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Assessment of Total Nitrogen and Total Phosphorus in Selected Surface Water of the National Park Service Northern Colorado Plateau Network, Colorado, Utah, and Wyoming, from 1972 through 2007

Scientific Investigations Report 2012–5043

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs. The Narrows of Halls Creek, Capitol Reef National Park, Utah. (Photographs by Juliane B. Brown).

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.004047	square kilometer (km^2)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Vertical Datum of 1988 (NAVD 88)."

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Datum of 1983 (NAD 83)."

Altitude, as used in this report, refers to distance above the vertical datum.

Acronyms

ARCH – Arches National Park
BLCA – Black Canyon of the Gunnison National Park
BRCA – Bryce Canyon National Park
CANY – Canyonlands National Park
CARE – Capitol Reef National Park
CEBR – Cedar Breaks National Monument
COLM – Colorado National Monument
CURE – Curecanti National Recreation Area
CWA – Clean Water Act
DINO – Dinosaur National Monument
DO – Dissolved oxygen
FAC – Flow-adjusted concentrations
FOBU – Fossil Butte National Monument
GOSP – Golden Spike National Historic Site
HOVE – Hovenweep National Monument
I&M – Inventory and Monitoring
KM – Kaplan Meier
LT-MDL – Long-term method detection limit
LRL – Laboratory reporting level
MLE – Maximum likelihood estimation
Mountain – forested mountains (aggregate nutrient Ecoregion II; also as “Mtn” in tables)
MRC – Median reference condition
NABR – Natural Bridges National Monument
NCPN – Northern Colorado Plateau Network
NPS – National Park Service
NWIS – National Water Information System (USGS)
NWQL – National Water Quality Laboratory
PISP – Pipe Spring National Monument
STORET – STORage and RETrieval System (USEPA)
TDS – Total dissolved solids
TICA – Timpanogos Cave National Monument
TMDL – total maximum daily load
TN – Total nitrogen
TP – Total phosphorus
USEPA – U.S. Environmental Protection Agency
USGS – U.S. Geological Survey
UTDWQ – Utah Department of Environmental Quality, Division of Water Quality
WWTP – wastewater treatment plant
Xeric – xeric west (aggregate nutrient Ecoregion III)
ZION – Zion National Park
< – Less than
<= – Equal to or less than
= – Equal to

Assessment of Total Nitrogen and Total Phosphorus in Selected Surface Water of the National Park Service Northern Colorado Plateau Network, Colorado, Utah, and Wyoming, from 1972 through 2007

By Juliane B. Brown[1] and David P. Thoma[2]

Abstract

Nutrients are a nationally recognized concern for water quality of streams, rivers, groundwater, and water bodies. Nutrient impairment is documented by the U.S. Environmental Protection Agency (USEPA) as a primary cause of degradation in lakes and reservoirs, and nutrients are related to organic enrichment and oxygen depletion, which is an important cause of degradation in streams. Recently (2011), an effort to develop State-based numeric nutrient criteria has resulted in renewed emphasis on nutrients in surface water throughout the Nation. In response to this renewed emphasis and to investigate nutrient water quality for Northern Colorado Plateau Network (NCPN) streams, the U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), assessed total nitrogen (TN) and total phosphorus (TP) concentration data for 93 sites in or near 14 National Park units for the time period 1972 through 2007.

For this study, nutrient (specifically, TN and TP) data collected from 1972 through 2007 from 93 stream water-quality sampling sites were screened for exceedances of nutrient standards or criteria, and 52 of these sites were analyzed for temporal, monotonic trends in ambient concentrations and flow-adjusted concentrations (FAC) of TN and TP. Concentrations of TN and TP at the 93 water-quality sampling sites were compared to applicable State of Utah standards or USEPA recommended nutrient criteria for aggregated Ecoregions II (forested mountains) and III (xeric west), and descriptive statistics were compiled for each site. Notable exceedances and median concentrations from water-quality sampling sites on the Colorado, Fremont, Green, Gunnison (and tributaries), Virgin, and Yampa Rivers were described. Not all sites had TN and(or) TP data for comparison. Sixty-two of 65 sites for TN and 92 of 93 sites for TP had one or more exceedances, and exceedances ranged from 2 to 100 percent of nutrient samples. The average frequency of exceedance for TN for all 65 sites was 74 percent and for TP for all 93 sites the average frequency of exceedance was 61 percent. Moreover, 45 percent of the 65 sites evaluated for TN exceedances and 35 percent of the 93 sites evaluated for TP exceedances had exceedances greater than or equal to 85 percent of samples. Throughout the NCPN, median TN concentrations ranged from 0.106 to 2.42 mg/L (overall median 0.633 mg/L), and median TP concentrations ranged from 0.006 to 0.367 mg/L (overall median 0.076 mg/L), excluding data from the one wastewater treatment plant outfall included in the dataset. Median concentrations were equal to or less than the applicable standard or criterion for data from 8 TN (12 percent) and 35 TP (38 percent) sites.

Trends in ambient concentrations (34 sites for TN and 51 sites for TP) and FAC (22 sites for TN and 27 sites for TP) were determined for 52 of the 93 sites with sufficient data, and relations between trends and changes in nutrient sources and streamflow were explored. Not all sites had TN and(or) TP data available for comparison. Analysis of data for trends in concentrations of TN and TP was completed for two groups of sites, each having similar periods of record: 6 sites (4 TN and 5 TP) with nutrient data from 1977 to 1998 (historical long-term period) and 15 sites (7 TN and 15 TP) with nutrient data from 2001 to 2006 (recent short-term period). Additionally, trend analysis of TN and(or) TP concentrations was completed for data from 30 and 42 sites, respectively, having variable periods of record collected from 1974 through 2007 using time periods specific and optimal for each site. Some sites were evaluated for more than one time period. Many sites evaluated for trends in ambient concentrations could not be evaluated for trends in FAC because of insufficient contemporaneous streamflow measurements or a high percentage of censoring.

The trend results for TN and TP were variable depending on the site, constituent, and time period evaluated. Historical long-term (1977–1998) downward trends were identified in ambient and flow-adjusted TN and TP concentrations at four and two sites, respectively. For TN, results from recent short-term (2001–2006) trend analysis indicated an upward trend in ambient TN concentrations at one site and an upward trend in FAC at another site. For TP, results from recent short-term (2001–2006) trend analysis indicated an upward trend in

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[2]National Park Service, Bozeman, Mont.

ambient TP concentrations at one site and a downward trend in FAC at another site. Most of the 30 TN and 42 TP sites with variable periods of record analyzed for trends indicated no trends or downward trends in nutrient concentrations; only four TN sites and two TP sites indicated upward trends in ambient and(or) flow-adjusted nutrient concentrations. Sites with upward trends were either tributary to or on the Gunnison River (TN and TP) or on the Green or Yampa Rivers (TN only).

Of all the 34 TN and 51 TP sites evaluated for trends in ambient and flow-adjusted TN concentrations, three TN sites and seven TP sites indicated upward or downward trends in ambient TN concentrations and no corresponding trend in FAC indicating streamflow was the driving factor in the trends identified at these sites; two TN sites indicated an upward trend in FAC and no corresponding trend in ambient TN concentrations; and one TP site indicated an upward trend in ambient and FAC. Most of the downward trends in ambient and flow-adjusted TN or TP concentrations were during earlier historical periods (generally starting in the 1970s or early 1980s and ending in the 1990s or 2000s). Many of the historical, long-term downward trends were identified on larger streams, including the Colorado, Dolores, Fremont, Green, Gunnison, Virgin, and Yampa Rivers. These long-term downward trends suggest that at least at these sites nutrient water quality is improving. These results suggest that nutrient reduction observed on these larger streams in the NCPN may be a function of large-scale environmental factors such as nationally mandated changes to improve municipal wastewater treatment, address nonpoint-source pollution, enhance management of public land, and guide the implementation of best-management practices such as improvements in fertilizer or manure application to help minimize erosion and nutrient runoff.

In contrast, the few upward trends in ambient and flow-adjusted TN or TP concentrations were during more recent sampling periods (1990s to 2000s and early to mid-2000s) suggesting more recent changes in these basins may be affecting water quality at these sites even when historical data indicated no trends or downward trends. Only two sites, one on the Green River and one on the Fremont River, indicated downward trends in ambient and FAC for TN and TP, suggesting that changes in these basins have contributed to an overall reduced nutrient loading to these streams.

Exceedances ranged from 51 to 100 percent of samples for sites identified with significant upward trends in TN or TP concentrations. The percentage of TN or TP exceedances may increase at these sites if upward trends in concentrations are sustained. Exceedances ranged from 25 to 100 percent of samples for sites identified with significant downward trends in TN or TP concentrations. The percentage of TN or TP exceedances may decrease at these sites if downward trends in concentrations are sustained. Many sites with high percentages of exceedances did not have significant upward or downward trends in concentrations.

Although few significant upward trends in TN or TP concentrations were identified in the NCPN data (five sites since the 1990s and early 2000s), exceedances of the State of Utah phosphorus standard or USEPA recommended nutrient water-quality criteria may indicate problem areas in surface water that warrant closer evaluation and continued water-quality sampling. Results evaluated in this report represent conditions for different periods of record and thus may not always represent basin conditions through time. This highlights the need to maintain long-term water-quality and streamflow sampling programs at key reference and integrator sites throughout the network. Sites with a high number of exceedances, elevated median concentrations, or upward trends in concentrations merit continued or renewed monitoring and assessment to evaluate future changes in nutrient concentrations that could result in nutrient enrichment and eutrophication.

Introduction

Understanding the condition of natural resources is central to the mission of the National Park Service (NPS) to effectively manage park resources. Across the Nation, the NPS is challenged by encroaching development; atmospheric deposition; land-use activities such as grazing, agriculture, and mining adjacent to and upstream from park units; recreational use within and upstream from park units; fire; and extreme weather-related events. These activities contribute to air- and water-quality degradation, soil erosion, loss of species diversity, and invasion by nonnative species. To address management concerns, the National Parks Omnibus Management Act of 1998 (U.S. Congress, 1998) created an Inventory and Monitoring (I&M) Program of park resources to establish baseline information and conditions and to provide for long-term monitoring of trends in the National Park System. These park resources include air quality, land surface (land cover, soils, and geology), biota (flora and fauna), water-body locations and classification, water quality, and climate. The purpose of this legislation was to “encourage the publication and dissemination of information derived from studies in the NPS” and to “ensure appropriate documentation of resource conditions in the National Park System.”

In 1999, as part of the National Parks Omnibus Management Act and to facilitate collaboration, information sharing, and cost sharing within the I&M Program, park units were grouped into 32 inventory and monitoring networks, including the Northern Colorado Plateau Network (hereafter referred to as “NCPN” or “the network”), which is the network used in this study (fig. 1). As part of the I&M Program, a comprehensive inventory of natural resources was conducted by network-resource management staff in collaboration with park-resource management staff to identify and prioritize “vital signs” (indicators of resource health), which include water quality

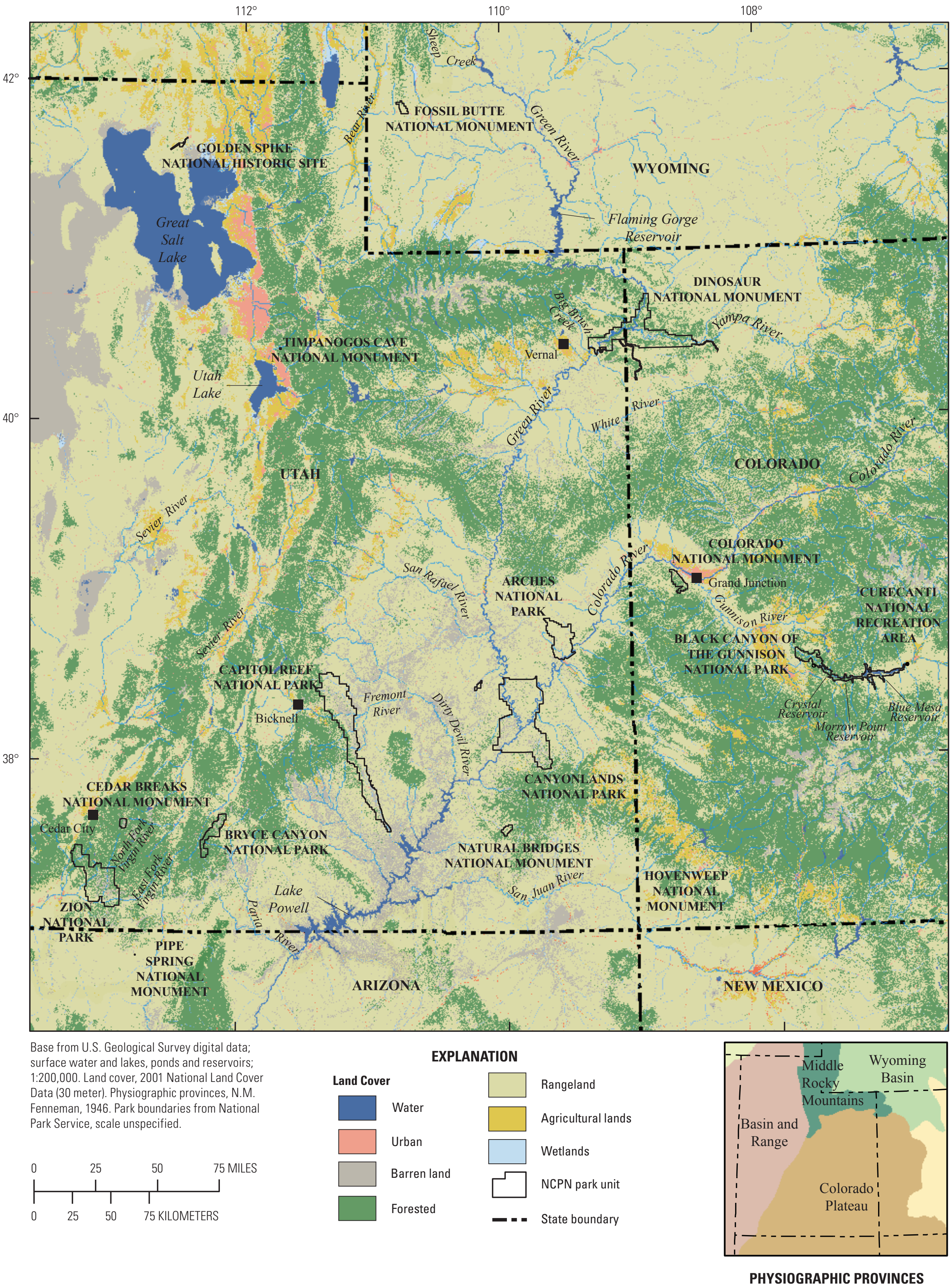


Figure 1. Northern Colorado Plateau Network (NCPN) showing park boundaries, land cover, physiographic provinces, and principal surface-water bodies.

(National Park Service, 2010). Two major goals of the I&M Program are to identify potential water-quality problem areas in park water and to determine how water-quality conditions change over time.

Nutrient impairment is documented by the U.S. Environmental Protection Agency (USEPA) as a primary cause of degradation in lakes and reservoirs, and nutrients are related to organic enrichment and oxygen depletion, which is the third most important cause of degradation in streams after pathogens and habitat alterations (U.S. Environmental Protection Agency, 2009). Recently (2011), an effort to develop State-based numeric nutrient criteria has resulted in renewed emphasis on nutrients in surface water throughout the Nation. In response to this renewed emphasis and to investigate nutrient water quality for NCPN streams, the U.S. Geological Survey (USGS), in cooperation with the NPS, assessed total nitrogen (TN) and total phosphorus (TP) concentration data for 93 sites in or near 14 National Park units for the time period 1972 through 2007. The TN and TP concentrations for these 93 sites were compared to applicable State water-quality standards or USEPA-recommended nutrient criteria, and descriptive statistics were compiled for each site. In addition, TN and TP data from 52 of the 93 sites, in or near 12 National Park units, were evaluated for temporal, monotonic trends in ambient measured concentrations and flow-adjusted measured concentrations. Ambient measured concentrations (hereafter referred to as "ambient concentrations") are unadjusted concentrations measured from samples collected in the stream. Flow-adjusted measured concentrations (hereafter referred to as "flow-adjusted concentrations" or "FAC") are concentrations measured in samples collected in the stream and subsequently adjusted to remove the effects of streamflow.

A more complete understanding of historical and current nutrient water-quality conditions throughout the NCPN is possible by evaluating both exceedance of standards and trend. Trend assessments are useful in evaluating antidegradation provisions or changes over long time intervals that may not be readily apparent in biennial assessments that focus primarily on current water-quality conditions relative to State standards. Antidegradation provisions consider the condition under which water quality may be lowered in surface water while maintaining and protecting the existing beneficial use, and for which water quality must be maintained at a condition better than is needed to protect existing beneficial uses, unless lower quality is deemed necessary to allow important economic or social development (U.S. Environmental Protection Agency, 1994). The purpose of this study was to improve the understanding of nutrients (specifically, TN and TP) and surface-water quality in the NCPN, to provide information for network and park natural-resource managers to inform future monitoring decisions, and to identify potential nutrient sources and influences on water quality in park units in the NCPN.

Purpose and Scope

This report describes an assessment of nutrients (specifically, TN and TP) in surface water in the NCPN. In this report, exceedances of standards or criteria, median concentrations, and temporal trends are described for TN and TP in streams in or near 14 NCPN park units (12 park units for trends). Exceedances were evaluated for 93 surface-water sites (65 sites for TN and 93 sites for TP) with available data from 1972 through 2007 using nutrient data collected by State and Federal agencies. For 52 of the 93 sites with sufficient data, trends in ambient concentrations (34 sites for TN and 51 sites for TP) and FAC (22 sites for TN and 27 sites for TP) were determined, and relations between trends and changes in nutrient sources and streamflow were explored. Trends were evaluated for a group of 6 sites with long-term historical data from 1977 through 1998 (4 TN sites and 5 TP sites), for a group of 15 sites with short-term recently collected data from 2001 through 2006 (7 TN sites and 15 TP sites), and for 43 sites (30 TN sites and 42 TP sites) with variable periods of record collected from 1974 through 2007 using time periods specific and optimal for each site.

Acknowledgments

The authors wish to express their appreciation to natural-resource managers of the NPS NCPN and park units for their assistance with the content of this report, including those who support water-quality data collection in specific park units. Additionally, the NPS, USGS, USEPA, and the Utah Department of Environmental Quality, Division of Water Quality (UTDWQ), contributed data to the previously compiled water-quality database used for this report. Finally, the authors thank Dustin W. Perkins (NPS NCPN Program Manager), David K. Mueller (USGS Central Region), and Katherine Walton-Day, Suzanne Paschke, Doug Druliner, and Betty Palcsak (USGS Colorado Water Science Center) for their technical and(or) editorial review of this report and the USGS publications staff for their assistance in preparing this report for publication.

Why Nutrients?

Nutrient enrichment from elevated concentrations of nutrients can result in acute and chronic effects to aquatic life as well as problems ranging from aesthetic issues and recreational impairment to serious health concerns (U.S. Environmental Protection Agency, 2000a). For example, nuisance algal blooms or high macrophyte growth, which can be the result of nutrient enrichment, can interfere with aesthetic enjoyment and recreational stream use; cause taste, odor, and water-treatment problems in drinking-water supplies; and may even result in cyanobacterial toxicity that can affect animal and human health (Carpenter and others, 1998; Chorus and Bartram, 1999; Smith and others, 1999; Vasconcelos, 1999). Although algae are an important food resource for certain macroinvertebrates and fish (Giller and Malmqvist, 1998; Cushing and Allan, 2001), harmful algal blooms can result in adverse ecological effects, including reduction of available habitat, decreased water clarity (increased turbidity), and alteration of native species composition and diversity of aquatic communities (Seehausen and others, 1997; Carpenter and others, 1998; Thiébaut and Muller, 1998; Riis and Sand-Jensen, 2001). Nutrient enrichment can result in reduced dissolved oxygen (DO) and increased pH, which can lead to mobilization of toxic metals stored in sediment and increase availability of toxic substances like ammonia and hydrogen sulfide that result in contamination of aquatic ecosystems (U.S. Environmental Protection Agency, 2000a; Rabalais, 2002).

Northern Colorado Plateau Network Description

The NCPN is composed of 16 NPS park units: 6 national parks, 8 national monuments, a national historic site, and a national recreation area. These park units are in northern Arizona, southwestern Colorado, southwestern Wyoming, and central and southern Utah (fig. 1). The units range in size from 40 acres to greater than 337,000 acres with a 2006 visitation total greater than 7.7 million people (table 1). For this study, nutrient data were available from sampling sites in or near 14 of the 16 NCPN park units for exceedance analysis and from sampling sites in or near 12 park units for trend analysis (figs. 2–12).

Of the 14 NCPN park units included in this analysis, 11 lie within the Colorado Plateau Physiographic Province; the remaining 3 are in the Middle Rocky Mountains Province (Timpanogos Cave National Monument, TICA), the Wyoming Basin Province (Fossil Butte National Monument, FOBU), and the Basin and Range Province (Golden Spike National Historic Site, GOSP) (fig. 1; O'Dell and others, 2005). Physiographic provinces generally describe areas with similar rock types, geologic structures, and common geologic history. Most of the water-quality data analyzed for this report are for surface-water sites in the Colorado Plateau. The Colorado Plateau Physiographic Province is characterized by broad plateaus of largely horizontal sedimentary rock, relatively high-altitude plateaus with deeply dissected canyons carved principally by the Colorado River and its tributaries, and ancient volcanic mountains resulting in basalt-capped plateaus and mesas (U.S. Geological Survey, 2004). It is sparsely vegetated resulting in generally low-biomass production and considerable natural erosion. The area contains substantial oil, natural gas, coal, oil shale, and uranium resources resulting in extraction activities in parts of the region (O'Dell and others, 2005). These factors combined with other human effects such as roads, recreation, development, sanitation facilities, and grazing and other agricultural activities in or near park units can collectively affect water-quality conditions throughout the area.

Climate in the NCPN is arid to semiarid and is characterized by periods of drought, irregular precipitation, high evapotranspiration rates, and low relative humidity. Monsoonal precipitation (typically July through August), which can result in flash floods, occurs primarily in southern parts of the network during summer months [occasionally extending as far north as Dinosaur National Monument (DINO)]; average rain or snow is typical in winter months (Maddox and others, 1980; O'Dell and others, 2005; D. Perkins, National Park Service, written commun., September 2010). In the NCPN, flash flooding typically occurs when excess and intense rain falls rapidly on saturated soil or on dry soil that has limited absorption capacity resulting in rapid flooding of low-lying areas such as washes and streams (Horton, 1933; Evenden and others, 2002). Average annual precipitation ranges from 7.59 inches per year (in/yr) (Capitol Reef National Park, CARE, 1967 to 2010) to 24.38 in/yr (TICA, 1946 to 2010) (Western Regional Climate Center, 2011). This persistent dryness, periodically interrupted by flash flooding, is characteristic of NCPN park units most of the year and results in water being a critical, limiting factor in ecological processes affecting soil moisture and erodibility, type and distribution of flora and fauna, and water quality throughout the Colorado Plateau area.

Within the NCPN, the Colorado River and its major tributary, the Green River, are the largest and most extensive water resource. The Green River flows through DINO, and the Colorado River flows along the northern boundary of Colorado National Monument (COLM) and the southeastern boundary of Arches National Park (ARCH). These streams merge in Canyonlands National Park (CANY). Blue Mesa, Morrow Point, and Crystal Reservoirs in Curecanti National Recreation Area (CURE), which are part of the Colorado River Storage Project (Bureau of Reclamation, 2008), encompass the largest exposed area of surface water in the NCPN (fig. 1). Several other major tributaries flow through the NCPN park units, including the Gunnison River, which flows westward through CURE and Black Canyon of the Gunnison National Park (BLCA) and joins the Colorado River near COLM; the Yampa River, which flows westward and joins the Green River in DINO; the Fremont River, which flows eastward through CARE and into the Dirty Devil River; and North and East Forks of the Virgin River, which flow south and southwest through Zion National Park (ZION). In contrast, the remaining NCPN park units are principally supported by small perennial, intermittent, or ephemeral water sources. These units include Bryce Canyon National Park (BRCA), Cedar Breaks National Monument (CEBR, park unit not included in this analysis), FOBU, GOSP, Hovenweep National Monument (HOVE), Natural Bridges National Monument (NABR), Pipe Spring National Monument (PISP, park unit not included in this analysis), and TICA. A substantial network of perennial, intermittent, or ephemeral springs, seeps, pools, washes, and streams—some that only may flow in the spring or after monsoon storms—sustains much of the floral and faunal diversity and abundance in this arid to semi-arid landscape. Unique and ecologically important water-dependent features such as hanging gardens (isolated physically and biologically unique mesophytic communities) and cottonwood stands are supported by springs and seeps (Evenden and others, 2002).

Table 1. National Park Service units in the Northern Colorado Plateau Network, including state, area, and visitation statistics.

[AZ, Arizona; CO, Colorado; Ecoregion "mtn" represents "forested mountains (Ecoregion II)" and "xeric" represents "xeric west (Ecoregion III)"; ft, feet; UT, Utah; WY, Wyoming; park units in the network that were excluded from analysis in this report shown in gray]

Northern Colorado Plateau Network park unit	Park abbreviation (Park code)	State	Ecoregions	Park unit acres[1]	Altitude range (ft) above mean sea level[2]		Number of recreational visitors in 2006[3]	Percent increase in number of visitors from first recorded year to 2006 (Number of visitors in first year, first year)[3]
					Low range (ft)	High range (ft)		
Arches National Park	ARCH	UT	xeric	76,679	3,957	5,659	833,049	166,510 (500, 1929)
Black Canyon of the Gunnison National Park	BLCA	CO	xeric	30,750	5,367	9,032	160,450	6,090 (2,592, 1934)
Bryce Canyon National Park	BRCA	UT	xeric, mtn	35,835	6,562	9,111	890,676	3,949 (21,997, 1929)
Canyonlands National Park	CANY	UT	xeric	337,598	3,740	7,182	392,537	1,923 (19,400, 1965)
Capitol Reef National Park	CARE	UT	xeric, mtn	241,904	3,878	8,957	511,511	34,001 (1,500, 1938)
Cedar Breaks National Monument	CEBR	UT	xeric	6,155	8,074	10,653	488,376	2,753 (17,120, 1934)
Colorado National Monument	COLM	CO	xeric	20,534	4,629	7,087	332,654	10,988 (3,000, 1919)
Curecanti National Recreation Area	CURE	CO	xeric, mtn	41,972	6,503	9,508	936,380	209 (302,600, 1968)
Dinosaur National Monument	DINO	CO/UT	xeric, mtn	210,278	4,731	9,012	278,473	5,373 (5,088, 1937)
Fossil Butte National Monument	FOBU	WY	xeric	8,198	6,601	8,091	16,631	1,563 (1,000, 1973)
Golden Spike National Historic Site	GOSP	UT	xeric	2,735	4,321	5,292	45,381	38 (32,900, 1967)
Hovenweep National Monument	HOVE	CO/UT	xeric	785	5,079	6,745	26,348	10,439 (250, 1925)
Natural Bridges National Monument	NABR	UT	xeric	7,636	5,584	6,624	91,288	456,340 (20, 1923)
Pipe Spring National Monument	PISP	AZ	xeric	40	4,905	5,115	50,923	1,173 (4,000, 1925)
Timpanogos Cave National Monument	TICA	UT	mtn	250	5,476	8,045	110,840	2,084 (5,074, 1934)
Zion National Park	ZION	UT	xeric, mtn	146,597	3,648	8,730	2,567,350	69,438 (3,692, 1920)
Totals				1,167,947			7,732,867	48,305 (Average)

[1] Acre data from National Park Service Public Use Statistics Office (National Park Service, 2011). Note: Acres may differ between legislated surveyed numbers and the Land Resources Division office records due to boundary amendments, legislation, acquisition, and improved data-processing techniques. Acres reflect gross area acres, which may include other public and private acres within the park unit.

[2] Elevation statistics from Evenden and others (2002).

[3] Visitation statistics from the National Park Service Public Use Statistics Office (National Park Service, 2007).

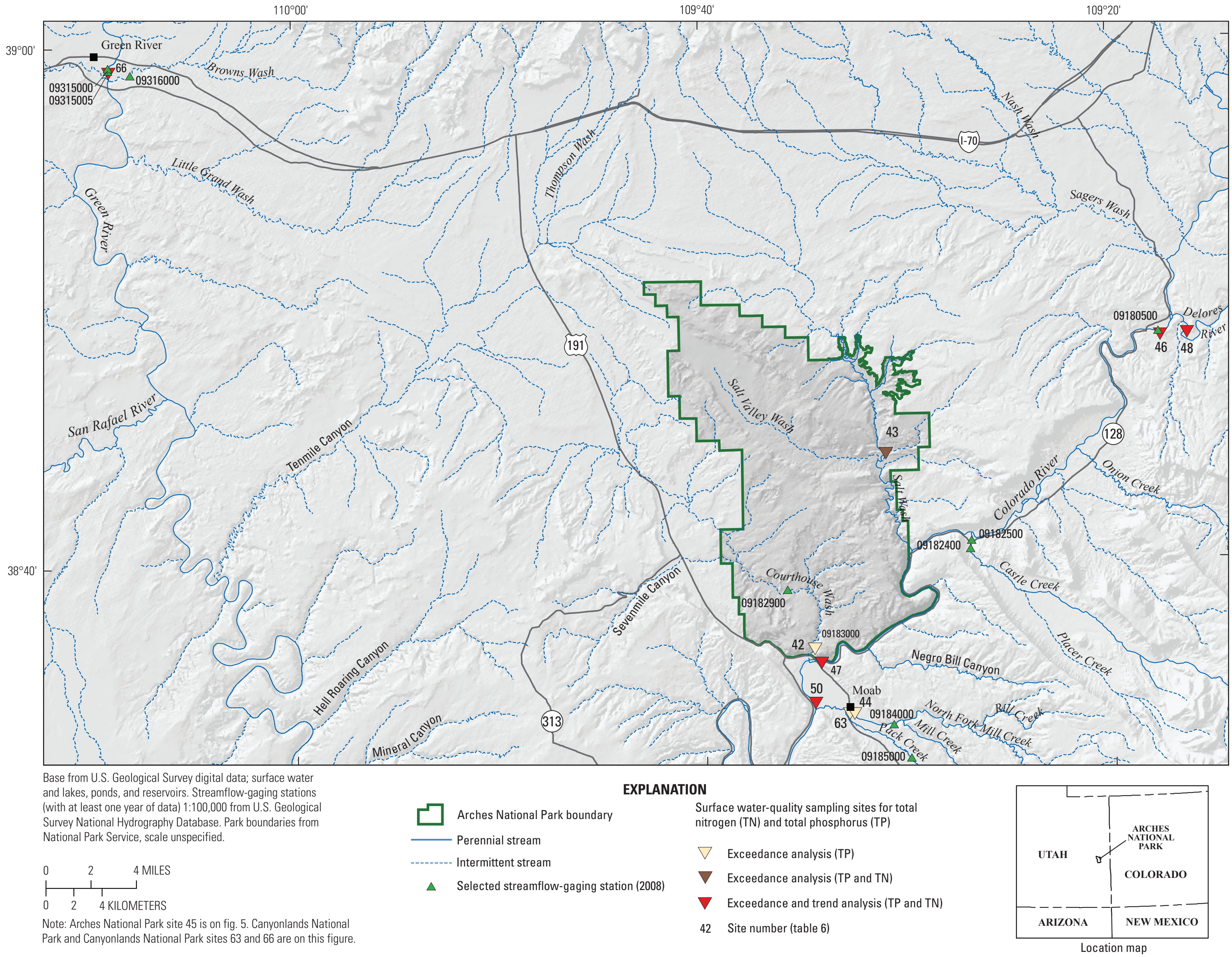


Figure 2. Arches National Park, Utah, and locations of water-quality sampling sites.

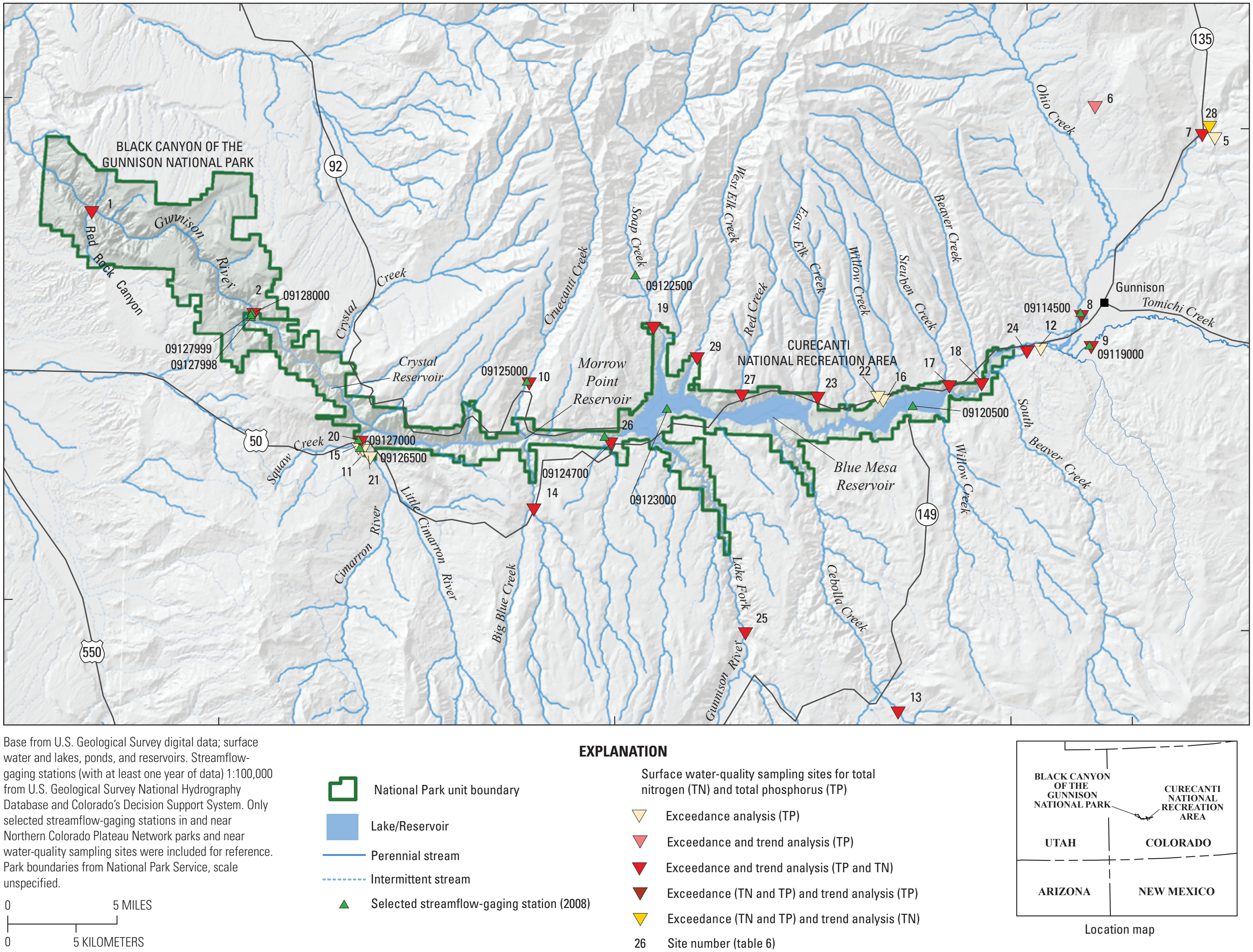


Figure 3. Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, Colo., and locations of water-quality sampling sites.

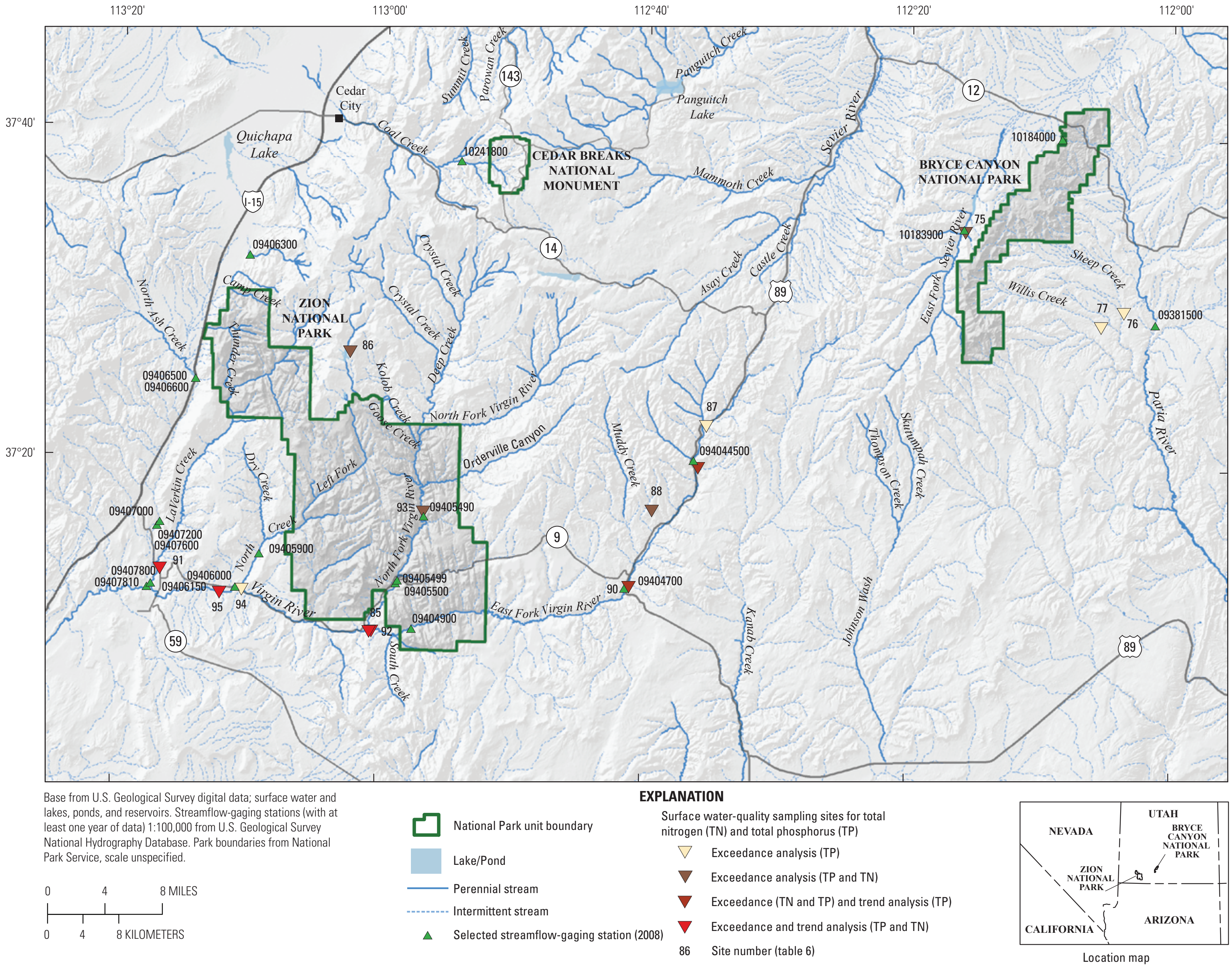


Figure 4. Bryce Canyon National Park and Zion National Park, Utah, and locations of water-quality sampling sites. [Cedar Breaks National Monument not included in this analysis.]

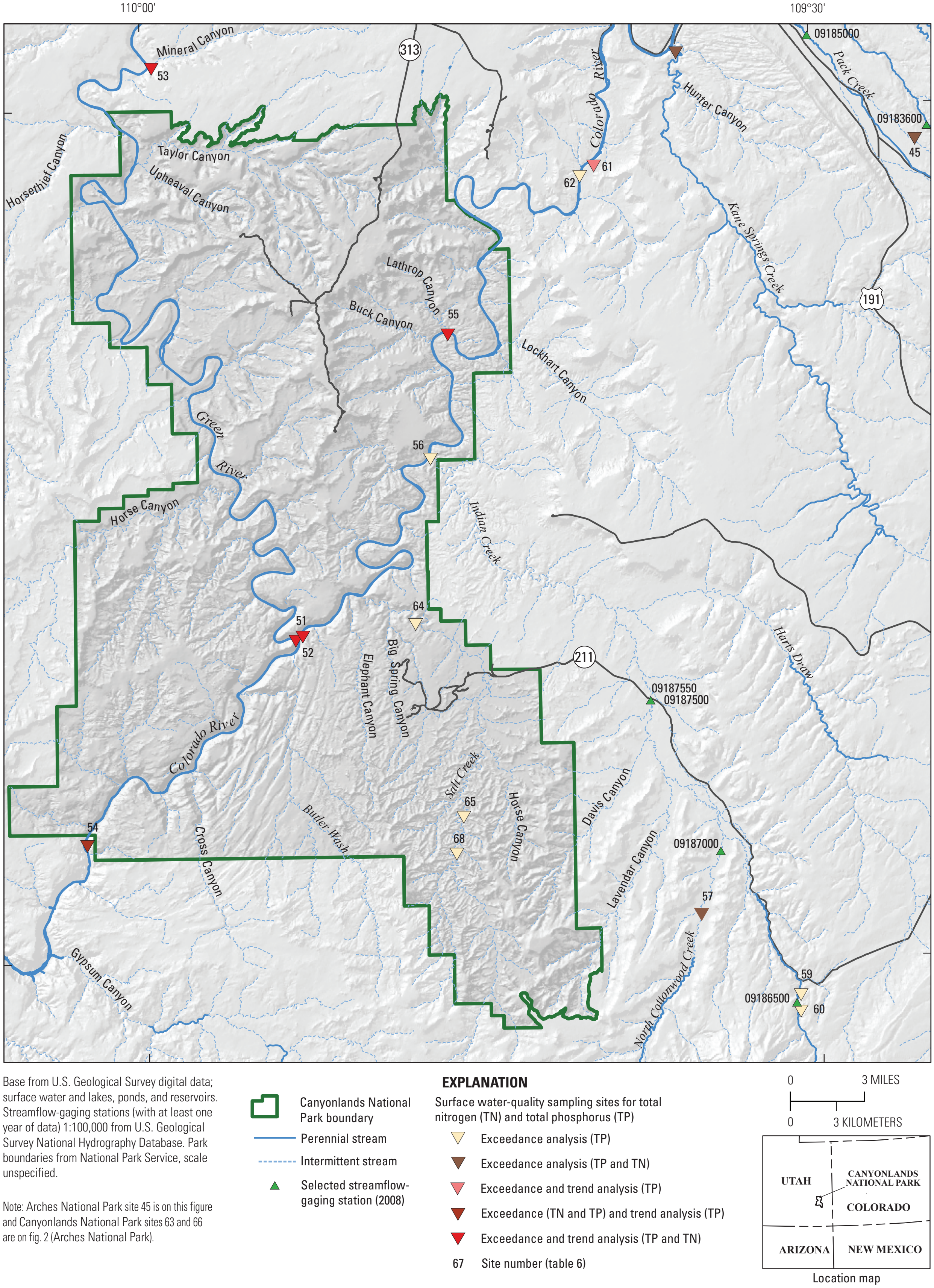


Figure 5. Canyonlands National Park, Utah, and locations of water-quality sampling sites.

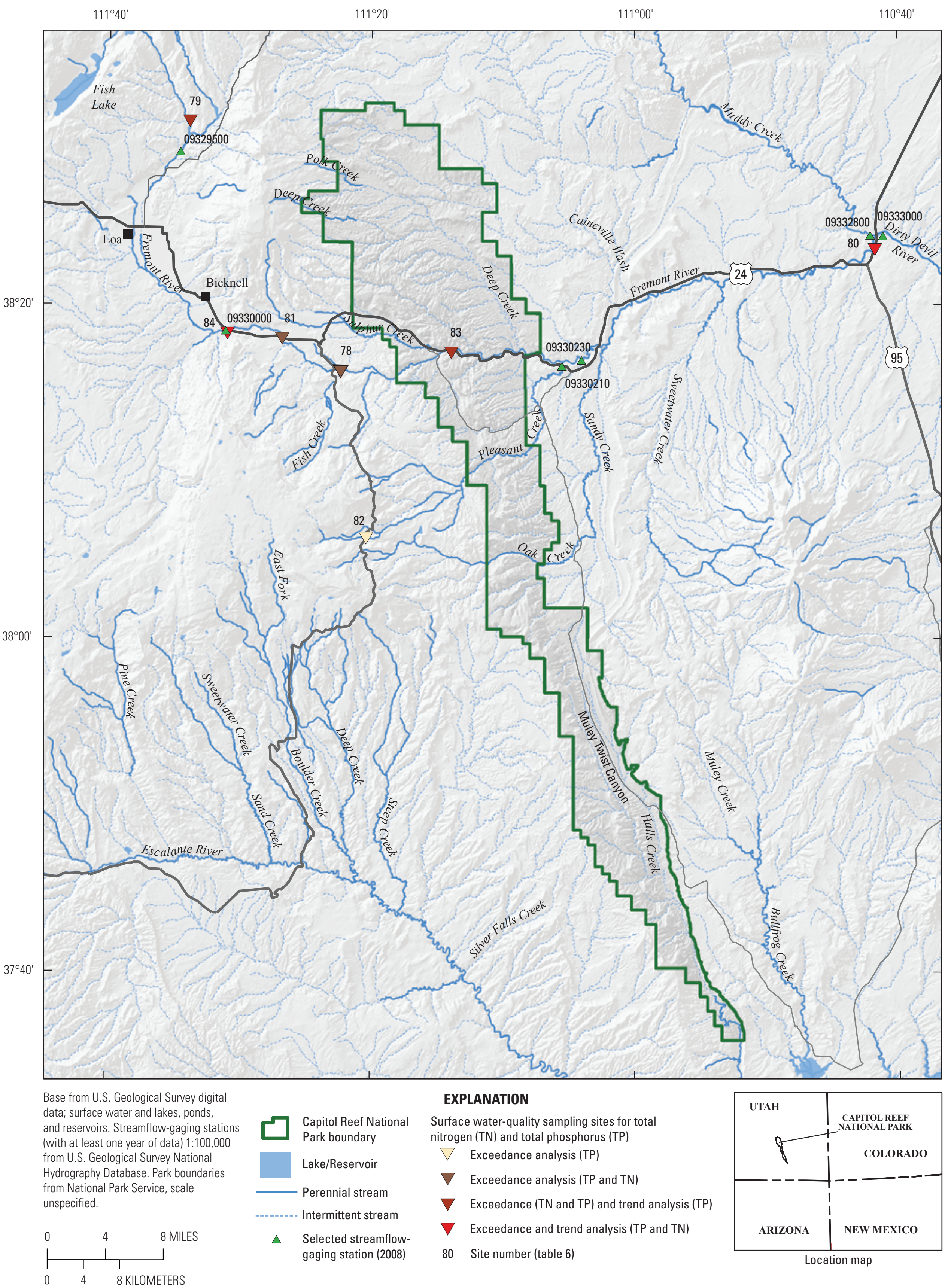


Figure 6. Capitol Reef National Park, Utah, and locations of water-quality sampling sites.

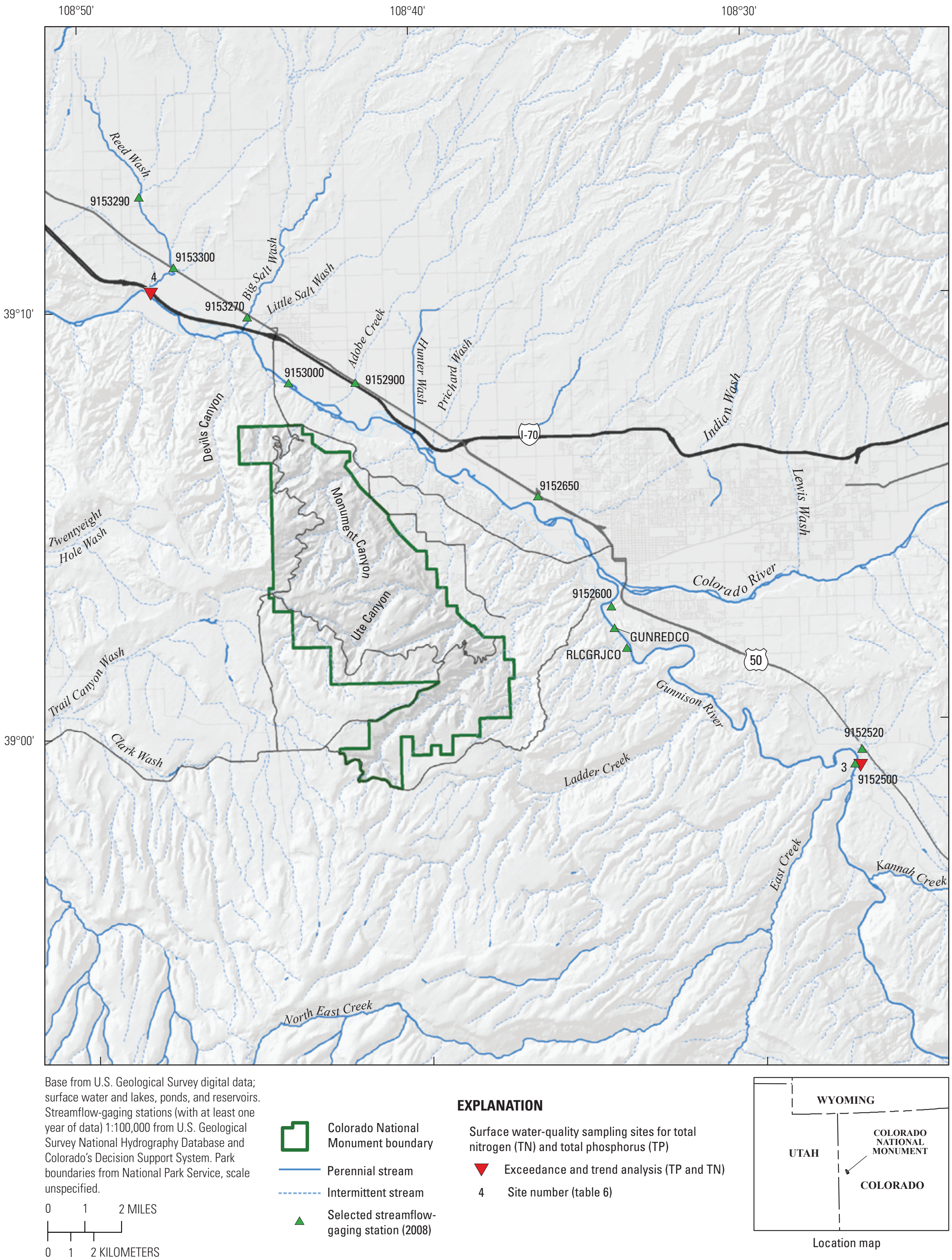


Figure 7. Colorado National Monument, Colo., and locations of water-quality sampling sites.

