

Water-Quality Characteristics of the Slate and East Rivers, Colorado, During the Winter Recreational Season, December 1996

By Norman E. Spahr and Jeffrey R. Deacon

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.

- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

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Chief Hydrologist

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Abstract

Periods of population influxes during winter recreation occur simultaneously with periods of extreme low flow in many Rocky Mountain areas. The ability of streams to assimilate additional nutrient loading is reduced by the low-flow conditions. Low-flow water-quality characteristics of the Slate and East Rivers, which drain the Crested Butte area, were investigated in December 1996. Six sites were chosen for evaluation—four on the Slate River and two on the East River—to assess water-quality conditions, including nutrient (nitrogen and phosphorus) concentrations and algal biomass, during a 24-hour period. Discharge in the Slate River ranged from about 18 to 30 cubic feet per second, and discharge in the East River downstream from the mouth of the Slate River was about 80 cubic feet per second. Chemical concentrations in water in the Slate and East Rivers generally were dilute with specific-conductance values of 175 to 300 microsiemens per centimeter and alkalinity values of 40 to 110 milligrams per liter during low-flow conditions.

Dissolved oxygen was at or near saturation at all measurements sites. Ammonia nitrogen concentrations increased downstream from Crested Butte and Mount Crested Butte in the Slate River and then returned to background concentrations in the East River. Concentrations of nitrite plus nitrate nitrogen increased downstream from the Crested Butte area, probably associated with the nitrification of the ammonia to nitrate, and concentrations then were diluted in

the East River downstream from the confluence of the Slate River. Phosphorus concentrations also increased slightly in the reach downstream from Crested Butte and Mount Crested Butte.

Algal biomass values increased downstream from the Crested Butte area, decreased to low values in a subsequent reach, and then returned to higher values downstream. Biomass values were similar to those found in unenriched to moderately enriched streams. The lower biomass and higher phosphorus values occurred in a reach that was covered completely with ice and snow. Algal biomass in this reach was extremely low, probably due to the absence of light. The biomass values upstream and downstream from this reach were moderately high and probably resulted in the lower phosphorus and possibly somewhat lower nitrogen, which suggests that benthic algae may be partially controlling the nutrient levels through assimilation and uptake. When light conditions restrict algal growth and subsequent loading occurs, the concentrations of phosphorus increase slightly. Once the physical limitation (absence of light) is removed, the biomass responds with a corresponding decrease in phosphorus.

The nutrient concentrations were low and well below stream standards. Nutrient increases were measured downstream from Crested Butte and Mount Crested Butte, and these increases resulted in an increase of algal biomass. Overall results indicate that, at the present time, the Slate and East Rivers can assimilate winter low-flow nutrient loads.

INTRODUCTION

The Upper Colorado River (UCOL) study unit is 1 of 59 National Water-Quality Assessment (NAWQA) study units. Hydrologic and water-quality assessments of the UCOL study unit began in 1994 by the U.S. Geological Survey (USGS). The environmental setting of the UCOL is described by Apodaca and others (1996). One of the high-priority water-quality issues in the UCOL study is the effect of increasing urban and recreational land uses in such areas as Crested Butte (Driver, 1994), which is drained by the Slate and East Rivers. A network of 14 surface-water monitoring stations was established in the UCOL (Spahr and others, 1996). The East River below Cement Creek (site E2, fig. 1) is one of these stations and was established to monitor water quality in an area of increasing urban and recreational land use.

Many areas within the Rocky Mountains experience large influxes of people during winter and summer periods for recreational pursuits. For example,

skier visits to Crested Butte Ski area during the 1996–97 season were about 519,000 (Colorado Ski Country, written commun., 1997), whereas, the estimated 1996 population for Crested Butte and Mount Crested Butte was about 1,400 (Colorado State Demography, written commun., 1997). Although skier visits are not broken down by shorter periods, the common perception is that holiday periods have larger influxes of people. In the winter, during low-flow conditions, the ability of rivers to assimilate additional nutrient loading may be reduced. Effects within the stream could include increases in nutrient levels (nitrogen and phosphorus) and algal productivity. Although moderate stream eutrophication can increase the productivity of sport fisheries, excessive benthic-algal growth in streams thought to be pristine is visible evidence of water-quality contamination to recreational users.

