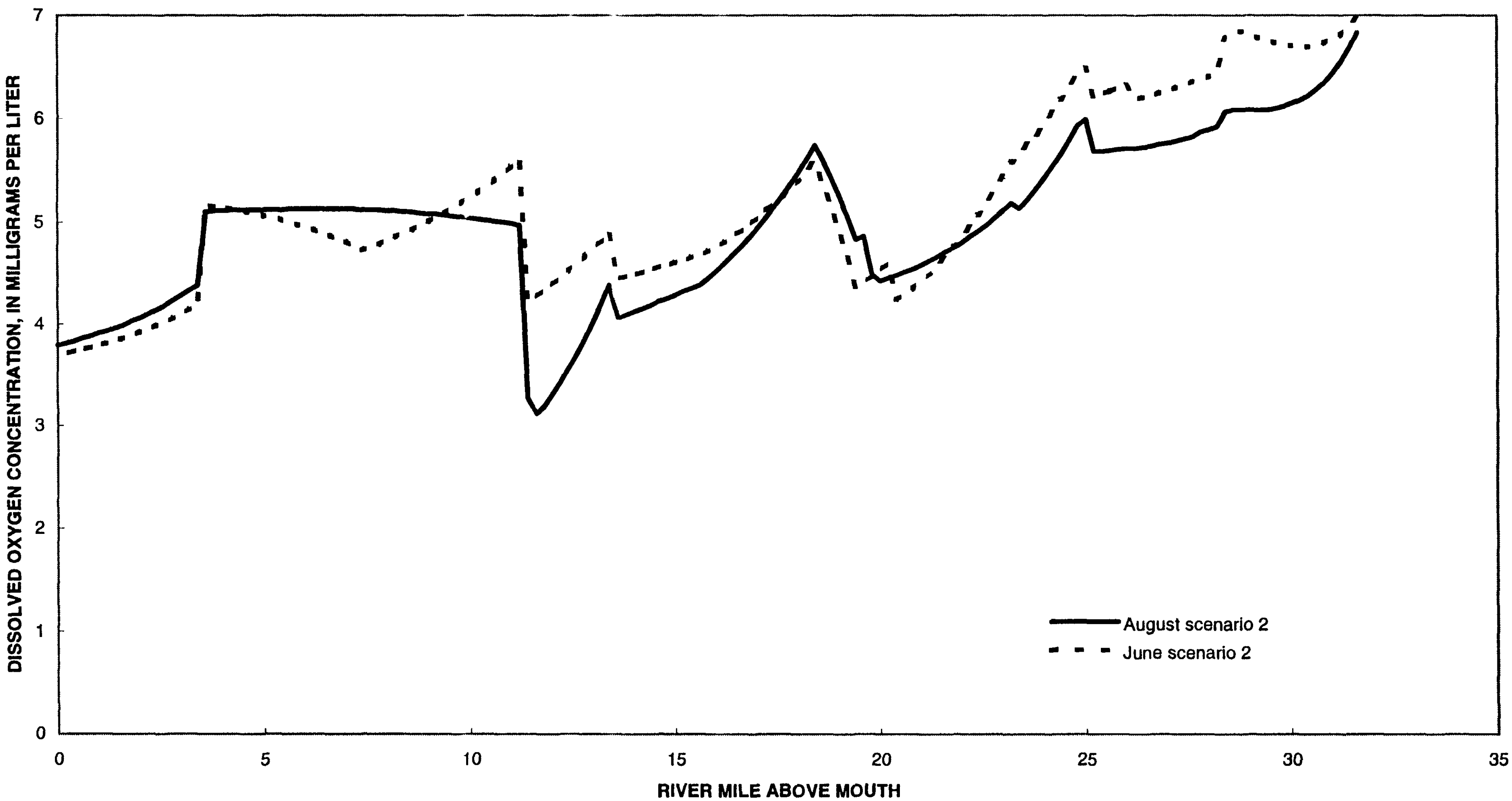

Figure 55. Simulated dissolved oxygen concentration profiles in Salt Creek in northeastern Illinois for 7-day, 10-year low stream and sewage-treatment plant flow corresponding to effluent scenario 2 for the June 27-28, 1995, and August 29-30, 1995, diel-survey conditions.

Critically low DO concentrations were simulated at the following three locations on Salt Creek:

1) River mile 20.1 (Railroad Avenue) in the vicinity of the active CSO's;

2) River mile 11.5 immediately upstream from Fullersburg Dam, where the long traveltimes and low reaeration-rate coefficient (0.2 day^{-1}) combine to yield very low DO concentrations under high effluent concentration conditions;

3) River miles 0 to 3.2 (confluence with the Des Plaines River and Maple Avenue), where low DO concentrations from Addison Creek and high SOD rates combine to yield low DO concentrations throughout the reach.

The DO concentration at river mile 11.5 is especially low for the simulations of the August 29-30, 1995, diel-survey conditions. This results because a very long traveltime is simulated in reach 10 (behind Fullersburg Dam) for the August 29-30, 1995, diel-survey conditions and for scenarios with high effluent concentrations, biological oxidation of high waste loads during the long traveltime result in very low DO concentrations. No DO concentration measurements are available to verify these very low concentrations upstream from Fullersburg Dam. Dissolved oxygen concentrations at river mile 20.1 and between river miles 0 and 3.2 (the other two locations with critically low DO concentrations) are similar for the simulations of the August 29-30, 1995, and June 27-28, 1995, diel-survey conditions as illustrated in figure 55. Thus, simulations for the June 27-28, 1995, diel-survey conditions may result in more reasonable DO concentrations for water-quality planning purposes.

The simulated DO concentrations in Salt Creek resulting from effluent concentration scenario 1 are far higher than those for any other effluent concentration scenario. For effluent concentration scenario 1, DO concentrations decrease below 5 mg/L only downstream from river mile 3.6 (confluence with Addison Creek) of Salt Creek for STP discharge levels 1 and 2. This results because all of the STP's are discharging $CBOD_u$ and total ammonia as nitrogen concentrations far below the permit limits during the June 27-28, 1995, and August 29-30, 1995, diel-survey periods.