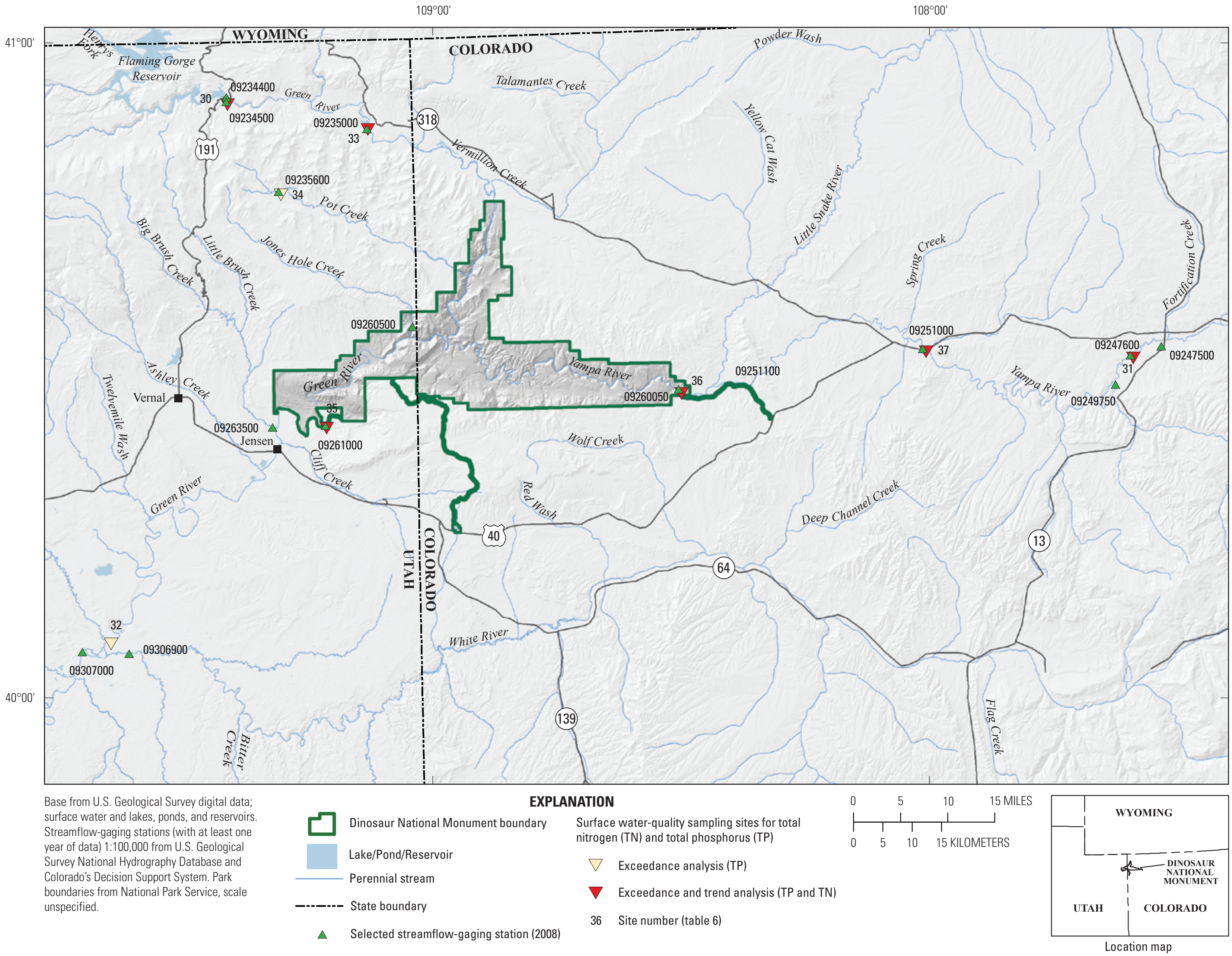


Figure 8. Dinosaur National Monument, Colo. and Utah, and locations of water-quality sampling sites.

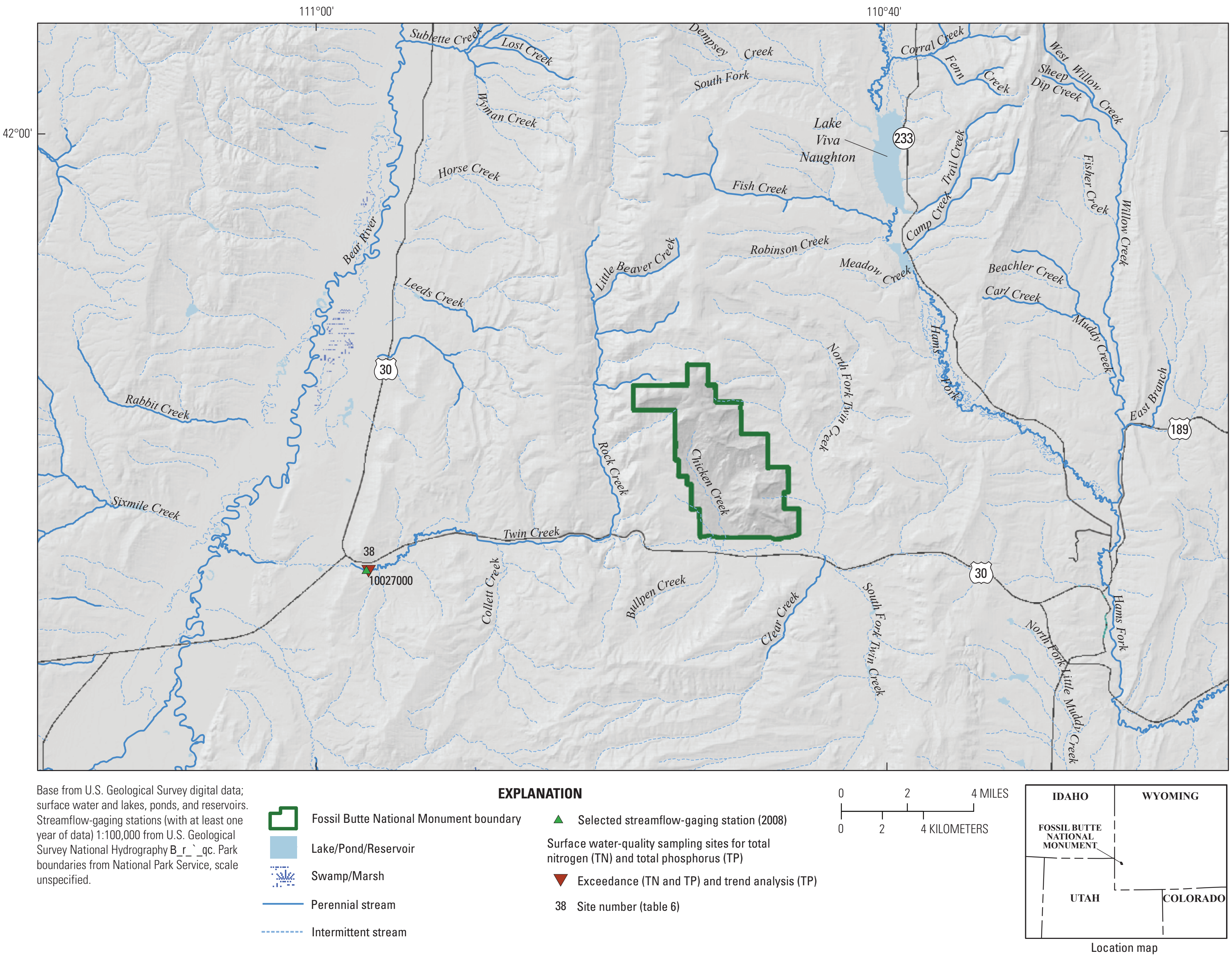


Figure 9. Fossil Butte National Monument, Wyo., and locations of water-quality sampling sites.

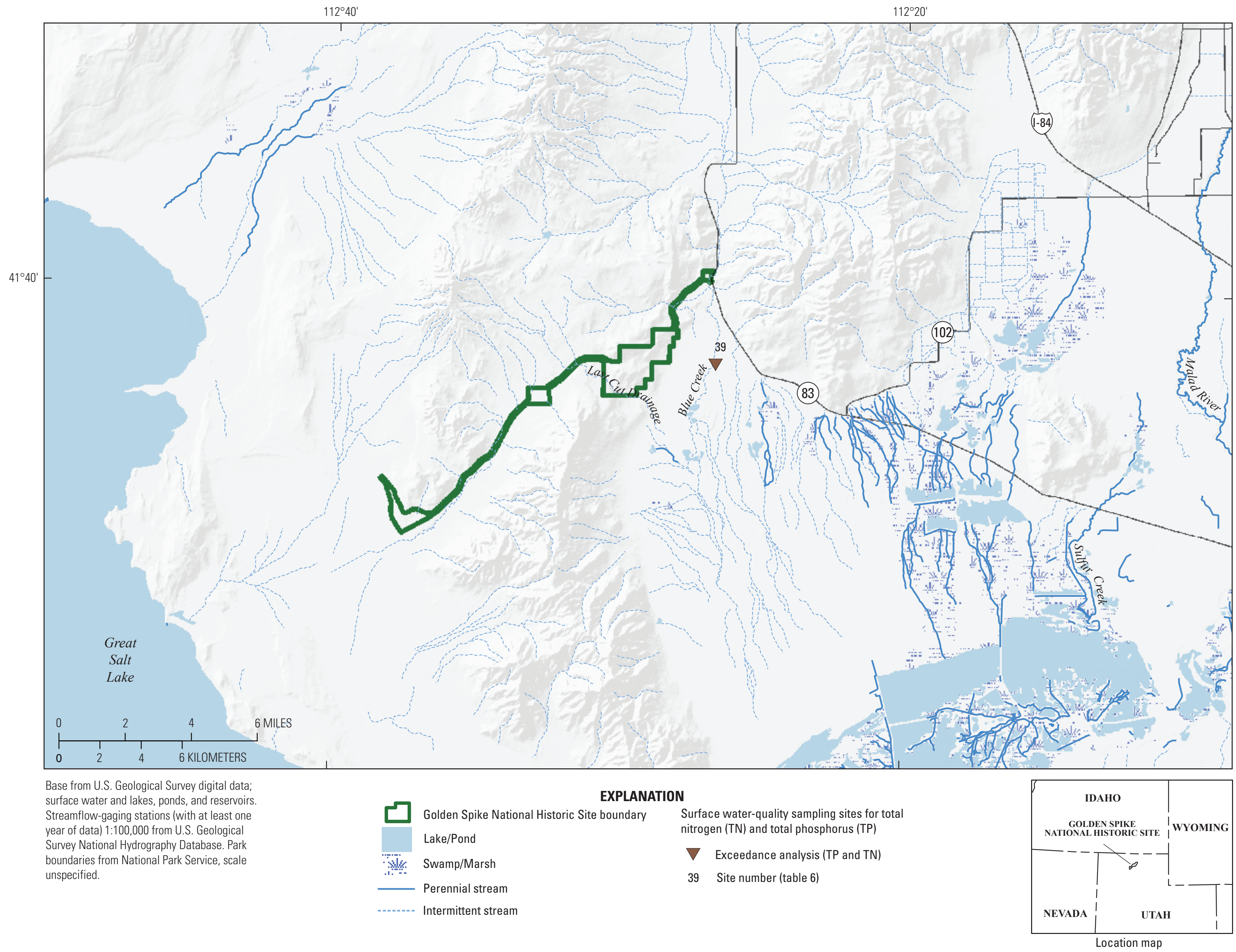


Figure 10. Golden Spike National Historic Site, Utah, and locations of water-quality sampling sites.

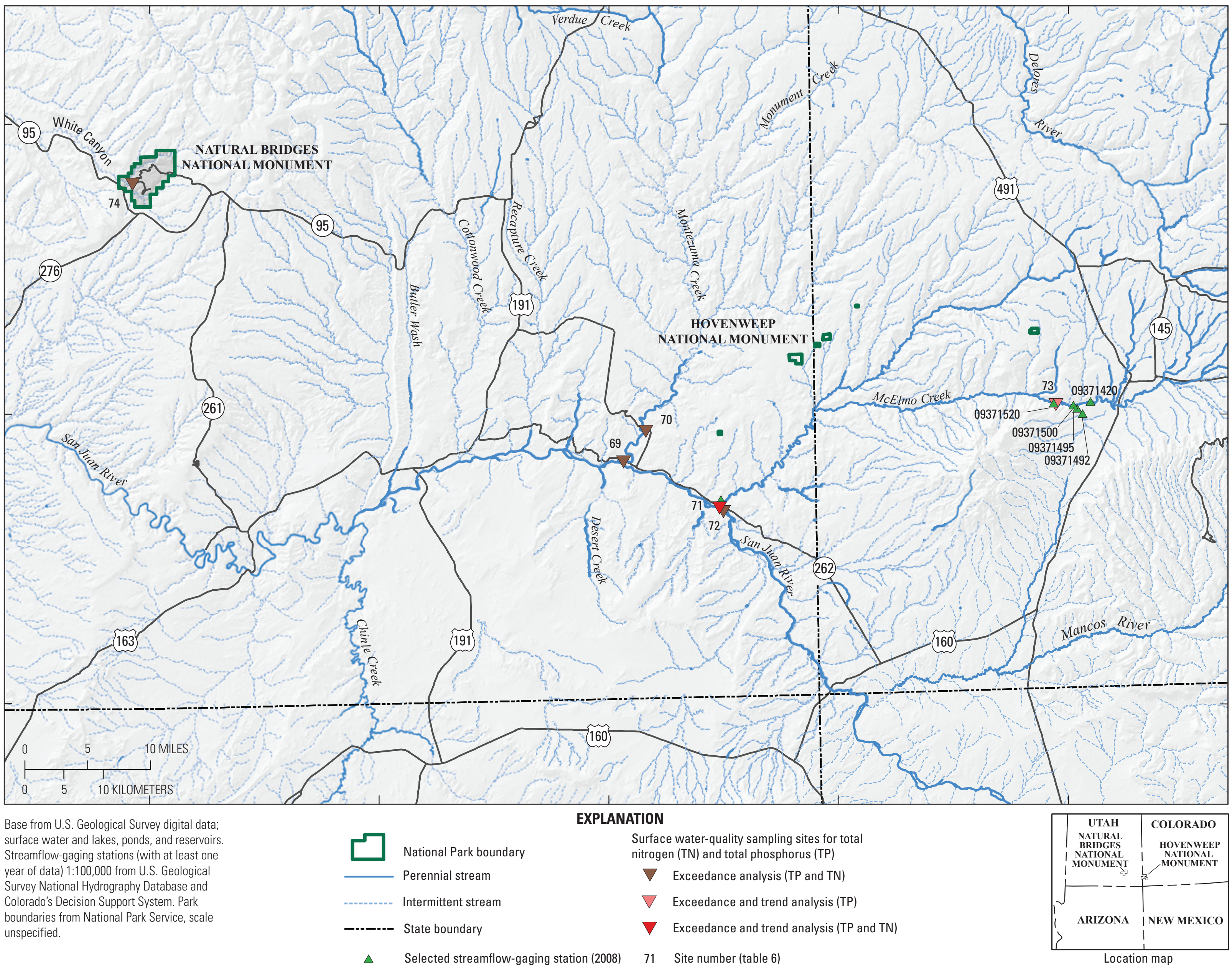
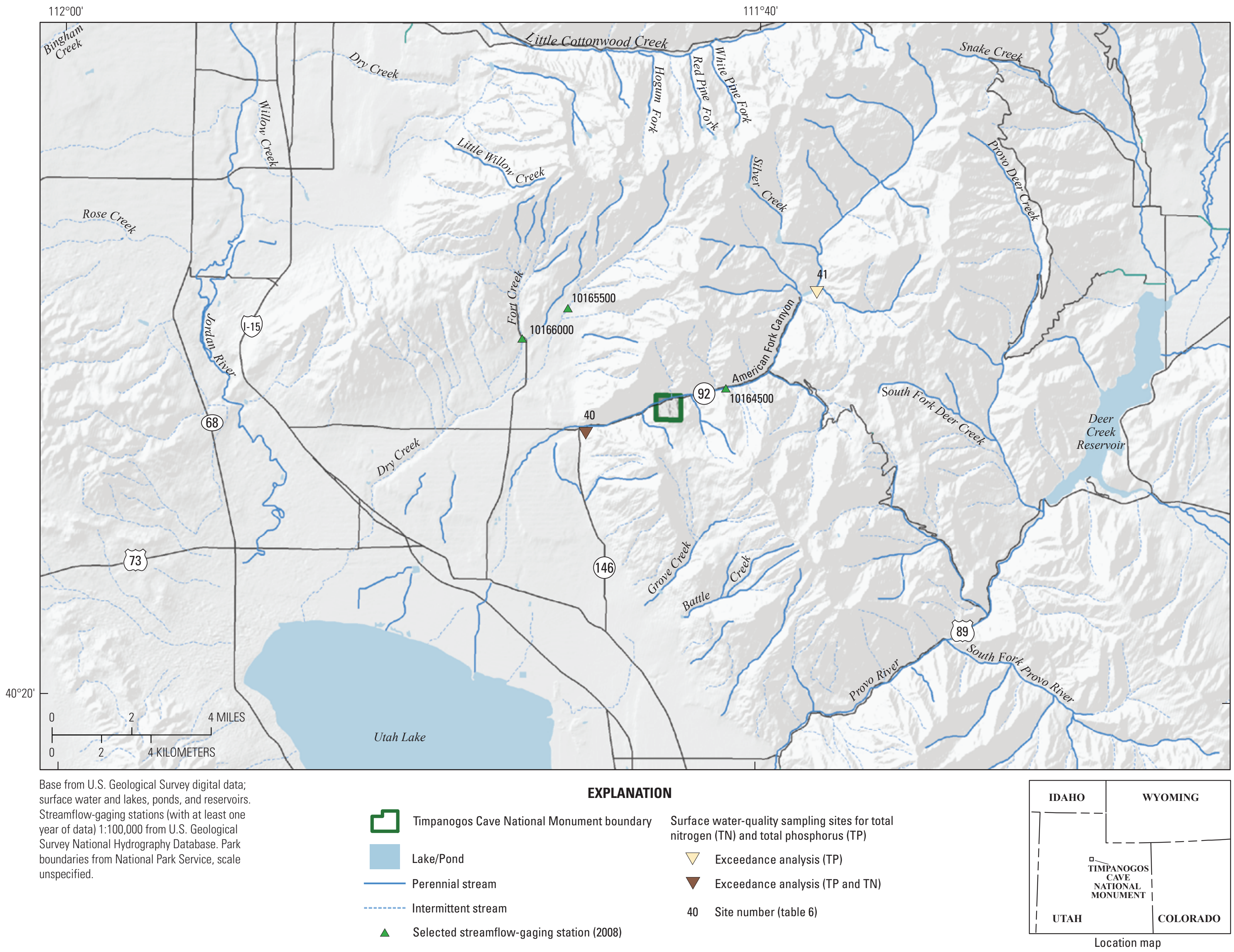


Figure 11. Natural Bridges National Monument, Utah, and Hovenweep National Monument, Colo. and Utah, and locations of water-quality sampling sites.



Base from U.S. Geological Survey digital data; surface water and lakes, ponds, and reservoirs. Streamflow-gaging stations (with at least one year of data) 1:100,000 from U.S. Geological Survey National Hydrography Database. Park boundaries from National Park Service, scale unspecified.

Figure 12. Timpanogos Cave National Monument, Utah, and locations of water-quality sampling sites.

Factors Affecting Nutrient Water Quality in the Northern Colorado Plateau Network

Multiple natural and human factors affect nutrient (nitrogen and phosphorus) water quality in the NCPN park units. Most of the NCPN units in this study (excluding BRCA, FOBU, and TICA) are characterized by flow-through systems (that is, surface water flows upstream to the park, into and through the park to locations downstream from the park), some of which have multiple upstream influences that contribute to nutrient water quality.

Natural weathering of nitrogen-bearing rocks (for example, Straight Cliffs Formation in and near BRCA, and Mancos Shale in and near ARCH and CARE and downstream from COLM) and phosphorus-rich minerals (for example, variscite) can locally contribute nitrogen and phosphorus to park streams (Lowe and Wallace, 2001, Waggaman, 1933, U.S. Department of Energy, 2011). Soils, organic leaves and debris, and waste from wild animals also can contribute nitrogen and phosphorus to streams (Loehr, 1974; Meyer, 1980; Doran and others, 1981). Nitrogen and phosphorus bound to soil particles and subsequently released through the combustion of organic matter to ash from fires can follow multiple pathways to surface water (Ranalli, 2004).

Naturally derived nitrogen compounds in atmospheric deposition cycle to the land and water in the form of wet (rain, snow, clouds, and fog) and dry (particles and gasses) deposition. However, human-influenced atmospheric deposition of nitrogen is equal to or exceeds contributions from natural sources for many of the nitrogenous compounds in the atmosphere (Porter and others, 2000) and has been linked to acidification of freshwater lakes, streams, and coastal water in the United States and Europe (Grennfelt and Hultberg, 1986; Puckett, 1994; Jaworski and others, 1997; Vitousek and others, 1997; Paerl and others, 2002). Human sources of nitrogen to streams from atmospherically derived nitrogen as wet or dry deposition can come from exhaust from on- and off-road vehicles and emissions from coal-fired power plants, agricultural machinery, fertilizer applications, livestock waste, and industrial processes (Fenn and others, 2003). Several studies (Baron and others, 2000; Baumgardner and others, 2002; Clow and others, 2003; Fenn and others, 2003; Báez and others, 2007) have reported upward trends in atmospheric deposition of nitrogen in areas of the western United States. In contrast, recent NCPN reports on air quality suggest nitrogen deposition may be leveling out (that is, showing no trend) or reducing in and near most NCPN park units (Perkins, 2009, 2010). Some studies such as those by Graham and Duce (1979) and Mahowald and others (2008) suggest atmospheric deposition of phosphorus also may be a contributing factor for phosphorus in surface water.

Numerous additional human influences occur upstream (or downwind) from, in, or near NCPN park areas that can contribute nitrogen and phosphorus to park streams. These influences include nutrient runoff, seepage, or volatilization from fertilized fields, manure applications, grazing (unconfined) animals, confined-animal feedlots, and manure-storage facilities, as well as nutrients attached to soil eroded and transported by wind or water as a result of agricultural activities (Apodaca and others, 1996; Miller and others, 2003). Development influences include runoff from residential and urban areas, seepage from septic systems, and discharges from municipal sewage-treatment plants. Domestic-animal waste can contribute nutrients when deposited in or near streams. Some individual park units also have facilities (for example, residential or visitor housing with septic systems and waste-treatment lagoons) and activities (for example, increasing numbers of recreational visitors— some of whom improperly dispose of human waste; table 1) within their boundaries that could contribute nutrients to streams.

Mining can contribute nutrients to surface water and groundwater from extraction of nitrogen or phosphorus-bearing source-rock materials. Gilsonite, which is an asphaltite with uniquely high nitrogen content, is mined to produce specialty asphalt. At least three large commercial Gilsonite facilities operate in northeastern Utah in the White River Basin that flows to the Green River south of DINO (Bon and Wakefield, 2008). Additionally, several large tar-sand facilities south and west of DINO are operational and more oil-shale operations are pending in the Uinta Basin (including the Green, Colorado, and White River Basins) in northeastern Utah and western Colorado as well as areas identified in and near CARE (Allison, 1997; Southern Utah Wilderness Alliance, 2006; Confluence Consulting, Inc., 2004; Bon and Wakefield, 2008). These mining processes use large quantities of water and energy and can cause large-scale land disturbance resulting in erosion, emissions from machinery and trucking operations (resulting in the release of nitrous oxides from exhaust), and increased discharges of wastewater containing nutrients from community municipal sewage-treatment facilities (U.S. Department of Energy, 2004?; The Wilderness Society, 2006; Nelson and Wall, 2008). Phosphorite and rock phosphate are commercially mined for fertilizer with mines operating near several NCPN park units in Utah and Colorado. For example, in the Big Brush Creek Basin that flows into the Green River there is a large commercial phosphate mine west of DINO and north of Vernal, Utah, (Bon and Wakefield, 2008; fig. 8).

Nutrient Water-Quality Standards and Criteria in Northern Colorado Plateau Network Park Units

The Federal Water Pollution Control Act Amendments of 1972 [U.S. Congress, 1972, commonly referred to as the Clean Water Act (CWA)] and major amendments, including the CWA of 1977 (U.S. Congress, 1977), provides authority for states to develop beneficial designated-use classifications for surface water (40 C.F.R §131 as authorized under section 303.33 U.S.C. §1313) that are intended to protect some or all domestic, recreational, wildlife, and agricultural uses and are subject to approval by the USEPA. The CWA indicates that state numeric standards are to be established at sufficiently stringent levels to conservatively protect uses. State water-quality standards serve as regulatory standards and provide the basis for beneficial-use assessments and implementation of nonpoint-source pollution control. Water bodies also are protected by the antidegradation provision of the CWA, which is intended to prevent degradation of a water body to the limit of beneficial designated use if existing water quality is better than standards established for its beneficial designated use.

Nutrient water-quality numeric standards differ by state but are based on USEPA recommendations or modifications or are to be determined by scientifically defensible methods that establish maximum allowable concentrations of measurable constituents that sustain beneficial designated uses (U.S. Environmental Protection Agency, 2000a, 2000b, and 2000c). Numeric standards, and use designations to which they apply, change over time in formal triennial reviews as the understanding of environmental effects improves and distribution, source, and timing of contaminants become better defined. In this report, results are compared against current (2011) State of Utah numeric nutrient water-quality standards for TP. Colorado and Wyoming do not currently (2011) have numeric standards established for TP in any use category, and none of the three states currently (2011) have numeric standards for TN in any use category. Nutrient standards for TP proposed by Utah and promulgated by USEPA are presented in table 2, and beneficial-use designations for streams in Utah are provided in table 3.

In cases where there are no applicable State standards (that is, for TP data from sites in Colorado or Wyoming and TN data from sites in Colorado, Utah, and Wyoming), results are compared against the USEPA recommended nutrient criteria for aggregate Ecoregions II forested mountains (also referred to as “mountain” or “mtn”) and aggregate Ecoregion III xeric west (also referred to as “xeric”) (U.S. Environmental Protection Agency, 2000b and 2000c). These numeric criteria are not laws or regulations but serve as guidance that the States may use as a starting point for developing standards that protect designated uses in the context of local conditions.

The xeric ecoregion is predominantly rangeland with some irrigated agriculture and is characterized by unforested basins, alluvial fans, plateaus, buttes, and scattered mountains. It is drier than the adjacent mountain ecoregion and is subject to large interannual seasonal and diurnal variations (U.S. Environmental Protection Agency, 2000c). The current recommended criteria for surface water of the aggregate xeric ecoregion are 0.38 mg/L for TN and 0.022 mg/L for TP (table 2; U.S. Environmental Protection Agency, 2000c). These criteria were determined by the USEPA upon establishing potential reference conditions for the 25th percentile of all seasons of data from 1990 through 1999 for the xeric aggregate ecoregion. For TN, the potential reference conditions were 0.223 milligrams per liter (mg/L) (calculated) and 0.377 mg/L (reported based on 154 values), and for TP the potential reference condition was 0.02188 mg/L (based on 808 values).

Table 2. Summary of State of Utah water-quality standards and U.S. Environmental Protection Agency recommended nutrient criteria used for exceedance analysis.

[N, nitrogen; P, phosphorus; UT, Utah; USEPA, U.S. Environmental Protection Agency; mtn, forested mountain (Ecoregion II); xeric, xeric west (Ecoregion III); 2A, 2B, 3A, and 3B are state of Utah beneficial designated uses described in table 3; mg/L, milligrams per liter]

Constituent	State water-quality standards for designated beneficial uses UT secondary recreation 2A, 2B and aquatic life 3A, 3B[1]	USEPA recommended nutrient criteria	
		USEPA mtn[2]	USEPA xeric[3]
Total nitrogen (mg/L as N)	No standard	0.12	0.38
Total phosphorus (mg/L as P)	[4]0.05	0.01	0.022

[1] Utah Administrative Code (2009).

[2] U. S. Environmental Protection Agency (2000b).

[3] U. S. Environmental Protection Agency (2000c).

[4] Total phosphorus concentration greater than 0.05 mg/L is not a standard but is considered by the State of Utah as an indication of impairment (Utah Administrative Code, 2009).

In contrast, the mountain ecoregion is predominantly forested mountains with limited cropland and some logging, grazing, and mining and is characterized by forests, mountain valleys, shrubs and grasses at lower altitudes, high relief terrain, steep slopes, and perennial streams. Precipitation is highly variable in this ecoregion because of rain shadow influences, altitude, and latitude (U.S. Environmental Protection Agency, 2000b). The current recommended criteria for surface water of the aggregate mountain ecoregion are 0.12 mg/L for TN and 0.01 mg/L for TP (table 2; U.S. Environmental Protection Agency, 2000b). These criteria were determined by the USEPA upon establishing potential reference conditions for the 25th percentile of all seasons of data from 1990 through 1999 for the mountain aggregate ecoregion. For TN, the potential reference conditions were 0.064 mg/L (calculated) and 0.12 mg/L (reported based on 239 values), and for TP the potential reference condition was 0.010 mg/L (based on 1,380 values).

Water-quality-standard exceedances noted in this report do not imply a water body did not attain or is not currently attaining its designated beneficial use(s) because that determination requires evaluation of additional chemical, physical, and biological data and is a task reserved by States in their biennial or triennial reviews. For additional information on how individual states establish water-quality standards see Colorado Department of Public Health and Environment (2001), Utah Division of Water Quality (2008), and Utah Administrative Code (2009).

Table 3. Applicable designated beneficial uses defined for Northern Colorado Plateau Network streams in Utah.

Use code	Designated beneficial use	Utah use code description[1]
2A	Primary recreation	Protected for primary-contact recreation such as swimming.
2B	Secondary recreation	Protected for secondary-contact recreation such as boating, wading, or similar uses.
3A	Cold-water aquatic life	Protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain.
3B	Warm-water aquatic life	Protected for warm-water species of game fish and other warm-water aquatic life, including the necessary aquatic organisms in their food chain.

[1] Utah Administrative Code (2009).

None of the streams in this report is presently on a state 303(d) list of nutrient-impaired water (Utah Division of Water Quality, 2006; Colorado Department of Public Health and Environment, 2008). However, two segments of the Fremont River (the Fremont River near Bicknell to the U.S. Forest Service boundary and the Fremont River and tributaries from confluence with the Dirty Devil River to the east boundary of CARE) were listed in 2000 as impaired because of high TP, elevated total dissolved solids (TDS), and low DO concentrations in the State of Utah 303(d) list (Utah Division of Water Quality, 2000; Fremont River Watershed Steering Committee and Millennium Science & Engineering, 2002; fig. 6 (sites 79, 83, and 84). Once the total maximum daily load (TMDL) analysis was completed and approved by USEPA, water bodies in the Fremont River Basin were removed from the list of impaired water (Utah Division of Water Quality, 2006). Additionally, various segments of the Virgin River, which is formed by the confluence of the North Fork and East Fork Virgin Rivers that flow through ZION (fig. 4) were listed on the State of Utah's 2002 303(d) list of impaired water for TDS, DO, temperature, or TP (Virgin River Watershed Advisory Committee, 2006). The TDS listing was applicable to ZION surface water because it included the North Creek tributary. The remaining water-quality constituents listed are not applicable to ZION surface water. The 2004 TMDL for the Virgin River Basin determined that the TDS listing was a result of naturally high concentrations in the environment as a result of naturally occurring hot springs and erosion or runoff from rock and soil high in soluble minerals resulting in the implementation of new site-specific TDS standards (Utah Division of Water Quality, 2004; Virgin River Watershed Advisory Committee, 2006).

Data Analysis Methods

A review of the database used for the nutrient data, data preprocessing, site selection, and methods for analysis of exceedances and trends are presented in this section. Prior to analysis, nutrient data were preprocessed, which involved re-censoring and aggregation as described herein. Methods are explained for calculating exceedances of water-quality criteria, including decision rules and summary statistics. Methods, including data selection, also are described for analyzing trends in ambient concentrations and FAC.

Description of Water-Quality Database

Beginning in 2003, NPS NCPN staff and USGS hydrologists cooperated in the acquisition, organization, management, and evaluation of available water-quality data from the NCPN park units as part of the I&M Program activities. These electronically available water-quality data (collected through December 2002) were retrieved and compiled for sampling sites within, adjacent to, and upstream from the 16 NCPN park units. Data were retrieved from the USEPA Legacy STOrage and RETrieval (Legacy STORET) and STORET X (that is, Modern STORET) databases (U.S. Environmental Protection Agency, 2011), the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2001), and additional digitally available NPS datasets (including bacteriological data for ZION and water-quality data for CURE and BLCA that also were input into NWIS). A relational Microsoft© Access database houses the compiled historical water-quality data (on file at the NPS office, Northern Colorado Plateau I&M Network, Moab, Utah). As part of this study, data were updated in the NCPN water-quality database to include results from the ongoing [collected as recently as February 2007] NCPN water-quality sampling program as well as data (through February 2007) collected by other State and Federal agencies and reported in Modern STORET or NWIS.

Prior to extraction of TN and TP data from the database for exceedance and trend analysis, all available nitrogen and phosphorus data were pre-processed, including re-censoring and data aggregation as described below.

Data Re-censoring

Data re-censoring involves adjusting data to common reporting conventions (Mueller and Spahr, 2005). Details on the laboratories and their associated analytical and reporting procedures were generally unknown for most of the historical nutrient data; however, for data obtained from the USGS National Water Quality Laboratory (NWQL), information on censoring and laboratory reporting conventions were available and used to re-censor applicable data before analysis. Before the 1990s, the NWQL censored data at the long-term method detection limit (LT-MDL), where the risk of false-positive detection is no greater than 1 percent (Oblinger and others, 1999). In the late 1990s, the NWQL began to censor data at the laboratory reporting level (LRL), a value generally twice the LT-MDL. Currently (2011) at the NWQL, values measured less than the LT-MDL are reported as less than the LRL. This approach can result in upward bias during statistical analysis of censored data (as used in this study) because the probability that an observation might land between the LT-MDL and LRL likely is overstated (Helsel, 2005). Mueller and Spahr (2005) suggest that the possibility of a few false negatives occurring is less of a concern than the problems caused by such a bias. Therefore, using current and historical LT-MDL documentation available from the NWQL (National Water Quality Laboratory, [2010]) each applicable constituent was re-censored by this study from the LRL to the associated LT-MDL to adjust for this change. When no documentation of an associated LT-MDL could be found, values were left censored at the LRL. Values with an “E” remark code, which are values measured between the LT-MDL and the LRL, were left unchanged as were all values from non-USGS data. Non-USGS estimated values [that is, those values with data qualifiers of “Q” (holding time exceeded before sample delivery or before analysis was complete (Legacy STORET remark code accessed on September 7, 2011, at *http://www.epa.gov/storet/legacy/rsultrmk.htm*)]. All USGS and non-USGS estimated values were interpreted the same as uncoded measured values in this study. Additionally, TP values from the NWQL originally reported as an uncensored numerical value less than 0.03 mg/L before October 1, 1998, were re-censored by this study to a censored value of “less than 0.03 mg/L,” including re-censoring non-detect data previously censored below this level. For example, data previously reported as 0.02 mg/L would now be reported as “less than 0.03 mg/L,” and data previously reported as “less than 0.01 mg/L” would now be reported as “less than 0.03 mg/L” on the basis of guidance from the NWQL (U.S. Geological Survey, 1998). Re-censoring can have implications for water-quality exceedance analysis where the standard or criterion is less than the adjusted censoring level. For example, the USEPA Ecoregion II recommended criteria for TP is 0.01 mg/L, which is less than the adjusted censoring level (0.03 mg/L) for applicable USGS data used in this analysis. Lastly, values reported as zero were re-censored by this study to a detection limit that was based on the lowest non-zero censored values reported during the sampling time period and the censoring levels during adjacent time periods for the same or similar sites. Similar sites were those identified from the same source agency with approximately the same sampling timeline, frequency, and range of concentrations.

Data Aggregation

Following data re-censoring, nutrient data were aggregated to facilitate analysis of the maximum amount of available TN and TP data for a given site, which included combining nitrate and nitrite data with organic nitrogen and ammonia data into aggregated “total nitrogen” and combining multiple phosphorus parameters into aggregated “total phosphorus.” In addition, data from multiple parameter codes and with various reporting conventions were aggregated, including unfiltered (total) and filtered (dissolved) data (nitrogen data only). For example, nitrate may have been reported in units of “milligrams per liter of nitrate” or “milligrams per liter of nitrogen.” Dissolved nitrogen and phosphorus data are defined by convention as samples able to pass through a 0.45-micrometer filter (Wilde and others, 2004). However, filter sizes used for processing samples typically are not described in the historical record for data used by this study; therefore, data used by this study are assumed to have been processed using a 0.45-micrometer filter. Values for unfiltered and filtered concentrations of ammonia, nitrite, nitrite plus nitrate, and orthophosphate were not statistically different in a previous comparison of paired total and dissolved samples analyzed at the NWQL (U.S. Geological Survey, 1992a). Where necessary, conversion factors were applied to ensure data were aggregated in like units. The procedures used to aggregate nutrient data are presented in table 4. This method was based on approaches used for a National nutrients synthesis completed by Mueller and others (1995) and a regional trends assessment completed by Sprague and others (2006). When a direct measurement of TN was unavailable, it was calculated from the sum of NOx (nitrate, NO_3, plus nitrite, NO_2) and ammonia plus organic nitrogen (also known as Kjeldahl nitrogen, KN). For NOx, total NOx was used preferentially; dissolved NOx was used only when total NOx was unavailable. For KN, total KN was used preferentially; dissolved KN was used only when total KN was unavailable. If a direct measurement of either dissolved or total NOx was unavailable, it was calculated as the sum of total or dissolved nitrite (NO_2) and total or dissolved nitrate (NO_3) as follows:

- if NO_2 and NO_3 were censored, NOx was censored to the sum of the two censoring levels (for example, NO_2 = <0.001 and NO_3 = <0.02; NOx = <0.021);
- if NO_2 was not censored (and greater than or equal to 10 times the absolute value of NO_3) and NO_3 was censored, NOx was set equal to NO_2(for example, NO_2 = 0.02 and NO_3 = <0.001; NOx = 0.02);
- if NO_2 was not censored (and less than 10 times the absolute value of NO_3) and NO_3 was censored, NOx was set equal to the difference between NO_2 and the absolute value of NO_3 and left as censored (for example, NO_2 = 0.001 and NO_3 = <0.02; NOx = <0.019);

- if NO_2 was censored and NO_3 was not censored (and greater than or equal to 10 times the absolute value of NO_2); NOx was set equal to NO_3 (for example, NO_2 = <0.001 and NO_3 = 0.02; NOx = 0.02);
- if NO_2 was censored and NO_3 was not censored (and less than 10 times the absolute value of NO_2; NOx was set equal to the difference between the absolute value of NO_2 and NO_3, and left as censored (for example, NO_2 = <0.02 and NO_3 = 0.001; NOx = <0.019);
- if both NO_2 and NO_3 were not censored, NOx was set equal to the sum of NO_2 and NO_3 (for example, NO_2 = 0.001 and NO_3 = 0.02; NOx = 0.021);
- if NO_2 was not measured and could not be calculated, but NO_3 was measured; NOx was set to NO_3;
- if NO_3 was not measured and could not be calculated, but NO_2 was measured; NOx was set to NO_2.

TN then was calculated as follows:

- if neither KN nor NOx were measured and NOx could not be calculated, TN was not calculated;
- if KN and NOx were censored, TN was censored to the sum of the two censoring levels (for example, KN = <0.2 and NOx = <0.01; TN = <0.21);
- if KN was not censored and NOx was censored, TN was set equal to KN (for example, KN = 2.1 and NOx = <0.01; TN = 2.1);
- if KN was censored and NOx was not censored, TN was set equal to NOx (for example, KN = <0.2 and NOx = 2.1; TN = 2.1);
- if KN and NOx were not censored, TN was set equal to the sum of KN and NOx (for example, KN = 0.2 and NOx = 2.1; TN = 2.3).

Data Selected for Exceedance and Trend Analysis

Following pre-processing, TN and TP data for selected surface-water sites were extracted from the NCPN water-quality database for the exceedance and trend analysis. The sources of nutrient data extracted from the database include Federal (USGS, USEPA, NPS, and U.S. Department of Agriculture Forest Service) and State (Colorado Department of Public Health and Environment and UTDWQ) agencies. Sites were selected on the basis of three characteristics: location (within, near, upstream from, or downstream from NCPN park boundaries), site type (surface-water stream sites), and data-collection period (TN or TP data had to have been collected within the last 20 years (1987) from the year of the most recent sample collection in the database (2007). For example, sites with data from 1980 through 1992 would have been selected, whereas sites with data from 1974 through 1986 would have been excluded by this study. Most of these data are from sites within or adjacent to park boundaries on streams that flow through NCPN park units. Some sites farther upstream from park boundaries on larger streams (including the Colorado, Fremont, Green, Gunnison, Virgin, and Yampa Rivers) also were included to provide a regional context for water flowing through the park units. For example, the Green River at Green River, Utah (CANY site 66; fig. 2), is on the Green River between DINO and CANY and was included in the study even though it is not near the boundary of either park. Another example is the Yampa River near Maybell (DINO site 37; fig. 8), which is approximately 38 miles (mi) upstream from DINO. This site was included in the study because it was the nearest water-quality sampling site upstream from the park boundary with a nutrient data and streamflow record sufficient for trend analysis. The nutrient data used by this study consist of nutrient water-quality and associated water-quantity information collected from February 16, 1972, through February 7, 2007, from surface-water sample sites on streams (including sites described as canyons, washes, creeks, and rivers) and from one outfall (Moab Wastewater Treatment Plant (WWTP) outflow, ARCH site 50; fig. 2). Data for springs, lakes (including, ponds, lakes, and reservoirs), diversions, and groundwater were not included in this analysis.

A summary (by park) of the number of sample sites, nutrient results, and streamflow measurements used by this study is given in table 5. All nutrient data summarized in table 5 were used for the exceedance analysis but not all of these data were used for the trend analysis. Data used in the trend analysis had to meet the data-analysis criteria described in “Selection of Data for Trend Analysis” in this section. For example, some sites with insufficient data were not analyzed for trends; other sites that had most or all data reported as less than the analytical detection limits were eliminated as candidates for trend analysis. Three park units (CANY, CURE, and DINO) had the largest number of nutrient samples collected within their park boundaries. Six park units (BRCA, COLM, FOBU, GOSP, HOVE, and TICA) had no available nutrient data for sample sites inside their park boundary, but data were available from surface-water sites near the park units (table 5; park boundary = Out). Three park units (CARE, DINO, and ZION) each had nutrient data collected inside their park boundary since the beginning of the 1970s; however, DINO is the only park of these three with a sizeable (greater than 200 results) data record.

Site-specific information on the sample sites used for exceedance and trend analysis is presented in table 6, which summarizes site number and identifiers, water sources, state, ecoregion, site location, earliest and most recent sample-collection dates, and the number of TN and TP results evaluated (including number of censored results). Sites shown in gray text were only analyzed for exceedances; sites shown in black text were analyzed for exceedances and trend. When more than one sample site was determined to be from

Table 4. Summary of procedures used to aggregate selected nutrient data into constituent groups for the Northern Colorado Plateau Network water-quality database.

[mg/L, milligram per liter; N, nitrogen; NO_2, nitrite; NO_3, nitrate; P, phosphorus; PO_4, orthophosphate; µg/L, microgram per liter; by standard definition, filtered indicates use of a 0.45-micron filter, though filter size was historically not recorded. Data compiled for this study are assumed to have been processed using a 0.45-micron filter]

Constituent group	Nutrient data parameter name	Nutrient data parameter code, in order of preference (conversion factor, if applicable)[1]
Nitrate, as N	Nitrate nitrogen, unfiltered (mg/L as N)	00620
	Nitrate nitrogen, unfiltered (mg/L as NO_3), converted to mg/L as N	71850 (multiplied by 0.2259)
	Nitrate plus nitrite nitrogen, unfiltered (mg/L as N) minus nitrite as [2]N	00630 (minus nitrite as N)
	Nitrate nitrogen, filtered (mg/L as N)	00618
	Nitrate nitrogen, filtered (mg/L as NO_3), converted to mg/L as N	71851 (multiplied by 0.2259)
	Nitrate plus nitrite nitrogen, filtered (mg/L as N) minus nitrite as [2]N	00631 (minus nitrite as N)
Nitrite, as N	Nitrite nitrogen, unfiltered (mg/L as N)	00615
	Nitrite nitrogen, unfiltered (mg/L as NO_2), converted to mg/L as N	71855 (multiplied by 0.30446)
	Nitrite plus nitrite nitrogen, unfiltered (mg/L as N) minus nitrate as [2]N	00630 (minus 00615)
	Nitrite nitrogen, filtered (mg/L as N)	00613
	Nitrite nitrogen, filtered (mg/L as NO_2), converted to mg/L as N	71856 (multiplied by 0.30446)
	Nitrite plus nitrite nitrogen, filtered (mg/L as N) minus nitrate as [2]N	00631 (minus 00618)
Total nitrogen, as N	Nitrogen, unfiltered (mg/L as N)	00600
	Nitrogen, unfiltered (mg/L as NO_3), converted to mg/L as N	71887 (multiplied by 0.2259)
	Ammonia plus organic nitrogen[3], unfiltered (mg/L as N) plus nitrate plus nitrite (mg/L as N)	00625 (plus 00630)
	Ammonia plus organic nitrogen[3], unfiltered (mg/L as N) plus nitrate as [2]N, plus nitrite as [2]N	00625 (plus nitrate as N, plus nitrite as N)
	Ammonia plus organic nitrogen[3], unfiltered, modified Jirka method (mg/L as N), plus nitrate as [2]N, plus nitrite as [2]N	99892 (plus nitrate as N, plus nitrite as N)
	Ammonia plus organic nitrogen[3], unfiltered, 1 determination (mg/L as N), plus nitrate as [2]N, plus nitrite as [2]N	00635 (plus nitrate as N, plus nitrite as N)
	Ammonia plus organic nitrogen[3], filtered (mg/L as N), plus nitrate as [2]N, plus nitrite as [2]N	00623 (plus 00631)
Total phosphorus, as P	Phosphorus, unfiltered (mg/L as P)	00665
	Phosphorus, unfiltered, modified Jirka method (mg/L as P)	99891
	Phosphorus, unfiltered (mg/L as PO_4), converted to mg/L as P	71886 (multiplied by 0.3261)
	Phosphorus, unfiltered, spectrograph method (µg/L as P), converted to mg/L	01070 (multiplied by 0.001)
	Phosphorus, total recoverable (µg/L as P), converted to mg/L	00662 (multiplied by 0.001)

[1] Parameter codes are a convention used by the U.S. Geological Survey National Water Information System (NWIS) and the U.S. Environmental Protection Agency Data Storage and Retrieval System (Legacy STORET).

[2] Parameter determined by using the procedure listed for nitrate as N and(or) nitrite as N. Missing values or values less than detection are omitted from this calculation.

[3] This parameter is also known as total Kjeldahl nitrogen. If this value is missing or less than detection, total nitrogen is not computed.

Table 5. Summary of total nitrogen and total phosphorus data and streamflow measurements available for stream sampling sites within and near Northern Colorado Plateau Network park unit boundaries used for water-quality standard exceedance and trend analyses, 1972 through 2007.