Although water-quality information has been collected during several studies in the Slate and East River Basins during the last 20 years, there is a lack of water-quality data for streams in the Crested Butte area during the low-flow winter season. In 1995, several local entities, in cooperation with the Upper Gunnison Water Conservancy District and the USGS NAWQA program, established the East River below Cement Creek station to develop long-term baseline water-quality data in an area of increasing urbanization. Using data from the UCOL NAWQA program, a comparison of nitrite plus nitrate concentrations in samples from the East River below Cement Creek and from a site in Rocky Mountain National Park (Colorado River below Baker Gulch) indicated that concentrations in the East River generally are greater, particularly during winter periods (fig. 2). The Colorado River below Baker Gulch is a site chosen to represent background (minimally impacted) conditions with respect to land-use effects on water quality. To further investigate water-quality conditions in the basin upstream from the East River below Cement Creek site, a winter low-flow synoptic was designed and implemented by the UCOL NAWQA during December 1996.

The Slate River is the major tributary to the East River. It originates in the mountains northwest of Crested Butte and directly, or by tributary input, drains Crested Butte, Mount Crested Butte, and the Crested Butte Ski Area. The Slate River empties into the East River about 9 river miles downstream from Crested Butte. The East River continues downstream for about

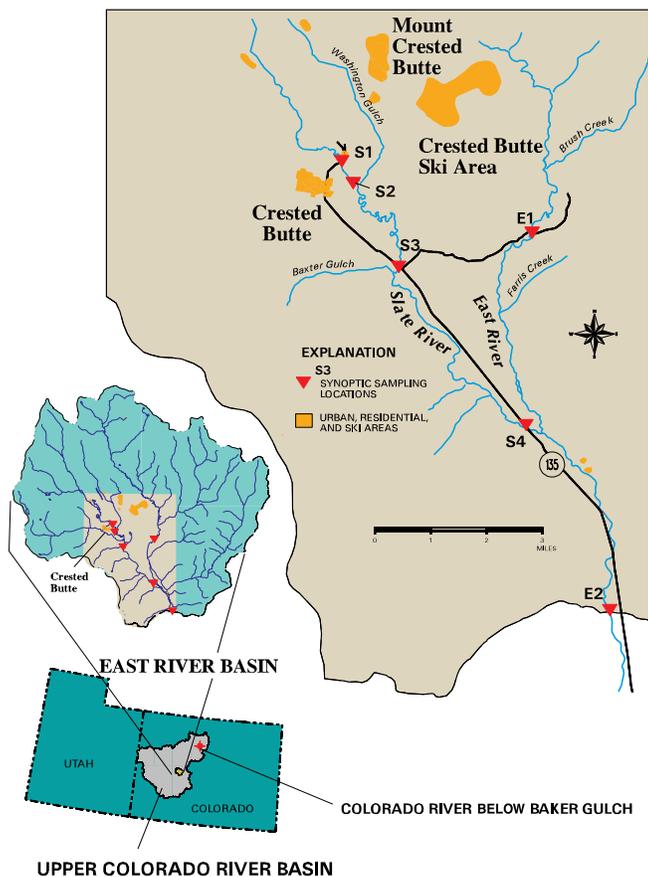


Figure 1. Study area and sampling sites (numbers refer to table 1).

13 river miles to the confluence with the Taylor River to form the Gunnison River. This report presents nutrient and general chemistry characteristics of the Slate and East Rivers in the Crested Butte area and the relations between nutrients and algal biomass during low-flow, cold-temperature conditions. Six sites were chosen to characterize water-quality conditions in the Slate and East River Basins (fig. 1). Measurements were made during the December 1996 low-flow high-recreation-use period.

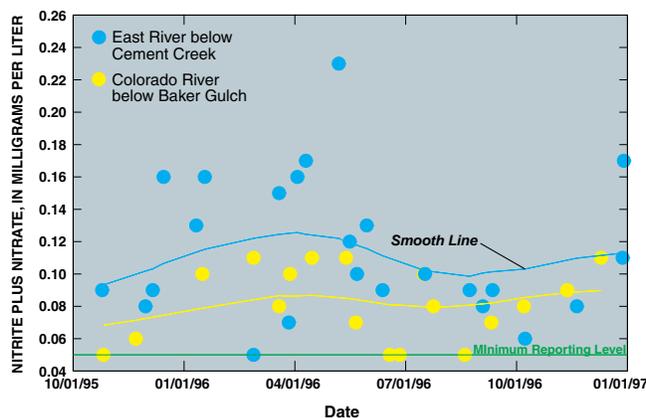


Figure 2. Nitrite plus nitrate concentrations in samples collected at East River below Cement Creek and Colorado River below Baker Gulch [smooth line, locally weighted scatterplot smoothing (LOWESS)].