The DO concentration profile for either the June or August diel-survey parameters for effluent concentration scenario 2 for STP flow level 1 indicates that if all STP's were discharging their permit limits for CBOD, DO concentrations would be below 5 mg/L for nearly all of Salt Creek downstream from river mile 23.1 (Fullerton Avenue) (fig. 54). The DO concentration profile for effluent concentration scenario 3 for STP flow level 1 indicates that if all STP's were discharging their permit limits for CBOD and total ammonia as nitrogen, DO concentrations would be below 5 mg/L for all of Salt Creek downstream from river mile 23.1 (figs. 53 and 54). Relatively small decreases in the permit limits for CBOD and total ammonia as nitrogen result in only marginal increases in DO concentrations. For example, if the 5-day CBOD effluent concentrations were one-half of the permit limits at Itasca, Wood Dale North, Wood Dale South, Addison North, and Addison South STP's (10 mg/L) and effluent total ammonia as nitrogen concentrations were two-thirds of the permit limits at all STP's (1.0 mg/L), effluent concentration scenario 8, DO concentrations similar to those for effluent concentration scenario 2 result (figs. 53 and 54). The decreases in CBOD load between scenarios 2 and 8 are offset by the increases in total ammonia as nitrogen load. Dissolved oxygen concentrations higher than 5 mg/L will be attained throughout most of Salt Creek only if effluent loads of CBOD and total ammonia as nitrogen are substantially below the permit limits at all STP's (effluent scenarios 1, 10, and 11).

Dissolved oxygen concentrations increase in the Salt Creek watershed with increases in STP discharge. This results because as discharge increases the volume of water supplying oxygen to meet SOD increases, and the effects of SOD on total DO concentration in the water column decrease.

The scenarios examined here are just a few of the possible effluent concentration and discharge scenarios that could be examined for water-quality planning purposes. The results of simulating the scenarios examined in this report illustrate the usefulness of the QUAL2E model calibrated to the August 29-30, 1995, diel survey and the QUAL2E model adjusted to the June 27-28, 1995, diel survey for water-quality planning in the Salt Creek watershed.

SUMMARY

Salt Creek and its tributaries in northeastern Illinois were identified by the Illinois Environmental Protection Agnecy (IEPA) as water-quality limited water bodies under section 303(d) of the Clean Water Act. The U.S. Geological Survey (USGS) and IEPA established a cooperative agreement in 1995 to study water-quality processes in Salt Creek and its two major tributaries, Spring Brook and Addison Creek. Water-quality processes in the Salt Creek watershed were simulated with a computer model. Selected waste-load scenarios for 7-day, 10-year low-flow conditions were simulated in the stream system. The model development involved the calibration of the U.S. Environmental Protection Agency QUAL2E model to water-quality constituent concentration data collected by the IEPA for a diel survey on August 29-30, 1995. The verification of this model was done with water-quality constituent concentration data collected by the IEPA for a diel period on June 27-28, 1995. In-stream measurements of sediment oxygen demand rates and carbonaceous biochemical oxygen demand (CBOD) decay rates by the IEPA and traveltime and reaeration-rate coefficients by the USGS facilitated the development of a model of water quality in the Salt Creek watershed. In general, the verification of the calibrated model

increased confidence in the utility of the model for water-quality planning in the Salt Creek watershed. However, the model was adjusted to better simulate constituent concentrations measured during the June 27-28, 1995, diel survey.

The QUAL2E model calibrated to the August 29-30, 1995, diel survey and the QUAL2E model adjusted to the June 27-28, 1995, diel survey were both utilized to simulate DO concentrations in Salt Creek for 33 selected effluent scenarios for water-quality planning in the Salt Creek watershed. The results of these simulations indicated that the QUAL2E model adjusted to the June 27-28, 1995, diel survey produces reliable information for water-quality planning. The results of these simulations also indicated that to maintain DO concentrations greater than 5 milligrams per liter (mg/L) throughout the major portion of Salt Creek for 7-day, 10-year low-flow conditions, the STP's effluent must contain CBOD and total ammonia as nitrogen concentrations substantially below the permit limits. If the STP's discharge effluent with CBOD and total ammonia as nitrogen concentrations at the permit limits for 7-day, 10-year low-flow conditions, DO concentrations less than 5 mg/L are expected for all of Salt Creek downstream from river mile 23.1 (Fullerton Avenue).