[In, inside park boundary; Out, outside park boundary (shaded rows); see table 1 for park code explanations; --, no sites; no nutrient data available for water-quality sample sites in or near CEBR or PISP; *italics* to emphasize differences between "number of sites" and "number of results"; not all data used for exceedance analyses were used for trend analyses]

Park code	Park boundary	Minimum sample date	Maximum sample date	Total *number of sites* used for water-quality standard exceedances and trend		Total *number of results* used for water-quality standard exceedances and trend		Number of streamflow measurements
				Total nitrogen	Total phosphorus	Total nitrogen	Total phosphorus	
ARCH	In	08/20/90	12/05/06	1	2	1	102	32
ARCH	Out	10/22/74	12/07/06	5	6	637	988	609
BLCA	In	12/13/94	02/05/07	2	2	127	148	143
BLCA	Out	--	--	--	--	0	0	0
BRCA	In	--	--	--	--	0	0	0
BRCA	Out	09/08/76	11/01/06	1	3	16	118	48
CANY	In	05/04/83	11/15/06	3	7	71	342	92
CANY	Out	01/24/74	12/07/06	5	10	238	608	316
CARE	In	03/24/77	06/18/03	1	1	21	74	34
CARE	Out	02/05/76	12/13/06	5	6	206	548	339
COLM	In	--	--	--	--	0	0	0
COLM	Out	02/16/72	09/24/02	2	2	280	607	271
CURE	In	06/18/82	02/07/07	8	10	240	495	425
CURE	Out	08/13/74	09/26/06	9	15	522	955	569
DINO	In	04/03/74	01/31/07	2	2	311	496	365
DINO	Out	02/23/72	08/15/06	4	6	552	604	513
FOBU	In	--	--	--	--	0	0	0
FOBU	Out	07/24/75	06/28/94	1	1	67	99	100
GOSP	In	--	--	--	--	0	0	0
GOSP	Out	05/31/79	06/15/93	1	1	19	30	21
HOVE	In	--	--	--	--	0	0	0
HOVE	Out	03/08/79	05/22/06	4	5	72	178	95
NABR	In	06/09/91	12/12/06	1	1	2	41	9
NABR	Out	--	--	--	--	0	0	0
TICA	In	--	--	--	--	0	0	0
TICA	Out	02/12/92	06/30/05	1	2	3	61	40
ZION	In	09/08/76	02/27/02	1	1	34	47	15
ZION	Out	04/19/79	12/13/06	8	10	302	1,010	658
Totals				65	93	3,721	7,551	4,694

Table 6. Summary of Northern Colorado Plateau Network water-quality sampling sites evaluated for water-quality standard exceedances or trends in total nitrogen and total phosphorus, 1972 through 2007.

[CO, Colorado; CR, creek; DD, decimal degrees; Max., maximum date for results (that is, most recent); Min., minimum date for results; no., number; R, river; STAID, station identifiers (original STAIDs shown below consolidated STAID used for study); UT, Utah; WY, Wyoming; WWTP, wastewater treatment plant; site names and STAIDS retained from original source database, except where consolidated; Ecoregion “mtn” represents “forested mountains (Ecoregion II)” and “xeric” represents “xeric west (Ecoregion III)”; date range is the possible range of data evaluated for trend analysis and(or) exceedances and may not reflect all historical data available for a site, actual time period used for trend analysis may be less than full range, and not all constituents have data for entire range; sites and results listed in gray text were screened for trend analysis but not analyzed for any trends because of insufficient data, large data gaps, too few seasons over period of record, or too many censored values. Other sites not grayed out below may have been analyzed for trend only for total nitrogen or total phosphorus (not necessarily both constituents). Site no. corresponds to figs. 2–12 (see park code subheaders for applicable figure); See table 1 for explanation of park codes. Sites 49 (with site 67) and 58 (with site 57) consolidated and removed after site-number assignments. Total number of censored values reflect total for entire date range not the percentage applicable to the trend analysis time periods]

Site no.	STAID (Original STAIDs for consolidated sites)	Water source	Site name	State	Eco-region	Lat-itude DD	Long-itude DD	Date range		Number of results (total number of censored results)	
								Min.	Max.	Total nitro-gen	Total phos-phorus
			BLCA (fig. 3)								
1	383537107471500	Red Rock CR	Red Rock Canyon at Mouth near Montrose	CO	xeric	38.594	-107.788	05/08/96	07/27/06	17 (0)	35 (0)
2	CURE_GR01 (09128000)	Gunnison R	Gunnison R below Gunnison Tunnel	CO	xeric	38.529	-107.649	12/13/94	02/05/07	110 (28)	113 (37)
			COLM (fig. 7)								
3	09152500	Gunnison R	Gunnison R near Grand Junction	CO	xeric	38.983	-108.451	02/16/72	09/24/02	181 (0)	270 (44)
4	COLO_3 (000050)	Colorado R	Colorado R at Loma	CO	xeric	39.175	-108.800	04/01/74	07/29/96	99 (23)	337 (48)
			CURE (fig. 3)								
5	000078	East R	East R at confluence with Taylor R	CO	mtn	38.664	-106.848	08/13/74	11/16/87	0	12 (0)
6	000151	Slate R	Slate R below Crested Butte	CO	mtn	38.681	-106.942	05/16/79	06/19/06	0	137 (8)
7	09112500	East R	East R at Almont	CO	mtn	38.664	-106.848	11/17/93	12/04/02	59 (17)	54 (27)
8	09114500	Gunnison R	Gunnison R near Gunnison	CO	mtn	38.542	-106.950	04/19/95	12/04/02	46 (18)	45 (19)
9	09119000	Tomichi CR	Tomichi CR at Gunnison	CO	mtn	38.522	-106.941	08/13/74	12/05/02	67 (18)	80 (12)
10	09125000	Curecanti CR	Curecanti CR near Sapinero	CO	mtn	38.488	-107.415	09/24/79	09/11/06	28 (4)	38 (0)
11	09126500	Cimarron R	Cimarron R at Cimarron	CO	xeric	38.441	-107.554	08/11/87	10/19/92	0	37 (0)
12	10203	Gunnison R	Gunnison R below Gunnison	CO	mtn	38.519	-106.984	01/23/01	05/24/06	0	35 (8)
13	381633107054700	Cebolla CR	Cebolla CR at Bridge southeast of Powderhorn	CO	mtn	38.276	-107.097	05/01/84	09/13/06	26 (3)	70 (0)
14	382418107242600	Blue CR	Blue CR at Highway 50 near Sapinero	CO	mtn	38.405	-107.408	11/06/96	09/25/06	41 (3)	42 (0)
15	382632107332501	Squaw CR	Squaw CR at mouth, at Cimarron	CO	xeric	38.442	-107.558	08/11/87	10/19/92	0	36 (0)
16	3828581070657	North Willow CR	Lower North Willow CR	CO	xeric	38.483	-107.116	06/10/82	06/15/92	0	28 (0)
17	382937107033500	Steuben CR	Steuben CR near mouth near Gunnison	CO	mtn	38.494	-107.060	05/09/95	08/28/06	25 (0)	57 (0)
18	382943107015300	Beaver CR	Beaver CR at Highway 50 near Gunnison	CO	mtn	38.495	-107.032	06/01/99	08/28/06	26 (1)	38 (1)
19	383137107183600	Soap CR	Soap CR above Chance CR near Sapinero	CO	mtn	38.527	-107.311	05/25/99	09/05/06	27 (1)	37 (3)
20	CIMM_1 (09127000, CURE CM10)	Cimarron R	Cimarron R below Squaw CR, near Cimarron	CO	xeric	38.446	-107.556	06/05/89	02/07/07	41 (0)	105 (0)
21	CURE_CM12	Cimarron R	Cimarron CR above Benny’s	CO	xeric	38.437	-107.548	10/08/87	10/19/92	0	35 (0)
22	CURE_NW11	North Willow CR	Upper North Willow CR	CO	xeric	38.485	-107.120	08/19/87	10/19/92	38 (0)	37 (0)

Table 6. Summary of Northern Colorado Plateau Network water-quality sampling sites evaluated for water-quality standard exceedances or trends in total nitrogen and total phosphorus, 1972 through 2007.—Continued

[CO, Colorado; CR, creek; DD, decimal degrees; Max., maximum date for results (that is, most recent); Min., minimum date for results; no., number; R, river; STAID, station identifiers (original STAIDs shown below consolidated STAID used for study); UT, Utah; WY, Wyoming; WWTP, wastewater treatment plant; site names and STAIDS retained from original source database, except where consolidated; Ecoregion “mtn” represents “forested mountains (Ecoregion II)” and “xeric” represents “xeric west (Ecoregion III)”; date range is the possible range of data evaluated for trend analysis and(or) exceedances and may not reflect all historical data available for a site, actual time period used for trend analysis may be less than full range, and not all constituents have data for entire range; sites and results listed in gray text were screened for trend analysis but not analyzed for any trends because of insufficient data, large data gaps, too few seasons over period of record, or too many censored values. Other sites not grayed out below may have been analyzed for trend only for total nitrogen or total phosphorus (not necessarily both constituents). Site no. corresponds to figs. 2–12 (see park code subheaders for applicable figure); See table 1 for explanation of park codes. Sites 49 (with site 67) and 58 (with site 57) consolidated and removed after site-number assignments. Total number of censored values reflect total for entire date range not the percentage applicable to the trend analysis time periods]

Site no.	STAID (Original STAIDs for consolidated sites)	Water source	Site name	State	Eco-region	Lat-itude DD	Long-itude DD	Date range		Number of results (total number of censored results)	
								Min.	Max.	Total nitro-gen	Total phos-phorus
				CURE (fig. 3)							
23	EELK_1 (382900107101600)	East Elk CR	East Elk CR near mouth near Sapinero	CO	mtn	38.483	-107.172	05/26/99	08/29/06	26 (1)	37 (0)
24	GUNN_1 (000057, 383103106594200, CURE_GR07)	Gunnison R	Gunnison R at County Road 32 below Gunnison	CO	mtn	38.517	-106.996	08/13/74	09/20/06	166 (76)	230 (62)
25	LFKG_1 (381934107133500, CURE_LF01)	Lake Fork Gunnison	Lake Fork Gunnison R below Gateview	CO	mtn	38.326	-107.227	09/28/74	09/26/06	53 (4)	87 (0)
26	PINE_1 (382702107203900)	Pine CR	Pine CR at Highway 50 near Sapinero	CO	mtn	38.451	-107.345	06/02/99	02/07/07	43 (0)	45 (0)
27	RED_1 (382902107140400)	Red CR	Red CR near mouth near Sapinero	CO	mtn	38.484	-107.235	05/26/99	08/29/06	26 (0)	37 (0)
28	TAYL_1 (09110000)	Taylor R	Taylor R at Almont	CO	mtn	38.664	-106.845	11/17/93	08/29/00	36 (18)	24 (14)
29	WELK_1 (383028107162200, CURE_WEC1)	West Elk CR	West Elk CR below Forest Boundary near Sapinero	CO	mtn	38.508	-107.273	06/18/82	09/11/06	26 (4)	67 (0)
				DINO (fig. 8)							
30	09234500	Green R	Green R near Greendale	UT	mtn	40.908	-109.423	05/23/72	04/25/01	241 (0)	206 (116)
31	09247600	Yampa R	Yampa R below Craig	CO	xeric	40.481	-107.614	06/26/75	10/30/02	103 (0)	94 (12)
32	4937020	Green R	Green R near Ouray at Highway U88 Crossing	UT	xeric	40.085	-109.676	03/06/97	06/21/06	0	45 (7)
33	493810	Green R	Green R at Browns Park-Bureau Reclamation Gaging Station	UT	xeric	40.866	-109.143	10/27/76	10/01/96	82 (0)	108 (27)
34	5937880	Pot CR	Pot CR above Matt Warner Reservoir	UT	xeric	40.769	-109.319	07/15/98	08/15/06	0	19 (2)
35	GREEN_1 (09261000, 4937900)	Green R	Green R near Jensen	UT	xeric	40.409	-109.235	10/26/76	11/07/06	190 (0)	329 (35)
36	YAMP_1 (09260050, 000040)	Yampa R	Yampa R at Deerlodge Park	CO	xeric	40.451	-108.523	04/03/74	01/31/07	121 (42)	167 (37)
37	YAMP_2 (09251000)	Yampa R	Yampa R near Maybell	CO	xeric	40.503	-108.030	02/23/72	09/04/02	126 (3)	132 (30)
				FOBU (fig. 9)							
38	10027000	Twin CR	Twin CR at Sage	WY	xeric	41.810	-110.971	07/24/75	06/28/94	67 (0)	99 (32)
				GOSP (fig. 10)							
39	413808112264000	Blue CR	Blue Spring CR at Promintory Road near Howell	UT	xeric	41.635	-112.445	05/31/79	06/15/93	19 (0)	30 (0)

Table 6. Summary of Northern Colorado Plateau Network water-quality sampling sites evaluated for water-quality standard exceedances or trends in total nitrogen and total phosphorus, 1972 through 2007.—Continued

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Site no.	STAID (Original STAIDs for consolidated sites)	Water source	Site name	State	Eco-region	Lat-itude DD	Long-itude DD	Date range Min.	Date range Max.	Number of results (total number of censored results) Total nitro-gen	Number of results (total number of censored results) Total phos-phorus
			TICA (fig. 12)								
40	4025541114500	American Fork R	American Fork R at Mouth of Canyon	UT	mtn	40.432	-111.750	02/12/92	06/23/00	3 (0)	46 (26)
41	5912840	North Fork American Fork R	North Fork American Fork CR above Tibble Fork Reservoir	UT	mtn	40.484	-111.640	06/30/99	06/30/05	0	15 (10)
			ARCH (fig. 2 sites 42–44, 46–50; fig. 5 site 45)								
42	09183000	Courthouse Wash	Courthouse Wash near Moab	UT	xeric	38.613	-109.580	08/29/90	12/05/06	0	58 (31)
43	3844141093109	Salt Wash	Salt Wash at Wolfe Ranch Road crossing	UT	xeric	38.737	-109.519	08/20/90	12/04/06	1 (0)	44 (22)
44	495639	Mill CR	Mill CR at Highway US191 crossing	UT	xeric	38.571	-109.550	07/24/95	06/29/00	0	16 (5)
45	595853	Mill CR	Mill CR above Kens Lake	UT	xeric	38.479	-109.423	05/29/89	08/14/01	1 (0)	12 (0)
46	COLO_1 (09180500, 495849, 4958490)	Colorado R	Colorado R near Cisco	UT	xeric	38.811	-109.293	10/22/74	12/07/06	379 (0)	502 (45)
47	COLO_2 (495700, 4957000)	Colorado R	Colorado R at Highway US191 Crossing near Moab	UT	xeric	38.604	-109.574	08/05/76	05/10/06	112 (0)	163 (11)
48	DOLO_1 (495860, 4958600)	Dolores R	Dolores R at Mouth	UT	xeric	38.812	-109.272	06/20/77	06/19/03	107 (0)	191 (21)
50	MOAB_1 (495655, 4956550)	Moab WWTP	Moab wastewater treatment plant	UT	xeric	38.578	-109.580	01/12/77	11/02/06	38 (0)	104 (0)
			CANY (fig. 5 sites 51–62, 64, 65, 67, and 68; fig. 2 sites 63 and 66)								
51	3811241095321	Green R	Green R above confluence with Colorado R	UT	xeric	38.190	-109.889	05/04/83	09/26/06	24 (0)	94 (1)
52	3811331095302	Colorado R	Colorado R above confluence with Green R	UT	xeric	38.193	-109.884	05/04/83	09/26/06	24 (0)	96 (1)
53	3831361095933	Green R	Green R at Mineral Bottoms	UT	xeric	38.527	-109.993	06/14/77	08/10/06	28 (0)	78 (2)
54	495238	Colorado R	Colorado R below Big Drop #3 Rapids	UT	xeric	38.071	-110.046	07/12/90	09/27/06	1 (0)	44 (1)
55	495242	Colorado R	Colorado R at Lathrop Canyon	UT	xeric	38.369	-109.774	06/15/83	08/06/98	23 (0)	48 (0)
56	495566	Colorado R	Colorado R at Indian CR	UT	xeric	38.296	-109.788	04/16/91	05/09/97	0	23 (0)
57	COTTON_1 (495581, 4955810)	North Cottonwood CR	North Cottonwood CR at Beef Basin Road crossing	UT	xeric	38.028	-109.589	08/02/77	09/11/06	6 (0)	56 (17)

Table 6. Summary of Northern Colorado Plateau Network water-quality sampling sites evaluated for water-quality standard exceedances or trends in total nitrogen and total phosphorus, 1972 through 2007.—Continued

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Site no.	STAID (Original STAIDs for consolidated sites)	Water source	Site name	State	Eco-region	Lat-itude DD	Long-itude DD	Date range		Number of results (total number of censored results)	
								Min.	Max.	Total nitro-gen	Total phos-phorus
			CANY (fig. 5 sites 51–62, 64, 65, 67, and 68; fig. 2 sites 63 and 66)								
59	495589	Indian CR	Indian CR below Exclosure near Newspaper Rock	UT	xeric	37.979	-109.518	07/06/93	06/14/00	0	12 (4)
60	495590	Indian CR	Indian CR above Exclosure near Newspaper Rock	UT	xeric	37.969	-109.518	07/06/93	06/14/00	0	12 (4)
61	495625	Colorado R	Colorado R 1/4 mile below confluence with Moab Salt Company Canyon #3	UT	xeric	38.461	-109.671	07/18/91	08/06/98	0	17 (0)
62	495629	Colorado R	Colorado R at Potash Boat Ramp	UT	xeric	38.467	-109.666	04/15/91	09/26/06	0	58 (0)
63	4956390	Mill CR	Mill Cr at Highway U191 Crossing	UT	xeric	38.571	-109.551	05/05/97	06/19/03	0	25 (10)
64	599512	Little Spring Canyon	Little Spring Canyon CR (LS2)	UT	xeric	38.201	-109.801	10/04/93	06/22/06	0	38 (29)
65	599515	Salt CR	Salt CR near Crescent Arch (SC-10)	UT	xeric	38.085	-109.766	06/14/95	11/15/06	0	33 (25)
66	GREEN_2 (09315000, 4931410)	Green R	Green R at Green R	UT	xeric	38.986	-110.151	01/24/74	12/07/06	202 (0)	277 (14)
67	KANE_1 (495595, 4955950)	Kane CR	Kane Canyon CR at Mouth	UT	xeric	38.532	-109.601	04/29/81	06/05/03	1 (0)	29 (6)
68	SALT_1 (599514)	Salt CR	Salt CR on Old Bates Wilson Road (SC-9)	UT	xeric	38.065	-109.772	06/14/95	02/11/02	0	10 (2)
			HOVE (fig. 11)								
69	495356	Montezuma CR	Montezuma CR at Highway US163 crossing	UT	xeric	37.272	-109.328	02/22/89	06/02/98	3 (0)	13 (0)
70	495360	Montezuma CR	Montezuma CR at Highway US262 crossing	UT	xeric	37.308	-109.293	03/08/79	06/29/88	15 (0)	15 (2)
71	495388	McElmo CR	McElmo CR at Highway US262 crossing	UT	xeric	37.218	-109.189	07/02/85	06/23/98	37 (0)	61 (5)
72	495390	San Juan R	San Juan R ab Aneth	UT	xeric	37.213	-109.186	09/15/88	06/23/98	17 (0)	41 (2)
73	9871	McElmo CR	McElmo CR above Trail Canyon at gage	CO	xeric	37.328	-108.701	06/24/98	05/22/06	0	48 (2)
			NABR (fig. 11)								
74	3736001100148	White Canyon CR	Armstrong Canyon near Kachina Bridge	UT	xeric	37.600	-110.030	06/09/91	12/12/06	2 (0)	41 (21)
			BRCA (fig. 4)								
75	10183900	East Fork Sevier R	East Fork Sevier R near Rubys Inn	UT	mtn	37.576	-112.266	09/08/76	09/14/99	16 (2)	47 (14)

Table 6. Summary of Northern Colorado Plateau Network water-quality sampling sites evaluated for water-quality standard exceedances or trends in total nitrogen and total phosphorus, 1972 through 2007.—Continued

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Site no.	STAID (Original STAIDs for consolidated sites)	Water source	Site name	State	Eco-region	Lat-itude DD	Long-itude DD	Date range		Number of results (total number of censored results)	
								Min.	Max.	Total nitro-gen	Total phos-phorus
			BRCA (fig. 4)								
76	5994340	Sheep CR	Sheep CR at Skutumpah Road crossing	UT	xeric	37.496	-112.065	08/27/98	11/01/06	0	42 (32)
77	5994350	Willis CR	Willis CR at Skutumpah Road crossing	UT	xeric	37.482	-112.093	09/21/98	11/01/06	0	29 (20)
			CARE (fig. 6)								
78	3816121112229	Fremont R	Fremont R at Highway US12 near Grover	UT	xeric	38.270	-111.375	10/22/86	12/13/06	14 (0)	51 (3)
79	383107111340301	Fremont R	Fremont R at inflow to Mill Meadow Reservoir	UT	mtn	38.519	-111.568	03/24/77	09/11/01	1 (0)	59 (1)
80	495433	Fremont R	Fremont R at Old Highway US24 crossing	UT	xeric	38.391	-110.697	11/17/76	06/05/02	98 (0)	180 (7)
81	495437	Fremont R	Fremont R near Teasdale at Highway US24 crossing	UT	xeric	38.303	-111.450	01/27/81	06/21/89	13 (0)	13 (2)
82	4954540	Pleasant CR	Pleasant CR ab div 1/4 mi ab U12	UT	mtn	38.103	-111.342	11/18/97	06/30/04	0	22 (1)
83	FREM_1 (495436, 4954360)	Fremont R	Fremont R at Hickman Bridge Trailhead	UT	xeric	38.289	-111.234	03/24/77	06/18/03	21 (0)	74 (3)
84	FREM_2 (09330000, 4954380)	Fremont R	Fremont R near Bicknell	UT	mtn	38.307	-111.519	02/05/76	12/13/06	80 (0)	223 (8)
			ZION (fig. 4)								
85	370947113003801	E Fork Virgin R	East Fork Virgin R above confluence	UT	mtn	37.163	-113.011	07/26/82	12/13/06	57 (0)	173 (28)
86	3726441130237	Kolob CR	Kolob CR above Kolob Reservoir	UT	mtn	37.446	-113.044	05/22/79	08/15/01	4 (0)	12 (0)
87	4951650	E Fork Virgin R	Eask Fork Virgin R above confluence with Stout CR	UT	xeric	37.377	-112.591	08/15/01	11/28/06	0	65 (51)
88	495183	Kanab CR	Kanab CR at Falls Crossing east of Glendale	UT	xeric	37.291	-112.659	06/17/80	04/26/02	3 (0)	41 (7)
89	EFVIR_1 (495160, 4951600)	E Fk Virgin R	East Fork Virgin R North of Glendale at Highway US89 crossing	UT	xeric	37.334	-112.601	01/29/86	11/28/06	38 (3)	136 (72)
90	EFVIR_2 (371247112410801, 4951550)	E Fk Virgin R	East Fork Virgin R at Mount Caramel Junction	UT	xeric	37.213	-112.686	04/19/79	11/28/06	14 (0)	132 (44)
91	LAVER_1 (3713221131641, 4950770)	Laverkin CR	La Verkin CR at Highway 17 Bridge	UT	xeric	37.223	-113.278	06/17/80	12/13/06	62 (0)	114 (16)

Table 6. Summary of Northern Colorado Plateau Network water-quality sampling sites evaluated for water-quality standard exceedances or trends in total nitrogen and total phosphorus, 1972 through 2007.—Continued

[CO, Colorado; CR, creek; DD, decimal degrees; Max., maximum date for results (that is, most recent); Min., minimum date for results; no., number; R, river; STAID, station identifiers (original STAIDs shown below consolidated STAID used for study); UT, Utah; WY, Wyoming; WWTP, wastewater treatment plant; site names and STAIDS retained from original source database, except where consolidated; Ecoregion "mtn" represents "forested mountains (Ecoregion II)" and "xeric" represents "xeric west (Ecoregion III)"; date range is the possible range of data evaluated for trend analysis and(or) exceedances and may not reflect all historical data available for a site, actual time period used for trend analysis may be less than full range, and not all constituents have data for entire range; sites and results listed in gray text were screened for trend analysis but not analyzed for any trends because of insufficient data, large data gaps, too few seasons over period of record, or too many censored values. Other sites not grayed out below may have been analyzed for trend only for total nitrogen or total phosphorus (not necessarily both constituents). Site no. corresponds to figs. 2–12 (see park code subheaders for applicable figure); See table 1 for explanation of park codes. Sites 49 (with site 67) and 58 (with site 57) consolidated and removed after site-number assignments. Total number of censored values reflect total for entire date range not the percentage applicable to the trend analysis time periods]

Site no.	STAID (Original STAIDs for consolidated sites)	Water source	Site name	State	Eco-region	Lat-itude DD	Long-itude DD	Date range		Number of results (total number of censored results)	
								Min.	Max.	Total nitro-gen	Total phos-phorus
			ZION (fig. 4)								
92	NFVIR_1 (370948113004401, 4950950)	North Fork Virgin R	North Fork Virgin R above confluence	UT	xeric	37.163	-113.013	04/19/79	12/13/06	66 (1)	186 (49)
93	NFVIR_2 (371705112565001)	North Fork Virgin R	North Fork Virgin R at Mouth of Narrows	UT	xeric	37.285	-112.948	09/08/76	02/27/02	34 (0)	47 (12)
94	NORTH_1 (495089, 4950890)	North CR	North Cr above confluence with Virgin R	UT	xeric	37.203	-113.174	04/03/96	12/13/06	0	35 (11)
95	VIRG_1 (495085)	Virgin R	Virgin R 1 mile east of Virgin	UT	xeric	37.199	-113.203	02/24/82	12/13/06	58 (0)	116 (4)

the same location, data were consolidated. Consolidation involved combining data under one site identifier (as documented in the "STAID" column in table 6) and removing any duplicate data. Thirty sites were consolidated prior to analysis by this study.

Sampling and preservation techniques and analytical methods varied from park to park and temporally as did data-collection objectives. Furthermore, sampling methodology, analytical methods, and quality assurance were not available for much of the historical data. These and related factors, including variable reporting limits, sample-collection methods, and analytical techniques, may affect data uncertainty and reduce confidence in the results from the exceedance and trend analysis. These factors were not explicitly evaluated for each site by this study.

Exceedance Analysis—Methods

Available TN and(or) TP concentrations from 93 sampling sites were evaluated for exceedance of State of Utah nutrient water-quality standards or of USEPA recommended nutrient criteria for aggregate Ecoregions II or III. The exceedance analysis used all the available data record for each sample site. Decision rules for analysis of exceedances and the methodology used for computing summary statistics for each site were determined prior to analysis, as described below.

Decision Rules for Exceedance Analysis

For the purpose of this report a water-quality exceedance was determined for sample results greater than the standard for the designated beneficial use or recommended criteria associated with the stream segment where the sample was collected (tables 2 [standards or criteria] and 3 [beneficial-use definitions]). Three outcomes were possible when comparing results to standards or criteria: exceed, not exceed, and indeterminate. The indeterminate outcome is when a censored value is greater than a standard or criteria and occurs most commonly for censored TP results compared to the relatively low TP standards. For this study, percentages of TN or TP concentrations exceeding a standard were calculated by considering the indeterminate evaluations as non-exceedance. This decision introduces a potential low bias and reduces the percent exceedance relative to the result count when indeterminate evaluations exist.

Summary Statistics for Data Used in Exceedance Analysis

Summary statistics, including minimum, maximum, and median values, were compiled using conventional methods for the TN and TP data from sites evaluated for exceedances with the following considerations. Median concentrations in the censored TN and TP datasets were calculated using robust methods suggested by Helsel (2005). The median concentration was determined using Kaplan-Meier (KM) when less than 50 percent of the data were censored or Maximum Likelihood Estimation (MLE) when 50 to 80 percent of the data were censored. The KM method computes descriptive statistics by flipping the survival-probability function of left-censored data; the median is the value on the survival curve exceeded by 50 percent of the results. The MLE method computes medians by assuming a distribution fits the shape of the observed data; descriptive statistics are computed on the basis of the detected value and proportions of data less than detection limits. Most of the medians computed for the NCPN were computed using KM; however, in a few instances, the median was computed by MLE. Statistics were computed using the "NADA" package (Lee and Helsel, 2007) in the R statistical computing software (R Development Core Team, 2010).

Temporal Trend Analysis—Methods

Tests for monotonic (unidirectional) temporal trends in ambient TN or TP concentrations and adjusted for seasonal and(or) streamflow effects were evaluated on a site-by-site basis using S-ESTREND (USGS ESTREND library version 4.0) in TIBCO Spotfire S+® 8.1 for Windows® (SPLUS®), which was created for use in USGS investigations of surface water-quality trends for multiple sites (Schertz and others, 1991). Within the S-ESTREND package, the nonparametric Seasonal Kendall test for uncensored data or the corresponding Seasonal Kendall test for censored data (recommended for those records with more than approximately 5 percent censoring) were used for the trend-analysis results in this study (Hirsch and others, 1982); criteria for these methods are summarized in table 7. Seasonality, censoring, and flow-adjustment were three important factors given careful consideration when evaluating NCPN TN and TP data for trends in ambient concentrations and FAC.

Interpreting trend in concentration requires caution when examining and reporting results. The concentrations of water-quality constituents are often correlated with streamflow though the relation may vary from constituent to constituent (Hirsch and others, 1982). In some cases, concentrations can exhibit multiple behaviors with streamflow; for example, TP concentrations in a stream could be diluted following a rain event from a point source such as a wastewater-treatment plant, but concentrations could conversely be increased as a result of runoff from the same rain event because phosphorus typically attaches to sediment or organic matter (Hirsch and others, 1991). Trends in ambient concentrations represent trends at a site from natural and human factors (Hirsch and others, 1991; Helsel and Hirsch, 1992; Sprague and others, 2006). Natural processes such as changes in surface runoff and streamflow may result in increases or decreases in nutrient concentrations reaching a stream (Sprague and others, 2006). Variations in precipitation can highly influence trends in concentration, and these trends can be reversed with a change in streamflow (Ravichandran, 2003; D.K. Mueller, U.S. Geological Survey, oral commun., May 2011). Human factors such as implementation of pollution-control strategies (for example, water-treatment improvements) are designed to reduce nutrients reaching streams, but their effects may be offset by changes in streamflow at some sites. The inclusion of all factors affecting concentration, including streamflow, allows trends affecting aquatic ecosystems and the status of the streams relative to water-quality standards to be evaluated for a site (Hirsch and others, 1991; Sprague and others, 2006; Sprague and Lorenz, 2009).

In contrast, analyzing for trends in FAC is principally of interest where it is desirable to remove variability in concentration caused by streamflow (which varies with precipitation). The exclusion of streamflow as a variable affecting concentration allows trends to be identified that reflect changes in the mobilization and transport of nutrients in the basin (rather than at the site) caused by factors other than streamflow (Schertz and others, 1991; Sprague and others, 2006; Sprague and Lorenz, 2009). These factors are typically anthropogenic and may include pollution-control strategies (for example, implementation of best-management practices to reduce nutrient runoff from cropland) or factors that may contribute to increased concentrations (for example, increased nutrients in wastewater discharge as a result of increasing population). However, Langland and others (2004) note that the results of flow adjustment do not represent all the changes in water quality that can result from human factors including management actions – only those separate from flow. For example, a change in urban-runoff practices that reduces surface runoff but increases groundwater recharge would not be captured using flow adjustment.

A trend in water-quality concentrations is expected to be monotonic if it results from changes (typically anthropogenic) that take place in the basin over a period of years such as changing land use, water treatment, or agricultural practices. A trend in ambient concentrations is rarely monotonic (that is, showing a consistent upward or downward trend through time) over more than a few years and is highly dependent on differences in streamflow in the early and late years of the period of record (D.K. Mueller, U.S. Geological Survey, oral commun., May 2011). Furthermore, a trend in ambient concentrations does not indicate whether the trend is from an environmental change or if it is related to a change in streamflow (Hirsch and others, 1991; Helsel and Hirsch, 1992; Sprague and others, 2006). Examples of challenges in interpreting trends in ambient concentrations and FAC are discussed in Sprague and Lorenz (2009). Where data were sufficient, trends in ambient concentrations and FAC were evaluated for the NCPN TN and TP data.

The log-log-loess model in S-ESTREND—a local regression relation developed using a loess smooth fit of the log of concentration and log of flow—was used to evaluate trends in FAC using the Seasonal Kendall test (Schertz and others, 1991). The loess procedure involves fitting a regression using distance and residual weighting functions with weighted

Table 7. Summary of criteria for the use of the Seasonal Kendall test for uncensored data and the Seasonal Kendall test for censored data for analysis of trend in stream water-quality data in S-ESTREND.

[Text modified from Schertz and others (1991); test methods from Hirsch and others (1982)]

Data criteria or recommendations	Seasonal Kendall test for uncensored data	Seasonal Kendall test for censored data
Censoring limits	Less than approximately 5 percent censoring	Greater than approximately 5 percent censoring
	Single censoring threshold[1]	Multiple censoring values accepted [2]
Flow-adjustment	Available[3]	Not available
Minimum data criteria	Minimum 5-year record determined by the difference in years between the beginning and ending observations	Same as for uncensored, but at least 10 uncensored observations required
	Minimum number of 10 observations and observations exceed at least 3 times the number of designated annual seasons	
User-defined options	Period of record	Same as for uncensored
	Minimum percentage of the total possible number of seasonal water-quality values in the beginning and ending fifths of the record (default is 50 percent)	
Estimator	Sen slope estimate[4]	Turnbull slope estimate[5]
S-ESTREND output	Trend results for raw and flow-adjusted data	Trend results for raw data only
	p-value uncorrected and corrected for seasonal correlation	p-value uncorrected and corrected for seasonal correlation
	Sen slope estimate (units per year)[4]	Turnbull slope estimate (units per year)
	Median concentration	Median concentration
	Subseries plots	Subseries plots

[1] Recommendation for single-censoring threshold is not enforced by the S-ESTREND software (that is, the program does not distinguish multiple levels of censoring). For this test, all data are used as reported values, no conversion from zero (0) values or censored values is made.

[2] For multiply censored records, the Seasonal Kendall test for censored data evaluates the data as reported values, no conversion from zero (0) values or censored values is made; all values detected and nondetected that are less than the specific reporting limit are recorded to zero and considered tied.

[3] For this analysis, all flow adjustments were described using a log-log loess regression model.

[4] Sen slope estimate from Sen (1968).

[5] Turnbull slope estimate described in Klein and Moeschberger (2003).

least squares to minimize the influence of outliers in fitting a smooth line to the data (Schertz and others, 1991). For this study, one-half of the observations for each site and each constituent were selected for the regression (f-value or smoothing factor of 0.5). An f-value of 0.5 provides a reasonably good fit to the data without over-smoothing or producing abrupt local changes for many water-quality constituents, including nutrients (Lanfear and Alexander, 1990). Residual plots, r-square values, and p-values were evaluated from the model output for each site and constituent to confirm that the selected model represented a reasonably good fit for the data. Evaluation of trends in FAC for sites with a large percentage of censoring (greater than approximately 5 percent) was generally not completed, because the variability caused by streamflow cannot be reliably removed from the water-quality records (Schertz and others, 1991); exceptions to this "5-percent rule" are detailed in the "Selection of Data for Trend Analysis" section of this report.

Seasonal variations in precipitation volume and intensity, temperatures, and evapotranspiration rates can be a major source of variation in constituent concentrations in surface water (Helsel and Hirsch, 1992). Although some of the variation in water quality may be explained by seasonal variation in streamflow, seasonality often remains even after streamflow is considered (Hirsch and others, 1982). Seasonal variation can be accounted for (that is, "removed") in order to better discern the trends in concentrations over time. If seasonality is not considered, little power may be available to detect trends that may actually be present (Helsel and Hirsch, 1992). Seasonal Kendall tests were used by this study to account for seasonality and to evaluate and define the number of annual seasons (for example, 12 seasons or monthly) for a given site and constituent. These tests limit the possible comparisons to water-quality values collected during the same seasonal period of each year to account for the seasonal effect. Large variations in data density resulting from changes in sampling frequency and data-collection objectives are typical of water-quality records in the NCPN dataset. For this study, NCPN nutrient data were evaluated for trends using 3, 4, 6, or 12 seasons by water year (October 1 through September 30). For example, a site evaluated for 6 seasons indicates sufficient samples were collected approximately bimonthly starting in October. Analysis of trends for sites with data sufficient for only 1 or 2 seasons were not included in this study because the samples were collected too infrequently over too long a period of time to be considered representative of discernible temporal trends. For S-ESTREND, if multiple samples are available within a single season, a single value nearest the midpoint is selected for use in the test (Schertz and others, 1991). For example, for a 6-season, 20-year record, a maximum of 120 samples can be used in the analysis, regardless of how many values are available. To compensate for this variation, the number of seasons used in the Seasonal Kendall tests was selected to reflect the water year(s) with generally the lowest sampling frequency available to prevent bias towards water years with denser data collection. In some cases, where the data record was sufficient, the starting and(or) ending water years were limited to maximize the number of seasons available for analysis.

Water-quality records can have multiple reporting limits when analytical methods are improved or changed or when different agencies sampling the same location use different analytical laboratories. The Seasonal Kendall test for censored data used by this study allows for analysis of multiply censored data. The use of this test was restricted for the NCPN dataset to sites with less than approximately 50-percent censoring. For this study, water-quality records for sites with severe censoring (greater than 57 percent in the NCPN dataset) were not evaluated for trends because the Seasonal Kendall test has little power to detect differences in central tendencies under these conditions (Helsel and Hirsch, 1992).

This study limited comparison of trend-test results between sites to sites with the same period of record because "[t]he frequent problem of multiple starting dates, ending dates, and gaps in a group of records presents a significant practical problem in trend analysis studies," (U.S. Geological Survey, 1991, p. 9). Trend results between sites with different periods of record, different seasonal definitions, or trends in ambient concentrations as compared to trends in FAC may not be directly comparable. Detection and interpretation of a trend must be considered within the context of the dataset and the limits of the test used. A temporal trend can be detected as a result of changes in sampling frequency (for example, routine sampling changed to storm sampling) or events that temporarily change the water quality over multiple samples. For example, a temporal trend in concentrations detected as a result of high flow at the beginning of the period of record and low flow at the end of the record (or vice versa) may be an artifact of the selected period of record; however, the detection of a trend (or not) could be different if alternative temporal end points were selected for analysis. Similarly, a trend that is (or is not) detected over one period of record for a given site may (or may not) be identified in an equivalent trend analysis (that is, using the same methodology) of a longer or shorter period of record. Additionally, a trend can result from changes in sampling methodology and(or) analytical method. For example, the USGS NWQL changed phosphorus methods in May 1990 and again in October 1991 because of an identified bias in the historic phosphorus method (U.S. Geological Survey, 1992b). Changes in reporting limits can cause changes in constituent concentrations. For example, reporting limits that decrease over time allow for reporting of concentrations at lower levels than previously reported. For these reasons, it is desirable to evaluate results from trend analysis for a given station, constituent, and time period within the context of other factors, including sampling history, analytical methods, reporting limits, and known landscape-scale events. For this study, which used water-quality data compiled from multiple source agencies over a large geographic region, historical information on these factors was often unrecorded or incomplete. Therefore, the cause of a detected trend may not be discernable and could be a result of gradual environmental change or other factors (for example, multiple sampling and(or) analytical techniques used at the same site).

Selection of Data for Trend Analysis

A total of 93 water-quality sampling sites on surface water flowing in, through, and out of park units was screened for trend analysis following data re-censoring, aggregation, and site selection (table 6). These 93 sites were screened according to S-ESTREND 'data-density' criteria imposed on the input data to prevent analysis of datasets with insufficient records (see 'minimum data criteria' and 'user defined options' in table 7). For this study, the minimum data-density criteria were a minimum 5-year record, a minimum number of 10 observations and a number of observations that must exceed at least three times the number of designated annual seasons, and a minimum percentage (the default of 50 percent was used by this study) of total possible number of seasonal values in the beginning and ending fifths of the record (Schertz and others, 1991). Additionally, as detailed in the previous section, sites with data sufficient for only 1- or 2-season trend analysis were excluded. Of the 93 sites screened, 52 sites (34 sites for TN and 51 sites for TP) were evaluated for trends in ambient concentrations for one or more time periods. A summary of the water-quality sites and data evaluated for trends is presented in table 6 (sites in gray text were excluded from the trend analysis as a result of not meeting one or more data-density criterion). A subset of these sites (22 sites for TN and 27 sites for TP) had corresponding instantaneous streamflow or mean daily streamflow measurements allowing for analysis of trends in FAC for one or more time periods. Data from some sites had too few corresponding streamflow measurements (that is, fewer measurements than the S-ESTREND program requires to meet the minimal data requirements described in table 7 and detailed later in this section) to be evaluated for trends in FAC.

Sampling periods of record and sampling frequency for TN and TP were highly variable between water-quality sampling sites. Data-density plots for the sites with available TN or TP concentrations (figs. 13 and 15) and sites with TN or TP concentrations with 10 or more corresponding streamflow measurements (figs. 14 and 16) were used to identify sites with common periods of record. The frequent lack of corresponding streamflow measurements for many of the water-quality samples and the large numbers of censored concentrations limited the number of sites analyzed for temporal trends by this study.

Differences between historical approaches to water-quality sampling and analysis limited the ability to collectively analyze and compare the results for park- and NCPN-wide trends. From the data-density plots, two groups of sites with similar periods of record were selected for analysis of trends in ambient TN and TP concentrations and FAC (for sites with a sufficient streamflow record). Within these two groups, results from individual sites were able to be compared. One group was selected to evaluate long-term historical (water years 1977 through 1998) trends, and the other group was selected to evaluate recent short-term (water years 2001 through 2006) trends. These groups were selected to maximize the available data for sites with similar sampling periods to allow for comparison between sites. The historical and recent site groups included 6 sites (4 for TN and 5 for TP) and 15 sites (7 for TN and 15 for TP), respectively, and collectively represented 7 of the NCPN park units (BLCA, COLM, CURE, DINO, ARCH, CANY, and CARE). Alternative grouping of sites with similar time periods, from sites in the same park unit, or from sites on the same water source (for example, samples collected from the Colorado River) also were considered during the initial data-evaluation process, and it was determined that these characteristics were too inconsistent to be used by this study.

The trend comparisons between data from sites in the historical and recent site groups excluded many sites because of differences in sampling period. Therefore, trends in ambient TN and(or) TP concentrations also were analyzed for various time periods at 43 of the 52 sites -- 30 sites for TN and 42 sites for TP -- that passed the S-ESTREND data screening. This total excludes CURE sites 10, 13, 14, 18, 19, 20, 23, 26, and 27 (fig. 3; table 6), which only were analyzed as part of the recent, short-term group because there was insufficient data to evaluate these nine sites for any alternative time periods. Time periods for these 43 sites were defined to optimize the amount of data analyzed for trends at each site. Although an effort was made to maximize the time period used for each site, sparsely sampled "tails" and(or) isolated sampling periods may not have been included in the final time period identified for the trend analysis. "Tails" are a few samples generally seen at the beginning and sometimes the end of a sampling period that are not typically characteristic of the sampling frequency during the primary data-collection period (Schertz and others, 1991). Of these 43 sites with variable periods of record, sites with greater than approximately 15 percent censoring or sites lacking contemporaneous streamflow measurements were not evaluated for trends in FAC. For sites with censoring greater than approximately 5 percent but less than approximately 15 percent, trend test results were compared between the censored and uncensored Seasonal Kendall tests to verify similarity between results. This approach allowed these sites with moderate levels of censoring to be tested for trends in FAC (for sites with sufficient streamflow data), which is not possible for sites evaluated with the censored Seasonal Kendall test. For these sites, results were reported for the uncensored Seasonal Kendall tests for trends in ambient concentrations and FAC.

To allow for comparison of TN and TP trend results from the same site, the maximal time period applicable to both constituents was used for analyzing sites with variable periods of record; therefore, the constituent with the most limiting sampling record determined the time period used for analysis. However, when one constituent (typically TP) had a substantially longer record than the other constituent, an alternative time period for trend also was evaluated to maximize the available data for the constituent with the longer record. For example, data from CURE site 25 (table 6) were evaluated for trends in ambient TN and TP concentrations and FAC for a 5-year time period (2001 through 2006) and for trends in ambient TP concentrations and FAC for a 10-year time period (1995 through 2006). Of the 43 sites with variable time periods evaluated for trends, 17 also were analyzed for alternative time periods. A limited number of sites were analyzed for trends for only one constituent where insufficient or no data existed for the other constituent. Because the time periods are generally different between these sites, interpretation between sites is limited and in some cases not practical.

For all sites with a contemporaneous streamflow record, evaluation of the completeness and comparability of the streamflow record relative to the water-quality data record determined if analysis of FAC was practicable. For example, if the streamflow record represented approximately the same time period analyzed for TN or TP, even though it may have been collected less frequently than the nutrient water-quality samples, the site was a candidate for FAC as long as it also represented the full hydrologic range of conditions, including low, average, and high streamflow. For sites with streamflow records only collected for a limited part of the time period relative to the time period of TN or TP data (for example, first half or second half of the nutrient data record), analysis of FAC was not completed. For sites with a streamflow record not representative of the full range of hydrologic conditions typical of the site, analysis of FAC was not completed. For all evaluations of trends in TN and TP FAC, sites still had to meet the data-density criteria specified by S-ESTREND (table 7). Generally, sites with 80 percent or greater

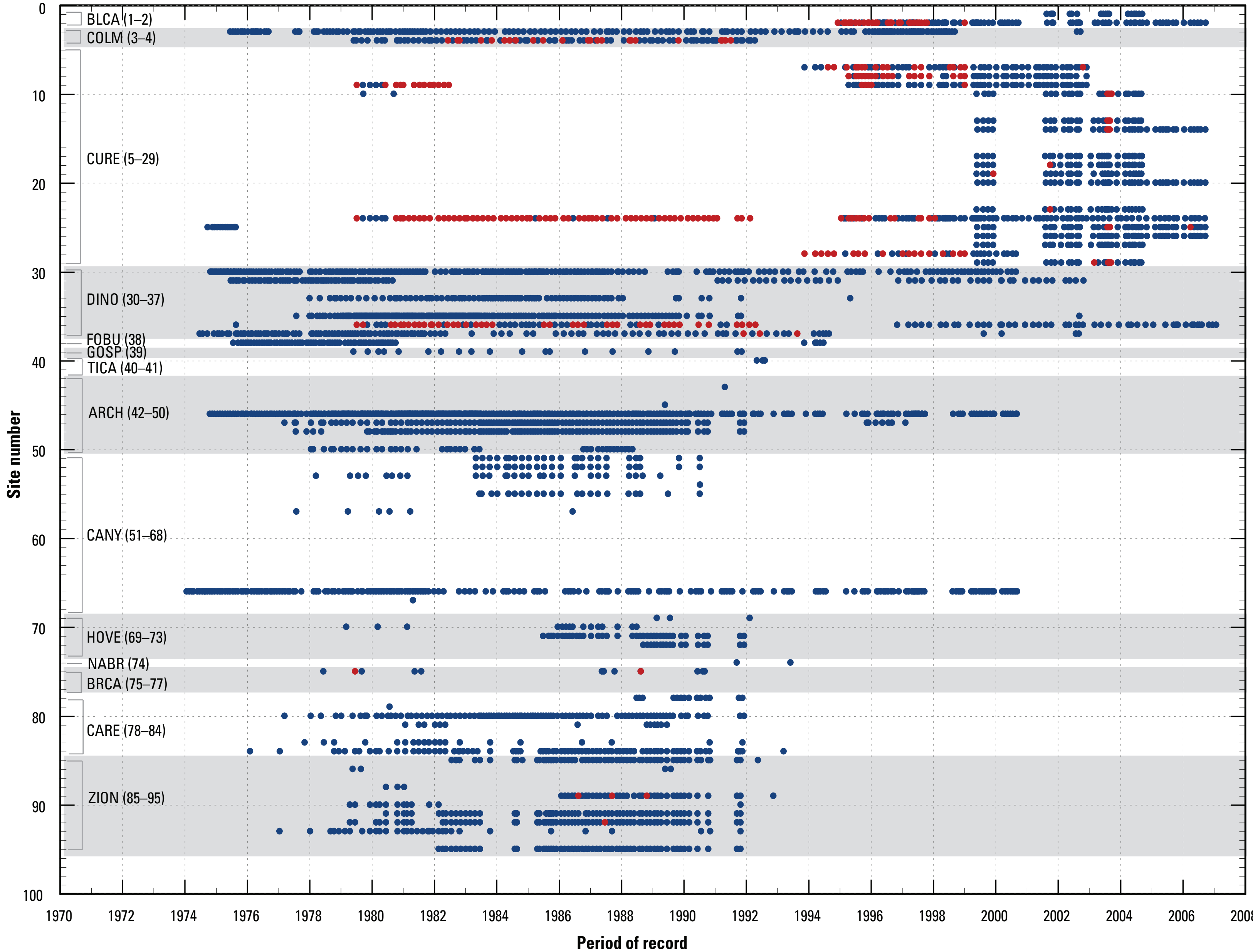

Figure 13. Sampling density and temporal frequency for water-quality sampling sites with total nitrogen data, Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–12. Numbers in parentheses following park code indicate range of site numbers for the park. Censored values shown in red.]