Approach

Water-quality and algae samples were collected at four sites on the Slate River and two sites on the East River (fig. 1 and table 1). Site S1 was the most upstream site on the Slate River and was upstream from point-source inputs. Site S1 was assumed to represent background conditions for the synoptic.

Site S2 on the Slate River was located downstream from the Crested Butte Wastewater Treatment Facility. Site S3 was located downstream from Washington Gulch (a tributary to the Slate River), which receives point-source inputs from the Mount Crested Butte area. Site S4 was located on the Slate River just upstream from the mouth. Sites on the East River included site E1, upstream from the mouth of the Slate River and site E2, the East River below Cement Creek UCOL NAWQA site. From five to six water-quality samples were collected at each site during a 24-hour period beginning on December 28, 1996, at about 11:00 am.

Field measurements for each sample included dissolved oxygen, water temperature, specific conductance, pH, and alkalinity. Discharge was measured or estimated by using stage values for each sample. A monitor for hourly measurements of dissolved oxygen was operated at site S2 for the 24-hour period. Water samples were collected using an equal-width-increment method and were processed onsite for preparation for shipping to the USGS National Water-Quality Laboratory. Laboratory analysis of the samples consisted of determination of concentrations of major ions, ammonia nitrogen, organic plus ammonia nitrogen (dissolved and total), nitrite nitrogen, nitrite plus nitrate nitrogen, phosphorus (total and dissolved), orthophosphate phosphorus, and dissolved and suspended organic carbon. All constituents, unless specifically designated as total, were analyzed for the dissolved phase, which is defined operationally as water that has been filtered through a 0.45-micrometer filter. At each site, one sample was collected for analysis of algal biomass and chlorophyll *a* and *b*. Algae samples were collected from the stream reach

Table 1. Synoptic sites on the Slate and East Rivers

Site number	USGS station number	Site name	River miles upstream from mouth of East River	Number of water-quality samples
S1	385237106583300	Slate River at Crested Butte	21.6	5
S2	09111500	Slate River near Crested Butte	20.8	6
S3	385106106571000	Slate River above Baxter Gulch	17.5	6
S4	384853106541500	Slate River near mouth	12.8	6
E1	09110500	East River near Crested Butte	16.6	6
E2	09112200	East River below Cement Creek	9.5	6

by brushing the entire surface of five representative rocks and determining the surface area by the foil template method (Porter and others, 1993). Three field blank samples were processed for concentrations of chemical and nutrient constituents. One replicate sample was collected for concentrations of chemical and nutrient constituents, algal biomass, and chlorophyll *a* and *b*.

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CHARACTERIZATION OF WATER QUALITY

Quality-Assurance Results

Three field blank samples, one by each measurement team, were processed during the 24-hour synoptic. Field blank samples provide information on bias or the potential for contamination of analytical results by sample collection, processing, shipping, and analysis. A field blank sample is processed using water that is free of the analytes of interest (blank water). The blank water is passed through all the sampling equipment and then processed as a typical water-quality sample. Analytical results from the field blank samples showed that concentrations for all constituents discussed in this report were at the minimum laboratory reporting level. Based upon these results, sample collection, processing, shipping, and analysis did not appear to contaminate samples or produce bias in the results.

One replicate sample was collected at site S4 for chemical analysis, and one replicate sample was collected at site E2 for ash-free dry mass (AFDM) and chlorophyll *a* and *b*. Replicate samples provide information on the variability of analytical results due to sample collection, processing, shipping, and analysis. Results of the replicate sample for nutrients showed that the differences in concentrations between the

environmental and replicate samples were about 0.01 mg/L (milligram per liter). Computed AFDM values for the replicate samples differed by 2 g/m² (grams per square meter). The chlorophyll *a* and *b* replicates had identical concentrations. The variability as determined by differences between the environmental and replicate samples is low and does not affect results presented in this report.