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APPENDIXES

APPENDIX A. QUAL2E DATA FILE FOR THE CALIBRATION TO THE AUGUST 29-30, 1995, DIEL-SURVEY DATA

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TITLE01             SALT CREEK, ILLINOIS, REVISED CALIBRATION (8/29/95)
TITLE02             SALT CREEK
TITLE03  YES        CONSERVATIVE MINERAL I
TITLE04   NO        CONSERVATIVE MINERAL II
TITLE05   NO        CONSERVATIVE MINERAL III
TITLE06   NO        TEMPERATURE
TITLE07  YES        BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES        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        DISOLVED OXYGEN IN MG/L
TITLE14   NO        FECAL COLIFORMS IN NO./100 ML
TITLE15   NO        ARBITRARY NON-CONSERVATIVE MG/L
ENDTITLE
LIST DATA INPUT
NO WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
TRAPEZOIDAL X-SECTIONS
NO PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=       0.        5D-ULT BOD CONV K COEF  =      0.23
INPUT METRIC (YES=1)    =       0.        OUTPUT METRIC (YES=1)   =        0.
NUMBER OF REACHES       =      17.        NUMBER OF JUNCTIONS     =        2.
NUM OF HEADWATERS       =       3.        NUMBER OF POINT LOADS   =       13.
TIME STEP (HOURS)       =       0.        LNTH  COMP  ELEMENT (DX)=       0.2
MAXIMUM ITERATIONS      =      30.        TIME INC. FOR RPT2 (HRS)=        0.
LATITUDE OF BASIN (DEG) =     41.9        LONGITUDE OF BASIN (DEG)=     87.96
STANDARD MERIDIAN (DEG) =      75.        DAY OF YEAR START TIME  =      241.
EVAP. COEFF. (AE)       =  0.00068        EVAP. COEFF. (BE)       =   0.00027
ELEV. OF BASIN (ELEV)   =     660.        DUST ATTENUATION COEF.  =      0.06
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)=   3.43  O UPTAKE BY NO2 OXID(MG O/MG N)=   1.14
O PROD  BY ALGAE (MG O/MG A)   =    1.6  O UPTAKE BY ALGAE (MG O/MG A)  =   1.95
N CONTENT OF ALGAE (MG N/MG A) =   0.09  P CONTENT OF ALGAE (MG P/MG A) =  0.015
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.6  ALGAE RESPIRATION RATE (1/DAY) =    0.5
N HALF SATURATION CONST (MG/L) =    0.3  P HALF SATURATION CONST  (MG/L)=   0.04
LIN ALG SHADE CO (1/H-UGCHA/L) =  0.000  NLIN SHADE (1/H-(UGCHA/L)**2/3)=     0.
LIGHT FUNCTION OPTION (LFNOPT) =     1.  LIGHT SATURATION COEF (INT/MIN)=   0.11
DAILY AVERAGING OPTION (LAVOPT)=     2.  LIGHT AVERAGING FACTOR         =   0.92
NUMBER OF DAYLIGHT HOURS (DLH) =  13.28  TOTAL DAILY SOLAR RADTN (INT)  =  1392.
ALGY GROWTH CALC OPTION(LGROPT)=     2.  ALGAL PREF FOR NH3-N (PREFN)   =    0.1
ALG/TEMP SOLR RAD FACTOR(TFACT)=   0.00  NITRIFICATION INHIBITION COEF  =    10.
ENDATA1A
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ENDATA1B
STREAM REACH       1.RCH=EGAN - SPRING BK   FROM         31.8     TO          28.4
STREAM REACH       2.RCH=SPRING BROOK       FROM          2.8     TO            0.
STREAM REACH       3.RCH=SPR BRK - ADD N    FROM         28.4     TO           25.
STREAM REACH       4.RCH=ADD N - ADD S      FROM          25.     TO          23.4
STREAM REACH       5.RCH=ADD S - ST CHAR    FROM         23.4     TO          20.4
STREAM REACH       6.RCH=CSO REACH          FROM         20.4     TO          19.4
STREAM REACH       7.RCH=STEEP REACH        FROM         19.4     TO          18.6
STREAM REACH       8.RCH=FLAT REACH         FROM         18.6     TO          15.6
STREAM REACH       9.RCH=FLAT REACH -31ST   FROM         15.6     TO          13.8
STREAM REACH      10.RCH=31ST - FULL PARK   FROM         13.8     TO          11.4
STREAM REACH      11.RCH=DWN FR FULL PARK   FROM         11.4     TO           7.4
STREAM REACH      12.RCH=TO CONF ADD CR     FROM          7.4     TO           3.6
STREAM REACH      13.RCH=BENSEVILLE DWNS    FROM         10.4     TO           7.2
STREAM REACH      14.RCH=ADDISON REACH 2    FROM          7.2     TO           5.8
STREAM REACH      15.RCH=ADDISON REACH 3    FROM          5.8     TO           3.2
STREAM REACH      16.RCH=TO CONF SALT CR    FROM          3.2     TO            0.
STREAM REACH      17.RCH=TO CONF DES PLAI   FROM          3.6     TO            0.
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.         17          1 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3
FLAG FIELD RCH=   2.         14          1 6 2 2 2 2 2 2 2 2 2 2 2 6
FLAG FIELD RCH=   3.         17          4 2 2 6 2 2 2 2 2 2 2 6 2 2 2 2 2
FLAG FIELD RCH=   4.          8          6 2 2 2 2 2 2 2
FLAG FIELD RCH=   5.         15          6 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   6           5          6 2 6 6 2
FLAG FIELD RCH=   7.          4          2 2 6 2
FLAG FIELD RCH=   8.         15          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   9.          9          2 2 2 2 2 2 2 2 6
FLAG FIELD RCH=  10.         12          2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  11.         20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  12.         19          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3
FLAG FIELD RCH=  13.         16          1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  14.          7          2 2 2 2 2 2 2
FLAG FIELD RCH=  15.         13          2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  16.         16          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  17.         18          4 2 2 2 2 2 2 6 2 2 2 2 2 2 2 2 2 5
ENDATA4
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HYDRAULICS RCH=   1.       60.        3.        6.       27.   0.00043     0.40
HYDRAULICS RCH=   2.       60.        3.      0.2       10.    0.0011     0.33
HYDRAULICS RCH=   3.       60.        2.        4.       35.    0.0003    0.110
HYDRAULICS RCH=   4.       60.        2.      1.5       35.   0.00038    0.110
HYDRAULICS RCH=   5.       60.      2.6        1.       34.   0.00041    0.110
HYDRAULICS RCH=   6.       60.      2.6        1.       34.   0.00041    0.110
HYDRAULICS RCH=   7.       60.        3.        5.       30.    0.0015     0.05
HYDRAULICS RCH=   8.       60.        3.        5.       30.   0.00004     0.06
HYDRAULICS RCH=   9.       60.        2.      1.5       25.   0.00068     0.10
HYDRAULICS RCH=  10.       60.        5.        5.       50.    0.0002     0.26
HYDRAULICS RCH=  11.       60.      5.6      4.4       55.   0.00055    0.052
HYDRAULICS RCH=  12.       60.      5.6      4.4       55.   0.00062    0.052