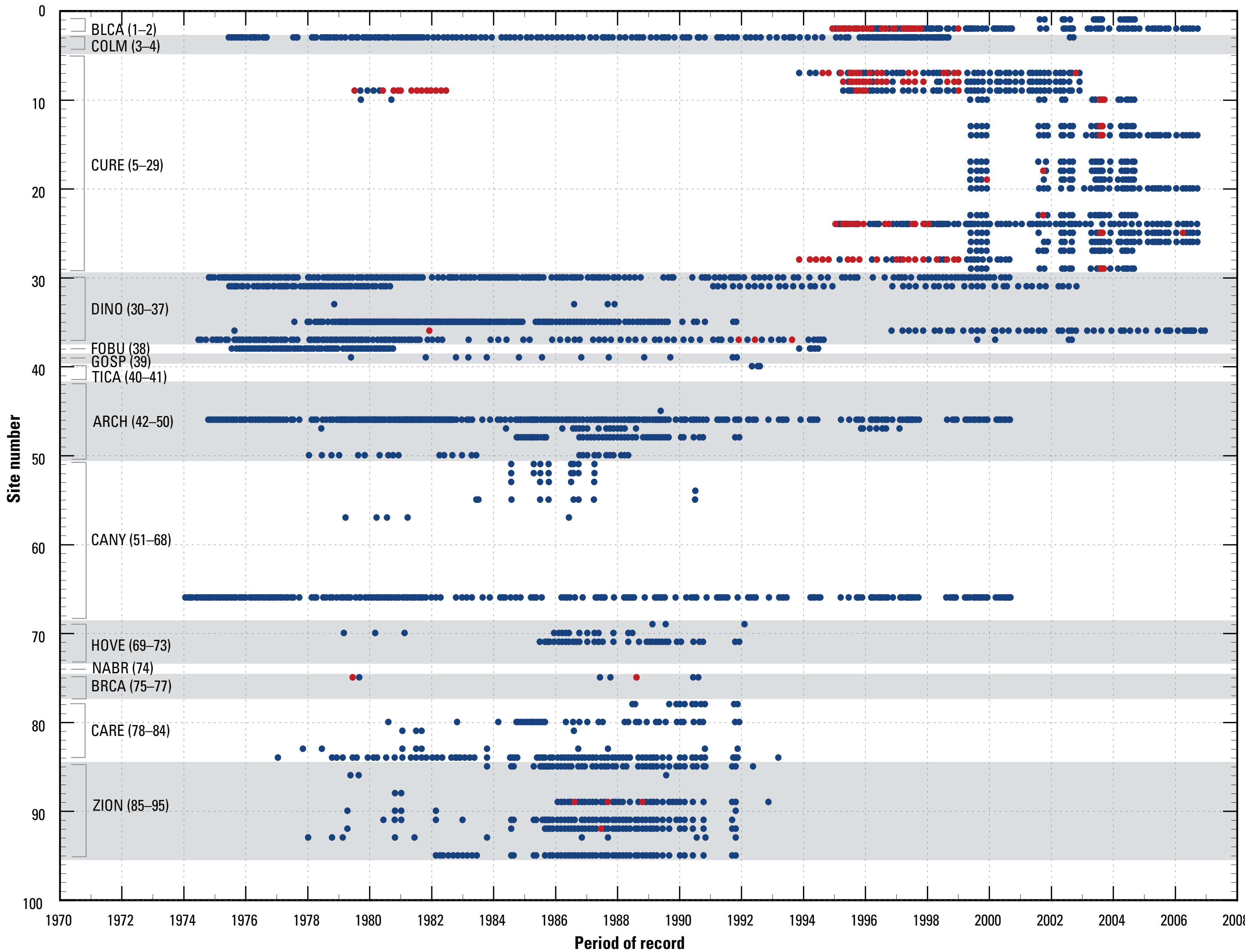

Figure 14. Sampling density and temporal frequency for water-quality sampling sites with total nitrogen data and 10 or more streamflow measurements, Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–12. Numbers in parentheses following park code indicate range of site numbers for the park. Censored values shown in red.]

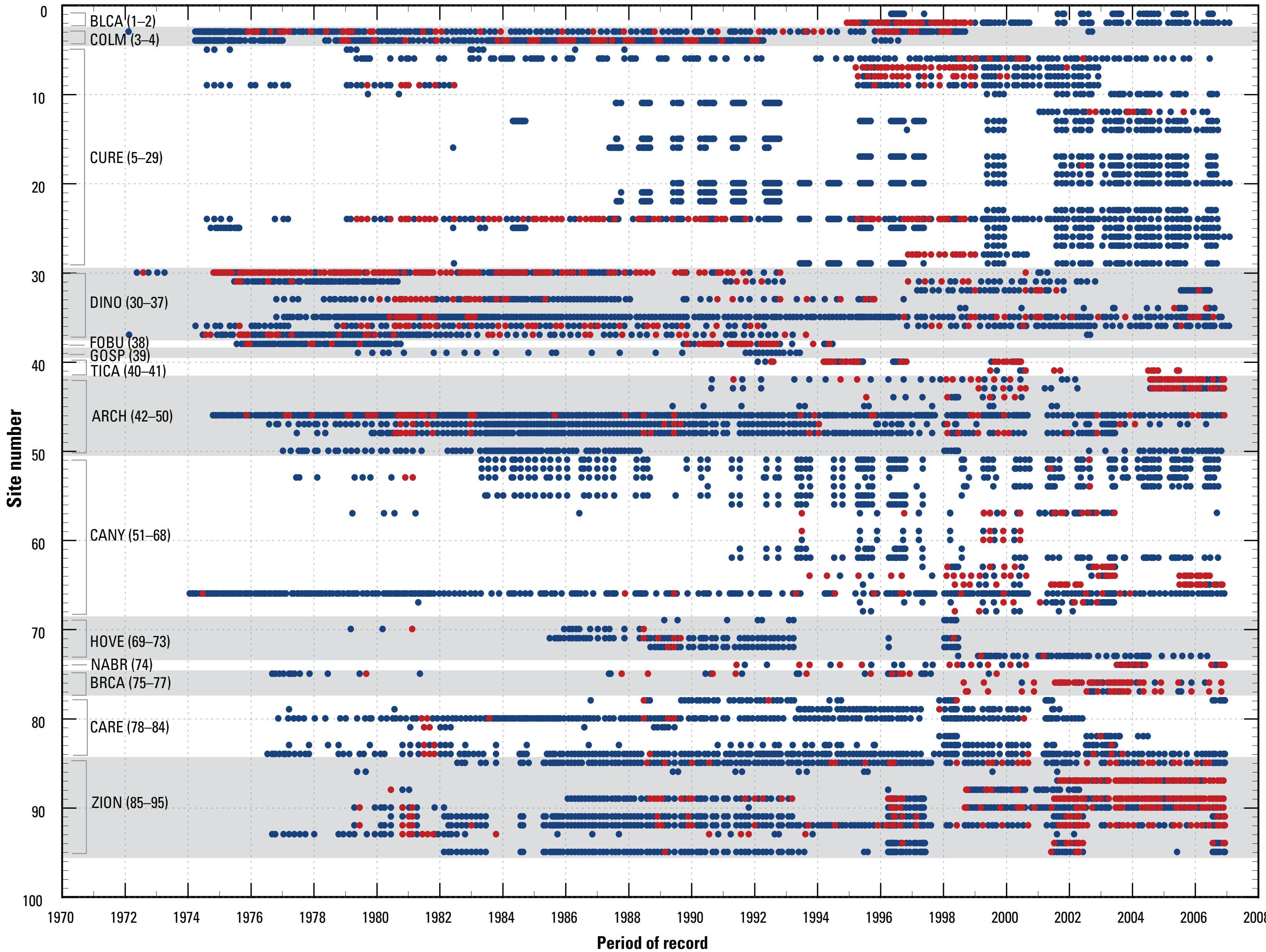

Figure 15. Sampling density and temporal frequency for water-quality sampling sites with total phosphorus data, Northern Colorado Plateau Network, for water years 1972 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–12. Numbers in parentheses following park code indicate range of site numbers for the park. Censored values shown in red.]

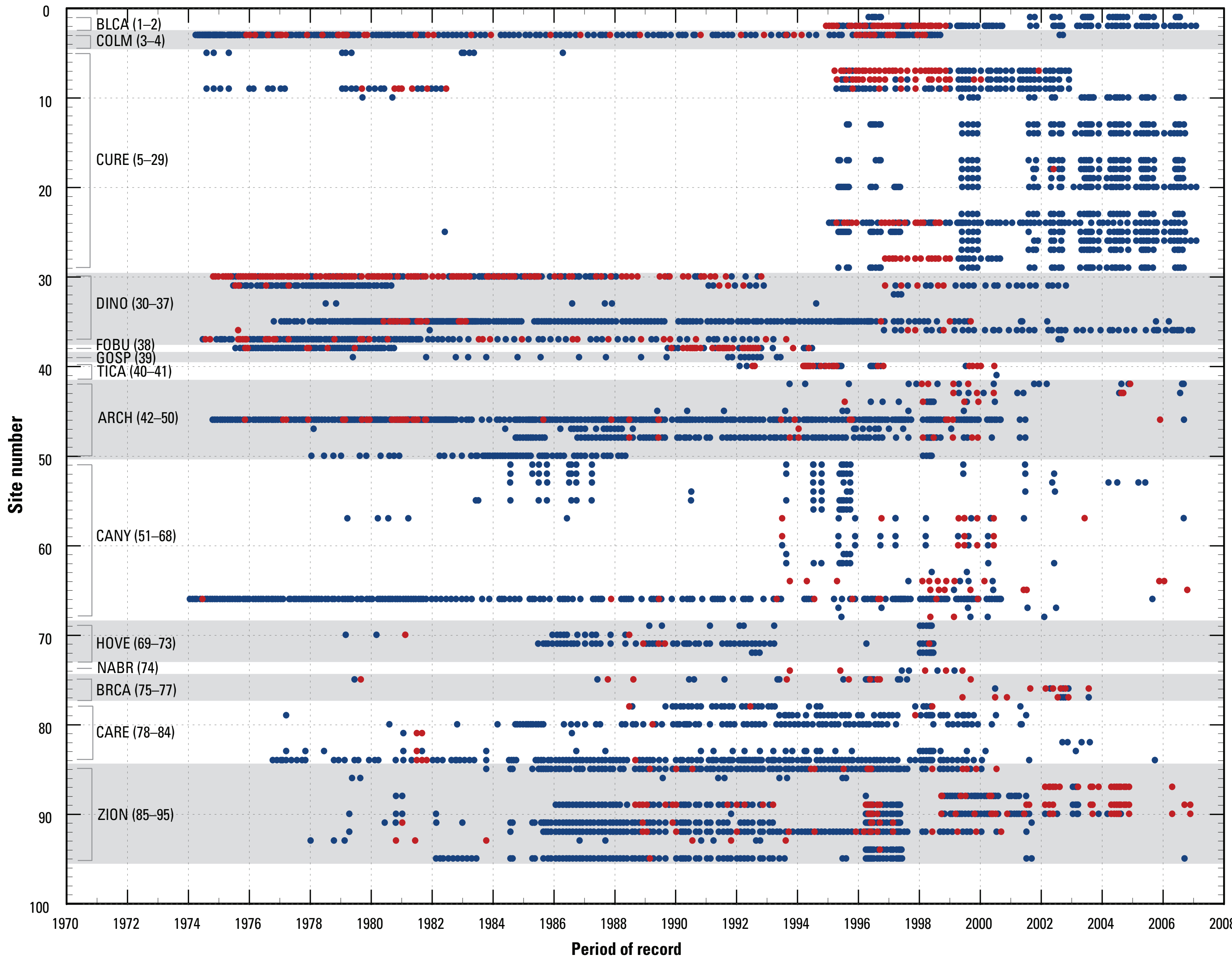

Figure 16. Sampling density and temporal frequency for water-quality sampling sites with total phosphorus data and 10 or more streamflow measurements, Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–12. Numbers in parentheses following park code indicate range of site numbers for the park. Censored values shown in red.]

streamflow measurements available relative to nutrient samples were evaluated for FAC; a few sites (CURE site 17, DINO site 36, ARCH site 50, CARE site 79, and ZION site 92; table 6) were evaluated for FAC with percentages of streamflow measurements between 57 and 80 percent of nutrient samples. Following evaluation of streamflow records, the sites evaluated for trends in TN and(or) TP FAC included 5 of the 7 historical, long-term trend sites (4 for TN and 3 for TP), all 15 of the recent, short-term trend sites (7 for TN and 15 for TP), and 23 of the 43 trend sites evaluated for variable periods of record (17 for TN and 18 for TP). Sites not evaluated for trends in FAC had greater than approximately 15 percent censoring and(or) insufficient contemporaneous streamflow measurements.

Assessment of Nutrient Water Quality

Exceedance and trend results evaluated in this report represent conditions for different periods of record and thus may not always represent basin conditions through time. This highlights the need to maintain long-term water-quality and streamflow sampling programs at key reference (typically in the headwaters of major basins to represent sites with limited human influences) and integrator (typically near the outlet of major basins at or near streamflow-gaging stations characterized by multiple land uses) sites throughout the network so that, in the future, statistically based comparison between upstream and downstream sites can be made. In some cases, observations in this report were based on data collected only in the 1970s and 1980s, which provided insight into historical conditions, but information on current conditions was unavailable. Future water-quality monitoring activities may benefit from sustained data-collection efforts with attention to site-specific issues and consideration of basin characteristics that affect source, transport, and fate of nutrients in aquatic systems.

Exceedance Analysis—Results and Discussion

The number of exceedances in the data record is based on an analysis of the entire time period of the available data record and is presented as a percentage of the results that exceed standards or criteria. Details on the applicable nutrient standards and criteria are provided in the “Nutrient Water-Quality Standards and Criteria in Northern Colorado Plateau Network Park Units” section of this report and in table 2. The numbers of results, percentage of indeterminate values and exceedances, descriptive statistics, and applicable standard or criterion for each site, by constituent, is listed in table 8. Comparisons of percentages between different time periods at a site or between sites with similar time periods are not directly comparable as a result of confounding factors, including frequency of sampling relative to time of year when changes in land use, precipitation, runoff, and biological activity might affect constituent concentrations. In this section of the report, exceedance results are summarized first for TN and then for TP. Exceedance information by ecoregions and general patterns for TN and TP exceedances and median concentrations are described. Notable exceedances and median concentrations from water-quality sampling sites on the Colorado, Fremont, Green, Gunnison (and tributaries), Virgin, and Yampa Rivers, also are described.

Exceedances—Total Nitrogen Results

Generally, major streams that flow in and through NCPN park units show large variability and, in some cases, relatively high numbers and percentages of TN exceedances, and few patterns between upstream and downstream sites. Of the 65 sites evaluated for TN exceedances, only 3 sites, ARCH sites 43 and 45 and NABR site 74, had no TN exceedances, but these sites only had 1 or 2 samples. The remaining 62 sites had one or more TN exceedances (ranging from 2 to 100 percent of samples) of State of Utah standards or USEPA ecoregion criteria (table 8). Of the 65 sites evaluated, 29 (45 percent) had exceedances greater than or equal to 85 percent of samples. Concentrations at sites in the xeric ecoregion had an average exceedance frequency of 76 percent for TN (43 sites); the average frequency of exceedance for TN (22 sites) concentrations at mountain ecoregion sites was 70 percent. The overall average for all 65 sites in the NCPN was 74 percent frequency of exceedance for TN. Of the 65 sites evaluated, 55 sites had no indeterminate values and 10 sites had indeterminate values (ranging from 2 to 46 percent of samples) (table 8).

Median TN concentrations generally were equal to or greater than the applicable standard or recommended criterion (table 8). In streams flowing in and near NCPN park units, median nitrogen concentrations ranged from 0.106 to 2.42 mg/L (overall median 0.633 mg/L), excluding the one WWTP outflow in the study (site 50) that had a median of 23.4 mg/L. All park units had an average of median TN concentrations greater than the standard or criterion; sites in and near HOVE had the highest overall median TN concentrations, and CURE and BRCA sites had the lowest overall median TN concentrations. Median TN concentrations also were low for a few other sites in BLCA, CANY, NABR, and ZION; however, some of these sites had a very limited data record. Median concentrations were equal to or less than the applicable standard or criterion for data from 8 TN (12 percent) sites. The highest median concentrations generally were not found at the lowest downstream site. The average of median TN concentrations at xeric ecoregion sites (1.40 mg/L) was higher than the average of median TN concentrations at mountain ecoregion sites (0.281 mg/L).

On the Colorado River, five of six sites (ARCH sites 46 and 47 and CANY sites 52, 54, and 55) had TN exceedances of 99 or 100 percent of samples; the sixth site (COLM site 4) had a TN exceedance of 76 percent. The highest median concentration of 1.30 mg/L on the Colorado River was from ARCH site 46 (based on 379 results from samples collected

Table 8. Percentage of total nitrogen and total phosphorus results from water-quality samples collected that exceed the State of Utah designated beneficial-use standard or the U.S. Environmental Protection Agency (USEPA) recommended nutrient critiera and descriptive statistics, Northern Colorado Plateau Network, various periods of record from 1972 through 2007.

[Site no., site number corresponding with table 6; No. res., number of results; No. cens., number of censored results; No. exd., number of results that exceed standard; % exd., percentage of results that exceed standard; % ind., percentage of indeterminate values (counted as non-exceedance); No. yrs., number of years between the first and last record; Min., minimum result value; Max., maximum result value; Med., median of results determined using robust methods (see footnote and text for details); mg/L, milligrams per liter; Standard, maximum chronic concentration intended to support designated beneficial use, or in cases where State standards do not exist Standard refers to USEPA recommended nutrient criteria (see table 2); Min. date, earliest date for records used in exceedance analysis; Max. date, most recent date for records used in exceedance analysis; xeric, USEPA ecoregion for dry landscapes in the intermountain West; mtn, USEPA ecoregion for forested mountain landscapes in the intermountain West; --, no data; <, less than detection limit; NCPN, Northern Colorado Plateau Network; results with 85 percent exceedance or greater are shown in **bold**; see table 1 for explanation of park codes. Number of results for each constituent varies among sites. Location of sites shown in figs. 2–12]

Site no.	USEPA eco region	Total nitrogen												Total phosphorus											
		No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date
BLCA																									
1	xeric	17	0	17	0	**100**	3	1.06	1.70	1.31	0.38	08/23/01	09/16/04	35	0	27	0	77	10	0.003	0.594	0.078	0.022	05/08/96	07/27/06
2	xeric	110	28	2	0	2	12	.050	.390	.200	.38	12/13/94	09/27/06	113	37	51	33	45	13	.010	.070	.024	.022	12/13/94	02/05/07
COLM																									
3	xeric	181	0	178	0	**98**	27	.280	6.90	1.40	.38	06/17/75	09/24/02	270	44	222	16	82	30	.020	2.30	.070	.022	02/16/72	09/24/02
4	xeric	99	23	75	23	76	13	.350	7.60	.780	.38	06/05/79	04/15/92	337	48	287	14	**85**	22	.020	5.10	.110	.022	04/01/74	07/29/96
CURE																									
5	mtn	--	--	--	--	--	--	--	--	--	--	--	--	12	0	12	0	**100**	13	.020	.620	.050	.01	08/13/74	11/16/87
6	mtn	--	--	--	--	--	--	--	--	--	--	--	--	137	8	129	1	**94**	27	<.010	4.05	.060	.01	05/16/79	06/19/06
7	mtn	59	17	27	27	46	9	<.020	.480	.122	.12	11/17/93	12/04/02	54	27	11	48	20	7	<.003	.064	.006	.01	03/25/95	12/04/02
8	mtn	46	18	22	35	48	7	<.010	.510	.150	.12	04/19/95	12/04/02	45	19	21	36	47	7	.003	.120	.015	.01	04/19/95	12/04/02
9	mtn	67	18	46	25	69	23	.020	1.50	.270	.12	07/10/79	12/05/02	80	12	68	15	**85**	28	.019	.270	.050	.01	08/13/74	12/05/02
10	mtn	28	4	22	0	79	25	<.040	.496	.190	.12	09/24/79	09/08/04	38	0	38	0	**100**	27	.035	.414	.065	.01	09/24/79	09/11/06
11	xeric	--	--	--	--	--	--	--	--	--	--	--	--	37	0	36	0	**97**	5	.015	.430	.140	.022	08/11/87	10/19/92
12	mtn	--	--	--	--	--	--	--	--	--	--	--	--	35	8	27	0	77	5	<.010	.110	.020	.01	01/23/01	05/24/06
13	mtn	26	3	20	0	77	5	<.040	.440	.210	.12	06/01/99	09/02/04	70	0	70	0	**100**	22	.030	.420	.080	.01	05/01/84	09/13/06
14	mtn	41	3	37	0	**90**	7	<.030	.531	.240	.12	06/03/99	09/25/06	42	0	42	0	**100**	10	.029	.181	.082	.01	11/06/96	09/25/06
15	xeric	--	--	--	--	--	--	--	--	--	--	--	--	36	0	36	0	**100**	5	.024	1.77	.180	.022	08/11/87	10/19/92
16	mtn	--	--	--	--	--	--	--	--	--	--	--	--	28	0	28	0	**100**	10	.074	.868	.140	.01	06/10/82	06/15/92
17	mtn	25	0	19	0	76	5	.062	.410	.174	.12	05/27/99	09/14/04	57	0	57	0	**100**	11	.023	.288	.074	.01	05/09/95	08/28/06
18	mtn	26	1	19	0	73	5	.001	.270	.181	.12	06/01/99	09/13/04	38	1	37	0	**97**	7	.004	.163	.089	.01	06/01/99	08/28/06
19	mtn	27	1	14	0	52	5	.024	.347	.120	.12	05/25/99	09/07/04	37	0	37	0	**100**	7	.026	.190	.042	.01	05/25/99	09/05/06
20	xeric	41	0	29	0	71	7	.045	1.92	.482	.38	06/03/99	09/25/06	105	0	105	0	**100**	18	.035	1.31	.104	.022	06/05/89	02/07/07
21	xeric	--	--	--	--	--	--	--	--	--	--	--	--	35	0	35	0	**100**	5	.054	.458	.150	.022	10/08/87	10/19/92
22	mtn	--	--	--	--	--	--	--	--	--	--	--	--	37	0	37	0	**100**	5	.065	.493	.160	.01	08/19/87	10/19/92
23	mtn	26	1	20	0	77	5	.012	.280	.200	.12	05/26/99	09/21/04	37	0	37	0	**100**	7	.086	.286	.161	.01	05/26/99	08/29/06
24	mtn	166	76	82	46	49	27	<.070	7.30	.233	.12	07/10/79	09/20/06	230	62	168	27	73	32	.014	1.16	.040	.01	08/13/74	09/20/06
25	mtn	53	4	27	2	51	32	<.030	3.48	.120	.12	09/28/74	09/26/06	87	0	87	0	**100**	32	.012	.499	.035	.01	09/28/74	09/26/06
26	mtn	43	0	43	0	**100**	7	.120	.854	.297	.12	06/02/99	09/25/06	45	0	45	0	**100**	8	.069	.196	.117	.01	06/02/99	02/07/07
27	mtn	26	0	25	0	**96**	5	.091	.670	.350	.12	05/26/99	09/21/04	37	0	37	0	**100**	7	.108	.260	.189	.01	05/26/99	08/29/06
28	mtn	36	18	12	44	33	7	<.010	.270	.140	.12	11/17/93	08/29/00	24	14	6	54	25	4	.004	.030	[1].010	.01	11/22/96	08/29/00
29	mtn	26	4	10	4	38	5	<.040	.351	.106	.12	06/02/99	09/07/04	67	0	67	0	**100**	24	.015	.636	.075	.01	06/18/82	09/11/06
DINO																									
30	mtn	241	0	235	0	**98**	26	.033	35.0	.680	.12	10/29/74	08/30/00	206	116	22	0	11	29	.001	.420	[1].020	.05	05/23/72	04/25/01
31	xeric	103	0	75	0	73	27	.060	2.80	.540	.38	06/26/75	10/30/02	94	12	81	13	**86**	27	.021	.380	.070	.022	06/26/75	10/30/02
32	xeric	--	--	--	--	--	--	--	--	--	--	--	--	45	7	22	0	49	9	<.020	1.88	.048	.05	03/06/97	06/21/06
33	xeric	82	0	57	0	70	17	.100	2.21	.490	.38	01/05/78	05/08/95	108	27	27	0	25	20	.005	.613	.020	.05	10/27/76	10/01/96
34	xeric	--	--	--	--	--	--	--	--	--	--	--	--	19	2	6	0	32	8	<.020	.201	.032	.05	07/15/98	08/15/06

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		Total nitrogen												Total phosphorus											
Site no.	USEPA eco region	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date
DINO—Continued																									
35	xeric	190	0	162	0	**85**	25	0.030	7.10	0.600	0.38	08/02/77	09/10/02	329	35	202	0	61	30	0.009	8.00	0.060	0.05	10/26/76	11/07/06
36	xeric	121	42	55	35	45	32	<.050	7.70	.540	.38	08/26/75	01/31/07	167	37	123	21	74	33	<.010	3.22	.059	.022	04/03/74	01/31/07
37	xeric	126	3	105	0	83	28	.140	8.80	.780	.38	06/26/74	09/04/02	132	30	102	23	77	30	<.030	1.60	.050	.022	02/23/72	09/04/02
FOBU																									
38	xeric	67	0	55	0	82	19	.060	3.70	.680	.38	07/24/75	06/28/94	99	32	67	32	68	19	<.030	3.80	.040	.022	07/24/75	06/28/94
GOSP																									
39	xeric	19	0	17	0	**89**	12	.300	2.60	1.06	.38	05/31/79	11/12/91	30	0	29	0	**97**	14	.046	4.17	.180	.05	05/31/79	06/15/93
TICA																									
40	mtn	3	0	2	0	67	0	.103	.616	.566	.12	05/07/92	08/10/92	46	26	1	0	2	8	<.010	.100	[1].010	.05	02/12/92	06/23/00
41	mtn	--	--	--	--	--	--	--	--	--	--	--	--	15	10	2	0	13	6	<.020	.062	[1].010	.05	06/30/99	06/30/05
ARCH																									
42	xeric	--	--	--	--	--	--	--	--	--	--	--	--	58	31	10	0	17	16	<.010	.166	[1].020	.05	08/29/90	12/05/06
43	xeric	1	0	0	0	0	0	--	--	--	.38	04/28/91	04/28/91	44	22	5	0	11	16	.008	.089	.011	.05	08/20/90	12/04/06
44	xeric	--	--	--	--	--	--	--	--	--	--	--	--	16	5	3	0	19	5	<.010	.241	.024	.05	07/24/95	06/29/00
45	xeric	1	0	0	0	0	0	--	--	--	.38	05/29/89	05/29/89	12	0	3	0	25	12	.010	1.38	.028	.05	05/29/89	08/14/01
46	xeric	379	0	377	0	**99**	26	.300	24.0	1.30	.38	10/22/74	09/07/00	502	45	366	0.2	73	32	<.005	4.15	.100	.05	10/22/74	12/07/06
47	xeric	112	0	111	0	**99**	20	.360	6.80	1.17	.38	03/17/77	02/13/97	163	11	125	0	77	30	<.005	4.63	.148	.05	08/05/76	05/10/06
48	xeric	107	0	102	0	**95**	14	.240	13.1	1.05	.38	07/26/77	12/12/91	191	21	121	0	63	26	<.005	7.53	.077	.05	06/20/77	06/19/03
[2]50	xeric	38	0	38	0	**100**	10	11.0	51.7	23.4	.38	01/19/78	05/12/88	104	0	103	0	**99**	29	.038	33.3	6.14	.05	01/12/77	11/02/06
CANY																									
51	xeric	24	0	20	0	83	7	.010	63.7	.780	.38	05/04/83	07/10/90	94	1	86	0	**91**	23	.020	3.02	.280	.05	05/04/83	09/26/06
52	xeric	24	0	24	0	**100**	7	.410	3.86	1.26	.38	05/04/83	07/10/90	96	1	85	0	**89**	23	.020	1.65	.164	.05	05/04/83	09/26/06
53	xeric	28	0	25	0	**89**	11	.100	56.4	.900	.38	03/20/78	04/05/89	78	2	70	0	**90**	29	.020	23.7	.210	.05	06/14/77	08/10/06
54	xeric	1	0	1	0	**100**	0	.910	.910	.910	.38	07/12/90	07/12/90	44	1	37	0	84	16	<.020	1.11	.244	.05	07/12/90	09/27/06
55	xeric	23	0	23	0	**100**	7	.580	6.09	1.22	.38	06/15/83	07/09/90	48	0	41	0	**85**	15	.010	1.95	.170	.05	06/15/83	08/06/98
56	xeric	--	--	--	--	--	--	--	--	--	--	--	--	23	0	20	0	**87**	6	.029	.368	.150	.05	04/16/91	05/09/97
57	xeric	6	0	3	0	50	9	.150	.750	.200	.38	08/02/77	06/12/86	56	17	20	0	36	27	<.010	.622	.032	.05	03/27/79	09/11/06
59	xeric	--	--	--	--	--	--	--	--	--	--	--	--	12	4	3	0	25	7	<.010	.094	.019	.05	07/06/93	06/14/00
60	xeric	--	--	--	--	--	--	--	--	--	--	--	--	12	4	3	0	25	7	<.010	.151	.019	.05	07/06/93	06/14/00
61	xeric	--	--	--	--	--	--	--	--	--	--	--	--	17	0	15	0	**88**	7	.010	.934	.130	.05	07/18/91	08/06/98
62	xeric	--	--	--	--	--	--	--	--	--	--	--	--	58	0	47	0	81	15	.020	1.02	.120	.05	04/15/91	09/26/06
63	xeric	--	--	--	--	--	--	--	--	--	--	--	--	25	10	4	0	16	6	.015	1.01	.024	.05	05/05/97	06/19/03
64	xeric	--	--	--	--	--	--	--	--	--	--	--	--	38	29	0	0	0	13	<.010	.042	[1].010	.05	10/04/93	06/22/06
65	xeric	--	--	--	--	--	--	--	--	--	--	--	--	33	25	1	0	3	11	<.020	.095	[1].010	.05	06/14/95	11/15/06
66	xeric	202	0	181	0	**90**	26	.120	31.0	.910	.38	01/24/74	09/11/00	277	14	230	0	83	32	<.020	9.10	.160	.05	01/24/74	12/07/06
67	xeric	1	0	1	0	**100**	0	.600	.600	.600	.38	04/29/81	04/29/81	29	6	9	0	31	22	<.020	1.16	.032	.05	04/29/81	06/05/03
68	xeric	--	--	--	--	--	--	--	--	--	--	--	--	10	2	3	0	30	7	.019	.090	.022	.05	06/14/95	02/11/02

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		Total nitrogen													Total phosphorus											
Site no.	USEPA eco region	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date
HOVE																									
69	xeric	3	0	3	0	**100**	3	2.16	6.99	2.42	0.38	02/22/89	02/12/92	13	0	11	0	**85**	9	0.031	0.932	0.211	0.05	02/22/89	06/02/98
70	xeric	15	0	13	0	**87**	9	.310	5.40	1.15	.38	03/08/79	06/29/88	15	2	12	0	80	9	.005	397	.150	.05	03/08/79	06/29/88
71	xeric	37	0	37	0	**100**	6	.420	4.12	1.34	.38	07/02/85	12/11/91	61	5	46	0	75	13	<.005	4.21	.126	.05	07/02/85	06/23/98
72	xeric	17	0	16	0	**94**	3	.247	1.89	.740	.38	09/15/88	12/11/91	41	2	30	0	73	10	<.005	1.48	.108	.05	09/15/88	06/23/98
73	xeric	--	--	--	--	--	--	--	--	--	--	--	--	48	2	44	0	**92**	8	<.010	1.40	.120	.022	06/24/98	05/22/06
NABR																									
74	xeric	2	0	0	0	0	2	.273	.360	[1].314	.38	09/13/91	06/07/93	41	21	4	0	10	15	<.010	.102	[1].020	.05	06/09/91	12/12/06
BRCA																									
75	mtn	16	2	10	6	63	12	.010	.850	.150	.12	06/14/78	09/06/90	47	14	6	0	13	23	<.005	1.00	.010	.05	09/08/76	09/14/99
76	xeric	--	--	--	--	--	--	--	--	--	--	--	--	42	32	1	0	2	8	<.020	.252	[1].010	.05	08/27/98	11/01/06
77	xeric	--	--	--	--	--	--	--	--	--	--	--	--	29	20	3	0	10	8	<.020	.195	[1].010	.05	09/21/98	11/01/06
CARE																									
78	xeric	14	0	10	0	71	3	.030	1.27	.540	.38	06/29/88	11/20/91	51	3	28	0	55	20	.005	.221	.056	.05	10/22/86	12/13/06
79	mtn	1	0	1	0	**100**	0	.600	.600	.600	.12	07/29/80	07/29/80	59	1	38	0	64	24	.010	.279	.054	.05	03/24/77	09/11/01
80	xeric	98	0	89	0	**91**	14	.200	24.5	.940	.38	03/15/77	12/11/91	180	7	161	0	**89**	26	<.005	95	.367	.05	11/17/76	06/05/02
81	xeric	13	0	12	0	**92**	8	.290	2.40	1.10	.38	01/27/81	06/21/89	13	2	7	0	54	8	.018	.350	.050	.05	01/27/81	06/21/89
82	mtn	--	--	--	--	--	--	--	--	--	--	--	--	22	1	4	0	18	7	.020	.405	.040	.05	11/18/97	06/30/04
83	xeric	21	0	16	0	76	14	.080	2.31	.900	.38	11/08/77	11/20/91	74	3	52	0	70	26	<.020	1.99	.080	.05	03/24/77	06/18/03
84	mtn	80	0	80	0	**100**	17	.270	12.6	.980	.12	02/05/76	03/17/93	223	8	150	0	67	30	.005	1.10	.060	.05	07/15/76	12/13/06
ZION																									
85	xeric	57	0	56	0	**98**	10	.240	2.78	.900	.38	07/26/82	05/21/92	173	28	78	0	45	24	<.005	3.06	.040	.05	07/26/82	12/13/06
86	mtn	4	0	2	0	50	10	.100	3.50	.110	.12	05/22/79	08/03/89	12	0	3	0	25	22	.006	.290	.020	.05	05/22/79	08/15/01
87	xeric	--	--	--	--	--	--	--	--	--	--	--	--	65	51	5	0	8	5	.007	.339	[1].010	.05	08/15/01	11/28/06
88	xeric	3	0	3	0	**100**	1	.450	.650	.600	.38	06/17/80	01/14/81	41	7	19	0	46	22	<.010	.979	.033	.05	06/17/80	04/26/02
89	xeric	38	3	6	0	16	6	.020	.940	.200	.38	01/29/86	11/18/92	136	72	5	0	4	20	<.005	.250	[1].010	.05	01/29/86	11/28/06
90	xeric	14	0	14	0	**100**	12	.550	3.55	.900	.38	04/19/79	10/30/91	132	44	44	0	33	27	<.010	1.61	.025	.05	04/19/79	11/28/06
91	xeric	62	0	45	0	73	11	.170	3.57	.520	.38	06/17/80	10/29/91	114	16	50	0	44	26	<.005	1.64	.040	.05	06/17/80	12/13/06
92	xeric	66	1	30	0	45	12	.040	1.10	.330	.38	04/19/79	10/29/91	186	49	58	0	31	27	<.005	1.01	.025	.05	04/19/79	12/13/06
93	xeric	34	0	18	0	53	14	.030	2.50	.400	.38	01/18/77	10/30/91	47	12	22	0	47	26	.005	.550	.040	.05	09/08/76	02/27/02
94	xeric	--	--	--	--	--	--	--	--	--	--	--	--	35	11	7	0	20	10	<.010	1.23	.020	.05	04/03/96	12/13/06
95	xeric	58	0	48	0	83	9	.140	3.12	.610	.38	02/24/82	10/29/91	116	4	71	0	61	24	.005	1.53	.065	.05	02/24/82	12/13/06

Table 8. Percentage of total nitrogen and total phosphorus results from water-quality samples collected that exceed the State of Utah designated beneficial-use standard or the U.S. Environmental Protection Agency (USEPA) recommended nutrient critiera and descriptive statistics, Northern Colorado Plateau Network, various periods of record from 1972 through 2007.—Continued

[Site no., site number corresponding with table 6; No. res., number of results; No. cens., number of censored results; No. exd., number of results that exceed standard; % exd., percentage of results that exceed standard; % ind., percentage of indeterminate values (counted as non-exceedance); No. yrs., number of years between the first and last record; Min., minimum result value; Max., maximum result value; Med., median of results determined using robust methods (see footnote and text for details); mg/L, milligrams per liter; Standard, maximum chronic concentration intended to support designated beneficial use, or in cases where State standards do not exist Standard refers to USEPA recommended nutrient criteria (see table 2); Min. date, earliest date for records used in exceedance analysis; Max. date, most recent date for records used in exceedance analysis; xeric, USEPA ecoregion for dry landscapes in the intermountain West; mtn, USEPA ecoregion for forested mountain landscapes in the intermountain West; --, no data; <, less than detection limit; NCPN, Northern Colorado Plateau Network; results with 85 percent exceedance or greater are shown in **bold**; see table 1 for explanation of park codes. Number of results for each constituent varies among sites. Location of sites shown in figs. 2–12]

		Total nitrogen												Total phosphorus											
Site no.	USEPA eco region	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date	No. res.	No. cens.	No. exd.	% ind.	% exd.	No. yrs.	Min. (mg/L)	Max. (mg/L)	Med. (mg/L)	Standard (mg/L)	Min. date	Max. date
		Averages for total nitrogen												Averages for total phosphorus											
						% exd.		Min. (mg/L)	Max. (mg/L)	Med. (mg/L)								% exd.		Min. (mg/L)	Max. (mg/L)	Med. (mg/L)			
NCPN						74		0.459	7.16	1.01								61		0.023	7.14	0.161			
Colorado Parks						67		.176	1.75	.346								86		.031	.805	086			
Utah Parks						73		.509	9.27	1.23								68		.010	14.7	.243			
Xeric ecoregion						76		.573	9.26	1.40								57		.018	10.1	.201			
Mtn ecoregion						70		.111	3.24	.281								70		.029	.516	.069			

[1]Median determined by the Kaplan-Meier method, all other values determined by maximum likelihood method (Helsel, 2005).

[2]Site is the outflow of the Moab Wastewater Treatment Plant.

from 1974 through 2000), which is immediately downstream from where the Dolores River enters the Colorado River (fig. 2). The median TN concentration from ARCH site 48, at the mouth of the Dolores River, was 1.05 mg/L (based on 107 results collected from 1977 through 1991), which may indicate some TN contributions from the Dolores River to the Colorado River. The next upstream site on the Colorado River near COLM (site 4; fig. 7) had a median TN concentration of 0.78 mg/L. Other potential sources of nitrogen to the Colorado River between COLM and ARCH include agricultural return flows, runoff, and natural background sources (for example, the Mancos Shale has been shown as a natural source of nitrogen and phosphorus; U.S. Department of Energy, 2011).

Only two sites on the Fremont River (CARE sites 80 and 84) were regularly sampled from the late 1970s through the early 1990s with 98 and 80 samples collected, respectively. These two sites had 91- and 100-percent exceedance of TN samples, respectively, and also had the highest recorded maximum TN concentrations of 24.5 and 12.6 mg/L, respectively, on the Fremont River. Site 84 is just downstream from the town of Bicknell and upstream from CARE and site 80 is at the mouth of the Fremont River, just upstream from the confluence with the Dirty Devil River (fig. 6). The other sites in and upstream from the park (CARE sites 78, 79, 81, and 83) had fewer samples collected—between 1 and 21 samples collected variously from 1977 through 1991—and between 71- and 100-percent exceedance. Median concentrations ranged from 0.540 to 1.10 mg/L; the highest median concentration was for data from site 81 (based on 13 results from samples collected from 1981 through 1989), which is upstream from the park boundary. Upstream to downstream patterns in exceedances or median concentrations were not discernable for the Fremont River sites.

Data from the Green and Yampa Rivers show a range of numbers and percentages of TN exceedances. The highest number and percentage of exceedances (235 exceedances for 98 percent of samples) on the Green River were for data from DINO site 30, the most upstream water-quality sampling site immediately downstream from Flaming Gorge Reservoir (fig. 8). However, this result is likely because the applicable criterion was 0.12 (USEPA mountain ecoregion) for this site but the other sites were compared to the higher 0.38 (USEPA xeric ecoregion) criterion. The remaining Green River sites (DINO sites 33 and 35 and CANY sites 51, 53, and 66) had TN exceedances ranging from 70 to 90 percent. On the Yampa River, the highest number and percentage of exceedances (105 exceedances for 83 percent of samples) were for data from DINO site 37 (Yampa River near Maybell, Colo.), 38 mi upstream from the monument (fig. 8). The Yampa joins the Green River in the monument upstream from DINO site 35. Median TN concentrations for data from sites in and near DINO on the Green and Yampa Rivers were generally similar. Median concentrations for data from the three Green River sites downstream from DINO and in or upstream from CANY (CANY sites 51, 53, and 66) are higher than medians from data collected from upstream Green River sites near DINO (DINO sites 30, 33, and 35)–ranging from 0.490 to 0.680 mg/L (upstream DINO sites) as compared to 0.780 to 0.910 mg/L (downstream CANY sites).

Since the late 1990s, NPS staff at BLCA and CURE has sustained a water-quality data-collection program in the Gunnison River Basin, which includes tributaries and main-stem stream sites sampled as part of the reservoir system of the Colorado River Storage Project (fig. 3). Data collected from the Gunnison River and its tributaries in and near the park units had TN exceedances generally lower than other NCPN streams. Percentage of exceedances were moderately low for main-stem Gunnison River samples from sites 8 and 24, just upstream from CURE (48- and 49-percent exceedance of 46 and 166 samples, respectively). For main-stem Gunnison River sites downstream from CURE, data from site 2 in BLCA had a very low exceedance (2 percent of 110 samples), whereas, site 3 near COLM had a 98-percent exceedance (of 181 samples). Of the tributaries sampled during this and earlier periods, data from 15 sites (7, 9–10, 13–14, 17–20, 23, 25–29) had 10 to 46 exceedances (33 to 100 percent of samples). Likewise, data collected from the Gunnison River and its tributaries in and near the park units had median TN concentrations generally lower than other NCPN streams. Median TN concentrations for data from CURE sites 2, 8, and 24 on the Gunnison River, in and just upstream from the park-unit boundaries, ranged from 0.150 to 0.233 mg/L, based on 46 to 166 results collected variously from 1979 through 2006. In contrast, median TN concentrations for data from COLM site 3 near COLM (Gunnison River near Grand Junction, Colo.; fig. 7) was 1.40 mg/L, based on 181 results from samples collected from 1975 through 2002, which is markedly elevated from the upstream sites. Median TN concentrations ranged from 0.106 mg/L (CURE site 29) to 0.482 mg/L (CURE site 20) for data from the 15 tributary sites. The generally lower TN concentrations in the Gunnison River and its tributaries in CURE and BLCA are likely influenced by the predominantly crystalline rock geology in the basin area, the proximity of these sampling sites to the headwaters, and the primary land cover of mixed-forest and grassland with limited development in the area (Thornberry-Ehrlich, 2005; U.S. Geological Survey, 2000; ESRI, 2011).

For TN data collected in and near ZION, the sampling record is limited with no data available after the early 1990s. The number and percentage of TN exceedances for the Virgin River and its North and East Fork tributaries were highly variable. Data from the East Fork Virgin River (sites 85, 89, and 90) had 6 to 56 TN exceedances (ranging from 16 to 100 percent of samples). Data from sites 92 and 93 on the North Fork of the Virgin River show less variation with 45-percent exceedance (of 66 samples) and 53-percent exceedance (of 34 samples), respectively. Downstream from where these tributaries meet to form the Virgin River, samples collected from site 95 had an 83-percent exceedance (of 58 samples). Median concentrations for all sites ranged from 0.200 mg/L (ZION site 89) to 0.900 mg/L (ZION sites 85 and 90).

Exceedances—Total Phosphorus Results

Major streams that flow in and through NCPN park units show large variability and, in some cases, relatively high numbers and(or) percentages of TP exceedances. One or more TP exceedances (ranging from 2 to 100 percent of samples) of State of Utah or USEPA ecoregion criteria were identified for TP concentration data from all but 1 of the 93 sites evaluated for the periods of record in this report. CANY site 64 was the exception with no TP exceedances on the basis of 38 results from samples collected from 1993 through 2006 (table 8). Of the 93 sites evaluated, 33 (35 percent) had exceedances greater than or equal to 85 percent of samples. Concentrations at all sites in the xeric ecoregion had an overall exceedance frequency of 57 percent for TP (64 sites); the overall frequency of exceedance for TP (29 sites) concentrations at mountain ecoregion sites was 70 percent. The overall average for all 93 sites was 61 percent frequency of exceedance for TP. Of the 93 sites evaluated, 79 sites had no indeterminate values and 14 sites had indeterminate values (ranging from 0.2 to 54 percent of samples) (table 8).

Median TP concentrations generally were greater than the applicable standard (that is, indicator of impairment) or recommended criterion although these values are currently (2011) under revision and further development in Colorado, Utah, and surrounding states. In streams flowing in and near NCPN park units, median TP concentrations ranged from 0.006 to 0.367 mg/L (excluding the one WWTP outflow in the study (site 50) that had a median of 6.14 mg/L), the overall median TP concentration for all NCPN sites was 0.161 mg/L. Most park units had an average of median TP concentrations greater than the standard or criterion; three park units had an average of median TP concentrations less than the standard or criterion (NABR, BRCA, and ZION). Median concentrations were equal to or less than the applicable standard or criterion for data from 35 TP (38 percent) sites. The average of median TP concentrations at xeric ecoregion sites (0.201 mg/L) was higher than the average of median TP concentrations at mountain ecoregion sites (0.069 mg/L).

The six main-stem Colorado River sites (COLM site 4, ARCH sites 46 and 47, and CANY sites 52, 54, and 55) had TP exceedances ranging from 73 to 89 percent of samples (for between 44 and 502 samples). The highest median TP concentration of 0.244 mg/L on the Colorado River was from CANY site 54, which is downstream from where the Green River enters the Colorado River (fig. 5). The median TP concentration from CANY site 51 at the mouth of the Green River was 0.280 mg/L (based on 94 results collected from 1983 through 2006), which may indicate some TP contributions from the Green River to the Colorado River. Upstream from CANY site 54, median concentrations ranged from 0.100 to 0.170 mg/L on the Colorado River.

Sites on the Fremont River (CARE sites 78–80 and 83–84) were sampled more regularly for TP than for TN (fig. 6). Site 81 was sampled only 13 times for both constituents (from 1981 through 1989). Collectively, these six sites had 54- to 89-percent exceedance of samples. Median TP concentrations ranged from 0.050 to 0.080 mg/L for data from sites upstream from and in the park (sites 78, 79, 81, 83, and 84). Downstream from the park, before the Fremont River joins the Dirty Devil River, the median TP concentration increased to 0.367 mg/L for data from site 80 (based on 180 results from samples collected from 1976 through 2002), which is nearly an order of magnitude higher than the current (2011) State of Utah standard of 0.05 mg/L, and is the second highest median value recorded for all of the NCPN sites (ARCH site 50, the Moab WWTP outflow, had a median TP concentration of 6.14 mg/L). Natural background sources, Pleasant Creek, agricultural return flows, and Cainville Wash (with two artesian wells contributing flow from the Mancos Shale to the wash) are potential sources of phosphorus in the Fremont River downstream from CARE (Fremont River Watershed Steering Committee and Millennium Science & Engineering, 2002; U.S. Department of Energy, 2011) (fig. 6).

Data from the Green and Yampa Rivers show a range of numbers and percentages of TP exceedances, and there appears to be a pattern of nutrient enrichment generally increasing in the downstream direction on the Green River. Three Green River sites downstream from DINO (CANY sites 51, 53, and 66) had the highest percentage of TP exceedances (83 to 91 percent of samples). The remaining Green River sites (DINO sites 30, 32, 33, and 35) had TP exceedances ranging from 11 to 61 percent. On the Yampa River, the highest percentage of exceedances (81 exceedances for 86 percent of samples) was for data from DINO site 31 (Yampa River below Craig, Colo.; fig. 8). Median TP concentrations for data from sites in and near DINO on the Green and Yampa Rivers were generally similar and ranged from 0.020 to 0.070 mg/L. Following the same pattern as TN, the median concentrations for data from the three Green River sites downstream from DINO in and upstream from CANY (CANY sites 51, 53, and 66) are higher than medians from data collected from upstream sites in and near DINO and ranged from 0.160 to 0.280 mg/L.

TP exceedances and median TP concentrations for the main-stem Gunnison River and tributaries in and near BLCA and CURE were not lower than other NCPN park units, unlike the notably low exceedances and median concentrations observed for the TN data. For main-stem Gunnison River sites (BLCA site 2, COLM site 3, and CURE sites 8, 12, and 24), exceedances ranged from 45 to 82 percent of samples. Exceedances ranged from 85 to 100 percent of samples for data from 20 tributary sites (CURE sites 5–6, 9–11, 13–23, 25–27, and 29). Two tributaries (CURE sites 7 and 28) had substantially lower percent exceedances of 20 and 25 percent, respectively. These two sites are approximately 16 mi upstream from the park units and are on headwater streams to the Gunnison River (fig. 3). Median TP concentrations were greater than the applicable USEPA ecoregion criterion for all main-stem and tributary sites, except CURE sites 7 and 28, which were less than or equal to the 0.01 mg/L USEPA mountain ecoregion criterion. Median concentrations for main-stem sites ranged from 0.015 to 0.070 mg/L and for tributary sites (excluding sites 7 and 28) from 0.035 to 0.189 mg/L.