Physical Characteristics

Shore and anchor ice was prevalent throughout streams in the study area; however, the center of flow was open to the atmosphere for most of the sites (fig. 3). The Slate River was covered completely with ice and snow for about 2 miles upstream and down-



Figure 3. Typical ice-free center of flow, Slate River, December 1996.

stream from site S3 (fig. 4). A cross section from bank to bank was cut through the snow and ice to allow sampling at site S3. Streamwater temperature ranged



Figure 4. Complete ice and snow cover on Slate River at site S3, December 1996.

from 0 to 3 degrees Celsius. With the frigid night-air temperatures and subsequent warming during the day, water moved into and out of ice storage making estimation of stage-discharge relations difficult and requiring the estimation of some discharge values

during the 24-hour period. Discharge values ranged from about 18 ft³/sec (cubic feet per second) at the upstream site (site S1) to about 80 ft³/sec at the downstream site (site E2). Results of discharge estimates and measurements are presented in figure 5.

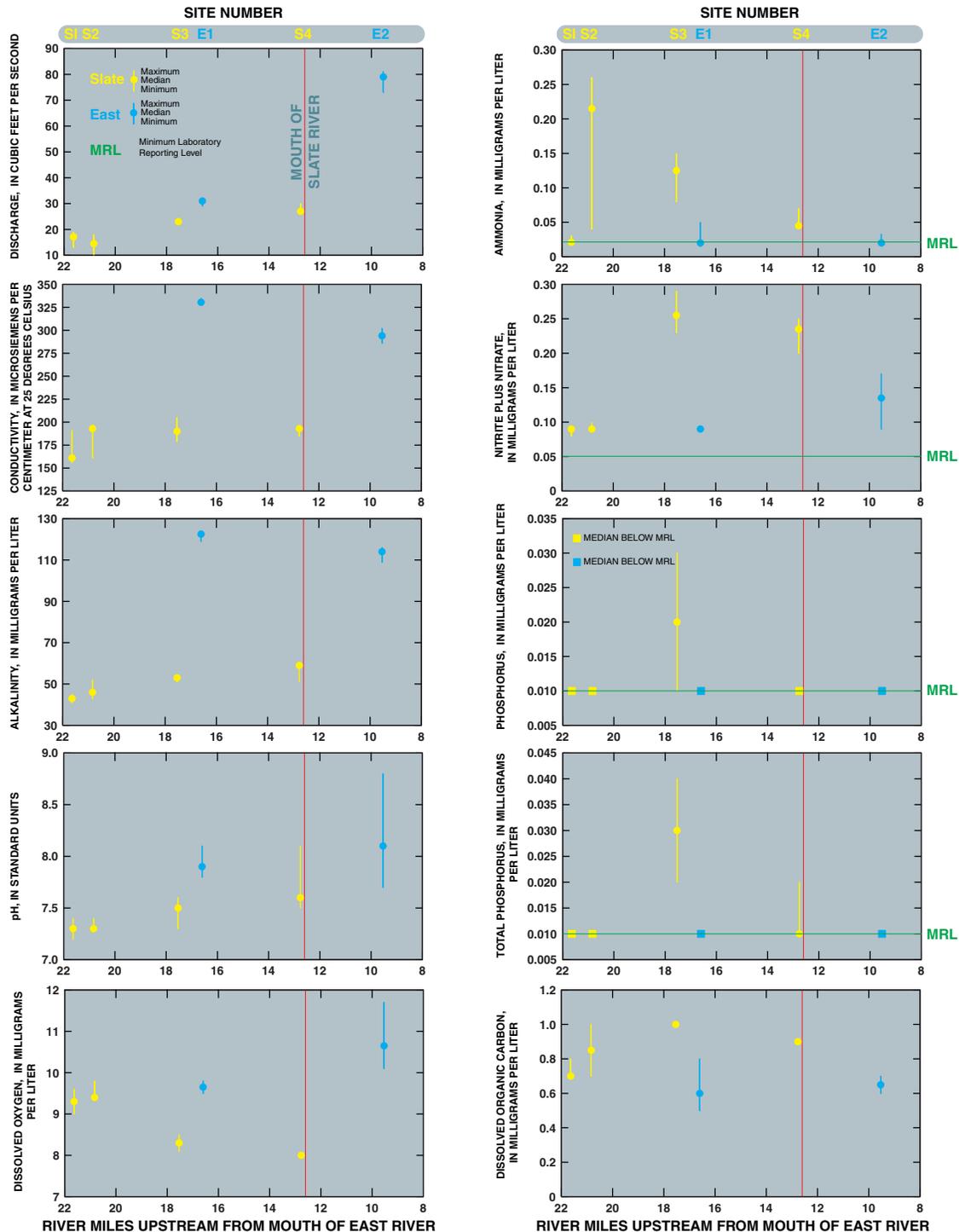


Figure 5. Discharge and specific-conductance measurements and concentrations of selected chemical constituents.