HYDRAULICS RCH=  13.       60.        1.        1.       32.    0.0008     0.20
HYDRAULICS RCH=  14.       60.        6.        2.       15.   0.00085     1.20
HYDRAULICS RCH=  15.       60.      2.5      2.5       25.   0.00056     0.08
HYDRAULICS RCH=  16.       60.      2.5      2.5       25.   0.00056     0.08
HYDRAULICS RCH=  17.       60.      2.6      3.3       39.   0.00025    0.052
ENDATA5
TEMP/LCD    RCH=   1.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   2.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   3.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   4.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   5.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   6.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   7.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   8.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=   9.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  10.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  11.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  12.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  13.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  14.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  15.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  16.      1000.   0.06     0.3     70.     60.    29.9     0.
TEMP/LCD    RCH=  17.      1000.   0.06     0.3     70.     60.    29.9     0.
ENDATA5A
REACT COEF RCH=   1.   0.144       0.     0.18  1.     2.1       0.      0.
REACT COEF RCH=   2.    0.14       0.    0.148  1.    2.23       0.      0.
REACT COEF RCH=   3.   0.139       0.    0.135  1.    1.86       0.      0.
REACT COEF RCH=   4.   0.159       0.     0.30  1.      2.       0.      0.
REACT COEF RCH=   5.   0.124       0.     0.30  1.      2.       0.      0.
REACT COEF RCH=   6.   0.124       0.     0.30  1.      2.       0.      0.
REACT COEF RCH=   7.    0.14       0.     0.12  1.      8.       0.      0.
REACT COEF RCH=   8.   0.156       0.     0.12  1.    0.86       0.      0.
REACT COEF RCH=   9.    0.14       0.     0.12  1.    0.86       0.      0.
REACT COEF RCH=  10.   0.143       0.     0.04  1.     0.2       0.      0.
REACT COEF RCH=  11.   0.148       0.     0.15  1.    2.76       0.      0.
REACT COEF RCH=  12.    0.14       0.     0.15  1.    2.76       0.      0.
REACT COEF RCH=  13.   0.154     -0.8     0.22  1.     5.2       0.      0.
REACT COEF RCH=  14.    0.15       0.     0.05  1.     0.6       0.      0.
REACT COEF RCH=  15.    0.15       0.     0.10  1.      2.       0.      0.
REACT COEF RCH=  16.    0.15       0.     0.20  1.      2.       0.      0.
REACT COEF RCH=  17.   0.113       0.     0.40  1.    2.76       0.      0.
ENDATA6
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N AND P COEF    RCH=   1.   0.02   -0.3     0.6      0.     10.     0.    1.0     0.
N AND P COEF    RCH=   2.   0.02   -0.15    1.0      0.     10.     0.     0.     0.
N AND P COEF    RCH=   3.   0.02    0.2     0.6      0.     10.     0.    1.0     0.
N AND P COEF    RCH=   4.   0.02    0.      0.6      5.     10.     0.    1.0     0.
N AND P COEF    RCH=   5.   0.02    0.      0.6      5.     10.     0.    1.0     0.
N AND P COEF    RCH=   6.   0.02    0.      0.6      5.     10.     0.    1.0     0.
N AND P COEF    RCH=   7.   0.02    0.      0.6      5.     10.     0.    1.0     0.
N AND P COEF    RCH=   8.   0.02    0.      0.6      5.     10.     0.    0.0     0.
N AND P COEF    RCH=   9.   0.02    0.      0.6      5.     10.     0.    1.0     0.
N AND P COEF    RCH=  10.   0.02    0.      0.6      0.     10.     0.    0.0     0.
N AND P COEF    RCH=  11.   0.02    0.      0.6      0.     10.     0.    1.0     0.
N AND P COEF    RCH=  12.   0.02    0.      0.6      0.     10.     0.    1.0     0.
N AND P COEF    RCH=  13.   0.02    0.     0.45  11.00     10.     0.    1.0     0.
N AND P COEF    RCH=  14.   0.02    0.     0.45      0.     10.     0.    1.0     0.
N AND P COEF    RCH=  15.   0.02    0.     0.45      0.     10.     0.    1.0     0.
N AND P COEF    RCH=  16.   0.02    0.     0.45      0.     10.     0.    1.0     0.
N AND P COEF    RCH=  17.   0.02    0.      0.6      0.     10.     0.    1.0     0.
ENDATA6A
ALG/OTHER COEF RCH=   1.    50.    0.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   2.    50.    0.6    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   3.    50.    3.3    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   4.    50.    0.6    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   5.    50.    1.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   6.    50.    1.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   7.    50.    0.6    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   8.    50.    1.5    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=   9.    50.    0.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  10.    50.    0.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  11.    50.    1.3    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  12.    50.    1.3    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  13.    50.    0.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  14.    50.    0.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  15.    50.   1.25    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  16.    50.    0.0    0.10      0.      0.     0.     0.
ALG/OTHER COEF RCH=  17.    50.    1.3    0.10      0.      0.     0.     0.
ENDATA6B
INITIAL COND-1 RCH=   1.   74.4     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   2.   77.6     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   3.   75.4     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   4.   75.7     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   5.   76.1     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   6.   76.1     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   7.   76.0     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   8.   75.9     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   9.   76.2     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  10.   76.6     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  11.   77.2     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  12.   77.2     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  13.   76.0     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  14.   77.4     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  15.   77.4     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  16.   76.1     0.      0.      0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  17.   77.0     0.      0.      0.      0.     0.     0.     0.