The TP concentration data collected in and near ZION is more extensive than the TN data record; TP data were collected from the late 1970s through 2006 at variable time periods. Data from the East Fork Virgin River (sites 85, 87, 89, and 90; fig. 4) had 5 to 78 TP exceedances (ranging from 4 to 45 percent of samples). Data from sites 92 and 93 on the North Fork of the Virgin River show less variation with 31-percent exceedance (of 186 samples) and 47-percent exceedance (of 47 samples), respectively. Downstream from where these tributaries meet to form the Virgin River, samples collected from site 95 had a 61-percent exceedance (of 116 samples). Median concentrations for all sites are relatively low and ranged from 0.010 mg/L (ZION sites 87 and 89) to 0.065 mg/L (ZION site 95).

Discussion and Synthesis of Exceedance Results

To synthesize and facilitate comparison between the results networkwide, the percentage of exceedances and median concentrations from all the evaluated TN and TP data (table 8) are summarized by site and park in figures 17 and 18, respectively. Generally, there were large numbers of exceedances identified for many NCPN sites, many sites had high percentages (greater than 85 percent) of exceedances, and many of these exceedances have been occurring for a long time period. Overall, TN or TP exceedances were identified at 89 of the 93 sites (62 of 65 sites for TN and 92 of 93 sites for TP) and ranged from 2 to 100 percent of samples collected from 1972 through 2007. Of the 65 sites evaluated for TN exceedances, 29 (45 percent) had exceedances greater than or equal to 85 percent of samples. Of these, TN data from 13 sites in 7 NCPN park units, including BLCA (1 site), CURE (1 site), ARCH (1 site), CANY (4 sites), HOVE (2 sites), CARE (2 sites), and ZION (2 sites) had 100-percent exceedance, though the numbers of results and time periods evaluated for the sites varied (fig. 17, table 8). The selection of standards (State numeric standards as compared to USEPA Ecoregion-based recommended nutrient criteria) likely affected the location and percentage of exceedances identified. Of the 93 sites evaluated for TP exceedances, 33 (35 percent) had exceedances greater than or equal to 85 percent of samples. Of these, data from 16 sites in CURE had 100-percent exceedance, though the number of results and time period evaluated for sites varied. Utah park units had a low percentage of TP exceedances compared to Colorado park units, which may, in part, be explained by the higher 0.05 mg/L State of Utah standard as compared to the lower USEPA mountain (0.022 mg/L) and xeric (0.01 mg/L) ecoregion criteria. Sites with indeterminate values may be biased low in their percentage of exceedances and may warrant closer examination.

Networkwide, the higher overall percentage of exceedance for TN than TP and the lower sample-collection frequency for TN (table 8) indicate greater monitoring and management attention may be warranted for TN. However, because of current (2011) nutrient-criteria development activities in states with NCPN park units continued monitoring of both constituents is warranted in order to make comparisons to updated standards or criteria in the future. Additionally, management and monitoring activities are better informed by knowledge of cumulative effects from nutrients (that is, TN and TP) as well as other water-quality constituents at basin scales that may result in the increasing concentrations and loads as water flows downstream.

The median TN concentrations ranged from 0.106 to 2.42 mg/L and the median TP concentrations ranged from 0.006 to 0.367 mg/L for data from all sites, excluding data from the Moab WWTP outflow (ARCH site 50) included in the dataset (fig. 18, table 8). As previously noted, the median TN concentrations are low for CURE and BRCA sites as compared to most other NCPN sites; most of these concentrations, however, were still greater than the USEPA TN criterion for mountain ecoregion (0.12 mg/L). Median concentrations also were low (that is, less than the USEPA TN criterion for xeric ecoregion of 0.38 mg/L) for a few sites in BLCA, CANY, NABR, and ZION (fig. 18); however, concentrations at some of these sites were based on a very limited data record (table 8). The median TP concentrations were relatively low (less than 0.10 mg/L) for eight NCPN park units, including BLCA, DINO, FOBU, TICA, NABR, BRCA, CARE (except for site 80), and ZION. Median concentrations were equal to or less than the applicable standard or criterion for data from 8 TN (12 percent) and 35 TP (38 percent) sites (table 8). Overall higher median TN concentrations did not generally correspond with higher median concentrations of TP. This observation suggests that particular natural or human factors in some areas may result in higher concentrations of one nutrient than another. In contrast, some lower median TN concentrations compared well to lower median concentrations of TP (for example, BLCA site 2; CURE sites 7, 8, 9, 24, 25, and 28; CANY site 57; NABR site 74; BRCA site 75; and ZION sites 86, 89, and 92). This observation suggests these sites are downstream from areas with limited natural or human factors resulting in lower median nutrient concentrations.

Additionally, concentrations were generally higher for sites in the xeric ecoregion as compared to sites in the mountain ecoregion (table 8). The averages of median TN and TP concentrations at xeric ecoregion sites were 1.40 and 0.201 mg/L, respectively, and the averages of median TN and TP concentrations at mountain ecoregion sites were 0.281 and 0.069 mg/L, respectively. The generally higher concentrations of TN and TP in xeric ecosystems was recognized in the USEPA strategy for determining recommended nutrient criteria following ecoregional boundaries because of differences in vegetation cover, geology and erosion (U.S. Environmental Protection Agency, 2000a, 2000b). It also was recognized by the state of Utah when developing a statewide TP standard (0.05 mg/L) higher than the USEPA xeric ecoregion standard (0.022 mg/L). Utah TP standards are less stringent than USEPA standards applied to Colorado park units, which reflects the native TP concentrations in Utah surface water as

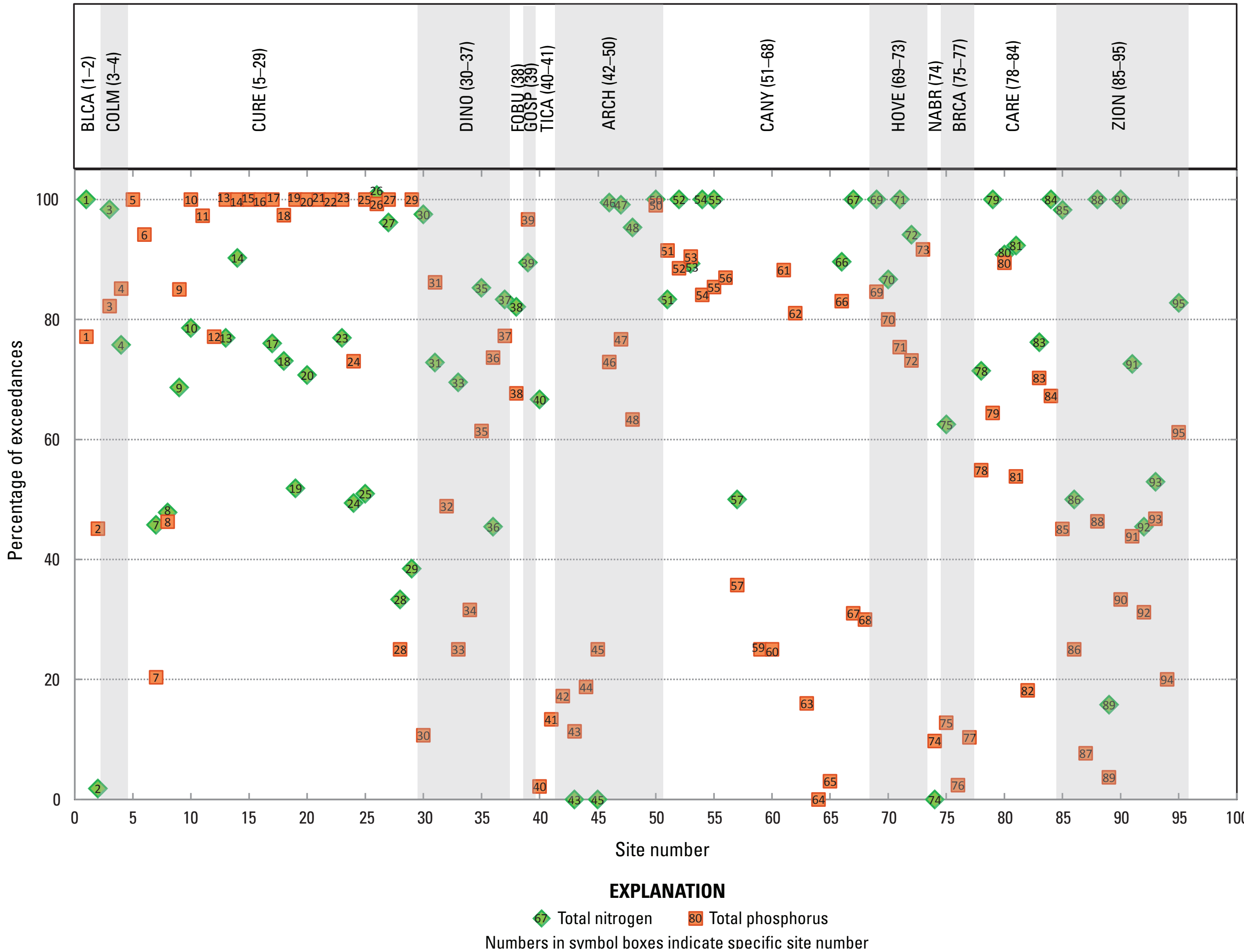


Figure 17. Percentage of exceedances for total nitrogen and total phosphorus by site number, Northern Colorado Plateau Network, from 1972 through 2007. [Park codes explained in table 1; site numbers detailed in table 6; numbers in parentheses following park code indicate range of site numbers for the park.

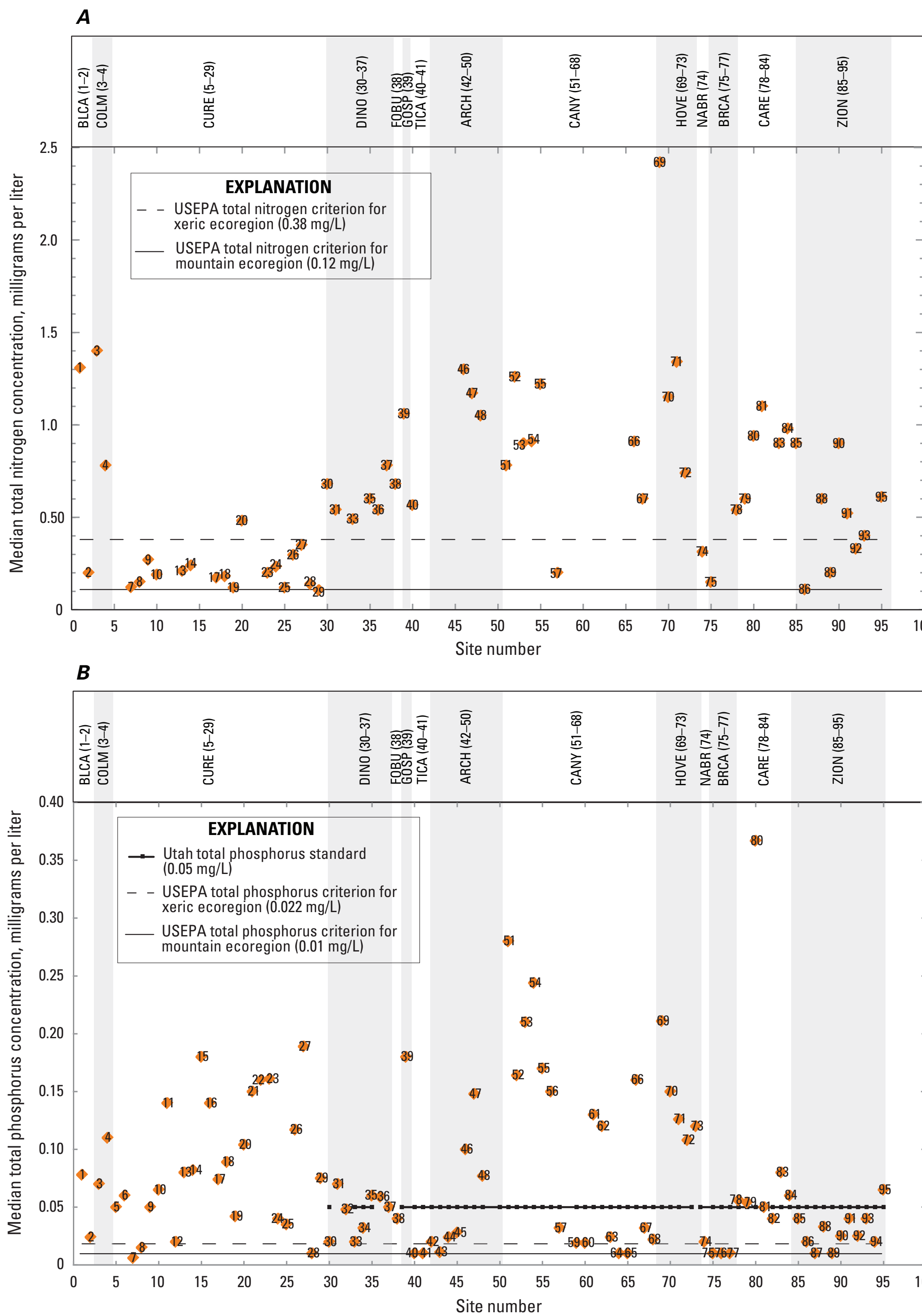


Figure 18. Median concentrations for *A*, total nitrogen and *B*, total phosphorus by site number, Northern Colorado Plateau Network, from 1972 through 2007. [Park codes explained in table 1; site numbers detailed in table 7; numbers in parentheses following park code indicate range of site numbers for the park. Numbers in symbol boxes indicate specific site number. Standards and U.S. Environmental Protection Agency (USEPA) criteria lines provided for reference only. Data from ARCH site 50 (Moab Wastewater Treatment Plant outflow) not shown on figures because of scaling (median for TN 23.4 milligrams per liter (mg/L), median for TP 6.14 mg/L).]

recognized by the UTDWQ and promulgated by USEPA in Rule 317-2 (Utah Administrative Code, 2009).

Both natural (that is, geologic) and human factors are likely contributing to elevated TN and(or) TP concentrations and frequent exceedances in streams near to and downstream from human activities such as agriculture, mining, and development. Although a regression analysis was not completed as part of this study, spatial occurrence of specific factors provide qualitative evidence for higher nutrient concentrations in some streams. For example, the Fremont River near its headwaters drains areas of volcanic geology on the Fish Lake Plateau, and has a history of grazing on public lands; additionally, it has intensive agricultural activities, including a fish hatchery, lower in the basin near the communities of Bicknell and Loa, Utah (site 84; fig. 6), all of which likely contribute to elevated TP concentrations. Further downstream near the mouth of the Fremont River (CARE site 80), TP concentrations may increase because of weathering and runoff from poorly vegetated landscapes or as a result of recreation-related activities (for example, improper disposal or treatment of human waste from park and area visitors) or other public-land management activities. Natural background sources (from the Mancos Shale), Pleasant Creek (affected by upstream and within-park influences including backpacking and 4-wheel-drive road recreation), agricultural return flows, and Cainville Wash (with two artesian wells contributing flow from the Mancos Shale to the wash) are potential sources of nutrients in the Fremont River downstream from CARE (Fremont River Watershed Steering Committee and Millennium Science & Engineering, 2002; U.S. Department of Energy, 2011) As a result of the USEPA 303(d) listing, best-management practices have been implemented in the Fremont River Basin to reduce nutrient loads to the stream (Fremont River Watershed Steering Committee and Millennium Science & Engineering, 2002). Few samples from any CARE water-quality sampling sites (mostly sampled in the 1980s) were analyzed for TN. Continued monitoring of nutrients in and downstream from CURE is warranted for the Fremont River given its limited data record for TN and its previous 303(d) listing for TP. Even though multiple natural and human factors affect some NCPN sites, specific factors (for example, geology) may be the dominant factor contributing to elevated TP concentrations in some NCPN park units. For example, four sites in CURE (16, 22, 23, and 27; fig. 3) that flow into Blue Mesa Reservoir from the north flow through an area dominated by volcanic geology that may be a natural source for higher TP concentrations in these streams (Ortiz, 2004). The Cimarron River and Squaw Creek in CURE (sites 11, 15, 20, and 21; fig. 3) also drain basins with volcanic geology and also may be affected by agricultural activity in the lower parts of the basins.

Temporal Trend Analysis—Results and Discussion

Results for analysis of trend in ambient and flow-adjusted TN and TP concentrations are presented and discussed in this section of the report. Results and discussion on trends in ambient TN concentrations and TN FAC are presented first and are organized according to the time periods evaluated (that is, historical, recent, and variable time periods). The second section provides the results and discussion on trends in ambient TP concentrations and TP FAC and is organized according to the same time periods. Finally, a synthesis of trend results and a synthesis of exceedance and trend results are provided to integrate the results from the TN and TP sections.

For this study, a trend was identified as significant if the p-value was less than or equal to 0.10, which is a common p-value used in statistics. Because the p-value is selected somewhat arbitrarily, the distinctions between significant and non-significant also may be considered arbitrary. For example, for a site where a significant trend (p-value of 0.08) was identified for ambient concentrations and a nonsignificant trend (p-value of 0.12) was identified for the corresponding FAC, then the distinction between a significant and non-significant trend may be an artifact of the determination of statistical significance. For this example there may be no practicable difference between the significance of the two trends analyzed for this site. Where applicable, identification of sites with these types of results is included herein. Median reference condition (MRC), output from S-ESTREND in SPLUS®, is a representative value for typical conditions in the middle of the trend test period. These values vary considerably throughout the NCPN and are presented for each site along with the number of values used for the trend analysis, the trend slope (in milligrams per liter (mg/L) per year per year), the p-value from the trend test, and the determination of trend (that is, none, up, or down). An elevated MRC or an increase or decrease in concentration over time (as indicated by the trend slope) may be more consequential in terms of aquatic-health or regulatory concern in one stream location than another. Trend plots showing the data available as compared to the data used for the trend analysis (based on selected season definition) and the corresponding trend line(s) are provided for all sites with a significant upward or downward trend. Trend lines for significant upward or downward trends in FAC are adjusted by the MRC to plot on the trend plots. Trend lines for nonsignificant ambient or FAC trends are not shown on the trend plots. Censored and estimated values are identified on trend plots. The percentages of censored values, when provided in the text, reflect the number of censored values in the trend time period analyzed and not the number of censored values (as provided in table 6) for the full date range of available data. Time-series plots of streamflow values used for FAC calculations are provided for sites where significant trends in ambient (or flow-adjusted) TN concentrations were determined, but corresponding trends in flow-adjusted (or ambient) TN concentrations were not identified.

Trends in Total Nitrogen

Trends in ambient and flow-adjusted TN concentrations were evaluated for 34 and 22 sites, respectively, in and near NCPN park units and are presented herein. Results for analysis of trend in ambient TN concentrations are presented followed by results for analysis of trend in TN FAC. Trends in ambient concentrations represents trends at a site from natural (including streamflow) and human factors; trends in FAC remove the variability in concentrations caused by streamflow. More information on interpreting these two types of trends are discussed in the "Temporal Trend Analysis—Methods" section and explored in the summary and discussion section following the results.

Ambient Total Nitrogen Concentrations

Trends in ambient TN concentrations are presented below for the 4 sites evaluated for historical long-term trend for water years 1977 through 1998 (table 9); the 7 sites evaluated for recent, short-term trends for water years 2001 through 2006 (table 10), and for the 30 sites evaluated for trends with variable periods of record between 5 and 28 years for water years 1974 through 2007 (table 11). MRC ranged from 0.070 to 24.2 mg/L for all of these sites.

Historical Long-Term Trends (For Water Years 1977 Through 1998)

Four sites—COLM site 3 (Gunnison River near Grand Junction, Colo.), DINO site 30 (Green River near Greendale, Utah), ARCH site 46 (Colorado River near Cisco, Utah), and CANY site 66 (Green River at Green River, Utah)—had sufficient data for evaluation of historical long-term trends in ambient TN concentrations for water years 1977 through 1998 (figs. 2, 7, and 8; table 6). The TN data for these sites were uncensored (that is, all samples were measured at concentrations greater than the detection limit) allowing for analysis of trend using the uncensored Seasonal Kendall test (as described in the "Temporal Trend Analysis—Methods" section). These data were collected approximately bi-monthly or monthly during most of their record resulting in the selection of six seasons (for example, first season of first water year was October 1, 1977, through November 30, 1977) for the trend tests. Using a 6-season definition, all sites had between 89 and 110 results analyzed over the 21-year period (table 9). MRC ranged from 0.500 mg/L (DINO site 30) to 1.40 mg/L (COLM site 3) for the four sites evaluated.

Trends in ambient TN concentrations for water years 1977 through 1998 are summarized in table 9. Significant downward trends in ambient TN concentrations were identified for all four sites. Trend slopes were between -0.033 and -0.043 mg/L per year with p-values ranging from less than 0.001 to 0.003. Plots showing the TN data available as compared to the TN data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figures 19–22.

Recent Short-Term Trends (For Water Years 2001 Through 2006)

Seven sites—BLCA site 2 (Gunnison River below Gunnison Tunnel, Colo.); CURE sites 14 (Blue Creek at Highway 50 near Sapinero, Colo.), 20 (Cimarron River below Squaw Creek near Cimarron, Colo.), 24 (Gunnison River at County Road 32 below Gunnison, Colo.), 25 (Lake Fork Gunnison River below Gateview, Colo.), and 26 (Pine Creek at Highway 50 near Sapinero, Colo.); and DINO site 36 (Yampa River at Deerlodge Park, Colo.)—on or tributary to the Gunnison or Yampa Rivers had sufficient data for evaluation of recent short-term trends in ambient TN concentrations for water years 2001 through 2006 (table 6). The TN concentrations generally had very low percentages of censoring (between 0 and 5 percent for the data used for analysis), and all data were analyzed for trends using the uncensored Seasonal Kendall test. The TN data were collected approximately bi-monthly during most of the time period resulting in the selection of six seasons for the trend tests, though some quarterly samples were collected during the middle part of the record for some sites. Using a 6-season definition, all sites had 20 to 25 results available for analysis of trends in ambient TN concentrations (table 10). MRC ranged from 0.102 mg/L (CURE site 25) to 0.470 mg/L (CURE site 20) for the seven sites evaluated.

Trends in ambient TN concentrations for water years 2001 through 2006 are summarized in table 10. One significant upward trend in ambient TN concentrations was identified for CURE site 26 (Pine Creek at Highway 50 near Sapinero, Colo.). For this site, the trend slope was 0.018 mg/L per year with a p-value of 0.038. The plot showing the TN data available as compared to the TN data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figure 23*A*.

Trends for Sites with Variable Periods of Record

Data from 30 sites—BLCA site 2; COLM sites 3 and 4; CURE sites 7–9, 24, and 28; DINO sites 30–31, 33, and 35–37; ARCH sites 46–48 and 50; CANY sites 51–53, 55, and 66; HOVE site 71; CARE sites 80 and 84; and ZION sites 85, 91–92, and 95 (see table 6 for site information)—had sufficient data for evaluation of trends in ambient TN concentrations for one or more time periods. These 30 sites include alternative time periods evaluated for the 4 sites evaluated for historical, long-term trends (for water years 1977 through 1998) and 1 of the 7 sites (CURE site 24) evaluated for recent, short-term trends (for water years 2001 through 2006) in TN concentrations. Optimal time periods and seasons were selected for each site as described in the "Selection of Data for Trend Analysis" section of this report. The TN concentrations were 0 to 50 percent censored. Uncensored data or data with censoring generally less than 5 percent were analyzed for trends using the uncensored Seasonal Kendall test; data from sites with censoring generally greater than 5 percent were analyzed using the censored Seasonal Kendall test as described in the "Temporal Trend Analysis—Methods" section of this report. The TN data-collection frequency was highly variable as were the periods of record (fig. 13). The time periods analyzed ranged from 5 to 28 years for data collected between water years 1974 and 2007; no site had data for the entire time span (table 11). Ambient TN concentrations for 27 sites were analyzed using a 6-season definition; 2 sites had sufficient data to evaluate 12 seasons; and 2 sites had sufficient data to evaluate 3 or 4 seasons. Trends in ambient TN concentrations were evaluated for more than one time period from three sites (DINO sites 30, 31, and 36). Depending on the time period and seasonal definition, sites had between 18 and 190 results used for the trend analysis (table 11). MRC generally ranged from 0.070 mg/L (CURE site 28) to 1.40 mg/L (COLM site 3); an elevated MRC of 24.2 mg/L was computed for ARCH site 50, which is the Moab WWTP outflow (fig. 3).

Table 9. Historical long-term trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus at selected sites in the Northern Colorado Plateau Network for water years 1977 through 1998.

[mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N; number of values used for trend analysis; no., number; STAID, station (site) identifier; <, less than detection limit; --, not analyzed/no data; tests used the Seasonal Kendall uncensored trend test for a 6-season, 21-year definition; trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982); significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Location of sites shown in figs. 2, 7, and 8]

Site no.	STAID	Site name	Park code	MRC (mg/L)	Ambient concentration				Flow-adjusted concentration			
					N	Trend	p-value	Trend slope (mg/L per year)	N	Trend	p-value	Trend slope (mg/L per year)
Total nitrogen												
3	09152500	Gunnison River near Grand Junction	COLM[1]	1.40	110	**down**	**0.003**	**-0.033**	110	**down**	**0.002**	**-0.030**
30	09234500	Green River near Greendale	DINO	.500	105	**down**	**<.001**	**-.037**	105	**down**	**<.001**	**-.035**
46	COLO_1	Colorado River near Cisco	ARCH	1.13	109	**down**	**<.001**	**-.043**	96	**down**	**<.001**	**-.044**
66	GREEN_2	Green River at Green River	CANY[2]	.790	89	**down**	**.002**	**-.040**	89	**down**	**.001**	**-.040**
Total phosphorus												
[3]3	09152500	Gunnison River near Grand Junction	COLM[1]	.060	112	none	.966	0	--	--	--	--
[3]35	GREEN_1	Green River near Jensen	DINO	.070	119	none	.251	-.001	--	--	--	--
46	COLO_1	Colorado River near Cisco	ARCH	.100	124	none	.122	-.003	110	none	.374	-.002
66	GREEN_2	Green River at Green River	CANY[2]	.140	99	**down**	**.044**	**-.005**	99	**down**	**.025**	**-.006**
84	FREM_2	Fremont River near Bicknell	CARE	.070	104	**down**	**.004**	**-.002**	103	**down**	**.003**	**-.002**

[1] COLM is nearest park to this site (fig. 7), but this river is not associated with COLM; it was included to be representative of conditions on the Gunnison River downstream from BLCA and upstream from the river joining the Colorado River near COLM.

[2] CANY is nearest park to this site, but it is approximately 71 miles upstream from the park boundary; it was included to represent conditions between DINO and CANY and to capture changes in the water quality between these parks. ARCH is the nearest park to this site, but this river is not associated with ARCH (fig. 2).

[3] Sites 3 and 35 had total phosphorus censoring greater than 10 percent, thus the Seasonal Kendall censored test was used for these data and no flow-adjusted concentration trends were analyzed.

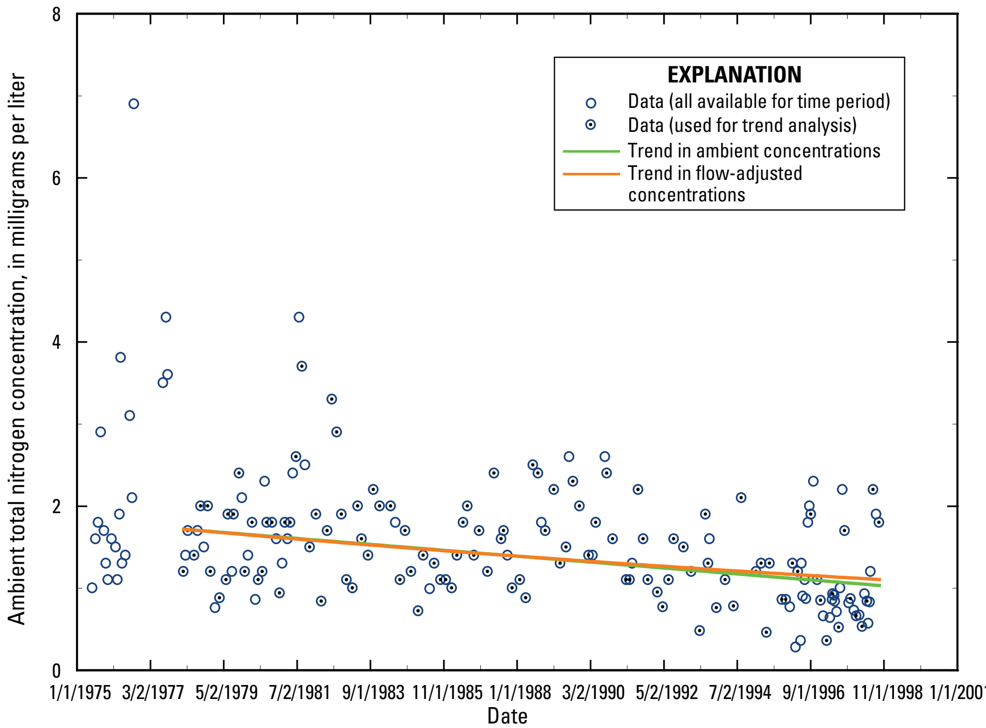


Figure 19. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 3, Gunnison River near Grand Junction, Colo., near Colorado National Monument, for water years 1977 through 1998. [Site information in table 6. Location of site shown in fig. 7.

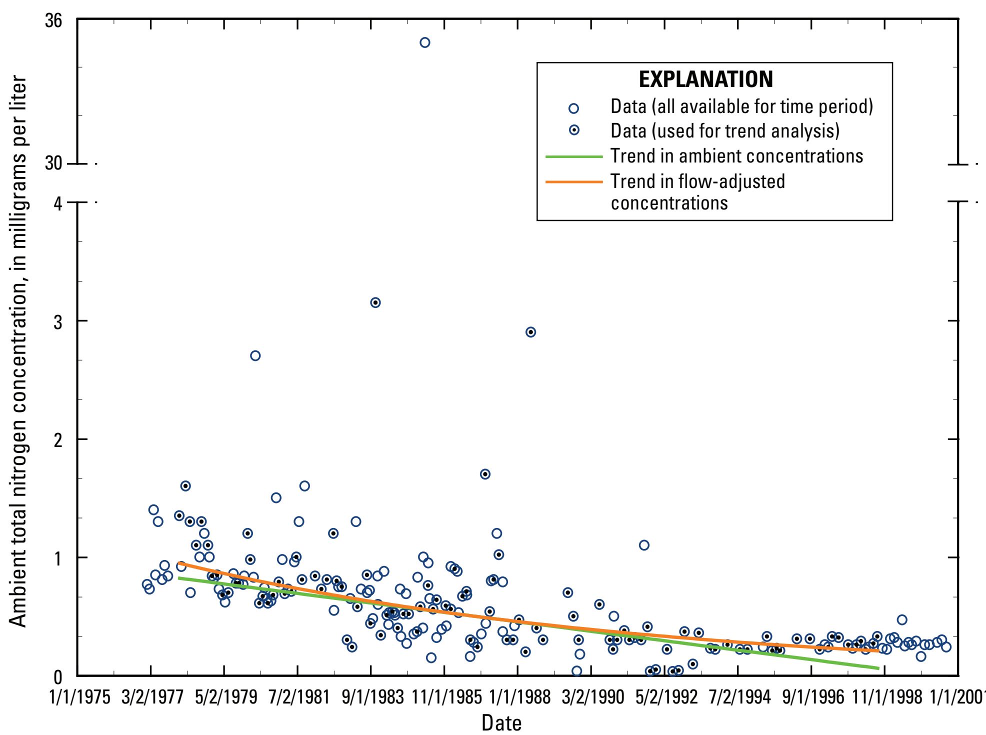


Figure 20. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 30, Green River near Greendale, Utah, upstream from Dinosaur National Monument, for water years 1977 through 1998. [Site information in table 6. Location of site shown in fig. 8.]

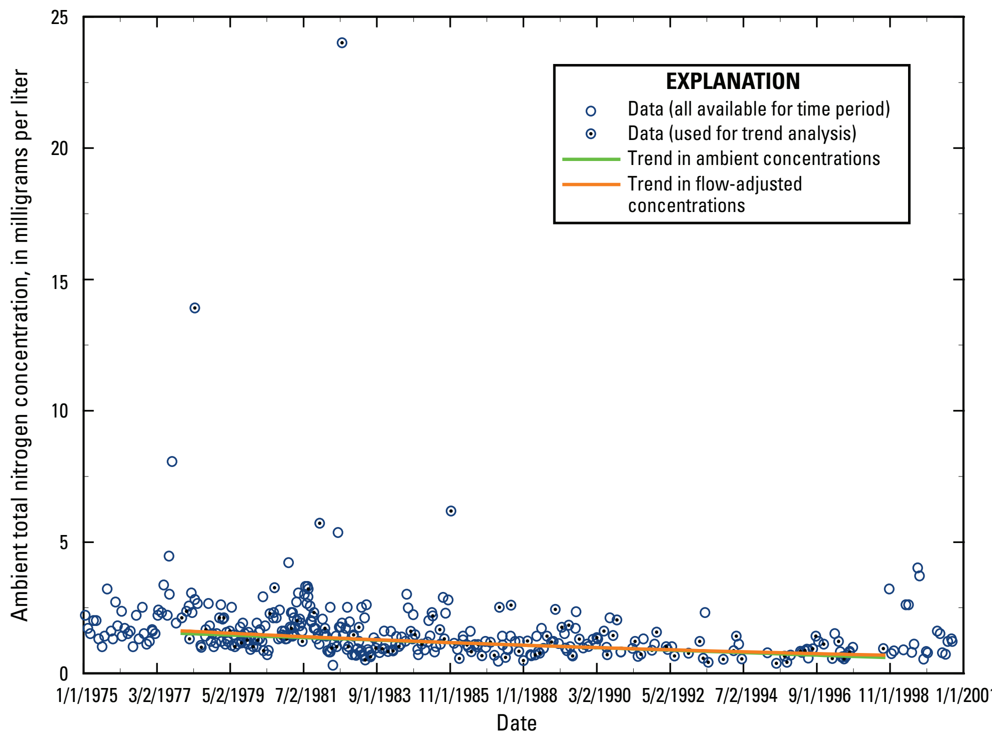


Figure 21. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 46, Colorado River near Cisco, Utah, upstream from Arches National Park, for water years 1977 through 1998. [Site information in table 6. Location of site shown in fig. 2.]

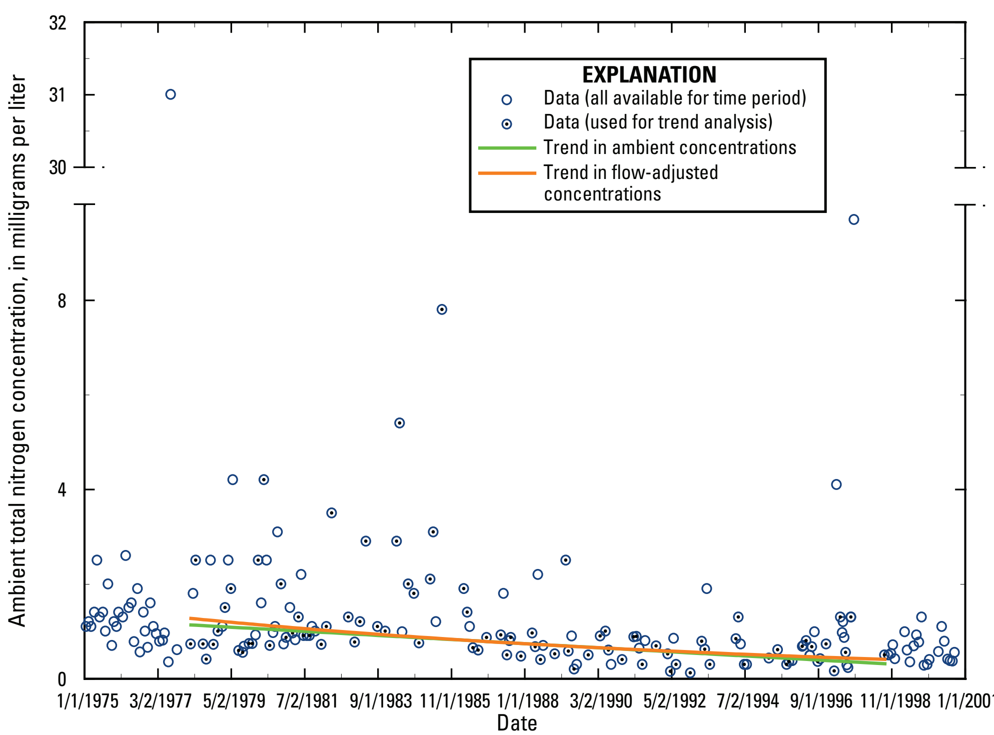


Figure 22. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 66, Green River at Green River, Utah, upstream from Canyonlands National Park, for water years 1977 through 1998. [Site information in table 6. Location of site shown in fig. 2.]

Table 10. Recent short-term trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus at selected sites in the Northern Colorado Plateau Network for water years 2001 through 2006.

[mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N; number of values used for trend analysis; no., number; STAID, station (site) identifier; <, less than detection limit; tests used the Seasonal Kendall uncensored trend test for a 6-season, 5-year definition; trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982); significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Location of sites shown in figs. 3 and 8]

Site no.	STAID	Site name	Park code	MRC (mg/L)	Ambient concentration				Flow-adjusted concentration			
					N	Trend	p-value	Trend slope (mg/L per year)	N	Trend	p-value	Trend slope (mg/L per year)
Total nitrogen												
2	CURE_GR01	Gunnison River below Gunnison Tunnel	BLCA	0.197	23	none	0.800	0.013	23	none	0.612	0.010
14	382418107-24600	Blue Creek at Highway 50 near Sapinero	CURE	.240	23	none	.897	-.004	21	none	1.00	<.001
20	CIMM_01	Cimarron River below Squaw Creek, near Cimarron	CURE	.470	23	none	.687	-.015	22	none	.491	-.013
24	GUNN_1	Gunnison River at County Road 32 below Gunnison	CURE	.233	25	none	.712	.009	24	none	.258	.011
25	LFKG_1	Lake Fork Gunnison River below Gateview	CURE	.102	24	none	.167	.009	20	**up**	**.071**	**.008**
26	PINE_1	Pine Creek at Highway 50 near Sapinero	CURE	.346	24	**up**	**.038**	**.018**	21	none	.578	.008
36	YAMP_1	Yampa River at Deer Lodge Park	DINO	.370	20	none	.869	.006	20	none	.620	-.025
Total phosphorus												
2	CURE_GR01	Gunnison River below Gunnison Tunnel	BLCA	.021	23	none	.311	.002	23	none	.447	.002
10	09125000	Curecanti Creek near Sapinero	CURE	.063	20	none	.451	-.003	16	**down**	**.091**	**-.005**
13	381633107-054700	Cebolla Creek at Bridge Southeast of Powderhorn	CURE	.068	21	none	.781	.002	17	none	.222	-.003
14	382418107-24600	Blue Creek at Highway 50 near Sapinero	CURE	.082	23	none	.697	.001	21	none	.578	.001
17	382937107-033500	Steuben Creek near Mouth near Gunnison	CURE	.065	21	none	.562	-.001	17	none	.222	.004
18	382943107-015300	Beaver Creek at High-Way 50 near Gunnison	CURE	.084	22	none	.789	.001	18	none	.575	.002
19	383137107-183600	Soap Creek above Chance Creek near Sapinero	CURE	.041	20	none	.437	-.002	16	none	.861	-.001
20	CIMM_01	Cimarron River below Squaw Creek, near Cimarron	CURE	.073	23	none	.104	.007	22	none	.890	.003
23	EELK_1	East Elk Creek near Mouth Near Sapinero	CURE	.151	22	none	.692	.001	18	none	.275	.003

Table 10. Recent short-term trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus at selected sites in the Northern Colorado Plateau Network for water years 2001 through 2006.—Continued

[mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N; number of values used for trend analysis; no., number; STAID, station (site) identifier; <, less than detection limit; tests used the Seasonal Kendall uncensored trend test for a 6-season, 5-year definition; trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982); significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Location of sites shown in figs. 3 and 8]

Site no.	STAID	Site name	Park code	MRC (mg/L)	Ambient concentration N	Ambient concentration Trend	Ambient concentration p-value	Ambient concentration Trend slope (mg/L per year)	Flow-adjusted concentration N	Flow-adjusted concentration Trend	Flow-adjusted concentration p-value	Flow-adjusted concentration Trend slope (mg/L per year
				Total phosphorus—Continued								
24	GUNN_1	Gunnison River at County Road 32 below Gunnison	CURE	0.028	25	none	0.804	<0.001	24	none	0.900	<0.001
25	LFKG_1	Lake Fork Gunnison River below Gateview	CURE	.023	24	none	.530	<.001	20	none	.332	.001
26	PINE_1	Pine Creek at Highway 50 near Sapinero	CURE	.110	24	none	1.00	0	21	none	.578	-.003
27	RED_1	Red Creek near Mouth near Sapinero	CURE	.185	22	none	.895	.001	18	none	1.00	-.001
29	WELK_1	West Elk Creek below Forest Boundary near Sapinero	CURE	.062	22	**up**	**.070**	**.003**	19	none	1.00	.001
36	YAMP_1	Yampa River at Deer Lodge Park	DINO	.045	24	none	.590	-.001	14	none	.798	-.007

Trends in ambient TN concentrations for sites with variable periods of record for water years 1974 through 2007 are summarized in table 11. Twenty-one sites indicated no trends, two sites indicated upward trends, and nine sites indicated downward trends. Significant upward trends in ambient TN concentrations were identified for DINO site 30 (Green River near Greendale, Utah) from 1991 through 2000, and for DINO site 31 (Yampa River below Craig, Colo.) from 1991 through 2002. For these two sites, the trend slopes were 0.010 and 0.017 mg/L per year, respectively, with a corresponding p-value of 0.027 for both sites. The plots showing the TN data available as compared to the TN data used (based on a 6-season (site 30) and 4-season (site 31) definition) for the trend analysis and the corresponding trend line are provided in figures 24 and 25.

Significant downward trends in ambient TN concentrations were identified for nine sites—COLM site 3 (Gunnison River near Grand Junction, Colo., from 1975 through 1998); DINO site 30 (Green River near Greendale, Utah, from 1974 through 1992 and also from 1974 through 2000) and site 35 (Green River near Jensen, Utah, from 1977 through 1990); ARCH site 46 (Colorado River near Cisco, Utah, from 1975 through 2001), site 47 (Colorado River at U.S. 191 crossing near Moab, Utah, from 1978 through 1990), and site 48 (Dolores River at mouth, Utah, from 1980 through 1990); CANY site 52 (Colorado River above confluence with Green River, Utah, from 1983 through 1988) and site 66 (Green River at Green River, Utah, from 1974 through 2000); and CARE site 84 (Fremont River near Bicknell, Utah, from 1979 through 1991) (see table 6 for additional site information). For these nine sites, between 5 and 26 years were analyzed for trends with time periods ranging from 1974 through 2001. Trend slopes ranged from -0.016 mg/L per year (DINO site 35) to -0.230 mg/L per year (CANY site 52) with p-values ranging from less than 0.001 to 0.083 for these nine sites. Trend plots showing the TN data available as compared to the TN data used for the trend analysis -- based on a 6-season (sites 3, 30, 35, 46, 47, 52, and 84) or a 12-season (sites 48 and 66) definition -- and the corresponding trend line are provided in figures 26 through 34 for sites 3, 30, 35, 46, 48, 47, 52, 66, and 84, respectively.

Flow-Adjusted Total Nitrogen Concentrations

For 22 sites with sufficient streamflow data (as described in the “Selection of Data for Trend Analysis” section), trends in flow-adjusted TN concentrations are presented for the same 4 sites evaluated for historical long-term trends in ambient TN concentrations for water years 1977 through 1998, the same 7 sites evaluated for recent short-term trends in ambient TN concentrations for water years 2001 through 2006, and for 17 of the 30 sites evaluated for trends in ambient TN concentrations with variable periods of record (ranging from 5 to 28 years for water years 1974 through 2007).

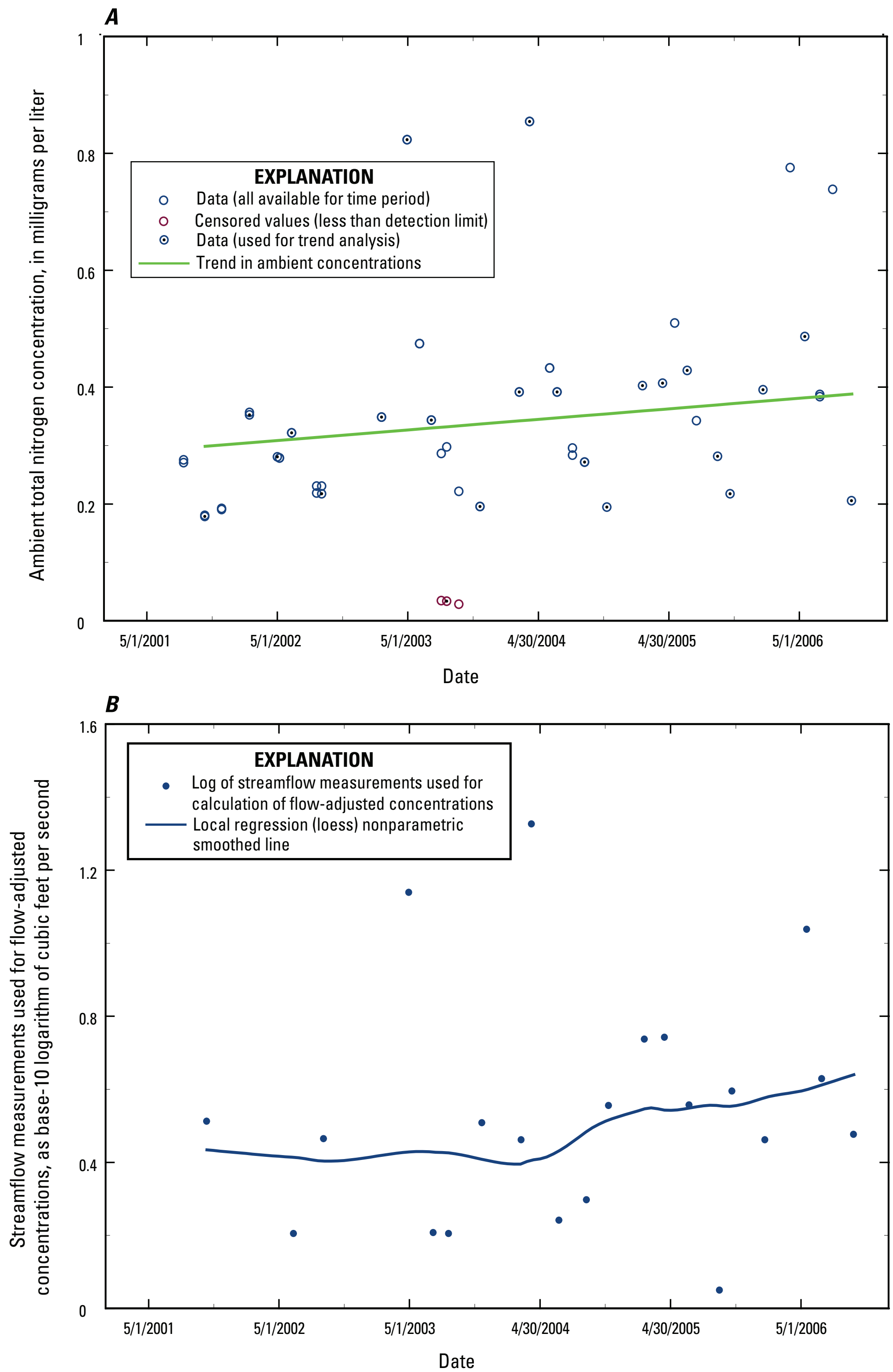


Figure 23. *A*, Trend in ambient total nitrogen concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 26, Pine Creek at Highway 50 near Sapinero, Colo., in Curecanti National Recreation Area, for water years 2001 through 2006. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3.]

Table 11. Trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus at selected sites in the Northern Colorado Plateau Network for variable periods of record for water years 1974 through 2007.