Chemical Characteristics

Results of chemical analyses are presented in figure 5. Specific conductance and alkalinity values reflect the dilute nature of the water and tend to be lower in the Slate River than the East River (fig. 5), probably due to different geology. Measurements of pH ranged from 7.2 to 8.8 and also are slightly greater in the East than the Slate River. Dissolved oxygen was at or near saturation at all sites during the 24 hours of sampling. All dissolved-oxygen values were greater than the 6-mg/L instream standard (Colorado Department of Public Health and Environment, 1995).

Concentrations of ammonia nitrogen are low (near the laboratory reporting limit of 0.015 mg/L) in the East River. Concentrations in the Slate River increase downstream from Crested Butte and then gradually decrease at subsequent sites downstream. After the Slate River empties into the East River, the concentrations return to low (about 0.015 mg/L) levels. Un-ionized ammonia concentrations as computed using the method described by Willingham (1976) are less than 0.001 mg/L, which is less than the 0.02 mg/L instream standard (Colorado Department of Public Health and Environment, 1995), at all synoptic sites. Nitrite plus nitrate concentrations peak at site S3, probably as a result of the ammonia nitrogen being converted to nitrate. Concentrations of nitrite plus nitrate at site S4 are similar to those at site S3, and concentrations are diluted downstream from site S4 in the East River (site E2). Concentrations in the East River upstream from the Slate River (site E1) are low (about 0.09 mg/L) and similar to the background concentrations in the Slate River (site S1). Measured concentrations are less than the 10 mg/L instream standard (Colorado Department of Public Health and Environment, 1995) for nitrate. Phosphorus concentrations, which are low (0.01 to 0.03 mg/L) in the Crested Butte area, are largest at site S3 and then return to concentrations similar to background downstream in the study area. Dissolved organic carbon (DOC) concentrations increase slightly in the Slate River below Crested Butte before returning to lower concentrations in the East River. Minimum DOC values for small watersheds are reported to be on the order of 0.5 to 1 mg/L (Meybeck, 1982; Meybeck and others, 1989), and concentrations from this synoptic were within this minimum range.

Loads of nitrogen and total phosphorus were estimated for each site using constituent concentra-

tions and measured (or estimated) discharge (fig. 6). Inorganic nitrogen loads were calculated using the sum of ammonia plus nitrite plus nitrate nitrogen concentrations. Inorganic nitrogen load is low [4.5 and 8.4 kilograms per day, (kg/d)] at the upstream sites S1 and E1. Inorganic nitrogen load increases to about 21 kg/d at site S3 probably as a result of point sources discharging to the Slate River and tributaries. The load decreases slightly between sites S3 and S4. Downstream from site S4, the Slate River enters the East River. Inorganic nitrogen load in the East River downstream reflects the load in the Slate River plus the load contributed from the upper East River, site E1 (upstream from the Slate River) plus additional loads from unmeasured tributaries.

Phosphorus loads were calculated using the concentrations of total phosphorus. When the total phosphorus concentration was less than the laboratory reporting limit (a less-than value), a value of one-half the reporting limit was used in the load computations. Phosphorus loads are low (about 0.2 kg/d) at site S1. The load increases slightly between sites S1 and S2 and increases again between sites S2 and S3. These increases probably are the result of point-source discharges. Phosphorus load decreases between sites S3 and S4. The load in the East River downstream from the Slate River (E2) is the result of loads in the Slate River, upstream loads in the East River, and loads in unmeasured tributaries.

Benthic Algae

Algae that are attached to submerged surfaces (benthic algae or periphyton) are affected by water-quality conditions at a specific location. Algae integrate water-quality conditions that occurred at a site during the previous several weeks to months, depending on antecedent hydrologic conditions. The abundance of algae increases when nutrient concentrations, light conditions, velocity, and other factors are favorable, but decreases because of hydrologic disturbance (scouring and washout during periodic high flows), chemical toxicity, and biological factors such as grazing by invertebrates and fish (Porter and others, 1993).