ENDATA7
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INITIAL COND-2 RCH=   1.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   2.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   3.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   4.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   5.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   6.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   7.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   8.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=   9.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  10.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  11.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  12.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  13.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  14.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  15.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  16.    0.     0.     0.     0.     0.     0.     0.
INITIAL COND-2 RCH=  17.    0.     0.     0.     0.     0.     0.     0.
ENDATA7A
INCR INFLOW-1  RCH=   1.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   2.  1.16   73.8  7.58  2.95 1090.    0.     0.     0.     0.
INCR INFLOW-1  RCH=   3.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   4.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   5.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   6.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   7.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   8.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   9.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  10.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  11.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  12.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  13.  0.46   73.1  3.39  7.38  711.    0.     0.     0.     0.
INCR INFLOW-1  RCH=  14.  0.20   73.1  3.39  7.38  711.    0.     0.     0.     0.
INCR INFLOW-1  RCH=  15.  0.38   73.1  3.39  7.38  711.    0.     0.     0.     0.
INCR INFLOW-1  RCH=  16.    0.    70.    0.    0.    0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  17.    0.    70.    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.  6.68  0.863     0.     0.  1.00 0.0131 0.0744
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.
INCR INFLOW-2  RCH=  12.    0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-2  RCH=  13.    0.  0.900   0.27     0.  2.37  0.064  0.361
INCR INFLOW-2  RCH=  14.    0.  0.900   0.27     0.  2.37  0.064  0.361
INCR INFLOW-2  RCH=  15.    0.  0.900   0.27     0.  2.37  0.064  0.361
INCR INFLOW-2  RCH=  16.    0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-2  RCH=  17.    0.     0.     0.     0.     0.     0.     0.
ENDATA8A
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STREAM JUNCTION        1.     JNC=                      17.        32.        31.
STREAM JUNCTION        2.     JNC=                     155.       208.       207.
ENDATA9
HEADWTR-1 HDW=   1.SALT CREEK @ BW      6.47   80.1  7.58  4.92  566.     0.     0.
HEADWTR-1 HDW=   2.SPRING BROOK         3.18   79.6  4.33  2.95 1005.     0.     0.
HEADWTR-1 HDW=   3.ADD CR-BEN STP       7.63   75.6  5.03  2.46  863.     0.     0.
ENDATA10
HEADWTR-2 HDW=   1.      0.     0. 32.93 0.933   0.04    0.  0.01 0.009 0.048
HEADWTR-2 HDW=   2.      0.     0. 23.58  1.02   0.32    0. 0.595 0.030 0.168
HEADWTR-2 HDW=   3.      0.     0.  5.00   1.1  0.054    0. 18.25 0.495 2.805
ENDATA10A
POINTLD-1 PTL=   1.EGAN             0.    31.33   72.5  7.02  2.56  870.     0.     0.
POINTLD-1 PTL=   2.NORDIC PARK      0.     0.27   71.5  6.08  1.97 2933.     0.     0.
POINTLD-1 PTL=   3.ITASCA           0.     2.11   74.1  5.63  5.90 1080.     0.     0.
POINTLD-1 PTL=   4.WOOD DALE N      0.     1.35   74.5  5.46  4.43  887.     0.     0.
POINTLD-1 PTL=   5.WOOD DALE S      0.     0.46   73.1  6.98  2.46  903.     0.     0.
POINTLD-1 PTL=   6.ADDISON N        0.     3.06   74.1  6.97  3.44  971.     0.     0.
POINTLD-1 PTL=   7.ADDISON S        0.     1.45   75.8  6.96  3.93  871.     0.     0.
POINTLD-1 PTL=   8.ST CHAR CSO      0.     0.00     0.    0.    0.    0.     0.     0.
POINTLD-1 PTL=   9.SC SD            0.     3.54   75.1  6.31  2.46  825.     0.     0.
POINTLD-1 PTL=  10.ELMHURST         0.     7.46   75.4  7.51  2.46  840.     0.     0.
POINTLD-1 PTL=  11.SUGAR CREEK      0.     5.23   79.6  4.33  7.38 1090.     0.     0.
POINTLD-1 PTL=  12.GINGER CREEK     0.     6.88   79.6  4.33  7.38 1090.     0.     0.
POINTLD-1 PTL=  13.DIVERSION        0.   -14.91   77.0  5.99  2.35 895.4     0.     0.
ENDATA11
POINTLD-2 PTL=    1.     0.     0.     0.  1.01  0.048    0.  11.7 0.505 2.865
POINTLD-2 PTL=    2.     0.     0.     0.  0.96  0.005    0.  14.0 0.480 2.720
POINTLD-2 PTL=    3.     0.     0.     0.  1.25  0.025    0.  22.5 0.405 2.295
POINTLD-2 PTL=    4.     0.     0.     0.  1.13  0.016    0.  18.7 0.420 2.380
POINTLD-2 PTL=    5.     0.     0.     0. 0.905  0.025    0.  22.0 0.409 2.316
POINTLD-2 PTL=    6.     0.     0.     0.  1.29   0.01    0.  17.9 0.442 2.508
POINTLD-2 PTL=    7.     0.     0.     0. 1.175  0.035    0.  21.0 0.525 2.975
POINTLD-2 PTL=    8.     0.     0.     0.    0.     0.    0.    0.    0.    0.
POINTLD-2 PTL=    9.     0.     0.     0.  0.46   1.59    0.  16.8 0.772 4.378
POINTLD-2 PTL=   10.     0.     0.     0.  0.97  0.034    0.  14.8 0.570 3.230
POINTLD-2 PTL=   11.     0.     0. 23.58  1.02   0.32    0. 0.595  0.12 0.680
POINTLD-2 PTL=   12.     0.     0. 23.58  1.02   0.32    0. 0.595  0.12 0.680
POINTLD-2 PTL=   13.     0.     0.   90.  1.12   0.08  0.01 10.36  0.06  2.09
ENDATA11A
DAM DATA  DAM=        1.    3.   17.   1.3  0.32   1.0   1.6
DAM DATA  DAM=        2.   10.    2.   1.3  0.33   1.0   1.6
DAM DATA  DAM=        3.   10.   12.   1.3  0.58   0.8   6.0
ENDATA12
ENDATA13
ENDATA13A
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APPENDIX B. QUAL2E DATA FILE FOR THE CALIBRATION TO THE JUNE 27-28, 1995, DIEL-SURVEY DATA