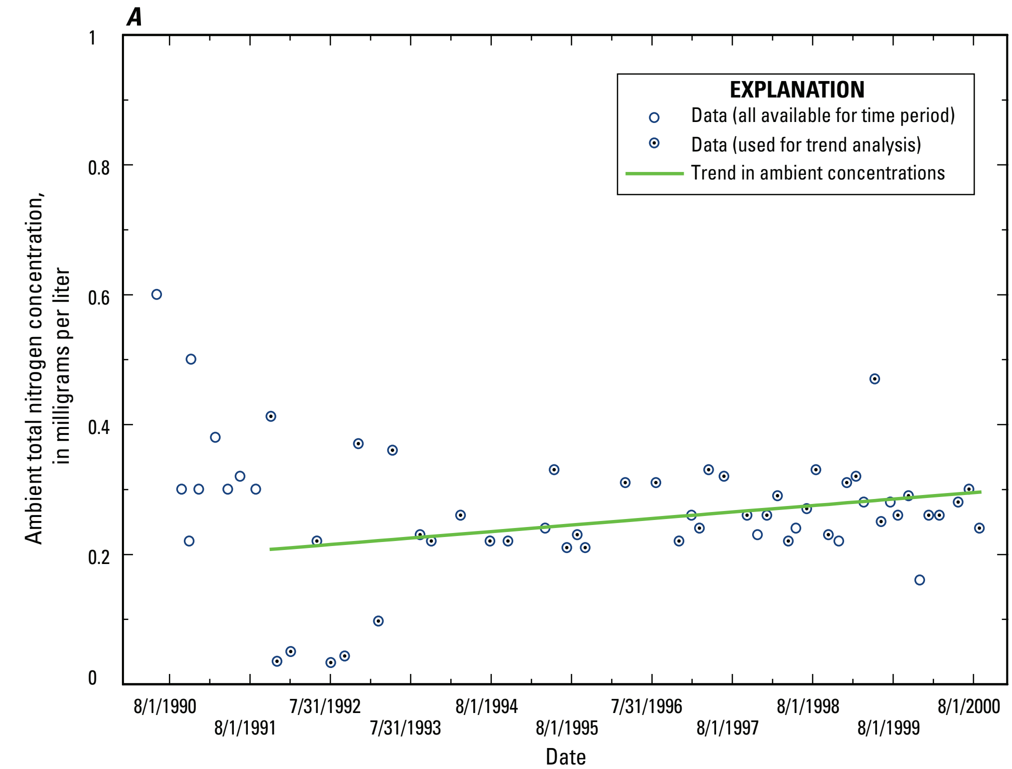
[BE year, beginning water year of trend analysis; mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N, number of values used for trend analysis; no., number; S, number of seasons; <, less than; --, no data, insufficient data, too many censored values, or insufficient corresponding streamflow data; *, sites with multiple time periods analyzed; significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Location of sites shown in figs. 2–8, and 11. Applicable figures for site locations listed beside park code subheaders. Trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982)]

Site no.	BE year	Years	S	MRC (mg/L)	Total nitrogen								MRC (mg/L)	Total phosphorus							
					Ambient concentration				Flow-adjusted concentration					Ambient concentration				Flow-adjusted concentration			
					N	Trend	p-value	Trend slope (mg/L per year)	N	Trend	p-value	Trend slope (mg/L per year)		N	Trend	p-value	Trend slope (mg/L per year)	N	Trend	p-value	Trend slope (mg/L per year)
BLCA (fig. 3)																					
1	1996	10	3	--	--	--	--	--	--	--	--	--	0.067	15	none	0.116	–0.001	13	none	0.186	–0.01
2	1999	7	6	0.199	30	none	0.425	0.002	29	none	0.234	0.007	.022	30	none	.535	.001	29	none	.522	.001
COLM (fig. 7)																					
3	1975	23	6	1.40	118	**down**	**.001**	**–.036**	118	**down**	**<.001**	**–.032**	.060	124	none	.574	<.001	--	--	--	--
4	1979	12	6	.790	64	none	.362	–.010	--	--	--	--	.130	71	**down**	**.059**	**–.005**	--	--	--	--
CURE (fig. 3)																					
6	1994	11	6	--	--	--	--	--	--	--	--	--	.030	57	none	.113	–.001	--	--	--	--
7	1995	7	6	.130	37	none	.815	–.001	--	--	--	--	.005	37	none	.210	–.001	--	--	--	--
8	1995	7	6	.135	34	none	.655	.010	--	--	--	--	.015	34	none	.699	<.001	--	--	--	--
9	1995	7	6	.270	35	none	.815	.005	--	--	--	--	.041	35	**up**	**.073**	**.001**	35	**up**	**.034**	**.003**
17	1995	10	4	--	--	--	--	--	--	--	--	--	.062	23	none	.930	.001	15	none	.175	.005
24	1998	8	6	.230	40	none	.849	–.001	39	none	.845	.003	.032	40	**down**	**.003**	**–.003**	39	**down**	**.016**	**–.002**
25	1995	10	4	--	--	--	--	--	--	--	--	--	.029	23	**down**	**.015**	**–.001**	18	none	.300	–.001
28	1994	6	6	.070	28	none	1.00	.018	--	--	--	--	--	--	--	--	--	--	--	--	--
29	1999	7	4	--	--	--	--	--	--	--	--	--	.066	21	**up**	**.056**	**.003**	17	none	.170	.005
DINO (fig. 8)																					
*30	1974	18	6	.710	98	**down**	**<.001**	**–.049**	98	**down**	**<.001**	**–.048**	.020	98	none	.406	<.001	--	--	--	--
*30	1974	26	6	.520	135	**down**	**<.001**	**–.034**	135	**down**	**<.001**	**–.031**	--	--	--	--	--	--	--	--	--
*30	1991	9	6	.260	42	**up**	**.027**	**.010**	42	none	.114	.009	--	--	--	--	--	--	--	--	--
*31	1975	27	6	.525	72	none	–.004	.251	71	none	.182	–.005	.070	64	**down**	**.005**	**–.002**	--	--	--	--
*31	1990	12	4	.400	39	**up**	**.027**	**.017**	39	**up**	**.080**	**.016**	.037	31	none	.489	.001	--	--	--	--
*33	1977	10	6	.510	52	none	.198	–.029	--	--	--	--	.020	53	none	1.00	0	--	--	--	--
*33	1976	19	3	--	--	--	--	--	--	--	--	--	.020	48	**down**	**.041**	**–.001**	--	--	--	--
*35	1977	13	6	.600	73	**down**	**.076**	**–.016**	70	none	.160	–.014	.070	75	none	.982	0	--	--	--	--
*35	1976	30	6	--	--	--	--	--	--	--	--	--	.054	167	**down**	**.002**	**–.002**	129	none	.145	–.001
*36	1996	10	6	.402	40	none	.580	–.003	40	none	1.00	<–.001	.044	46	none	.606	–.001	30	none	.738	–.001
*36	1978	28	6	.530	105	none	.136	–.016	--	--	--	--	.050	115	none	.324	<–.001	--	--	--	--
37	1974	18	6	.850	77	none	.632	–.007	77	none	.654	–.008	.050	86	none	.172	–.001	--	--	--	--
FOBU (fig. 9)																					
38	1975	19	6	--	--	--	--	--	--	--	--	--	.040	54	none	.535	–.001	--	--	--	--
ARCH (fig. 2, fig. 5 site 45)																					
*46	1975	26	6	1.20	133	**down**	**.001**	**–.032**	114	**down**	**.008**	**–.030**	.090	151	none	.468	<–.001	129	none	.525	–.001
*46	1975	32	12	--	--	--	--	--	--	--	--	--	.092	307	none	.192	–.001	--	--	--	--
*47	1978	12	6	1.19	68	**down**	**.083**	**–.037**	--	--	--	--	.160	69	none	.498	–.004	--	--	--	--
*47	1977	22	6	--	--	--	--	--	--	--	--	--	.144	108	none	.208	–.003	--	--	--	--

Table 11. Trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus at selected sites in the Northern Colorado Plateau Network for variable periods of record for water years 1974 through 2007.—Continued

[BE year, beginning water year of trend analysis; mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N, number of values used for trend analysis; no., number; S, number of seasons; <, less than; --, no data, insufficient data, too many censored values, or insufficient corresponding streamflow data; *, sites with multiple time periods analyzed; significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Location of sites shown in figs. 2–8, and 11. Applicable figures for site locations listed beside park code subheaders. Trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982)]

Site no.	BE year	Years	S	Total nitrogen: MRC (mg/L)	Total nitrogen, Ambient concentration: N	Trend	p-value	Trend slope (mg/L per year)	Total nitrogen, Flow-adjusted concentration: N	Trend	p-value	Trend slope (mg/L per year)	Total phosphorus: MRC (mg/L)	Total phosphorus, Ambient concentration: N	Trend	p-value	Trend slope (mg/L per year)	Total phosphorus, Flow-adjusted concentration: N	Trend	p-value	Trend slope (mg/L per year)
ARCH (fig. 2, fig. 5 site 45)—Continued																					
*48	1980	10	12	1.03	84	**down**	**0.019**	**–0.078**	--	--	--	--	0.083	86	none	0.139	–0.006	--	--	--	--
*48	1980	18	12	--	--	--	--	--	--	--	--	--	.086	137	**down**	**.051**	**–.003**	--	--	--	--
*50	1978	10	6	24.2	29	none	.166	–.644	20	none	1.00	0	6.45	47	**down**	**.041**	**–.173**	38	**down**	**0.021**	**–0.184**
*50	1977	30	6	--	--	--	--	--	--	--	--	--	6.14	74	**down**	**<.001**	**–.126**	42	**down**	**.003**	**–.181**
CANY (fig. 5, fig. 2 sites 63 and 66)																					
*51	1983	5	6	.790	19	none	.252	–.070	--	--	--	--	.270	19	none	.747	–.020	--	--	--	--
*51	1983	23	4	--	--	--	--	--	--	--	--	--	.315	57	none	.605	–.002	--	--	--	--
52	1983	5	6	1.26	19	**down**	**.024**	**–.230**	--	--	--	--	.200	19	none	.623	–.001	--	--	--	--
*53	1979	9	3	.890	19	none	.550	.026	--	--	--	--	.260	19	none	.842	.003	--	--	--	--
*53	1983	23	4	--	--	--	--	--	--	--	--	--	.216	47	none	.932	<–.001	--	--	--	--
54	1999	7	6	--	--	--	--	--	--	--	--	--	.204	22	none	.211	.026	--	--	--	--
*55	1983	5	6	1.31	18	none	.452	–.163	--	--	--	--	.115	18	none	.119	–.020	--	--	--	--
*55	1983	13	4	--	--	--	--	--	--	--	--	--	.135	34	none	.448	–.010	--	--	--	--
62	1992	14	6	--	--	--	--	--	--	--	--	--	.110	40	none	.626	<–.001	--	--	--	--
66	1974	26	12	.910	190	**down**	**.001**	**–.030**	190	**down**	**<.001**	**–.030**	.160	207	**down**	**.062**	**–.003**	203	**down**	**.048**	**–.004**
HOVE (fig. 11)																					
*71	1985	5	6	1.25	23	none	.782	–.025	21	none	.873	.078	.084	24	**down**	**.051**	**–.031**	22	none	.309	–.016
*71	1985	8	6	--	--	--	--	--	--	--	--	--	.126	38	none	.727	.003	36	none	1.00	.001
73	1998	8	6	--	--	--	--	--	--	--	--	--	.108	34	none	.173	.006	--	--	--	--
CARE (fig. 6)																					
79	1993	8	6	--	--	--	--	--	--	--	--	--	.052	39	**down**	**.081**	**–.002**	28	**down**	**.064**	**–.003**
*80	1979	11	6	.890	61	none	.977	–.001	--	--	--	--	.335	62	none	.496	–.010	--	--	--	--
*80	1977	25	6	--	--	--	--	--	--	--	--	--	.367	127	none	.752	–.001	--	--	--	--
83	1977	26	4	--	--	--	--	--	--	--	--	--	.080	49	none	.221	–.001	--	--	--	--
*84	1979	12	6	.975	54	**down**	**.031**	**–.034**	53	**down**	**.084**	**–.028**	.080	58	**down**	**.036**	**–.004**	57	**down**	**.012**	**–.005**
*84	1976	30	6	--	--	--	--	--	--	--	--	--	.060	153	**down**	**<.001**	**–.002**	117	**down**	**<.001**	**–.002**
ZION (fig. 4)																					
*85	1984	6	6	.900	31	none	.226	–.060	28	none	.445	–.036	.041	33	**down**	**.056**	**–.010**	30	none	.326	–.007
*85	1983	23	6	--	--	--	--	--	--	--	--	--	.039	120	**down**	**.043**	**–.001**	--	--	--	--
89	1986	20	12	--	--	--	--	--	--	--	--	--	.010	118	none	.302	<–.001	--	--	--	--
90	1997	9	12	--	--	--	--	--	--	--	--	--	.024	93	none	.625	0	--	--	--	--
91	1981	9	6	.510	39	none	.376	–.023	31	none	.855	–.009	.080	41	**down**	**.009**	**–.019**	33	none	.934	–.004
*92	1980	10	6	.345	44	none	.277	–.013	28	none	.773	.013	.040	46	**down**	**.061**	**–.011**	--	--	--	--
*92	1980	26	6	--	--	--	--	--	--	--	--	--	.025	130	**down**	**.016**	**–.001**	--	--	--	--
95	1982	8	6	.530	37	none	.338	.020	35	none	.153	.030	.110	39	**down**	**.048**	**–.014**	37	none	.384	–.007



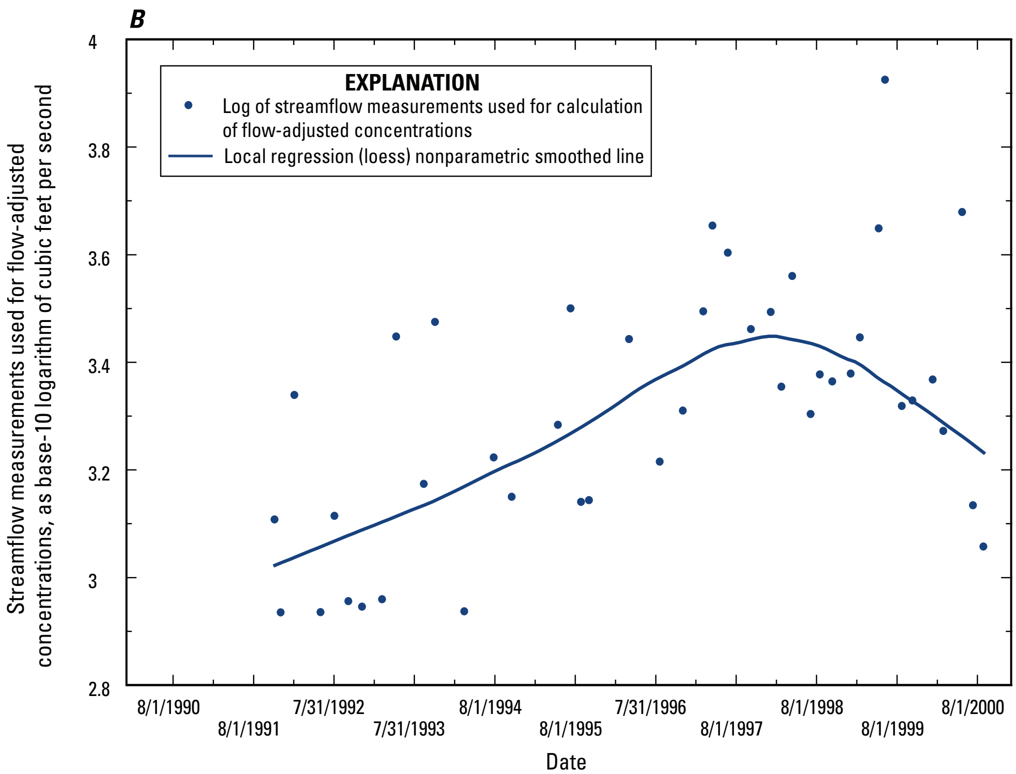


Figure 24. *A*, Trend in ambient total nitrogen concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 30, Green River near Greendale, Utah, upstream from Dinosaur National Monument, for water years 1991 through 2000. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 8.]

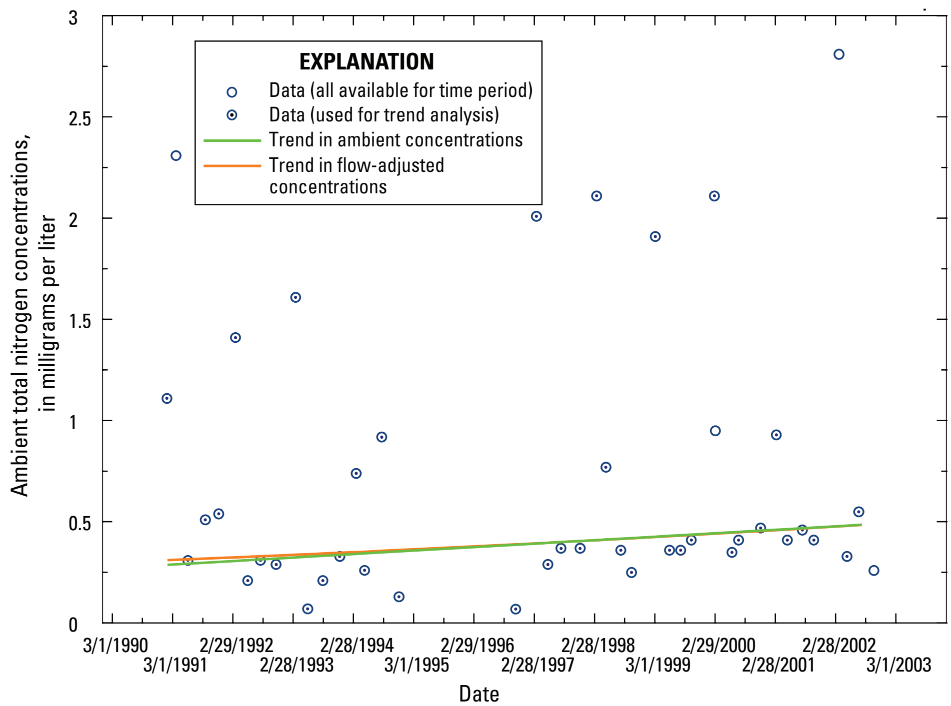


Figure 25. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 31, Yampa River below Craig, Colo., upstream from Dinosaur National Monument, for water years 1990 through 2002. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 8.]

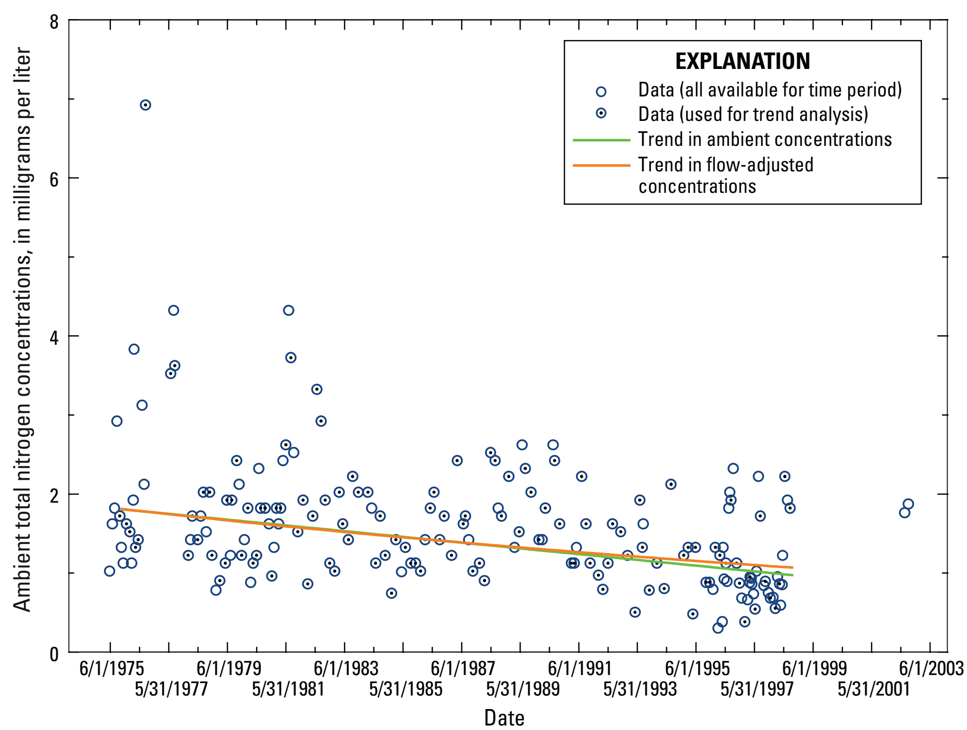


Figure 26. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 3, Gunnison River near Grand Junction, Colo., near Colorado National Monument, for water years 1975 through 1998. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 7.]

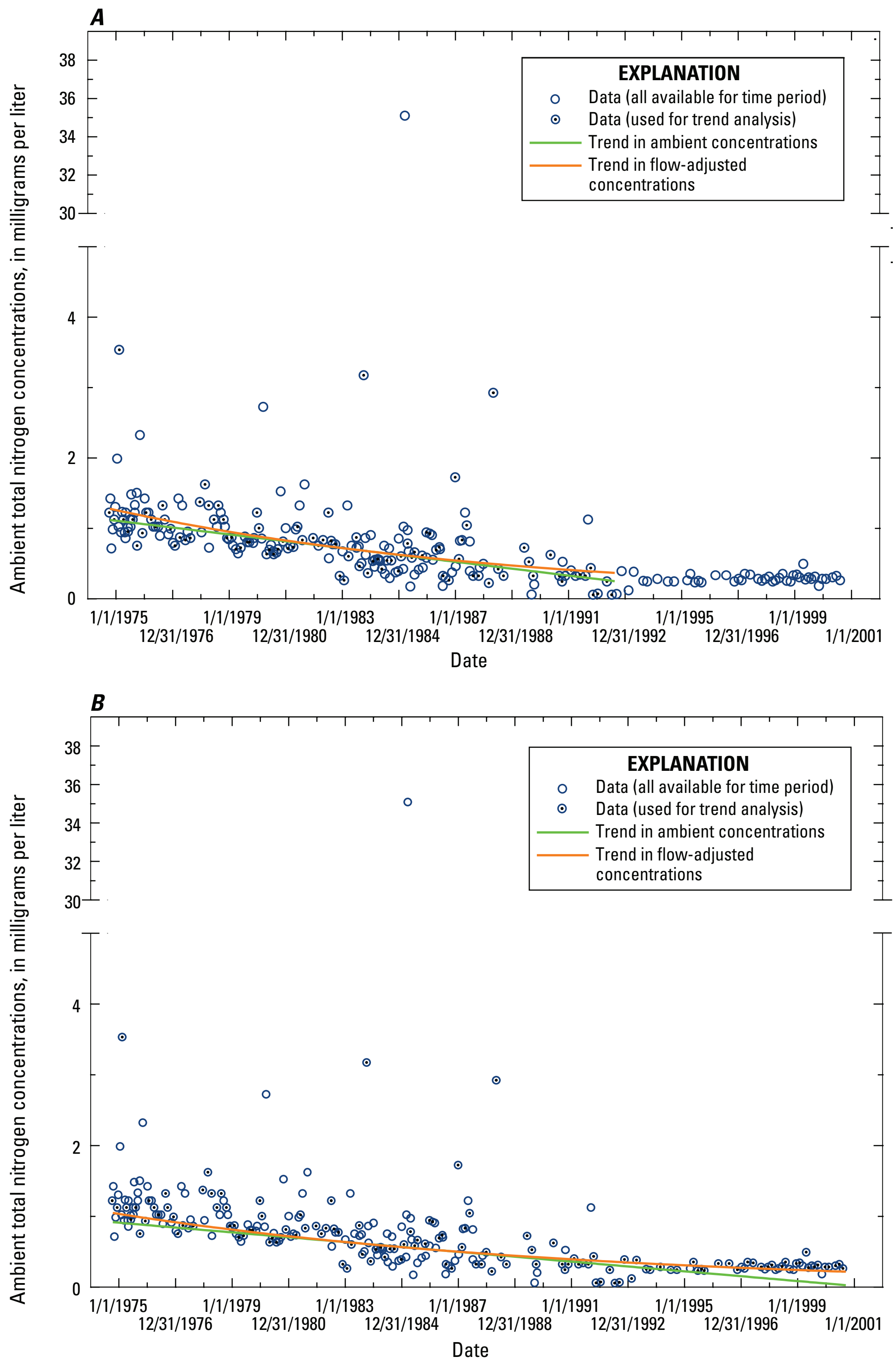


Figure 27. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 30, Green River near Greendale, Utah, upstream from Dinosaur National Monument, for water years *A*, 1974 through 1992 and *B*, 1974 through 2000. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 8.]

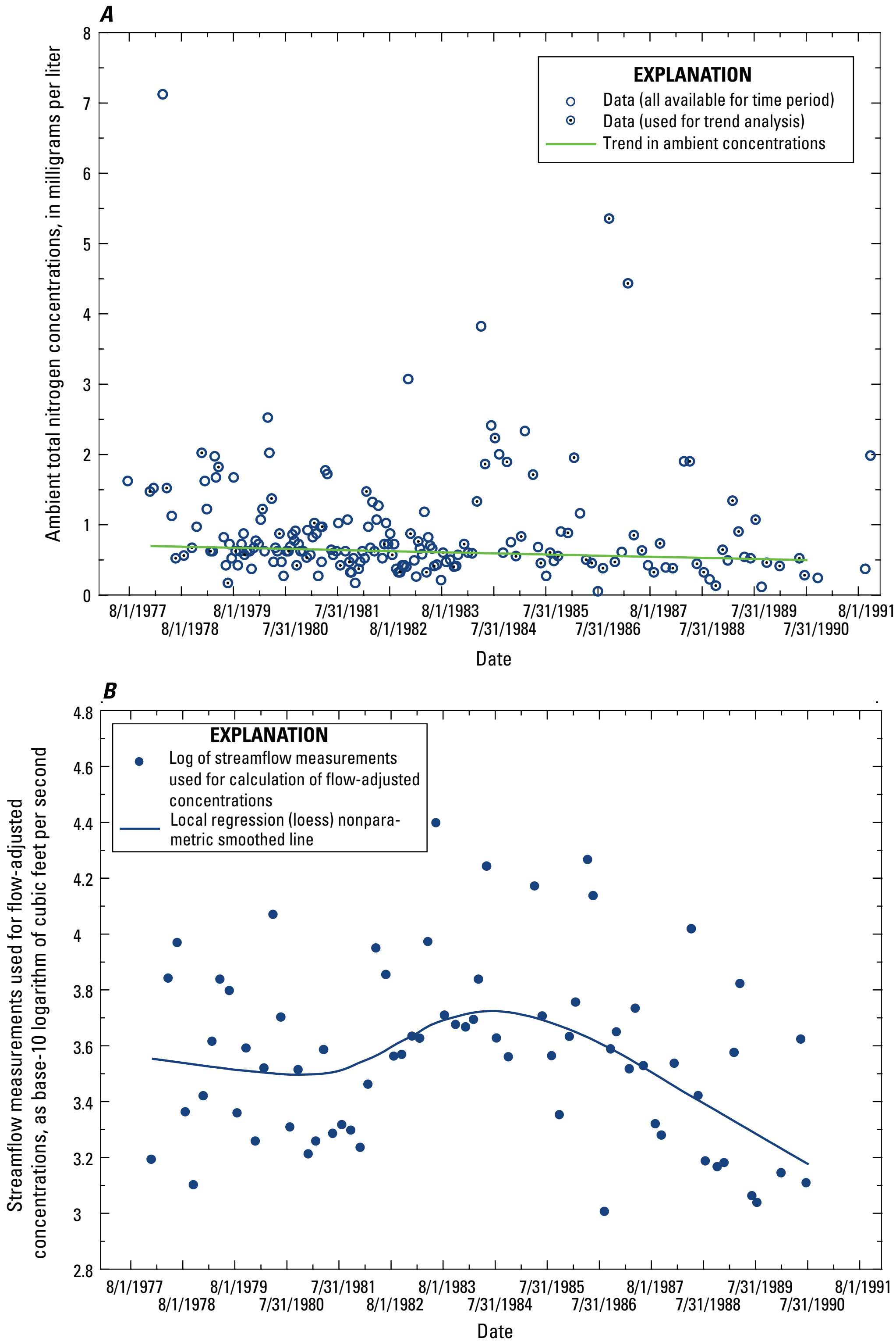


Figure 28. *A*, Trend in ambient total nitrogen concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 35, Green River near Jensen, Utah, downstream from Dinosaur National Monument, for water years 1977 through 1990. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 8.]

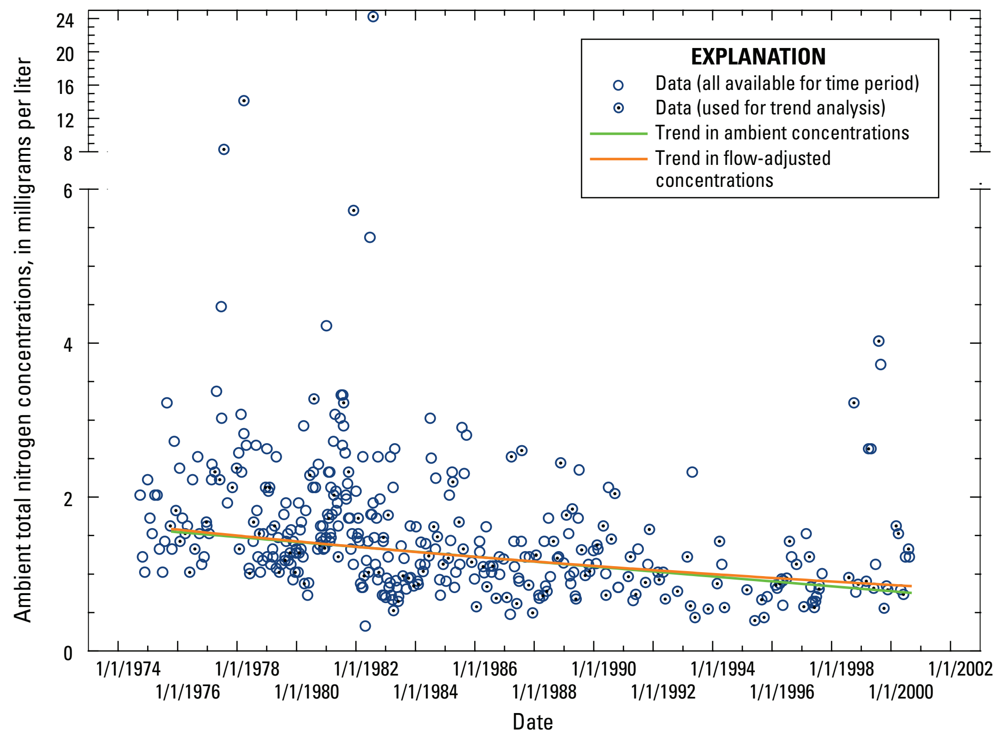


Figure 29. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 46, Colorado River near Cisco, Utah, upstream from Arches National Park, for water years 1975 through 2001. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 2.]

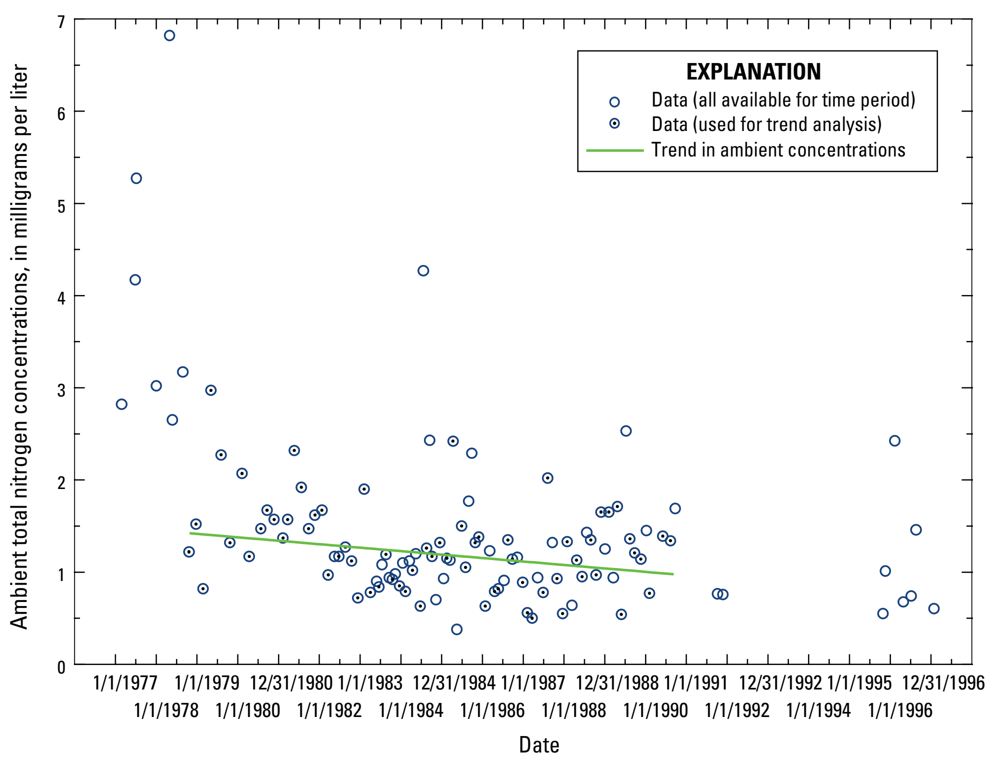


Figure 30. Trend in ambient total nitrogen concentrations for site 47, Colorado River at U.S. 191 crossing near Moab, Utah, downstream from Arches National Park, for water years 1978 through 1990. [Site information in table 6. Location of site shown in fig. 2.]

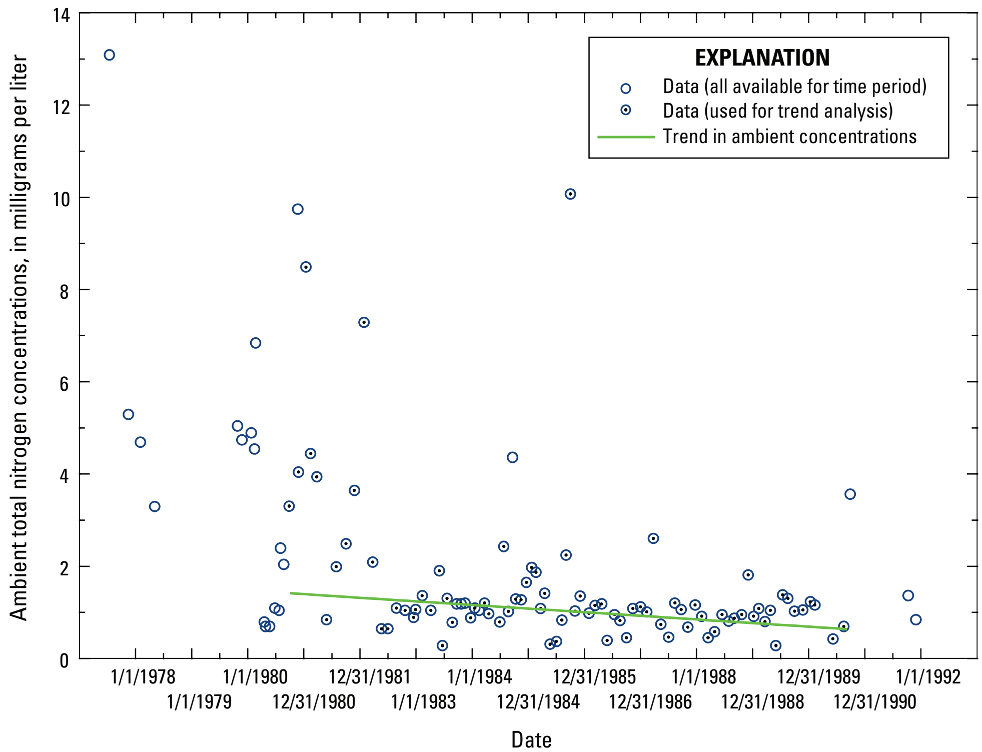


Figure 31. Trend in ambient total nitrogen concentrations for site 48, Dolores River at mouth, Utah, upstream from Arches National Park, for water years 1980 through 1990. [12-season definition used for trend analysis. Site information in table 6. Location of site shown in fig. 2.]

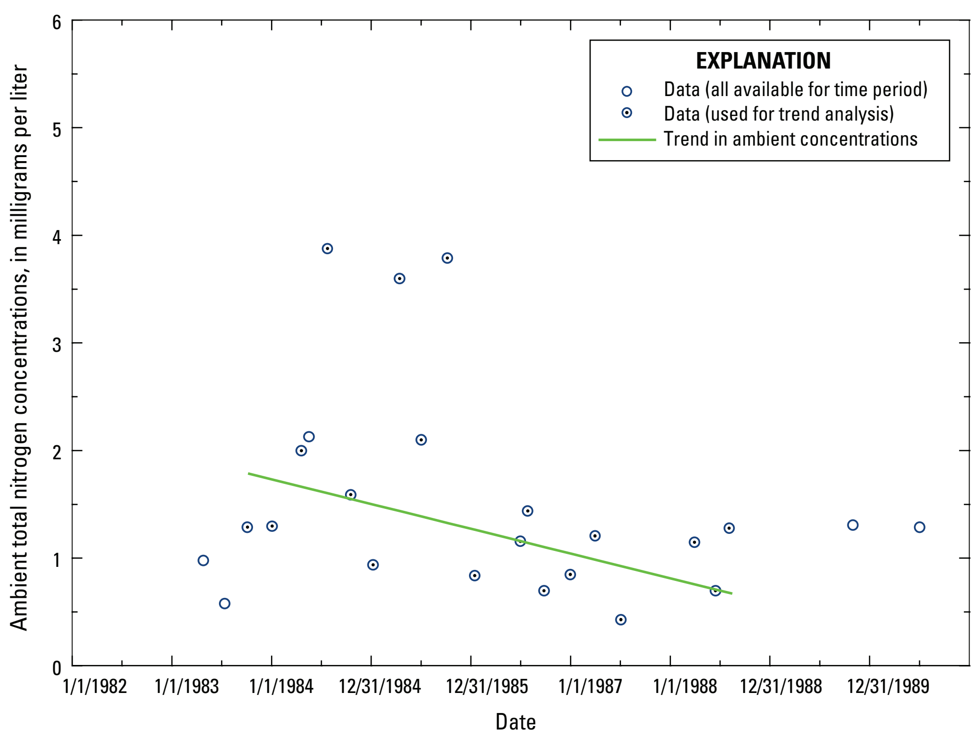


Figure 32. Trend in ambient total nitrogen concentrations for site 52, Colorado River above confluence with Green River, Utah, in Canyonlands National Park, for water years 1983 through 1988. [12-season definition used for trend analysis. Site information in table 6. Location of site shown in fig. 5.]

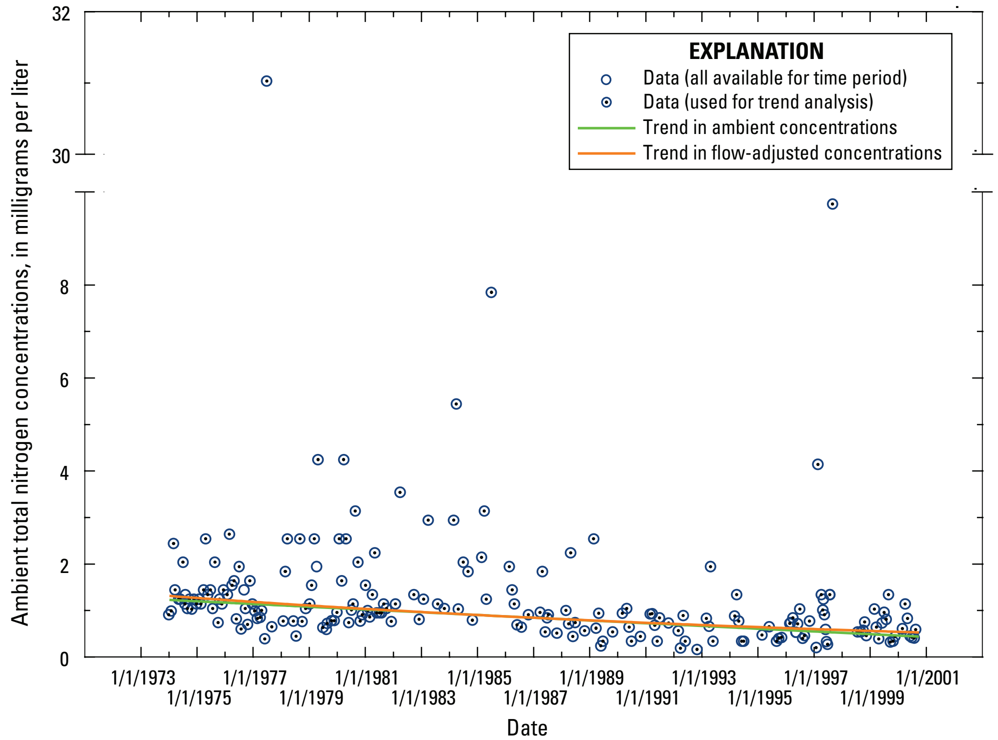


Figure 33. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 66, Green River at Green River, Utah, upstream from Canyonlands National Park, for water years 1974 through 2000. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 2.]

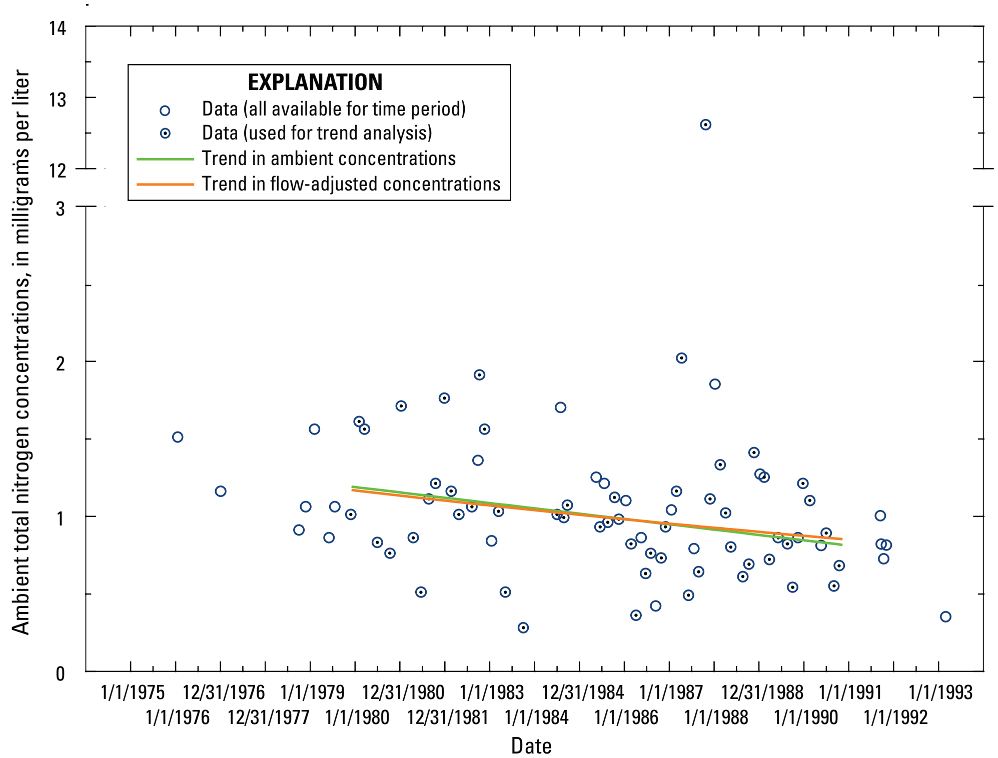


Figure 34. Trends in ambient total nitrogen concentrations and flow-adjusted concentrations for site 84, Fremont River near Bicknell, Utah, upstream from Capitol Reef National Park, for water years 1979 through 1991. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 6.]

Plots for streamflow measurements used for FAC calculations are presented for sites where differences in trends were identified for ambient concentrations as compared to FAC. For these sites, results for trends in streamflow using linear regression or Seasonal Kendall test (as described in the "Selection of Data for Trend Analysis" section) are described when significant (p-value less than 0.10). These trend tests used all available streamflow measurements corresponding with all water-quality samples collected during the time periods analyzed for each site.

Historical Long-Term Trends (For Water Years 1977 Through 1998)

The same four sites evaluated for historical long-term trends in ambient TN concentrations —COLM site 3 (Gunnison River near Grand Junction, Colo.), DINO site 30 (Green River near Greendale, Utah), ARCH site 46 (Colorado River near Cisco, Utah), and CANY site 66 (Green River at Green River, Utah)—had sufficient data for evaluation of trends in flow-adjusted TN concentrations for water years 1977 through 1998 (table 6). As previously stated, the TN data for these four sites were uncensored, which allowed for analysis of FAC using the log-log loess model with the Seasonal Kendall test (as described in the "Temporal Trend Analysis—Methods" section) using the same 6-season definition. Using six seasons, all sites had between 89 and 110 results analyzed over this 21-year period (table 9). Site 46 was the only site where fewer data (96 results instead of 109 results or 88 percent) were used for the trend in FAC than were used for the trend in ambient concentrations.

Trends in FAC for water years 1977 through 1998 are summarized in table 9. Significant downward trends in FAC were identified for all four sites, which also had significant downward trends in ambient TN concentrations. Trend slopes were between -0.030 and -0.044 mg/L per year with p-values ranging from less than 0.001 to 0.002, which are comparable to the values determined for the downward trend in ambient TN concentrations. Plots showing the TN data available as compared to the TN data used (based on a 6-season definition) for the trend analysis and the corresponding FAC trend line are provided in figures 19–22.

Recent Short-Term Trends (For Water Years 2001 Through 2006)

The same seven sites evaluated for recent short-term trends in ambient TN concentrations—BLCA site 2 (Gunnison River below Gunnison Tunnel, Colo.); CURE sites 14 (Blue Creek at Highway 50 near Sapinero, Colo.), 20 (Cimarron River below Squaw Creek near Cimarron, Colo.), 24 (Gunnison River at County Road 32 below Gunnison, Colo.), 25 (Lake Fork Gunnison River below Gateview, Colo.), and 26 (Pine Creek at Highway 50 near Sapinero, Colo.); and DINO site 36 (Yampa River at Deerlodge Park, Colo.)—had sufficient data for evaluation of trends in flow-adjusted TN concentrations for water years 2001 through 2006. As previously stated, the TN data for these seven sites had low percentages of censoring, which allowed for analysis of FAC using the log-log loess model with the Seasonal Kendall test (as described in the "Temporal Trend Analysis - Methods" section) using the same 6-season definition. Using six seasons, all sites had between 20 and 24 results analyzed over this 5-year period (table 10). Sites had contemporaneous streamflow measurements for between 83 and 100 percent of the TN data.

Trends in FAC for water years 2001 through 2006 are summarized in table 10. Trends in FAC were different from corresponding trends in ambient concentrations at two sites (CURE sites 25 and 26). A significant upward trend in FAC was identified for CURE site 25 (Lake Fork Gunnison River below Gateview, Colo.) without a corresponding trend in ambient TN concentrations. For this site, the trend slope was 0.008 mg/L per year with a p-value of 0.071. The plot showing the TN data available as compared to the TN data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figure 35. Although a significant upward trend in ambient TN concentrations was not identified for this site, the results were generally comparable (slope = 0.009 mg/L per year, p-value = 0.167) suggesting that the differences between trends for the ambient and FAC tests may be an artifact of the determination of statistical significance. Streamflow measurements used for the FAC calculations for site 25 are presented in figure 35*B*. A significant trend in streamflow was not identified for site 25; however, two higher [greater than 500 cubic feet per second (ft^3/s)] streamflow measurements made in 2005 may have obscured the weak trend evident in the ambient TN concentrations.

In contrast to site 25, when the effects of streamflow are removed, no upward trend in flow-adjusted TN concentrations was identified for site 26 (Pine Creek at Highway 50 near Sapinero, Colo.; table 10). Streamflow measurements used for the FAC calculations for site 26 are presented in figure 23*B*. Although a significant trend in streamflow was not identified for site 26 from 2001 through 2006, streamflow may have influenced the upward trend in ambient TN concentrations as a result of a positive concentration-streamflow relation (that is, both concentration and streamflow were increasing during this time period).