Benthic algal biomass is the mass of algal organic matter that has accumulated on an area of substratum over time. Many methods of measurement are used to estimate algal biomass, and each have rela-

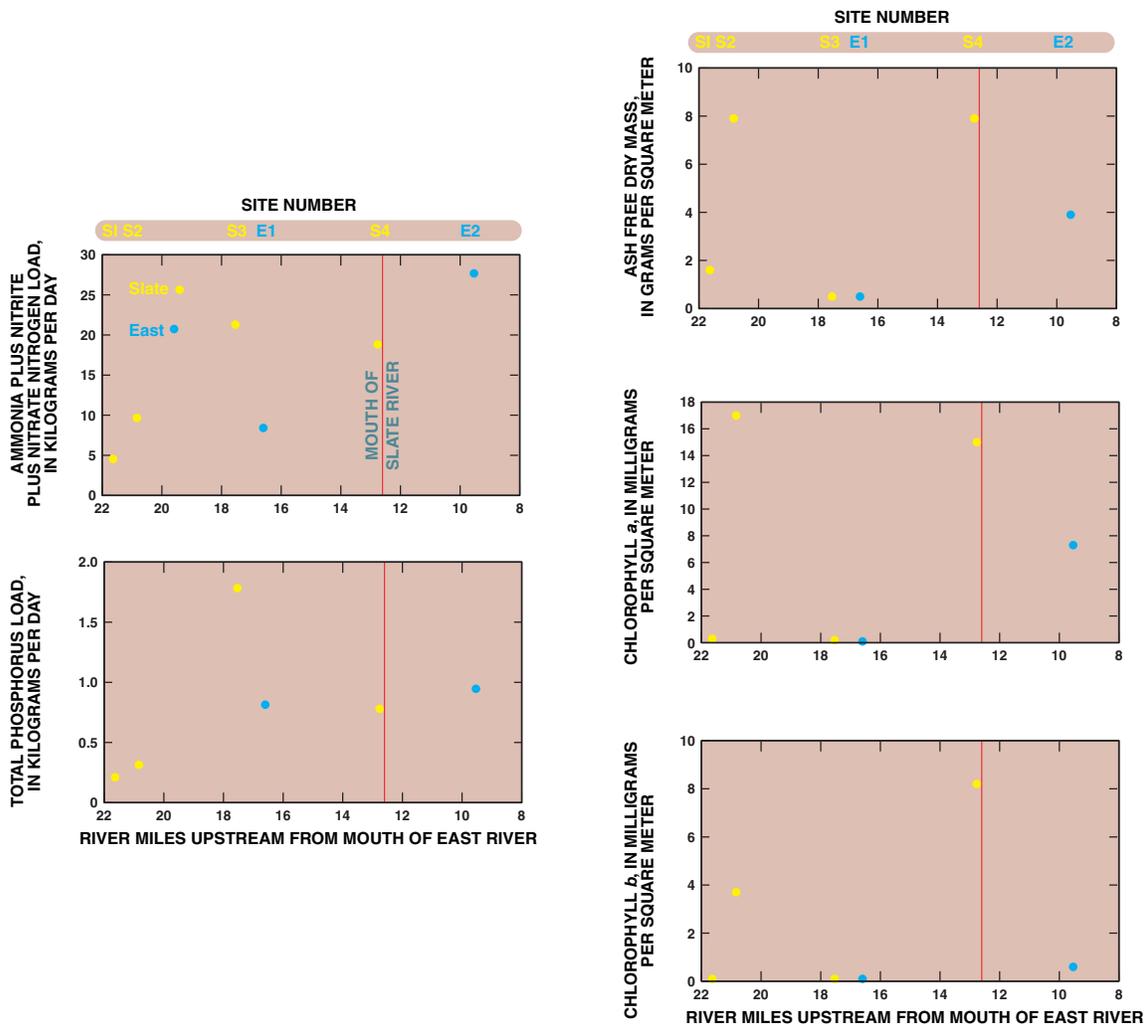


Figure 6. Load computations and concentrations of ash-free dry mass and Chlorophyll *a* and *b*.

tive advantages and disadvantages (Stevenson and others, 1996). AFDM and chlorophyll *a* and *b* values are used in this report to estimate algal biomass and its relation to nutrients. AFDM (weight of the algae) is the portion of the sample that is organic or contains carbon. When detritus (for example, leaves) and heterotrophic organisms (invertebrates) are not prevalent, AFDM can be a good estimate of algal biomass. Chlorophyll *a* is the portion of the sample that represents all algae (for example, green, blue-green, diatoms), whereas chlorophyll *b* is the portion of the sample that represents only green algae.