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TITLE01              SALT CREEK, ILLINOIS, JUNE CALIBRATION (revised)
TITLE02              SALT CREEK
TITLE03  YES         CONSERVATIVE MINERAL I
TITLE04   NO         CONSERVATIVE MINERAL II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06   NO         TEMPERATURE
TITLE07  YES         BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         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         DISOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORMS IN NO./100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE MG/L
ENDTITLE
LIST DATA INPUT
NO WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
TRAPEZOIDAL X-SECTIONS
NO PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=      0.        5D-ULT BOD CONV K COEF  =     0.23
INPUT METRIC (YES=1)    =      0.        OUTPUT METRIC (YES=1)   =       0.
NUMBER OF REACHES       =     17.        NUMBER OF JUNCTIONS     =       2.
NUM OF HEADWATERS       =      3.        NUMBER OF POINT LOADS   =      13.
TIME STEP (HOURS)       =      0.        LNTH  COMP  ELEMENT (DX)=      0.2
MAXIMUM ITERATIONS      =     30.        TIME INC. FOR RPT2 (HRS)=       0.
LATITUDE OF BASIN (DEG) =    41.9        LONGITUDE OF BASIN (DEG)=    87.96
STANDARD MERIDIAN (DEG) =     75.        DAY OF YEAR START TIME  =     241.
EVAP. COEFF. (AE)       =  0.00068       EVAP. COEFF. (BE)       =  0.00027
ELEV. OF BASIN (ELEV)   =    660.        DUST ATTENUATION COEF.  =     0.06
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)=   3.43  O UPTAKE BY NO2 OXID(MG O/MG N)=   1.14
O PROD  BY ALGAE (MG O/MG A)   =    1.6  O UPTAKE BY ALGAE (MG O/MG A)  =   1.95
N CONTENT OF ALGAE (MG N/MG A) =   0.09  P CONTENT OF ALGAE (MG P/MG A) =  0.015
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.6  ALGAE RESPIRATION RATE (1/DAY) =    0.5
N HALF SATURATION CONST (MG/L) =    0.3  P HALF SATURATION CONST  (MG/L)=   0.04
LIN ALG SHADE CO (1/H-UGCHA/L) =  0.000  NLIN SHADE (1/H-(UGCHA/L)**2/3)=     0.
LIGHT FUNCTION OPTION (LFNOPT) =     1.  LIGHT SATURATION COEF (INT/MIN)=   0.11
DAILY AVERAGING OPTION (LAVOPT)=     2.  LIGHT AVERAGING FACTOR         =   0.92
NUMBER OF DAYLIGHT HOURS (DLH) =  15.22  TOTAL DAILY SOLAR RADTN (INT)  =  1199.
ALGY GROWTH CALC OPTION(LGROPT)=     2.  ALGAL PREF FOR NH3-N (PREFN)   =    0.1
ALG/TEMP SOLR RAD FACTOR(TFACT)=   0.00  NITRIFICATION INHIBITION COEF  =    10.
ENDATA1A
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ENDATA1B
STREAM REACH       1.RCH=EGAN - SPRING BK   FROM        31.8      TO         28.4
STREAM REACH       2.RCH=SPRING BROOK       FROM         2.8      TO           0.
STREAM REACH       3.RCH=SPR BRK - ADD N    FROM        28.4      TO          25.
STREAM REACH       4.RCH=ADD N - ADD S      FROM         25.      TO         23.4
STREAM REACH       5.RCH=ADD S - ELMHURST   FROM        23.4      TO         20.4
STREAM REACH       6.RCH=CSO REACH          FROM        20.4      TO         19.4
STREAM REACH       7.RCH=STEEP REACH        FROM        19.4      TO         18.6
STREAM REACH       8.RCH=FLAT REACH         FROM        18.6      TO         15.6
STREAM REACH       9.RCH=FLAT REACH -31ST   FROM        15.6      TO         13.8
STREAM REACH      10.RCH=31ST - FULL PARK   FROM        13.8      TO         11.4
STREAM REACH      11.RCH=DWN FR FULL PARK   FROM        11.4      TO          7.4
STREAM REACH      12.RCH=TO CONF ADD CR     FROM         7.4      TO          3.6
STREAM REACH      13.RCH=BENSEVILLE DWNS    FROM        10.4      TO          7.2
STREAM REACH      14.RCH=ADDISON REACH 2    FROM         7.2      TO          5.8
STREAM REACH      15.RCH=ADDISON REACH 3    FROM         5.8      TO          3.2
STREAM REACH      16.RCH=TO CONF SALT CR    FROM         3.2      TO           0.
STREAM REACH      17.RCH=TO CONF DES PLAI   FROM         3.6      TO           0.
ENDATA2
ENDATA3
FLAG FIELD RCH=    1.        17          1 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3
FLAG FIELD RCH=    2.        14          1 6 2 2 2 2 2 2 2 2 2 2 2 6
FLAG FIELD RCH=    3.        17          4 2 2 6 2 2 2 2 2 2 2 6 2 2 2 2 2
FLAG FIELD RCH=    4.         8          6 2 2 2 2 2 2 2
FLAG FIELD RCH=    5.        15          6 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=    6.         5          6 2 6 6 2
FLAG FIELD RCH=    7.         4          2 2 6 2
FLAG FIELD RCH=    8.        15          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=    9.         9          2 2 2 2 2 2 2 2 6
FLAG FIELD RCH=   10.        12          2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   11.        20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   12.        19          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3
FLAG FIELD RCH=   13.        16          1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   14.         7          2 2 2 2 2 2 2
FLAG FIELD RCH=   15.        13          2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   16.        16          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   17.        18          4 2 2 2 2 2 2 6 2 2 2 2 2 2 2 2 2 5
ENDATA4
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HYDRAULICS RCH=   1.       60.        3.        6.       27.   0.00043     0.56
HYDRAULICS RCH=   2.       60.        3.        0.2      10.    0.0011     0.33
HYDRAULICS RCH=   3.       60.        2.        4.       35.    0.0003     0.11
HYDRAULICS RCH=   4.       60.        2.        1.5      35.   0.00038     0.11
HYDRAULICS RCH=   5.       60.        2.6       1.       34.   0.00041    0.110
HYDRAULICS RCH=   6.       60.        2.6       1.       34.   0.00041    0.110
HYDRAULICS RCH=   7.       60.        3.        5.       30.    0.0015     0.05
HYDRAULICS RCH=   8.       60.        3.        5.       30.   0.00004     0.06
HYDRAULICS RCH=   9.       60.        2.        1.5      25.   0.00068     0.10
HYDRAULICS RCH=  10.       60.        5.        5.       50.    0.0002     0.07
HYDRAULICS RCH=  11.       60.        5.6       4.4      55.   0.00055    0.052
HYDRAULICS RCH=  12.       60.        5.6       4.4      55.   0.00062    0.052
HYDRAULICS RCH=  13.       60.        1.        1.       32.    0.0008     0.20