Trends for Sites with Variable Periods of Record

Data from 17 sites with variable periods of record—BLCA site 2; COLM site 3; CURE site 24; DINO sites 30–31 and 35–37; ARCH sites 46 and 50; CANY site 66; HOVE site 71; CARE site 84; and ZION sites 85, 91–92, and 95 (see table 6 for site names and information)—had sufficient data for evaluation of trends in flow-adjusted TN concentrations for one or more time periods. The same time periods and seasons used for the analysis of trends in ambient concentrations were used for the sites evaluated for trends in FAC. The process used to determine the optimal time period evaluated for each site is described in the "Selection of Data for Trend Analysis" section of this report. These 17 sites were analyzed for trends in FAC using the uncensored Seasonal Kendall test

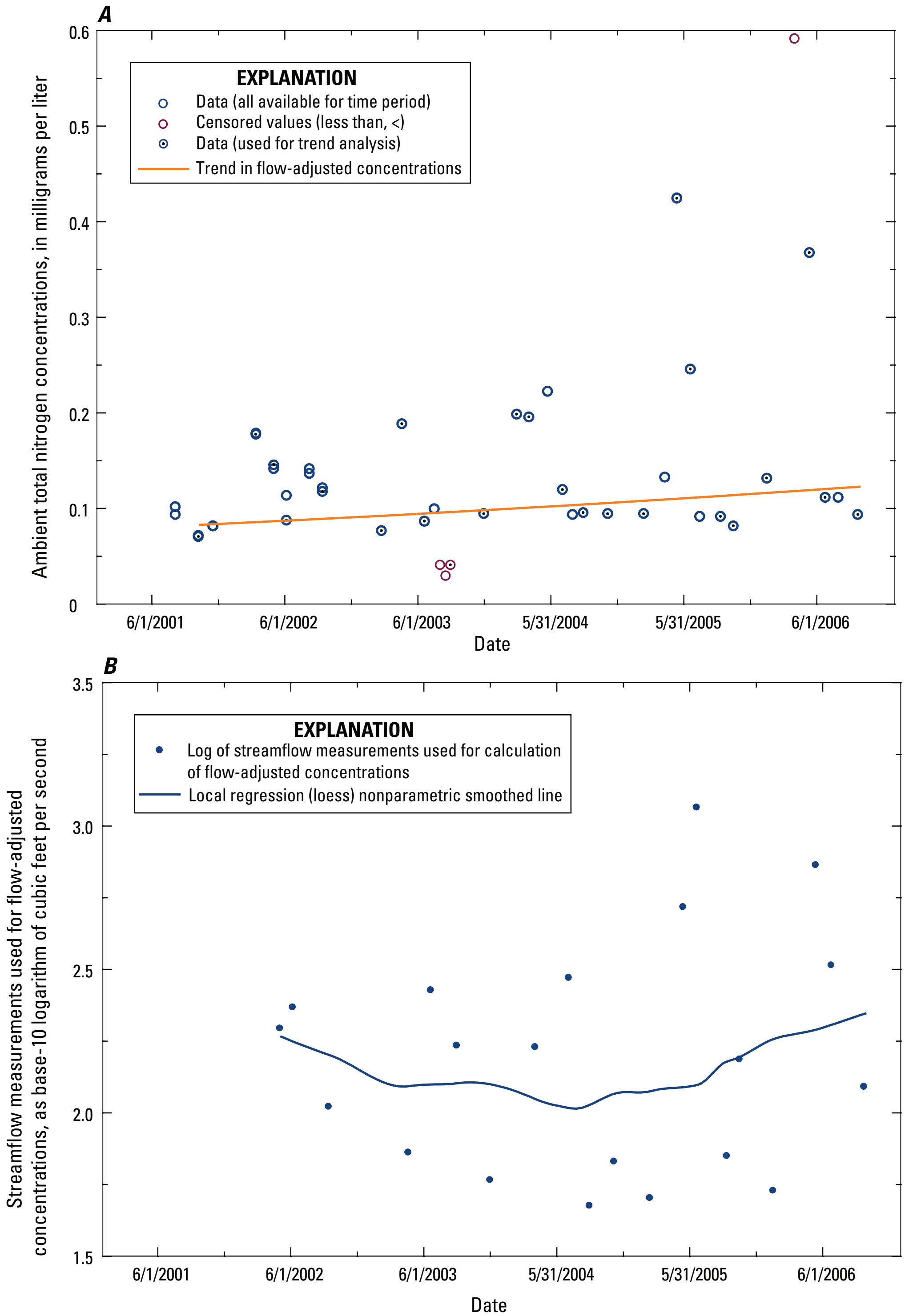


Figure 35. *A*, Trend in flow-adjusted concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 25, Lake Fork Gunnison River below Gateview, Colo., near Curecanti National Recreation Area, for water years 2001 through 2006. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3]

(table 11.) Fifteen of the 17 sites had contemporaneous streamflow measurements for 80 to 100 percent of the TN data; two sites (ARCH site 50 and ZION site 92) had contemporaneous streamflow measurements for between 64 and 79 percent of the TN data. The process used to determine if the streamflow data were sufficient to evaluate trends in FAC is described in the “Selection of Data for Trend Analysis” section of this report. The frequency of TN samples collected with contemporaneous streamflow measurements was highly variable as were the periods of record (fig. 14). The time periods analyzed ranged from 5 to 27 years for data collected between water years 1974 and 2007, and no site had data for the entire time span (table 11). Flow-adjusted TN concentrations for 16 of the 17 sites were analyzed using a 6-season definition; 1 site (CANY site 66) had sufficient data to evaluate 12 seasons; and 1 site (DINO site 31, which also was evaluated for a 6-season definition) had sufficient data to use a 4-season definition. Trend in FAC were evaluated for more than one time period from two sites (DINO sites 30 and 31). Depending on the time period and seasonal definition, sites had between 20 and 190 results used for the trend analysis (table 11).

Trends in FAC for sites with variable periods of record for water years 1974 through 2007 are summarized in table 11. Thirteen sites indicated no trends, one site indicated an upward trend, and five sites indicated downward trends. Trends in FAC were the same as the corresponding trends in ambient concentrations at six sites (COLM site 3, DINO sites 30 (historical time periods) and 31, ARCH site 46, CANY site 66, and CARE site 84). Trends in FAC were different from corresponding trends in ambient concentrations at two sites (DINO sites 30 (recent time period) and 35).

One significant upward trend in FAC was identified for DINO site 31 (Yampa River below Craig, Colo.) from 1990 through 2002 with a corresponding upward trend in ambient TN concentrations. The trend slope was 0.016 mg/L per year with a p-value of 0.080, which is comparable to the slope (0.017 mg/L per year) and p-value (0.027) for the upward trend in ambient TN concentrations calculated for this site. The plot showing the TN data available as compared to the TN data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figure 25. When a longer time period (from 1975 through 2002) was analyzed for site 31, no trend in ambient TN concentrations or FAC was identified (table 11).

In contrast, an upward trend in FAC was not identified for DINO site 30 (Green River near Greendale, Utah) from 1991 through 2000, and the site was identified as having an upward trend in ambient TN concentrations for this time period (trend slope = 0.010 mg/L per year, p-value = 0.027; fig. 24*A*). However, the results for trend in FAC were generally comparable (slope = 0.009 mg/L per year, p-value = 0.114) suggesting that the differences between trends for the ambient and FAC tests may be an artifact of the determination of statistical significance. Streamflow measurements used for computing the FAC for site 30 are shown in fig. 24*B*. Streamflow increased from 1991 through 2000 (p-value = 0.07 for Seasonal Kendall test using all streamflow measurements associated with water-quality samples for site 30 from water year 1991 through 2000), which possibly influenced the upward trend in ambient TN concentrations identified for this site as a result of a positive concentration-streamflow relation.

Significant downward trends in flow-adjusted TN concentrations were identified for five sites with corresponding downward trends in ambient TN concentrations: COLM site 3 (Gunnison River near Grand Junction, Colo., from 1975 through 1998), DINO site 30 (Green River near Greendale, Utah, from 1974 through 1992 and also from 1974 through 2000), ARCH site 46 (Colorado River near Cisco, Utah, from 1975 through 2001), CANY site 66 (Green River at Green River, Utah, from 1974 through 2000), and CARE site 84 (Fremont River near Bicknell, Utah, from 1979 through 1991). These five sites had contemporaneous streamflow measurements corresponding to between 86 and 100 percent of the TN data. Trend slopes were between -0.028 and -0.048 mg/L per year with p-values ranging from less than 0.001 to 0.084 (table 11). The trend slopes and p-values are generally comparable to the results from the analysis of trend in ambient TN concentrations. Plots showing the TN data available as compared to the TN data used (based on a 6-season definition for sites 3, 30, 46, and 84 and a 12-season definition for site 66) for the trend analysis and the corresponding FAC trend line are provided in figures 26, 27, 29, 33, and 34 for sites 3, 30, 46, 66, and 84, respectively.

In contrast, a downward trend in FAC was not identified for DINO site 35 (Green River near Jensen, Utah) from 1977 through 1990, and the site was identified as having a downward trend in ambient TN concentrations for this time period (fig. 28*A*). Streamflow measurements used for computing the FAC for site 35 are shown in figure 28*B*. Although a monotonic downward trend in streamflow was not identified for the entire 13-year trend time period, streamflow measurements did show a significant decrease from 1984 through 1990 (p-value = 0.012 for Seasonal Kendall test using all streamflow measurements associated with water-quality samples for site 35 from water year 1984 through 1990), which possibly influenced the downward trend in ambient TN concentrations identified for this site.

Summary and Discussion of Trends in Total Nitrogen

The significant upward or downward trends in ambient and flow-adjusted TN concentrations (p-value less than 0.10) for sites evaluated for historical long-term trend from 1977 through 1998 (table 9), recent, short-term trend from 2001 through 2006 (table 10), or with variable periods of record (table 11) are summarized in table 12. Generally, these results represent temporal trend periods from the middle to late 1970s or early 1980s through the 1990s or early 2000s, although time periods varied for the sites.

Few upward trends in ambient or flow-adjusted TN concentrations were identified for the 34 and 22 sites, respectively, evaluated in and near the NCPN park units (tables 9, 10, and 11). Four sites—CURE sites 25 and 26 and DINO sites 30 and 31—on tributaries to the Gunnison River or on the Green or Yampa Rivers had significant upward trends in ambient and(or) flow-adjusted TN concentrations (table 12). These sites had short to moderate data records of between 6 and 12 years with all upward temporal trends identified for time periods between 1990 and 2007 suggesting more recent changes at the site or in the basin increased TN concentrations in these streams. Two sites (CURE site 26 and DINO site 30) with upward trends in ambient concentrations did not show corresponding trends in FAC suggesting the trends at these two sites may be driven by a change in streamflow, although the differences in trend identified for site 30 may be an artifact of the determination of statistical significance. One site (CURE site 25) with an upward trend in FAC did not show a corresponding trend in ambient concentrations; however, this difference in trend also may be an artifact of the determination of statistical significance. Nutrient water-quality monitoring at sites 25, 30, and 31 may be warranted to determine if the recent upward trends in TN concentrations at these sites are indicative of human activities in the basin that might be managed or are a result of streamflow and climate variations.

Nine sites with one or more significant downward trends in ambient and flow-adjusted TN concentrations were identified in COLM (site 3), DINO (sites 30 and 35), ARCH (sites 46, 47, and 48), CANY (sites 52 and 66), and CARE (site 84). These sites are on the Colorado, Fremont, Green, Gunnison, or Yampa Rivers. More than one downward trend in ambient and flow-adjusted TN concentrations was identified at four of these sites (sites 3, 30, 46, and 66) for different time periods. The trend results from sites evaluated for multiple time periods were generally comparable, except for the recent time period evaluated for DINO site 30 (from 1991 through 2000) that indicated an upward trend, which differed from the downward trends identified for this site over three longer time periods. Sites 35, 47, 48, 52, and 84 had short to moderate data records of between 5 and 13 years with downward trends; sites 3, 30, 46, and 66 had longer records of between 18 and 26 years with downward trends. Only one of the nine sites (site 35) had a downward trend in ambient concentration without a corresponding trend in FAC suggesting the trend at this site was driven by a change in streamflow. Two of the nine sites (sites 47 and 48) lacked sufficient streamflow measurements for analysis of FAC.

Sites with trends in flow-adjusted TN concentrations indicate the mobilization and transportation of nutrients have changed in the basin (irrespective of streamflow). Most of these trends (except for the upward trend in FAC identified at CURE site 25 and DINO site 31) indicate changes have resulted in reduced nitrogen concentrations in streams. These downward trends may be the result of improved wastewater treatment, which would have taken place in upstream communities and in the park units during the intervening years (late 1970s and 1980s) of these moderate and longer time periods evaluated for trend. Wastewater-treatment technology and recognition of nonpoint pollution were advanced during this time period with the goal of reducing and removing nutrients and improving receiving water quality. These advancements were primarily driven by the CWA of 1972 (U.S. Congress, 1972) and by major amendments, including the CWA of 1977 (U.S. Congress, 1977) and the Water Quality Act of 1987 (U.S. Congress, 1987). The CWA of 1972 authorized funds for research and construction grants for new or improved wastewater collection and treatment infrastructure; the CWA of 1977 (33 U.S.C. §208) provided for the development of best-management practices as part of area-wide waste-treatment planning programs; and the Water Quality Act of 1987 (33 U.S.C. §319) authorized funds for States to develop nonpoint-source management and control programs with USEPA oversight (Brown and others, 1993; Burian and others, 2000;U.S. Fish and Wildlife Service, 2000). It is also possible that improvement in grazing, timber harvesting, and irrigated agriculture through the implementation of best-management practices (for example, switch from flood irrigation to sprinkler irrigation or fencing off streams to livestock) have resulted in lower nutrient concentrations. The passage of the Federal Land Policy and Management Act of 1976 (U.S. Congress, 1976) and the Public Rangelands Improvement Act of 1978 (U.S. Congress, 1978) focused on inventorying and improving the management of public lands, including public rangeland conditions, through increased management and improvement funding and charging fees for livestock grazing permits. However, because of the mixed land uses in most of these basins it is possible that multiple changes have taken place upstream from these sites and influenced the downward trend in TN concentrations. For example, TN concentrations were possibly reduced upstream from CARE site 84 as a result of improved wastewater treatment in the communities of Bicknell, Loa, Lyman, and Fremont, as well as improvements in handling of the fish hatchery wastes near Loa, and implementation of best-management practices by the agricultural industry in the basin. In some cases, nutrient concentrations in streams may have been influenced by upstream reservoir operations [for example, DINO site 30 may reflect the trapping of nutrients in sediment behind Flaming Gorge Reservoir, which was completed in 1964 (Bureau of Reclamation, 2007)].

Trends in Total Phosphorus

Total phosphorus concentrations for 51 and 27 sites in and near NCPN park units were evaluated for trend in ambient and flow-adjusted TP concentrations, respectively. Results for analysis of trend in ambient TP concentrations are presented followed by results for analysis of trend in flow-adjusted TP concentrations. A summary and discussion section follows the results.

Table 12. Summary of significant upward or downward trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus in water samples for selected sites in the Northern Colorado Plateau Network for variable periods of record for water years 1974 through 2007.

[BE year, beginning water year of trend analysis; mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N, number of values used for trend analysis; S, number of seasons; <, less than detection limit; --, no data, insufficient data, too many censored values, or insufficient corresponding streamflow data; *, sites with multiple time periods analyzed with multiple significant trends; significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Data includes sites with significant trends from tables 9, 10, and 11. Location of sites shown in figs. 2–8, and 11. Trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982)]

					Total nitrogen										Total phosphorus							
						Ambient concentration				Flow-adjusted concentration					Ambient concentration				Flow-adjusted concentration			
Site no.	Water source	BE year	Yrs	S	MRC (mg/L)	N	Trend	p-value	Trend slope (mg/L per year)	N	Trend	p-value	Trend slope (mg/L per year)	MRC (mg/L)	N	Trend	p-value	Trend slope (mg/L per year)	N	Trend	p-value	Trend slope (mg/L per year)
										COLM												
*3	Gunnison River	1975	23	6	1.40	118	**down**	**0.001**	**–0.036**	118	**down**	**<0.001**	**–0.032**	0.060	124	none	0.574	<0.001	--	--	--	--
*3	Gunnison River	1977	21	6	1.40	110	**down**	**.003**	**–.033**	110	**down**	**.002**	**–.030**	.060	112	none	.966	0	--	--	--	--
4	Colorado River	1979	12	6	.790	64	none	.362	–.010	--	--	--	--	.130	71	**down**	**.059**	**–.005**	--	--	--	--
										CURE												
9	Tomichi Creek	1995	7	6	.270	35	none	.815	.005	--	--	--	--	.041	35	**up**	**.073**	**.001**	35	**up**	**0.034**	**.003**
10	Curecanti Creek	2001	6	6	--	--	--	--	--	--	--	--	--	.063	20	none	.451	–.003	16	**down**	**.091**	**–.005**
24	Gunnison River	1998	8	6	.230	40	none	.849	–.001	39	none	.845	.003	.032	40	**down**	**.003**	**–.003**	39	**down**	**.016**	**–.002**
*25	Lake Fk Gunnison River	1995	10	4	--	--	--	--	--	--	--	--	--	.029	23	**down**	**.015**	**–.001**	18	none	.300	–.001
*25	Lake Fk Gunnison River	2001	6	6	.102	24	none	.167	.009	20	**up**	**.071**	**.008**	.023	24	none	.530	<.001	20	none	.332	.001
26	Pine Creek	2001	6	6	.346	24	**up**	**.038**	**.018**	21	none	.578	.008	.110	24	none	1.00	0	21	none	.578	–.003
*29	West Elk Creek	1999	7	4	--	--	--	--	--	--	--	--	--	.066	21	**up**	**.056**	**.003**	17	none	.170	.005
*29	West Elk Creek	2001	6	6	--	--	--	--	--	--	--	--	--	.062	22	**up**	**.070**	**.003**	19	none	1.00	.001
										DINO												
*30	Green River	1974	18	6	.710	98	**down**	**<.001**	**–.049**	98	**down**	**<.001**	**–.048**	.020	98	none	.406	<.001	--	--	--	--
*30	Green River	1974	26	6	.520	135	**down**	**<.001**	**–.034**	135	**down**	**<.001**	**–.031**	--	--	--	--	--	--	--	--	--
*30	Green River	1977	21	6	.500	105	**down**	**<.001**	**–.037**	105	**down**	**<.001**	**–.035**	--	--	--	--	--	--	--	--	--
*30	Green River	1991	9	6	.260	42	**up**	**.027**	**.010**	42	none	.114	.009	--	--	--	--	--	--	--	--	--
*31	Yampa River	1975	27	6	.525	72	none	–.004	.251	71	none	.182	–.005	.070	64	**down**	**.005**	**–.002**	--	--	--	--
*31	Yampa River	1990	12	4	.400	39	**up**	**.027**	**.017**	39	**up**	**.080**	**.016**	.037	31	none	.489	.001	--	--	--	--
33	Green River	1976	19	3	--	--	--	--	--	--	--	--	--	.020	48	**down**	**.041**	**–.001**	--	--	--	--
*35	Green River	1977	13	6	.600	73	**down**	**.076**	**–.016**	70	none	.160	–.014	.070	75	none	.982	0	--	--	--	--
*35	Green River	1976	30	6	--	--	--	--	--	--	--	--	--	.054	167	**down**	**.002**	**–.002**	129	none	.145	–.001
										ARCH												
*46	Colorado River	1975	26	6	1.20	133	**down**	**.001**	**–.032**	114	**down**	**.008**	**–.030**	.090	151	none	.468	<–.001	129	none	.525	–.001
*46	Colorado River	1977	21	6	1.13	109	**down**	**<.001**	**–.043**	96	**down**	**<.001**	**–.044**	.100	124	none	.122	–.003	110	none	.374	–.002
47	Colorado River	1978	12	6	1.19	68	**down**	**.083**	**–.037**	--	--	--	--	.160	69	none	.498	–.004	--	--	--	--
*48	Dolores River	1980	10	12	1.03	84	**down**	**.019**	**–.078**	--	--	--	--	.083	86	none	.139	–.006	--	--	--	--
*48	Dolores River	1980	18	12	--	--	--	--	--	--	--	--	--	.086	137	**down**	**.051**	**–.003**	--	--	--	--
*50	Moab Wastewater Treatment Plant	1978	10	6	24.2	29	none	.166	-.644	20	none	1.00	0	6.45	47	**down**	**.041**	**–.173**	38	**down**	**.021**	**–.184**
*50	Moab Wastewater Treatment Plant	1977	30	6	--	--	--	--	--	--	--	--	--	6.14	74	**down**	**<.001**	**–.126**	42	**down**	**.003**	**–.181**

Table 12. Summary of significant upward or downward trends in ambient concentrations and flow-adjusted concentrations of total nitrogen and total phosphorus in water samples for selected sites in the Northern Colorado Plateau Network for variable periods of record for water years 1974 through 2007.—Continued

[BE year, beginning water year of trend analysis; mg/L, milligrams per liter; MRC, median reference condition (representative value for typical conditions in the middle of the trend test period); N, number of values used for trend analysis; S, number of seasons; <, less than detection limit; --, no data, insufficient data, too many censored values, or insufficient corresponding streamflow data; *, sites with multiple time periods analyzed with multiple significant trends; significant trends (p-value <0.10) identified by **bold** type; Site no. corresponds to table 6; see table 1 for explanation of park codes. Data includes sites with significant trends from tables 9, 10, and 11. Location of sites shown in figs. 2–8, and 11. Trend tests completed using S-ESTREND program in SPLUS® modified from Schertz and others (1991) using test methods from Hirsch and others (1982)]

Site no.	Water source	BE year	Yrs	S	Total nitrogen MRC (mg/L)	Total nitrogen Ambient concentration N	Trend	p-value	Trend slope (mg/L per year)	Total nitrogen Flow-adjusted concentration N	Trend	p-value	Trend slope (mg/L per year)	Total phosphorus MRC (mg/L)	Total phosphorus Ambient concentration N	Trend	p-value	Trend slope (mg/L per year)	Total phosphorus Flow-adjusted concentration N	Trend	p-value	Trend slope (mg/L per year)
CANY																						
52	Colorado River	1983	5	6	1.26	19	**down**	**0.024**	**–0.230**	--	--	--	--	0.200	19	none	0.623	–0.010	--	--	--	--
*66	Green River	1974	26	12	.910	190	**down**	**.001**	**–.030**	190	**down**	**<0.001**	**–0.030**	.160	207	**down**	**.062**	**–.003**	203	**down**	**0.048**	**–0.004**
*66	Green River	1977	21	6	.790	89	**down**	**.002**	**–.040**	89	**down**	**.001**	**–.040**	.140	99	**down**	**.044**	**–.005**	99	**down**	**.025**	**–.006**
HOVE																						
71	McElmo Creek	1985	5	6	1.25	23	none	.782	–.025	21	none	.873	.078	.084	24	**down**	**.051**	**–.031**	22	none	.309	–.016
CARE																						
79	Fremont River	1993	8	6	--	--	--	--	--	--	--	--	--	.052	39	**down**	**.081**	**–.002**	28	**down**	**.064**	**–.003**
*84	Fremont River	1979	12	6	.975	54	**down**	**.031**	**–.034**	53	**down**	**.084**	**–.028**	.080	58	**down**	**.036**	**–.004**	57	**down**	**.012**	**–.005**
*84	Fremont River	1976	30	6	--	--	--	--	--	--	--	--	--	.060	153	**down**	**<.001**	**–.002**	117	**down**	**<.001**	**–.002**
*84	Fremont River	1977	21	6	--	--	--	--	--	--	--	--	--	.070	104	**down**	**.004**	**–.002**	103	**down**	**.003**	**–.002**
ZION																						
*85	East Fork Virgin River	1984	6	6	.900	31	none	.226	–.060	28	none	.445	–.036	.041	33	**down**	**.056**	**–.010**	30	none	.326	–.007
*85	East Fork Virgin River	1983	23	6	--	--	--	--	--	--	--	--	--	.039	120	**down**	**.043**	**–.001**	--	--	--	--
91	LaVerkin Creek	1981	9	6	.510	39	none	.376	–.023	31	none	.855	–.009	.080	41	**down**	**.009**	**–.019**	33	none	.934	–.004
*92	North Fork	1980	10	6	.345	44	none	.277	–.013	28	none	.773	.013	.040	46	**down**	**.061**	**–.011**	--	--	--	--
*92	Virgin River	1980	26	6	--	--	--	--	--	--	--	--	--	.025	130	**down**	**.016**	**–.001**	--	--	--	--
95	Virgin River	1982	8	6	.530	37	none	.338	.020	35	none	.153	.030	.110	39	**down**	**.048**	**–.014**	37	none	.384	–.007

Ambient Total Phosphorus Concentrations

Trends in ambient TP concentrations are presented below for the 5 sites evaluated for historical long-term trends for water years 1977 through 1998 (table 9); the 15 sites evaluated for recent, short-term trends for water years 2001 through 2006 (table 10), and for the 42 sites evaluated for trends with variable periods of record between 5 and 32 years for water years 1974 through 2007 (table 11). MRC ranged from 0.005 to 6.45 mg/L for all of these sites.

Historical Long-Term Trends (For Water Years 1977 Through 1998)

Five sites—COLM site 3 (Gunnison River near Grand Junction, Colo.), DINO site 35 (Green River near Jensen, Utah), ARCH site 46 (Colorado River near Cisco, Utah), CANY site 66 (Green River at Green River, Utah), and CARE site 84 (Fremont River near Bicknell, Utah)—had sufficient data for evaluation of historical long-term trends in ambient TP concentrations for water years 1977 through 1998 (figs. 2, 6, 7, and 8; table 6). The TP data for sites 46, 66, and 84 were moderately censored (from 3.5 to 9.4 percent) allowing for analysis of trends using the uncensored Seasonal Kendall test. The TP data for sites 3 and 35 had higher percentages of censoring (21 and 11 percent, respectively); these sites were evaluated for trends using the censored Seasonal Kendall test. These tests are described in the “Temporal Trend Analysis—Methods” section. The data were collected approximately bi-monthly or monthly during most of their record resulting in the selection of six seasons for the trend tests. Using a 6-season definition, all sites had between 99 and 124 results analyzed over the 21-year period (table 9). MRC ranged from 0.060 mg/L (COLM site 3) to 0.140 mg/L (CANY site 66) for the five sites evaluated.

Trends in ambient TP concentrations for water years 1977 through 1998 are summarized in table 9. Significant downward trends in ambient TP concentrations were identified for CANY site 66 and CARE site 84 with trend slopes of -0.005 mg/L per year (p-value = 0.044) and -0.002 mg/L per year (p-value = 0.004), respectively. Plots showing the TP data available as compared to the TP data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figures 36–37.

Recent Short-Term Trends (For Water Years 2001 Through 2006)

Fifteen sites—BLCA site 2 (Gunnison River below Gunnison Tunnel, Colo.); CURE sites 10 (Curecanti Creek near Sapinero, Colo.), 13 (Cebolla Creek at Bridge southeast of Powderhorn, Colo.), 14 (Blue Creek at Highway 50 near Sapinero, Colo.), 17 (Steuben Creek near mouth near Gunnison, Colo.), 18 (Beaver Creek at Highway 50 near Gunnison, Colo.), 19 (Soap Creek above Chance Creek near Sapinero, Colo.), 20 (Cimarron River below Squaw Creek near Cimarron, Colo.), 23 (East Elk Creek near mouth near Sapinero, Colo.), 24 (Gunnison River at County Road 32 below Gunnison, Colo.), 25 (Lake Fork Gunnison River below Gateview, Colo.), 26 (Pine Creek at Highway 50 near Sapinero, Colo.), 27 (Red Creek near mouth near Sapinero, Colo.), and 29 (West Elk Creek below forest boundary near Sapinero, Colo.); and DINO site 36 (Yampa River at Deerlodge Park, Colo.)—on or tributary to the Gunnison or Yampa Rivers had sufficient data for evaluation of recent short-term trends in ambient TP concentrations for water years 2001 through 2006 (table 6). The TP data were between 0 and 3 percent censored for all but site 19, which was 8.3 percent censored. All data were analyzed for trends using the uncensored Seasonal Kendall test. The TP data were collected approximately bi-monthly during most of the time period resulting in the selection of six seasons for the trend tests, though some samples were collected quarterly during the middle part of the record for some sites resulting in the selection of six seasons for the trend tests. Using a 6-season definition, all sites had 20 to 25 results available for analysis of trends in ambient TP concentrations (table 10). MRC ranged from 0.021 mg/L (BLCA site 2) to 0.185 mg/L (CURE site 27) for the 15 sites evaluated.

Trends in ambient TP concentrations for water years 2001 through 2006 are summarized in table 10. One significant upward trend in ambient TP concentrations was identified for CURE site 29 (West Elk Creek below forest boundary near Sapinero, Colo.). For this site, the trend slope was 0.003 mg/L per year with a p-value of 0.070. The plot showing the TP data available as compared to the TP data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figure 38*A*.

Trends for Sites with Variable Periods of Record

Data from 42 sites—BLCA sites 1 and 2; COLM sites 3 and 4; CURE sites 6–9, 17, 24, 25, and 29; DINO sites 30, 31, 33, and 35–37; FOBU site 38; ARCH sites 46–48 and 50; CANY sites 51–55, 62, and 66; HOVE sites 71 and 73; CARE sites 79, 80, 83, and 84; and ZION sites 85, 89–92, and 95 (see table 6 for site information)—had sufficient data for evaluation of trends in ambient TP concentrations for one or more time periods. These 42 sites include alternative time periods evaluated for the 5 sites evaluated for historical, long-term trends (for water years 1977 through 1998) and 6 of the 15 sites evaluated for recent, short-term trends (for water years 2001 through 2006) in TP concentrations. Optimal time periods and seasons were selected for each site as described in the “Selection of Data for Trend Analysis” section of this report. The TP concentrations were 0 to 58 percent censored. As previously described, uncensored data or data with censoring generally less than 5 percent were analyzed for trends using the uncensored Seasonal Kendall test; data from sites with censoring generally greater than 5 percent were analyzed using the censored Seasonal Kendall test. The TP data-collection frequency was highly variable as were the periods of record (fig. 15). The time periods analyzed ranged from 5 to 32 years

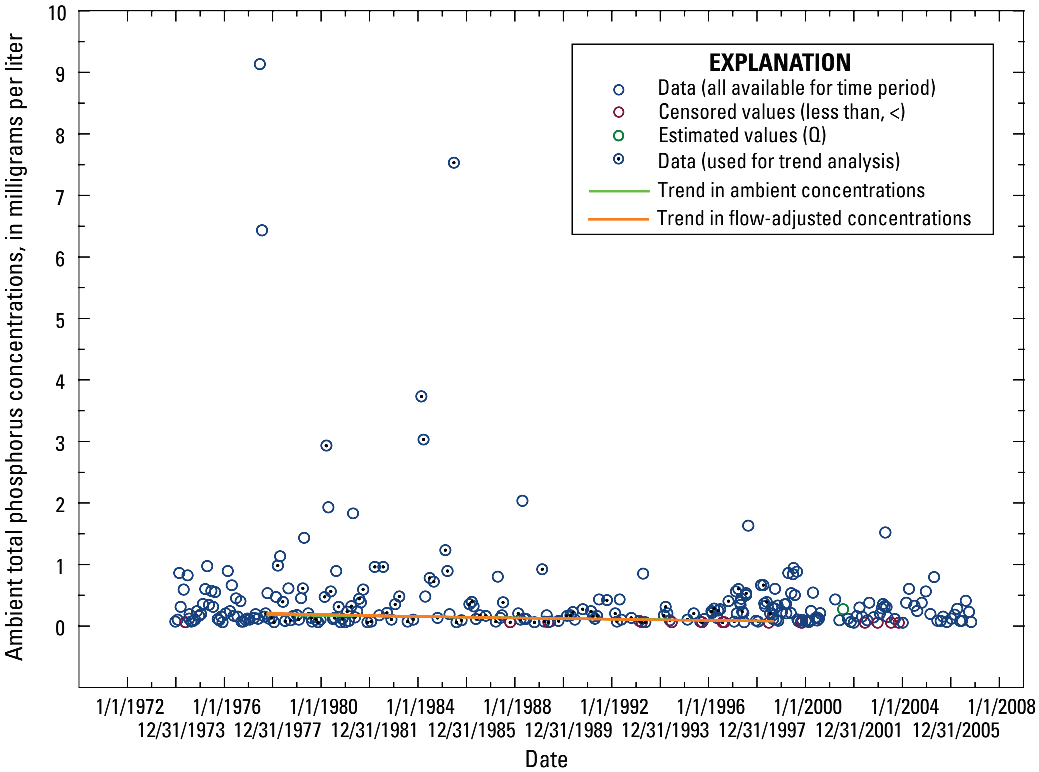


Figure 36. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 66, Green River at Green River, Utah, upstream from Canyonlands National Park, for water years 1977 through 1998. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 2.]

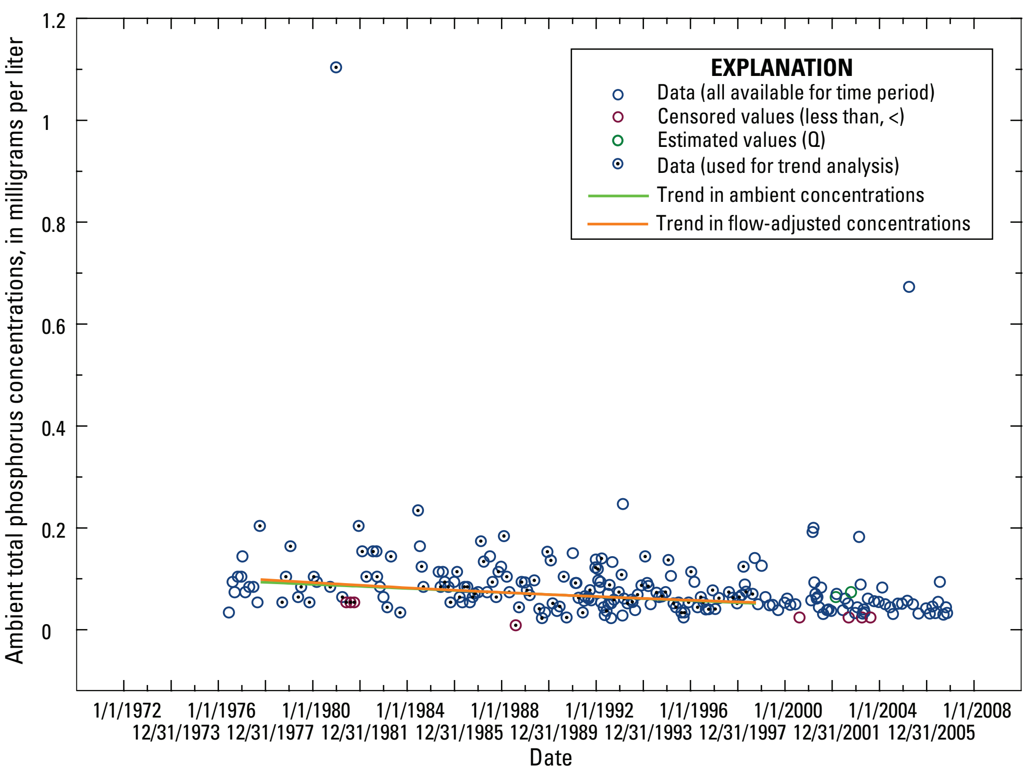


Figure 37. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 84, Fremont River near Bicknell, Utah, upstream from Capitol Reef National Park, for water years 1977 through 1998. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 6. Estimated values: Q, holding time exceeded before sample delivery or before analysis was completed.]

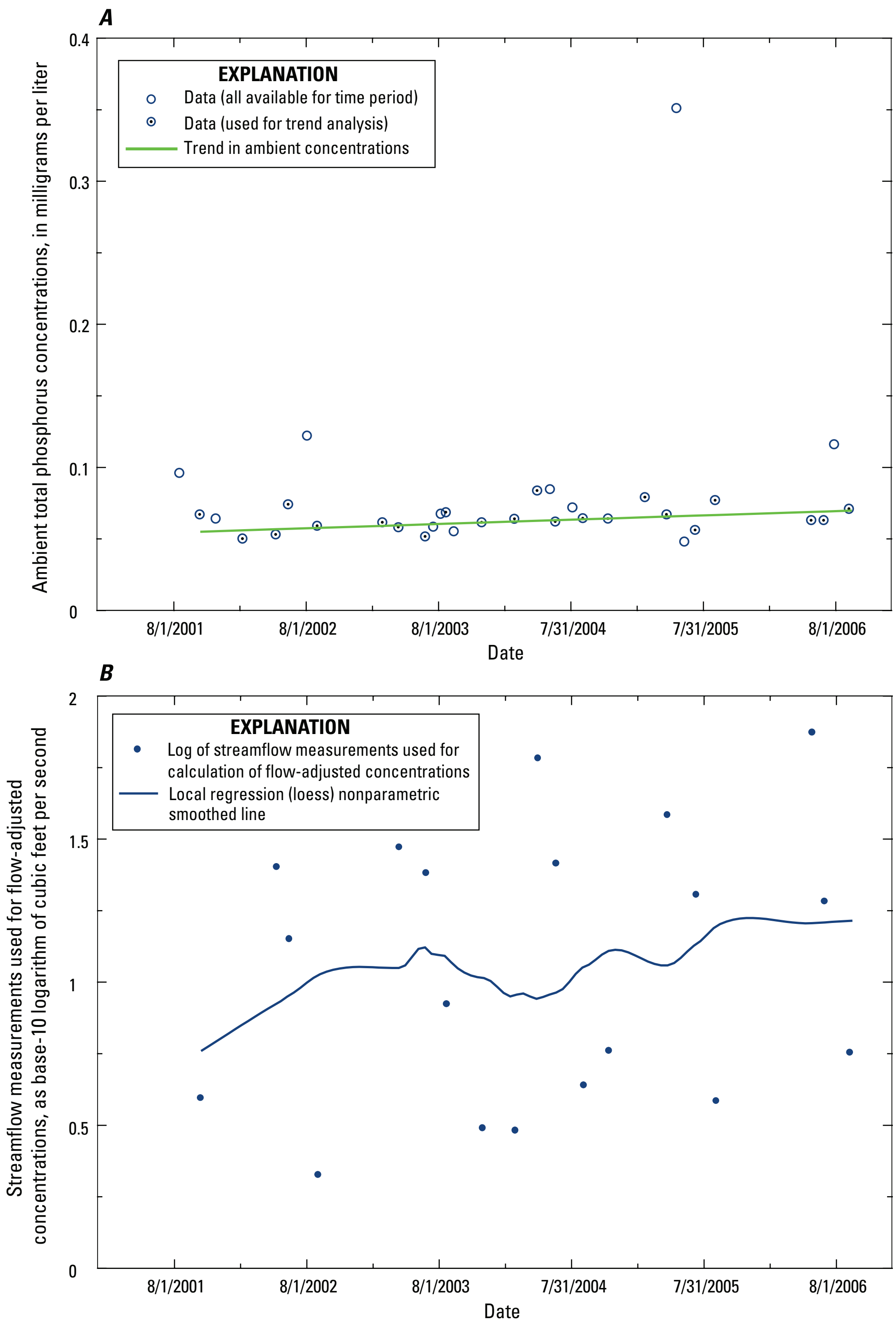


Figure 38. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 29, West Elk Creek below forest boundary near Sapinero, Colo., upstream from Curecanti National Recreation Area, for water years 2001 through 2006. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3.]

for data collected between water years 1974 and 2007; no site had data for the entire time span (table 11). Trends in ambient TP concentrations were evaluated for more than one time period for 16 sites (DINO sites 31, 33, 35, and 36; ARCH sites 46–48, and 50; CANY sites 51, 53, and 55; HOVE site 71; CARE sites 80 and 84; and ZION sites 85 and 92). Ambient TP concentrations for 33 sites were analyzed using a 6-season definition; 5 sites had sufficient data to evaluate 12 seasons; and 10 sites had sufficient data to evaluate 3 or 4 seasons. Depending on the time period and seasonal definition, sites had between 15 and 307 results used for the trend analysis (table 11). MRC generally ranged from 0.005 mg/L (CURE site 7) to 0.367 mg/L (CARE site 80); elevated MRCs of 6.14 and 6.45 mg/L were computed for ARCH site 50, which is the Moab WWTP outflow (fig. 3).

Trends in ambient TP concentrations for sites with variable periods of record for water years 1974 through 2007 are summarized in table 11. Twenty-nine sites indicated no trends, 2 sites indicated upward trends, and 16 sites indicated downward trends. Significant upward trends in ambient TP concentrations were identified for CURE site 9 (Tomichi Creek at Gunnison, Colo.) from 1995 through 2002, and CURE site 29 (West Elk Creek below forest boundary near Sapinero, Colo.) from 1999 through 2006. For these two sites, the trend slopes were 0.001 mg/L per year (p-value = 0.073) and 0.003 mg/L per year (p-value = 0.056), respectively. The plots showing the TP data available as compared to the TP data used for the trend analysis (based on a 6-season (site 9) and 4-season (site 29) definition) and the corresponding trend line are provided in figures 39 and 40.

Significant downward trends in ambient TP concentrations were identified for 16 sites for variable time periods: COLM site 4; CURE sites 24 and 25; DINO sites 31, 33, and 35; ARCH sites 48 and 50; CANY site 66; HOVE site 71; CARE sites 79 and 84; and ZION sites 85, 91, 92, and 95 (see table 11 for trend results; see table 6 for site information). Sites 50, 84, 85, and 92 had significant downward trends identified for more than one trend time period. For the 16 sites, between 5 and 30 years were analyzed for trends with time periods ranging from 1974 through 2007. Trend slopes ranged from -0.001 mg/L per year (sites 25, 33, 85, and 92) to -0.173 mg/L per year (site 50) with p-values ranging from less than 0.001 to 0.081 for the 16 sites. Trend plots showing the TP data available as compared to the TP data used for the trend analysis—based on a 6-season (sites 4, 24, 31, 35, 50, 71, 79, 84, 85, 91, 92, and 95), 12-season (sites 48 and 66), or 3- or 4-season (sites 25 and 33) definition— and the corresponding trend line are provided in figures 41 through 57 for sites 4, 24, 25, 31, 33, 35, 48, 50, 66, 71, 79, 84, 85, 91, 92, and 95, respectively.

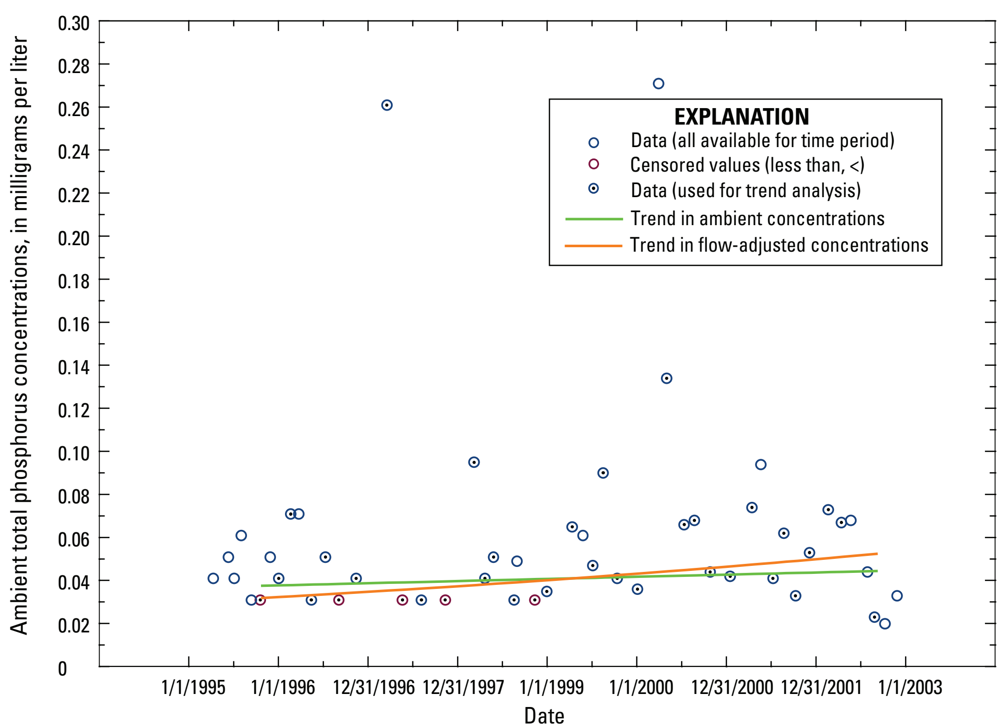


Figure 39. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 9, Tomichi Creek at Gunnison, Colo., upstream from Curecanti National Recreation Area, for water years 1995 through 2002. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3.]

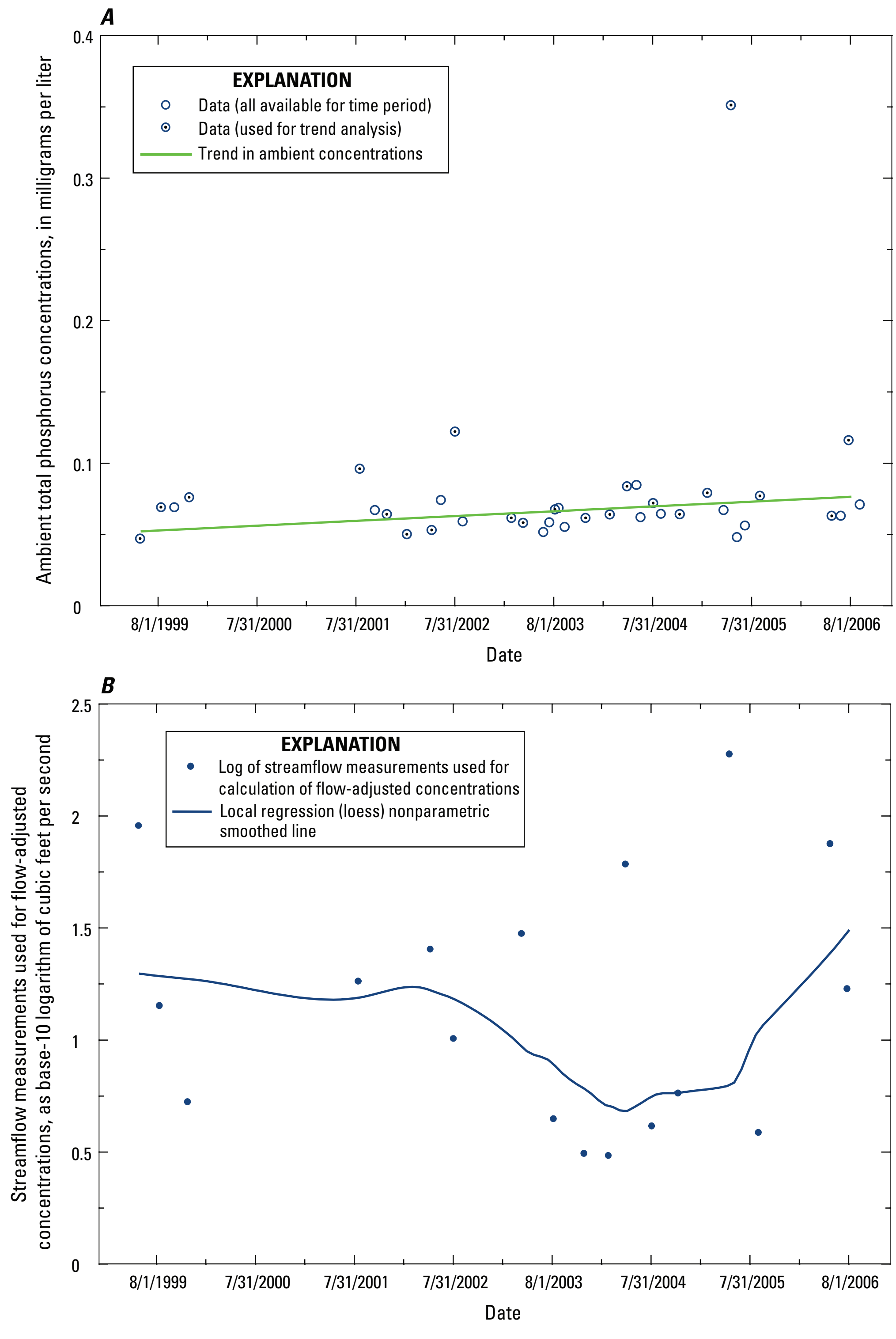


Figure 40. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 29, West Elk Creek below forest boundary near Sapinero, Colo., upstream from Curecanti National Recreation Area, for water years 1999 through 2006. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3.]

Flow-Adjusted Total Phosphorus Concentrations

For the 27 sites with sufficient streamflow data (as described in the “Selection of Data for Trend Analysis” section), trends in flow-adjusted TP concentrations were examined. Of the sites evaluated for trends in ambient TP concentrations, 3 of the 5 sites evaluated for historical long-term trends for water years 1977 through 1998, the same 15 sites evaluated for recent short-term trends in ambient TP concentrations for water years 2001 through 2006, and 18 of the 42 sites with variable periods of record (ranging from 5 to 32 years for water years 1974 through 2007) were analyzed for trends in TP FAC.

Plots for streamflow measurements used for FAC calculations are presented for sites where differences in trends were identified for ambient concentrations as compared to FAC. For these sites, results for trends in streamflow using linear regression or Seasonal Kendall test (as described in the “Selection of Data for Trend Analysis” section) are described when determined to be significant (p-value less than 0.10). These trend tests used all available streamflow measurements corresponding with all water-quality samples collected during the time periods analyzed for each site.

Historical Long-Term Trends (For Water Years 1977 Through 1998)

Three of the five sites evaluated for historical long-term trends in ambient TP concentrations—ARCH site 46 (Colorado River near Cisco, Utah), CANY site 66 (Green River at Green River, Utah), and CARE site 84 (Fremont River near Bicknell, Utah)—had sufficient data for evaluation of trends in flow-adjusted TP concentrations for water years 1977 through 1998 (table 6). As previously stated, the TP data for sites 46, 66, and 84 were moderately censored (from 3.5 to 9.4 percent) allowing for analysis of trends using the uncensored Seasonal Kendall test, which allowed for analysis of FAC using the log-log loess model with the Seasonal Kendall test (as described in the “Temporal Trend Analysis—Methods” section) using the same 6-season definition. Using six seasons, all sites had between 99 and 110 results analyzed over this 21-year period (table 9). Site 46 had fewer data (110 results instead of 124 results or 89 percent) used for the trend in FAC than were used for the trend in ambient concentrations.

Trends in FAC for water years 1977 through 1998 are summarized in table 9. Significant downward trends in FAC were identified for sites 66 and 84, which also indicated significant downward trends in ambient TP concentrations. Trend slopes were -0.006 mg/L per year (p-value = 0.025) and -0.002 mg/L per year (p-value = 0.003) for sites 66 and 84, respectively, and are comparable to the values determined for the downward trends in ambient TP concentrations. Plots showing the TP data available as compared to the TP data used (based on a 6-season definition) for the trend analysis and the corresponding FAC trend line are provided in figures 36 and 37.