AFDM and chlorophyll *a* and *b* measurements followed similar patterns among sites (fig. 6). AFDM ranged from 0.5 to 7.9 g/m²; chlorophyll *a* ranged from 0.1 to 17 milligrams per square meter (mg/m²); and chlorophyll *b* ranged from 0.1 to 8.2 mg/m².

Typical median biomass values for unenriched, moderately enriched, and enriched streams for AFDM are 1.5, 4.8, and 15 g/m², respectively (Biggs, 1996). Typical median biomass values for unenriched, moderately enriched, and enriched streams for chlorophyll *a* are 1.7, 21, and 84 mg/m², respectively (Biggs, 1996). Sites S1 and E1, which represent background conditions for this study, were characterized by low algal biomass and low concentrations and loads of nutrients. Nutrient loads increase from sites S1 to S2 and again from sites S2 to S3, because of inputs to the stream between these sites. Site S2 is located just downstream from a point-source discharge in Crested Butte. Increases in AFDM and chlorophyll *a* and *b* concentrations at site S2 may be a response to the nutrient discharges. Values for AFDM and chlorophyll *a* and *b* at site S3 were low and similar to background

conditions at site S1. Site S3 was completely iced over prior to the synoptic study. The ice cover limited availability of sunlight for the algae. Although nutrient loads were highest at this site, algal biomass did not increase with nutrient concentrations, probably because of insufficient light to sustain algal growth. The low (0.5 g/m^2) algal biomass at site S3 may be associated with the higher dissolved nutrients concentrations. If the stream reach at site S3 were exposed to light, higher algal productivity would be expected, resulting in higher rates of nutrient uptake, and thus relatively lower concentrations of dissolved nutrients. Once the streamflow opened back to the atmosphere, increases in AFDM and chlorophyll *a* and *b* were observed at site S4 (mouth of Slate River) with a corresponding decrease in dissolved nutrients. Algal uptake may be a major factor for the decrease in the dissolved nutrient load at this site. When comparing site S4 to site E2, decreases were observed in AFDM and chlorophyll *a* and *b*. Nitrogen and phosphorus at site E2 reflect the combined loads of the Slate and East Rivers (fig. 6) and any algal uptake. A decrease in chlorophyll *a* and an increase in chlorophyll *b* from site S2 to S4 (fig. 6) may indicate that the composition of the algal community shifts and contains a larger abundance of green algal species. Cursory identification of this sample indicated an abundance of *Ulothrix*, a green algal taxon (Dev Niyogi and Stephen Porter, USGS, oral commun., 1997). Studies have shown that growth of *Ulothrix* is stimulated by phosphorus, and higher densities of *Ulothrix* can effectively remove phosphorus from the system (Tate and others, 1991; Tate and others, 1995).

SUMMARY AND CONCLUSIONS

The Slate and East Rivers near Crested Butte, Colorado, are affected by increasing urbanization and recreational uses. Increases in population due to winter-recreation activities can produce added nutrient (nitrogen and phosphorus) loads to receiving waters during low-flow periods. Slightly higher nitrite plus nitrate concentrations were measured during low flow in the East River as compared to a site with minimal land-use effects on water quality (Colorado River below Baker Gulch). Water-quality and algae samples were collected at six sites within the Slate and East River Basins to investigate potential increases in nutrients and algal biomass during peak winter-recreation

use. Dissolved oxygen was at or near saturation at all sites. Nutrient concentrations and loads were low but increased along the Slate and East Rivers. State standards for concentrations of nitrate and un-ionized ammonia were not exceeded during this study period at any sites. The abundance of algae increases when nutrient concentrations, light conditions, velocity, and other factors are favorable. Biomass generally responded to higher nutrient loads in the study area with the exception of site S3. Ice cover at this site limited availability of sunlight, which affected the algal biomass. Algal-biomass values at the synoptic sites reflected those of unenriched to moderately enriched streams. Overall results of this study indicated that during 1996 peak winter-recreation use, the streams were able to assimilate the nutrient loadings.

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