HYDRAULICS RCH=  14.       60.        6.        2.       15.   0.00085     1.20
HYDRAULICS RCH=  15.       60.        2.5       2.5      25.   0.00056     0.08
HYDRAULICS RCH=  16.       60.        2.5       2.5      25.   0.00056     0.08
HYDRAULICS RCH=  17.       60.        2.6       3.3      39.   0.00025    0.052
ENDATA5
TEMP/LCD   RCH=   1.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   2.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   3.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   4.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   5.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   6.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   7.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   8.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=   9.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  10.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  11.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  12.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  13.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  14.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  15.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  16.     1000.  0.06    0.3    70.    60.   29.9    0.
TEMP/LCD   RCH=  17.     1000.  0.06    0.3    70.    60.   29.9    0.
ENDATA5A
REACT COEF RCH=   1.  0.144     0.    0.20  1.    2.1      0.      0.
REACT COEF RCH=   2.   0.14     0.   0.148  1.   2.23      0.      0.
REACT COEF RCH=   3.  0.139     0.    0.15  1.   1.86      0.      0.
REACT COEF RCH=   4.  0.159     0.    0.30  1.     2.      0.      0.
REACT COEF RCH=   5.  0.124     0.    0.45  1.     2.      0.      0.
REACT COEF RCH=   6.   1.60     0.    0.45  1.     2.      0.      0.
REACT COEF RCH=   7.   1.60     0.    0.12  1.     8.      0.      0.
REACT COEF RCH=   8.  0.156     0.    0.12  1.   0.86      0.      0.
REACT COEF RCH=   9.   0.14     0.    0.12  1.   0.86      0.      0.
REACT COEF RCH=  10.  0.143     0.    0.04  1.    0.2      0.      0.
REACT COEF RCH=  11.  0.148     0.    0.23  1.   2.76      0.      0.
REACT COEF RCH=  12.   0.14     0.    0.15  1.   2.76      0.      0.
REACT COEF RCH=  13.  0.154    0.0    0.22  1.    5.2      0.      0.
REACT COEF RCH=  14.   0.15     0.    0.05  1.    0.6      0.      0.
REACT COEF RCH=  15.   0.15     0.    0.10  1.     2.      0.      0.
REACT COEF RCH=  16.   0.15     0.    0.35  1.     2.      0.      0.
REACT COEF RCH=  17.  0.113     0.    0.45  1.   2.76      0.      0.
ENDATA6
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N AND P COEF    RCH=   1.   0.02  -0.15    0.6     0.     10.     0.    1.0     0.
N AND P COEF    RCH=   2.   0.02  -0.15    1.0     0.     10.     0.     0.     0.
N AND P COEF    RCH=   3.   0.02     0.    0.6     0.     10.     0.    1.0     0.
N AND P COEF    RCH=   4.   0.02     0.    0.6    10.     10.     0.    1.0     0.
N AND P COEF    RCH=   5.   0.02     0.    0.6    10.     10.     0.    1.0     0.
N AND P COEF    RCH=   6.   0.02     0.    0.6    10.     10.     0.    1.0     0.
N AND P COEF    RCH=   7.   0.02     0.    0.6    10.     10.     0.    1.0     0.
N AND P COEF    RCH=   8.   0.02     0.    0.6    10.     10.     0.    0.0     0.
N AND P COEF    RCH=   9.   0.02     0.    0.6    10.     10.     0.    1.0     0.
N AND P COEF    RCH=  10.   0.02     0.    0.6     0.     10.     0.    0.0     0.
N AND P COEF    RCH=  11.   0.02     0.    0.6     0.     10.     0.    1.0     0.
N AND P COEF    RCH=  12.   0.02     0.    0.6     0.     10.     0.    1.0     0.
N AND P COEF    RCH=  13.   0.02     0.   0.45   0.00     10.     0.    1.0     0.
N AND P COEF    RCH=  14.   0.02     0.   0.45     0.     10.     0.    1.0     0.
N AND P COEF    RCH=  15.   0.02     0.   0.45     0.     10.     0.    1.0     0.
N AND P COEF    RCH=  16.   0.02     0.   0.45     0.     10.     0.    1.0     0.
N AND P COEF    RCH=  17.   0.02     0.    0.6     0.     10.     0.    1.0     0.
ENDATA6A
ALG/OTHER COEF RCH=   1.    50.    0.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   2.    50.    0.6   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   3.    50.    3.3   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   4.    50.    0.6   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   5.    50.    1.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   6.    50.    1.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   7.    50.    0.6   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   8.    50.    1.5   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=   9.    50.    0.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  10.    50.    0.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  11.    50.    1.3   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  12.    50.    1.3   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  13.    50.    0.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  14.    50.    0.0   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  15.    50.   1.25   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  16.    50.    1.1   0.10     0.      0.     0.     0.
ALG/OTHER COEF RCH=  17.    50.    1.8   0.10     0.      0.     0.     0.
ENDATA6B
INITIAL COND-1 RCH=   1.   69.6     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   2.   74.5     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   3.   71.0     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   4.   72.0     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   5.   71.8     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   6.   71.8     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   7.   71.6     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   8.   71.5     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=   9.   72.5     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  10.   73.5     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  11.   74.6     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  12.   74.8     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  13.   70.2     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  14.   73.4     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  15.   73.1     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  16.   71.7     0.     0.     0.      0.     0.     0.     0.
INITIAL COND-1 RCH=  17.   74.2     0.     0.     0.      0.     0.     0.     0.
ENDATA7
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INITIAL COND-2 RCH=   1.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   2.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   3.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   4.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   5.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   6.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   7.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   8.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=   9.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  10.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  11.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  12.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  13.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  14.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  15.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  16.      0.      0.      0.      0.      0.      0.      0.
INITIAL COND-2 RCH=  17.      0.      0.      0.      0.      0.      0.      0.
ENDATA7A
INCR INFLOW-1  RCH=   1.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   2.    0.97   67.3   6.71   7.62 1090.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   3.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   4.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   5.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   6.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   7.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   8.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=   9.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  10.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  11.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  12.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  13.    0.69   67.2   4.08  25.07  898.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  14.    0.30   67.2   4.08  25.07  898.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  15.    0.56   67.2   4.08  25.07  898.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  16.      0.    70.     0.     0.     0.     0.     0.     0.     0.
INCR INFLOW-1  RCH=  17.      0.    70.     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.    6.68   1.01    0.11      0.   0.83  0.025   0.14
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.
INCR INFLOW-2  RCH=  12.      0.      0.      0.      0.      0.      0.      0.
INCR INFLOW-2  RCH=  13.      0.  0.733    0.27      0.   1.30  0.071  0.401
INCR INFLOW-2  RCH=  14.      0.  0.733    0.27      0.   1.30  0.071  0.401
INCR INFLOW-2  RCH=  15.      0.  0.733    0.27      0.   1.30  0.071  0.401
INCR INFLOW-2  RCH=  16.      0.      0.      0.      0.      0.      0.      0.
INCR INFLOW-2  RCH=  17.      0.      0.      0.      0.      0.      0.      0.
ENDATA8A
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STREAM JUNCTION        1.      JNC=                         17.       32.        31.
STREAM JUNCTION        2.      JNC=                        155.      208.       207.
ENDATA9
HEADWTR-1 HDW=   1.SALT CREEK @ BW      3.38   77.8  8.94  5.90  935.      0.      0.
HEADWTR-1 HDW=   2.SPRING BROOK         3.64   78.0  6.30  3.93 1302.      0.      0.
HEADWTR-1 HDW=   3.ADD CR-BEN STP       6.77   70.3  5.40  3.93  960.      0.      0.
ENDATA10
HEADWTR-2 HDW=   1.      0.     0. 48.82  1.27   0.03    0.  1.60 0.074 0.417
HEADWTR-2 HDW=   2.      0.     0. 52.55  1.15   0.25    0.  0.10 0.030 0.170
HEADWTR-2 HDW=   3.      0.     0.  6.50  1.80   1.20    0. 21.80 0.480 2.720
ENDATA10A
POINTLD-1 PTL=   1.EGAN            0.   25.5   68.0  7.10  3.93  914.      0.      0.
POINTLD-1 PTL=   2.NORDIC PARK     0.   0.23   67.9  7.04  0.98  334.      0.      0.
POINTLD-1 PTL=   3.ITASCA          0.   3.40   68.2  5.21  3.93 1196.      0.      0.
POINTLD-1 PTL=   4.WOOD DALE N     0.   1.96   68.5  5.68  3.93  954.      0.      0.
POINTLD-1 PTL=   5.WOOD DALE S     0.   0.33   69.3  7.15  0.98  977.      0.      0.
POINTLD-1 PTL=   6.ADDISON N       0.   5.10   68.8  7.98  1.97 1036.      0.      0.
POINTLD-1 PTL=   7.ADDISON S       0.   3.63   70.4  7.84  1.97  945.      0.      0.
POINTLD-1 PTL=   8.ST CHAR CSO     0.   0.51   72.7  4.89  442.  956.      0.      0.
POINTLD-1 PTL=   9.SC SD           0.   3.09   69.0  6.92  1.97  960.      0.      0.
POINTLD-1 PTL=  10.ELMHURST        0.   8.92   68.8  7.37  0.98  975.      0.      0.
POINTLD-1 PTL=  11.SUGAR CREEK     0.     0.     0.    0.    0.    0.      0.      0.
POINTLD-1 PTL=  12.GINGER CREEK    0.     0.     0.    0.    0.    0.      0.      0.
POINTLD-1 PTL=  13.DIVERSION       0.     0.     0.    0.    0.    0.      0.      0.
ENDATA11
POINTLD-2 PTL=    1.     0.     0.     0.  1.56 0.140    0.  13.8 0.600 3.400
POINTLD-2 PTL=    2.     0.     0.     0.  0.96 0.020    0.  14.4 0.435 2.465
POINTLD-2 PTL=    3.     0.     0.     0.  1.64 0.260    0.  24.8 0.510 2.890
POINTLD-2 PTL=    4.     0.     0.     0.  1.80 1.000    0.  13.9 0.480 2.720
POINTLD-2 PTL=    5.     0.     0.     0.  1.15  0.05    0.  22.3 0.390 2.210
POINTLD-2 PTL=    6.     0.     0.     0.  1.55  0.05    0.  16.7 0.458 2.593
POINTLD-2 PTL=    7.     0.     0.     0.  1.42  0.08    0.  12.4 0.465 2.635
POINTLD-2 PTL=    8.     0.     0.     0.    5.   30.    0.  0.03  0.78  4.42
POINTLD-2 PTL=    9.     0.     0.     0.  1.20  1.70    0.  20.4 0.825 4.675
POINTLD-2 PTL=   10.     0.     0.     0.  1.31  0.09    0.  17.9 0.630 3.570
POINTLD-2 PTL=   11.     0.     0.     0.    0.    0.    0.    0.    0.    0.
POINTLD-2 PTL=   12.     0.     0.     0.    0.    0.    0.    0.    0.    0.
POINTLD-2 PTL=   13.     0.     0.     0.    0.    0.    0.    0.    0.    0.
ENDATA11A
DAM DATA  DAM=        1.    3.    17.   1.3  0.32   1.0   1.6
DAM DATA  DAM=        2.   10.     2.   1.3  0.33   1.0   1.6
DAM DATA  DAM=        3.   10.    12.   1.3  0.58   0.8   6.0
ENDATA12
ENDATA13
ENDATA13A
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