Recent Short-Term Trends (For Water Years 2001 Through 2006)

The same 15 sites evaluated for recent short-term trends in ambient TP concentrations—BLCA site 2 (Gunnison River below Gunnison Tunnel, Colo.); CURE sites 10 (Curecanti Creek near Sapinero, Colo.), 13 (Cebolla Creek at Bridge southeast of Powderhorn, Colo.), 14 (Blue Creek at Highway 50 near Sapinero, Colo.), 17 (Steuben Creek near mouth near Gunnison, Colo.), 18 (Beaver Creek at Highway 50 near Gunnison, Colo.), 19 (Soap Creek above Chance Creek near Sapinero, Colo.), 20 (Cimarron River below Squaw Creek near Cimarron, Colo.), 23 (East Elk Creek near mouth near Sapinero, Colo.), 24 (Gunnison River at County Road 32 below Gunnison, Colo.), 25 (Lake Fork Gunnison River below Gateview, Colo.), 26 (Pine Creek at Highway 50 near Sapinero, Colo.), 27 (Red Creek near mouth near Sapinero, Colo.), and 29 (West Elk Creek below forest boundary near Sapinero, Colo.); and DINO site 36 (Yampa River at Deerlodge Park, Colo.)—on or tributary to the Gunnison or Yampa Rivers had sufficient data for evaluation of trends in flow-adjusted TP concentrations for water years 2001 through 2006 (table 6). As previously stated, the TP concentrations were 0 and 3 percent censored for all but site 19, which was 8.3 percent censored; this low percentage of censoring allowed for analysis of FAC using the log-log loess model with the Seasonal Kendall test (as described in the “Temporal Trend Analysis—Methods” section) using the same 6-season definition. Using six seasons, all sites had between 14 and 24 results analyzed over this 5-year period (table 10). Sites had contemporaneous streamflow measurements for between 58 percent (site 36) and 100 percent (site 2) of the TP data.

Trends in FAC for water years 2001 through 2006 are summarized in table 10. Trends in FAC were different from corresponding trends in ambient concentrations at two sites (CURE sites 10 and 29). A significant downward trend in FAC was identified for CURE site 10 (Curecanti Creek near Sapinero, Colo.), but a downward trend in ambient TP concentrations was not identified for this site. The FAC trend slope was -0.005 mg/L per year with a p-value of 0.091. The plot showing the TP data available as compared to the TP data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are presented in figure 58. Streamflow measurements used for the FAC calculations for site 10 are presented in figure 58*B*. A significant trend in streamflow was not identified for site 10.

In contrast to site 10, when the effects of streamflow are removed, no upward trend in flow-adjusted TP concentrations was identified for site 29 (West Elk Creek below Forest Boundary near Sapinero, Colo.; table 10). Streamflow measurements used for the FAC calculations for site 29 are presented in figure 38*B*. Although a significant trend in streamflow was not identified for site 29 from 2001 through 2006, streamflow may have influenced the upward trend in ambient TP concentrations as a result of a positive concentration-streamflow relation (that is, both concentration and streamflow were increasing during this time period).

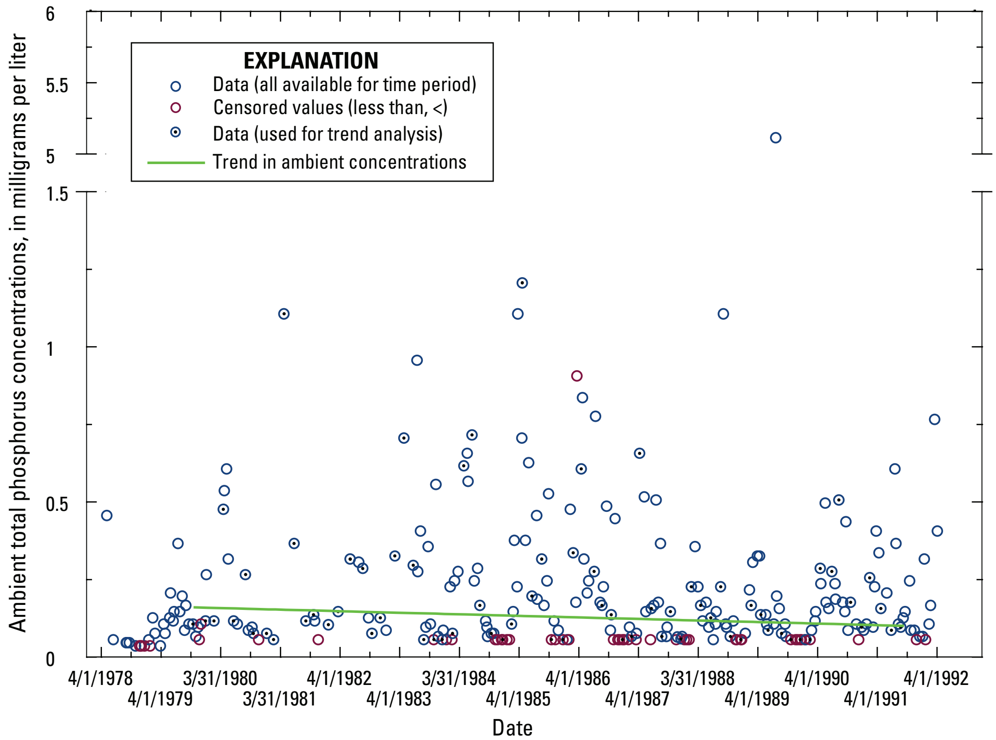


Figure 41. Trend in ambient total phosphorus concentrations for site 4, Colorado River at Loma, Colo., near Colorado National Monument, for water years 1979 through 1991. [Site information in table 6. Location of site shown in fig. 7.]

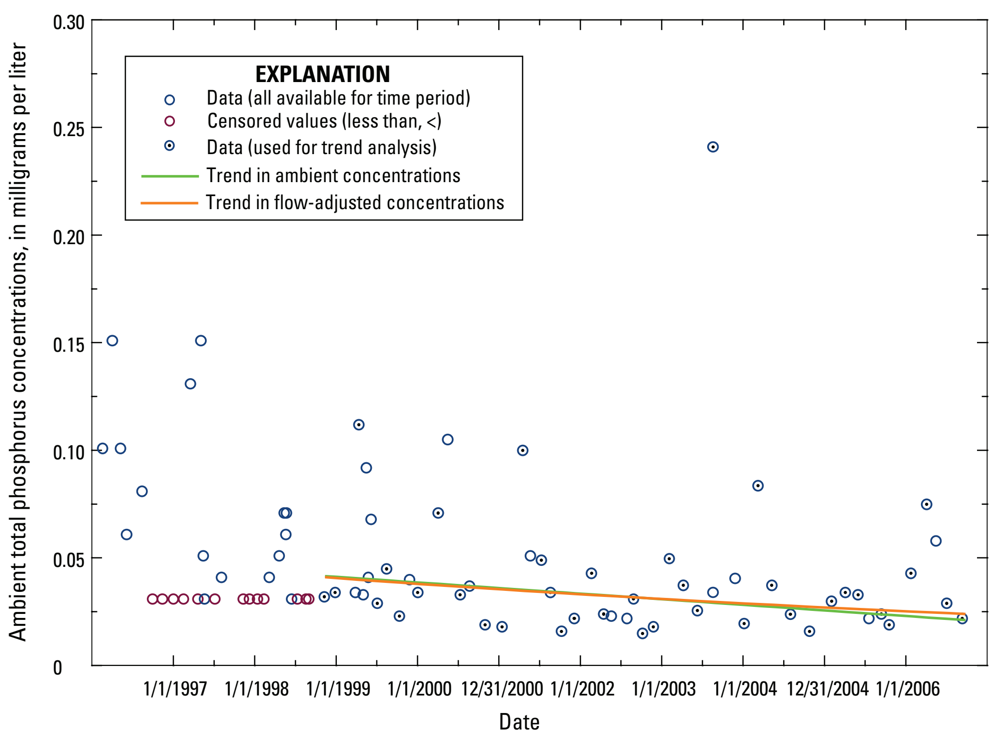
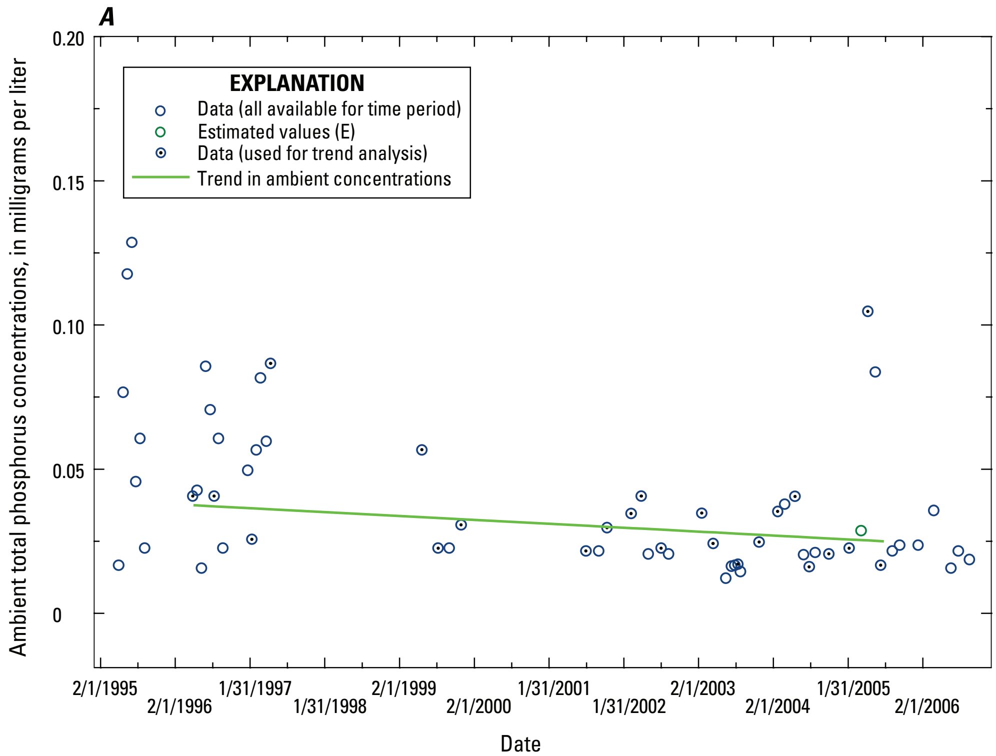


Figure 42. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 24, Gunnison River at County Road 32 below Gunnison, Colo., upstream from Curecanti National Recreation Area, for water years 1998 through 2006. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 3.]



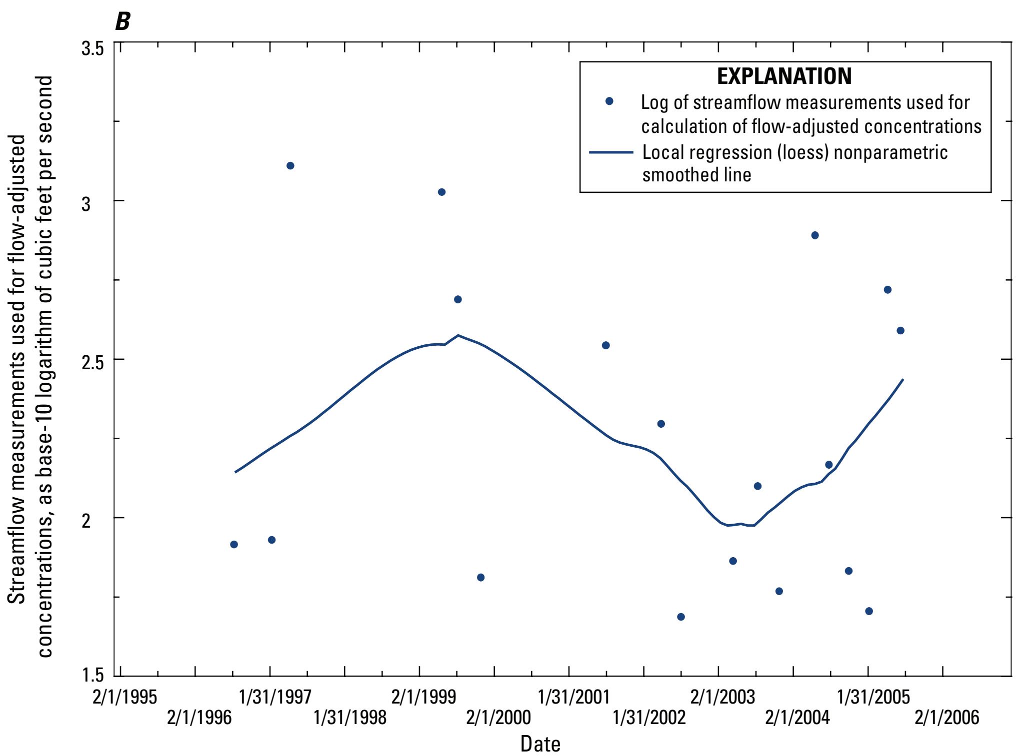


Figure 43. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 25, Lake Fork Gunnison River below Gateview, Colo., upstream from Curecanti National Recreation Area, for water years 1995 through 2005. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3.]

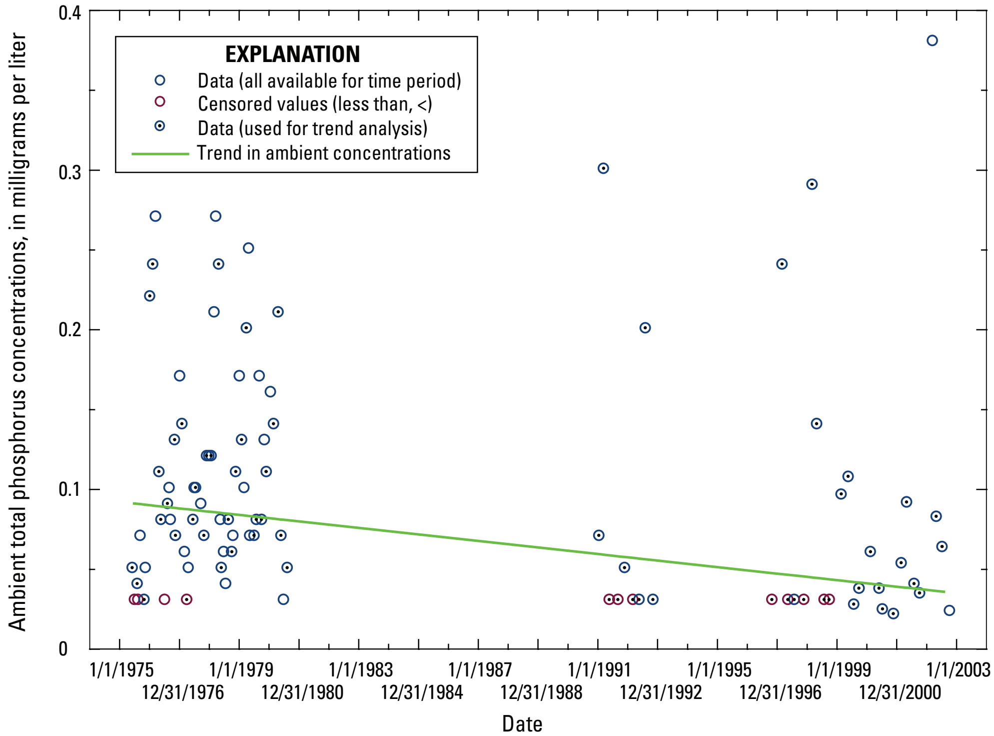


Figure 44. Trend in ambient total phosphorus concentrations for site 31, Yampa River below Craig, Colo., upstream from Dinosaur National Monument, for water years 1975 through 2002. [Site information in table 6. Location of site shown in fig. 8.]

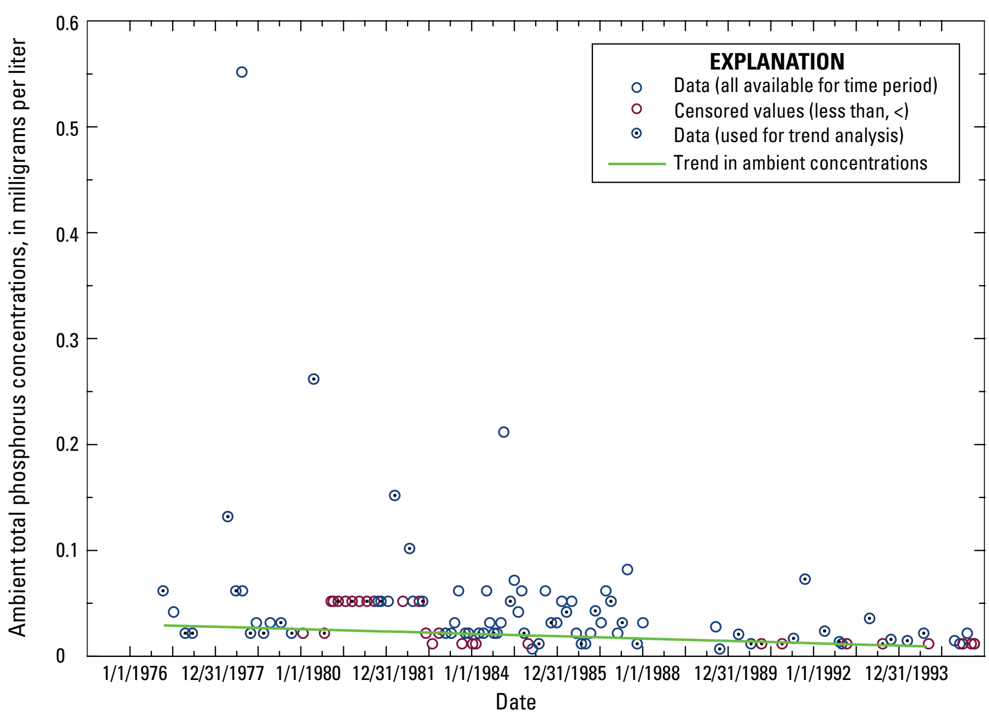


Figure 45. Trend in ambient total phosphorus concentrations for site 33, Green River at Browns Park Bureau of Reclamation gaging station, Utah, upstream from Dinosaur National Monument, for water years 1976 through 1995. [Site information in table 6. Location of site shown in fig. 8.]

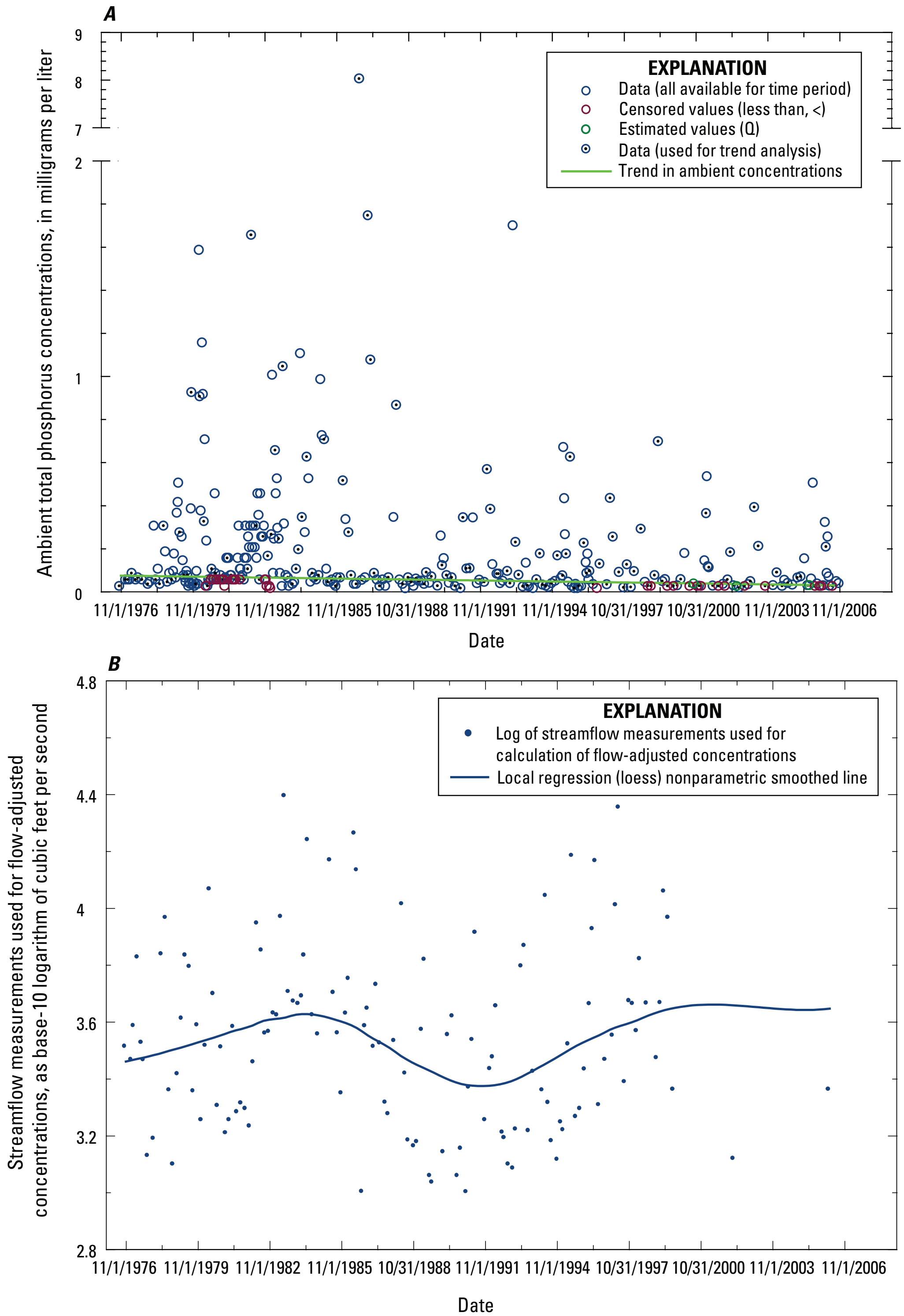


Figure 46. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 35, Green River near Jensen, Utah, in Dinosaur National Monument, for water years 1976 through 2006. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 8. Estimated values: Q, holding time exceeded before sample delivery or before analysis was completed.]

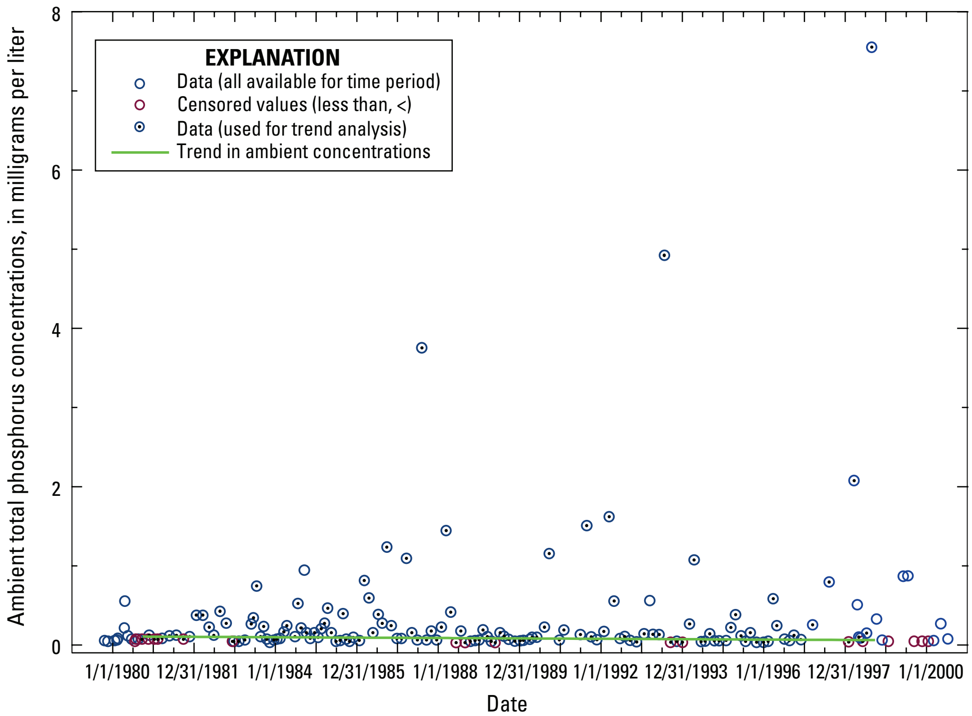


Figure 47. Trend in ambient total phosphorus concentrations for site 48, Dolores River at mouth, Utah, upstream from Arches National Park, for water years 1980 through 1998. [Site information in table 6. Location of site shown in fig. 2.]

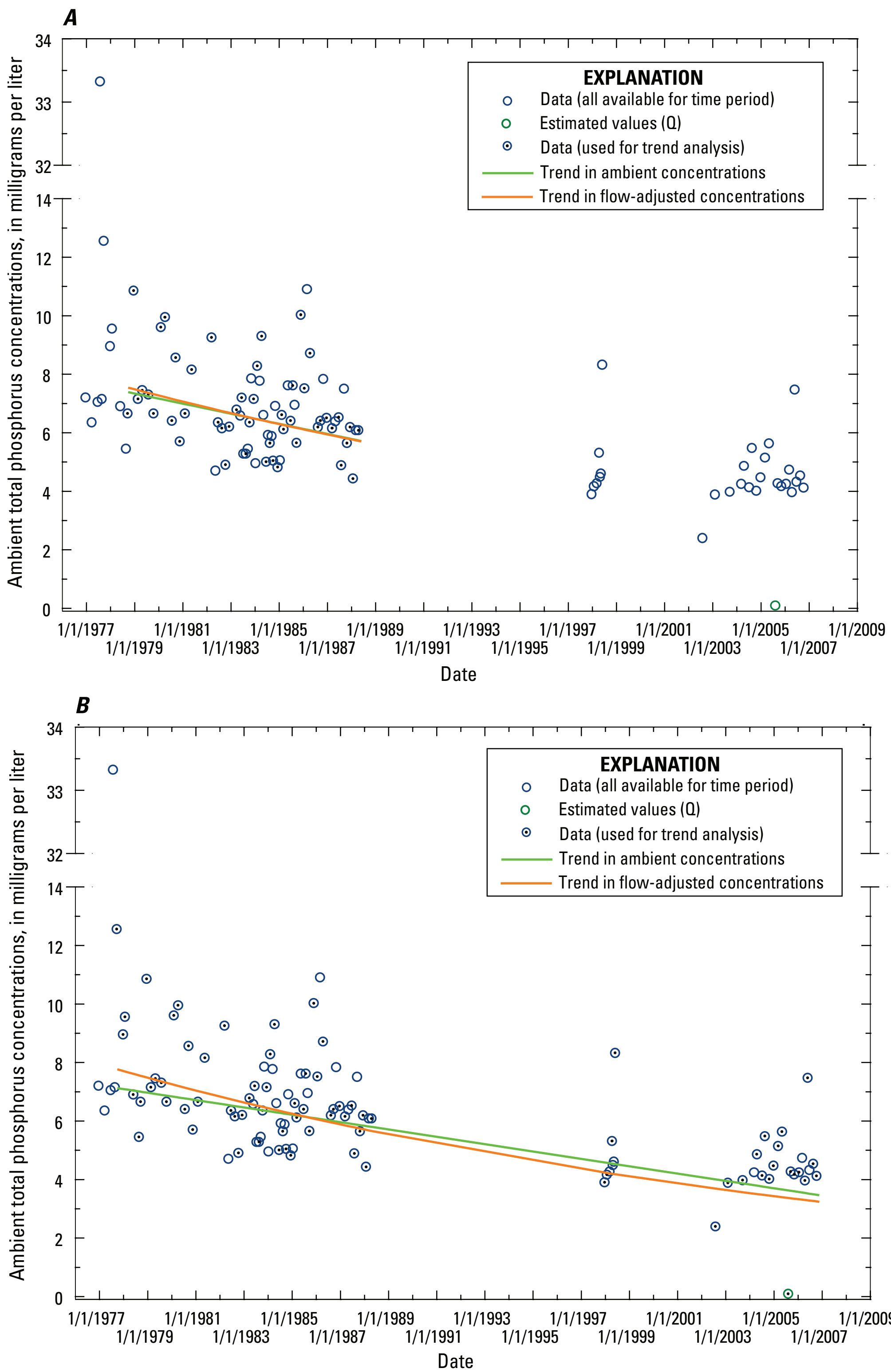


Figure 48. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 50, Moab Wastewater Treatment Plant outflow, Moab, Utah, downstream from Arches National Park, for water years *A*, 1978 through 1988, and *B*, 1977 through 2007. [Calculated flow-adjusted calculations not shown on figure. Site information in table 6. Location of site shown in fig. 2. Estimated values: Q, holding time exceeded before sample delivery or before analysis was completed.]

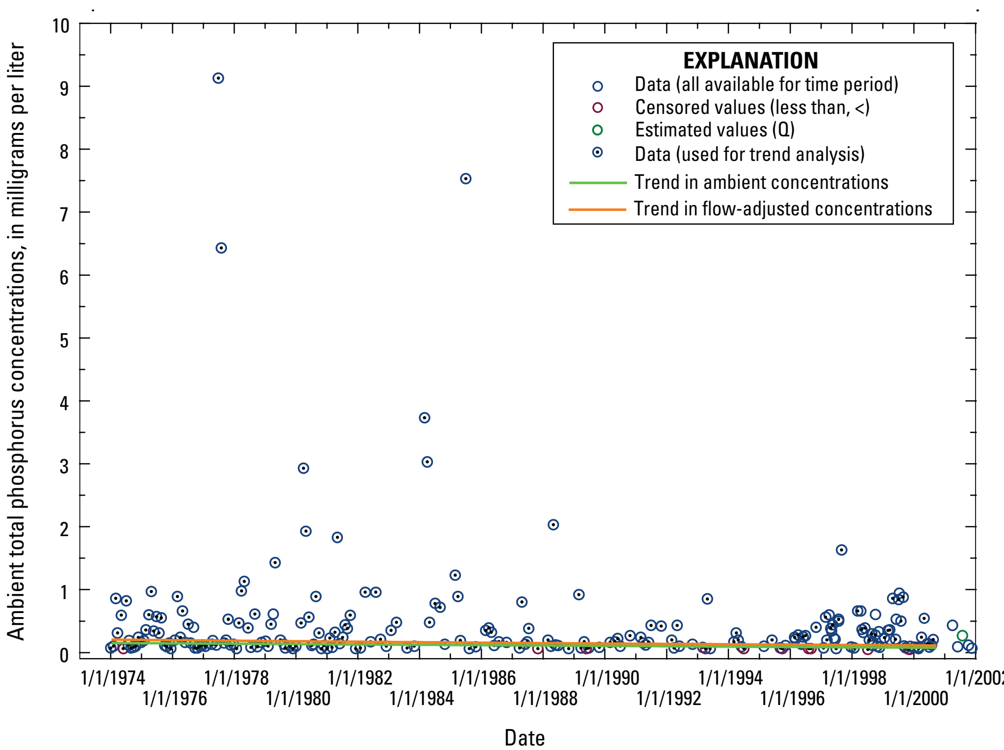


Figure 49. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 66, Green River at Green River, Utah, upstream from Canyonlands National Park, for water years 1974 through 2000. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 2. Estimated values: Q, holding time exceeded before sample delivery or before analysis was completed.]

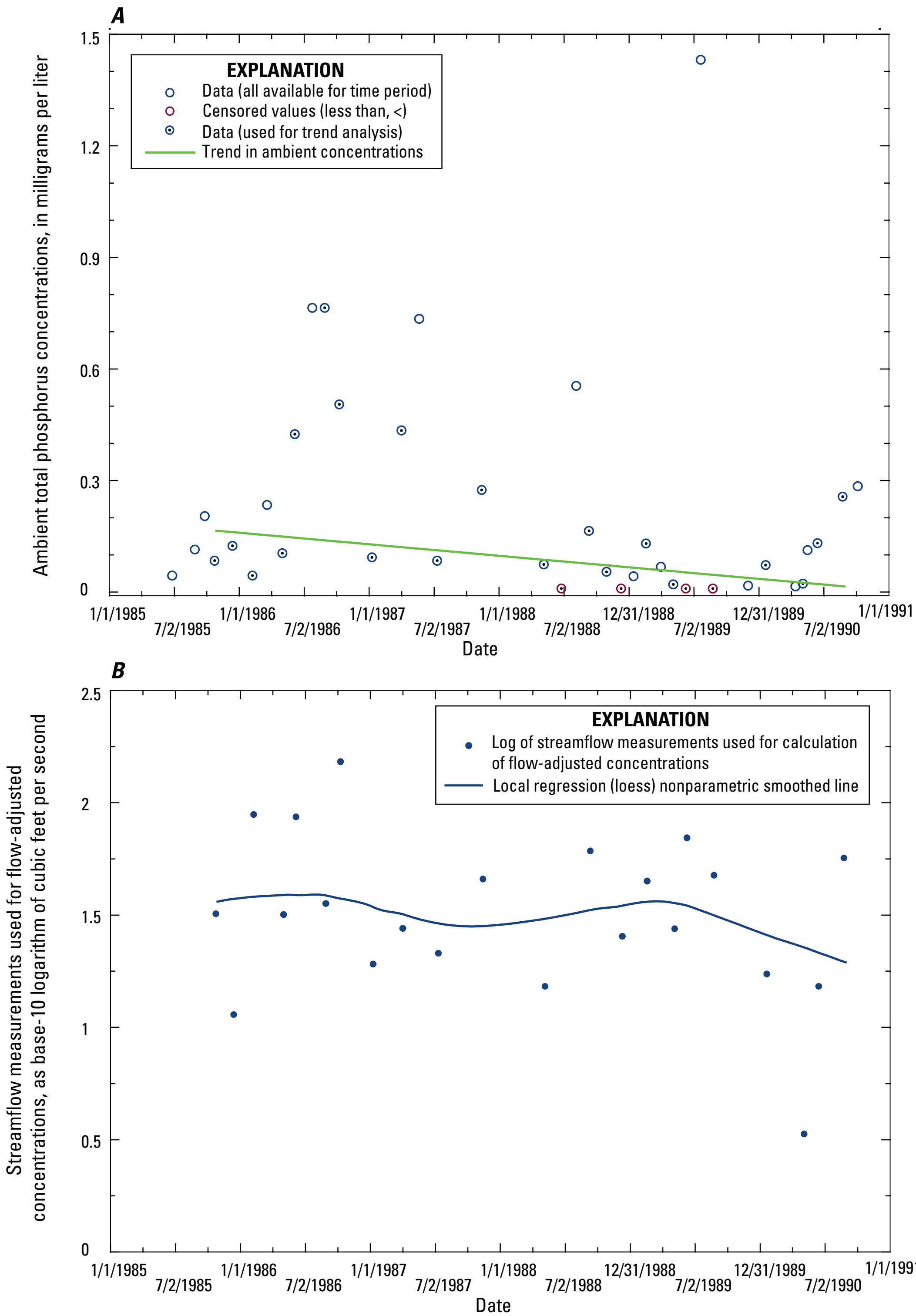


Figure 50. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 71, McElmo Creek at Highway U262 crossing, Utah, near Hovenweep National Monument, for water years 1985 through 1990. [Calculated flow-adjusted calculations not shown on figures. Site information in table 6. Location of site shown in fig. 11.]

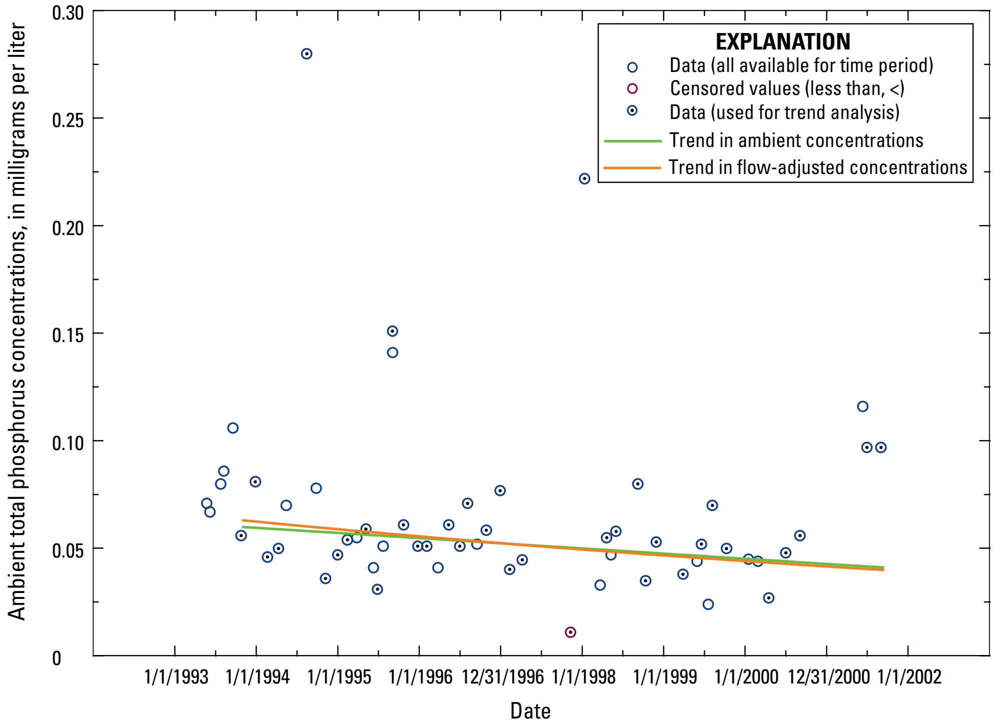
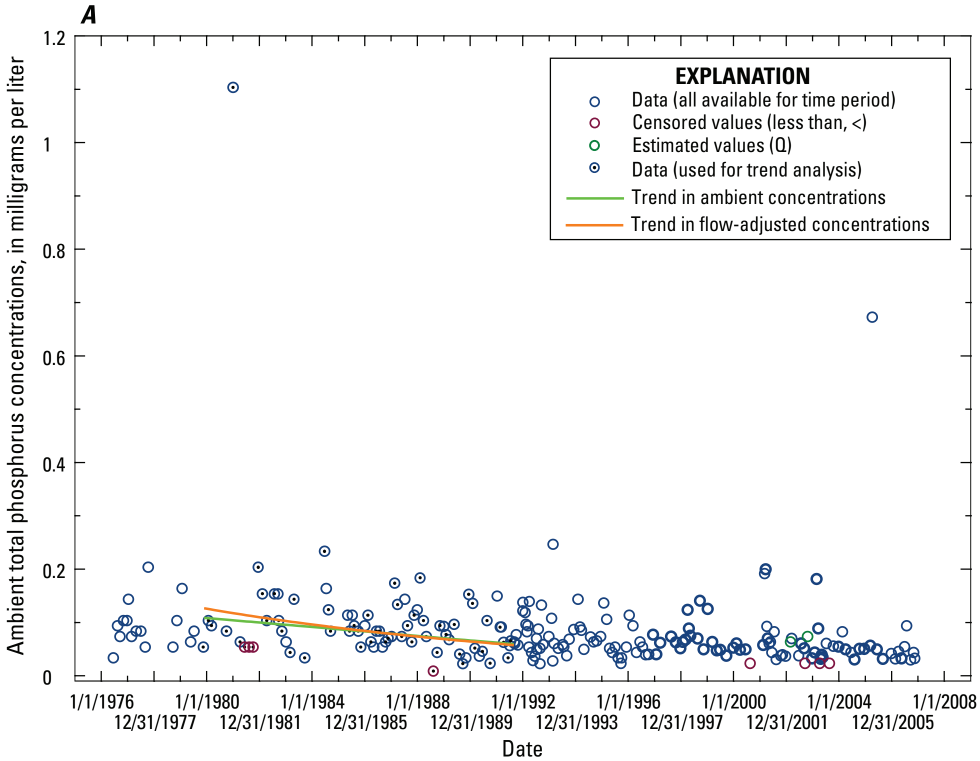


Figure 51. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 79, Fremont River at inflow to Mill Meadow Reservoir, Utah, upstream from Capitol Reef National Park, for water years 1993 through 2001. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 6.]



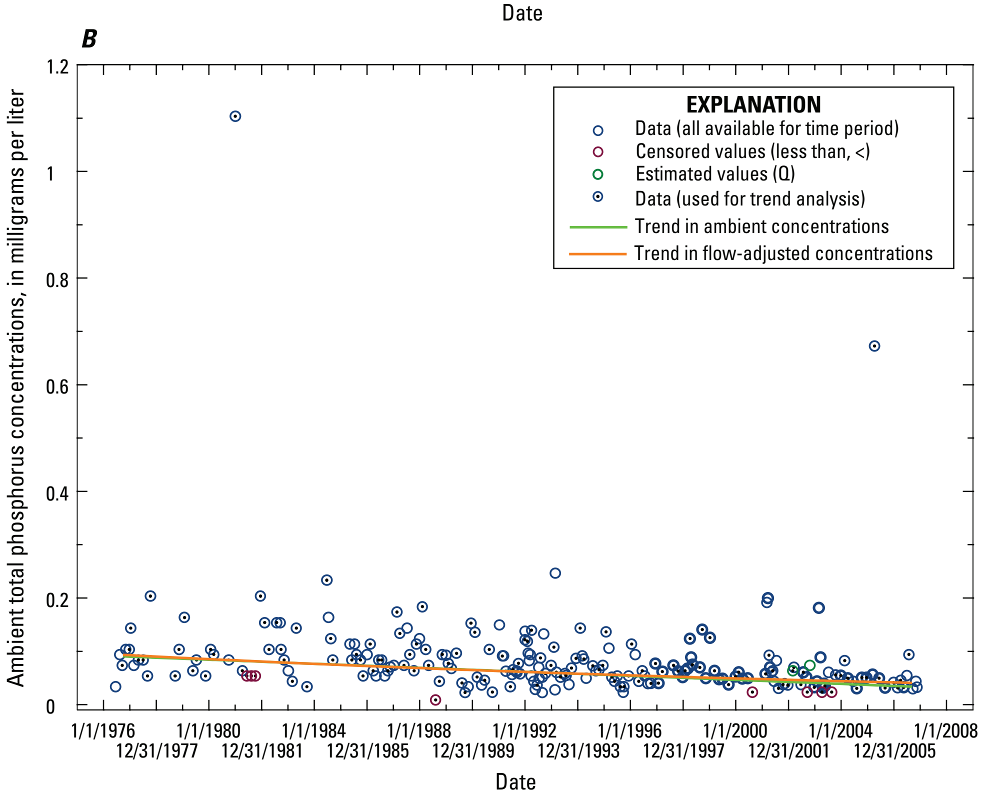


Figure 52. Trends in ambient total phosphorus concentrations and flow-adjusted concentrations for site 84, Fremont River near Bicknell, Utah, upstream from Capitol Reef National Park, for water years *A*, 1979 through 1991, and *B*, 1976 through 2006. [Calculated flow-adjusted concentrations not shown on figure. Site information in table 6. Location of site shown in fig. 6. Estimated values: Q, holding time exceeded before sample delivery or before analysis was completed.]

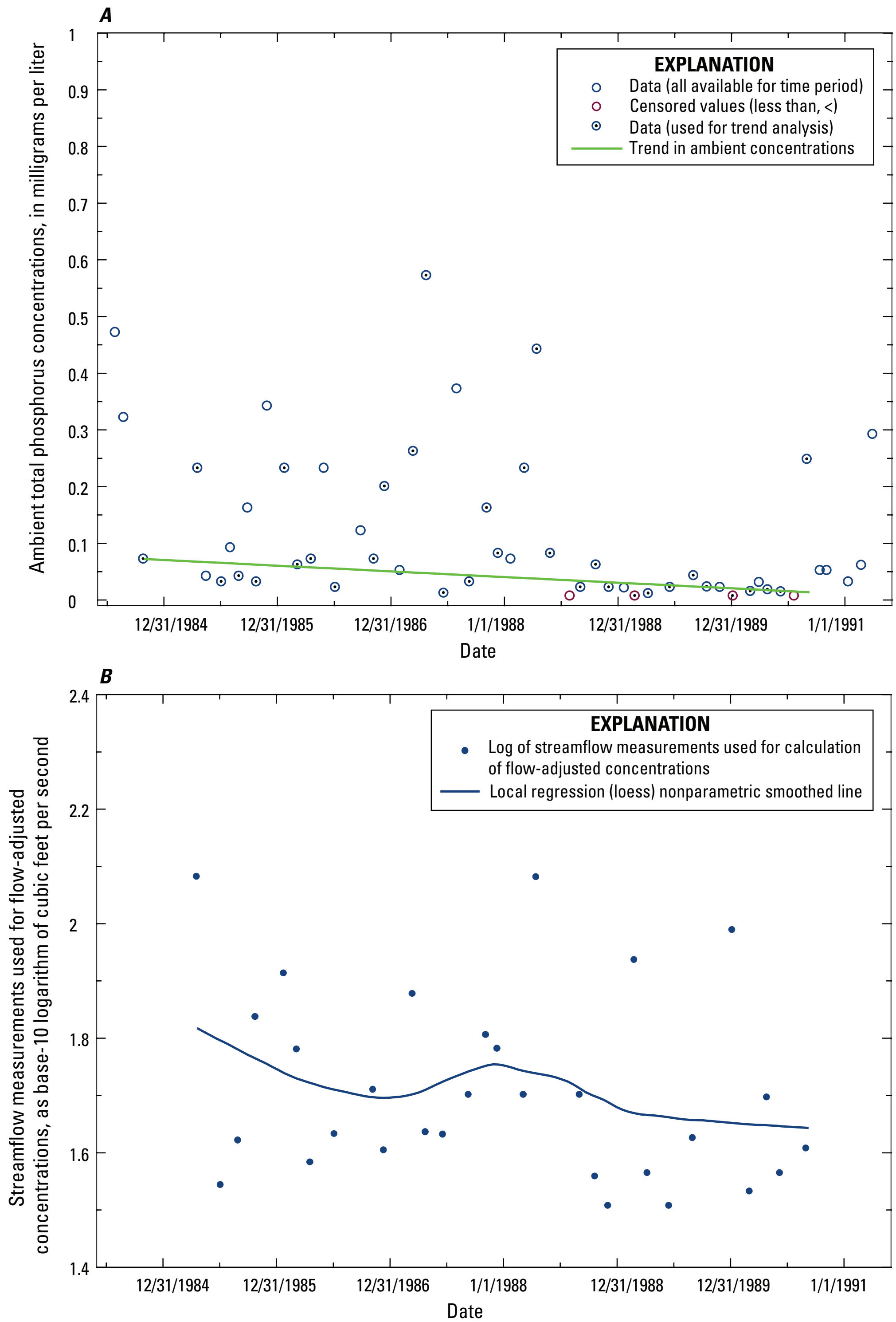


Figure 53. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 85, East Fork Virgin River above confluence, Utah, downstream from Zion National Park, for water years 1984 through 1990. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 4.]

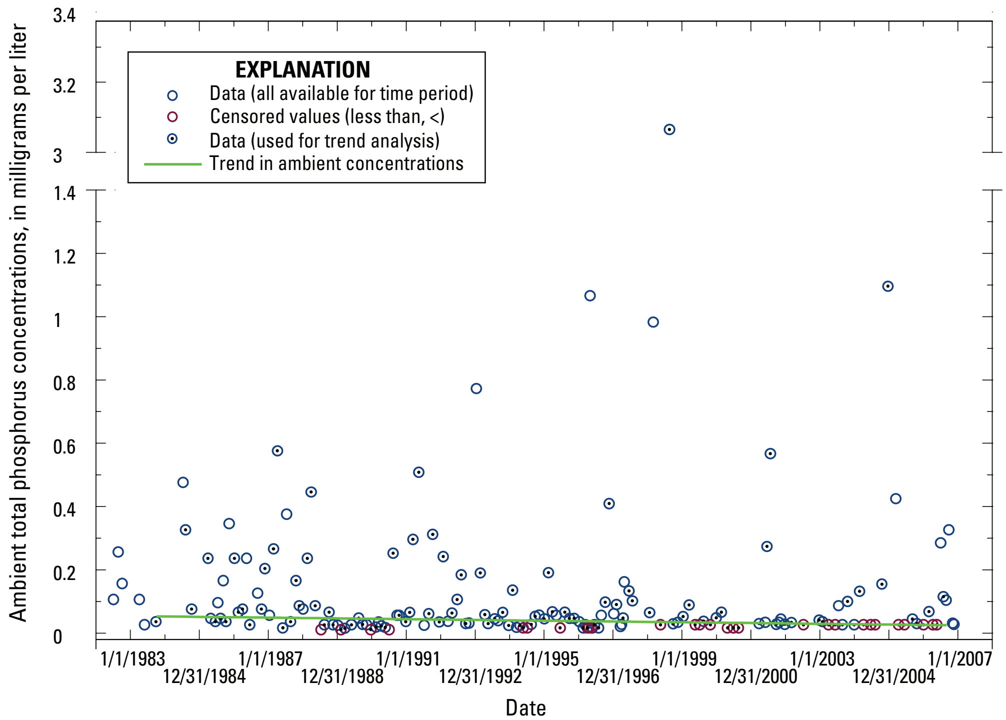


Figure 54. Trend in ambient total phosphorus concentrations for site 85, East Fork Virgin River above confluence, Utah, downstream from Zion National Park, for water years 1983 through 2006. [Site information in table 6. Location of site shown in fig. 4.]

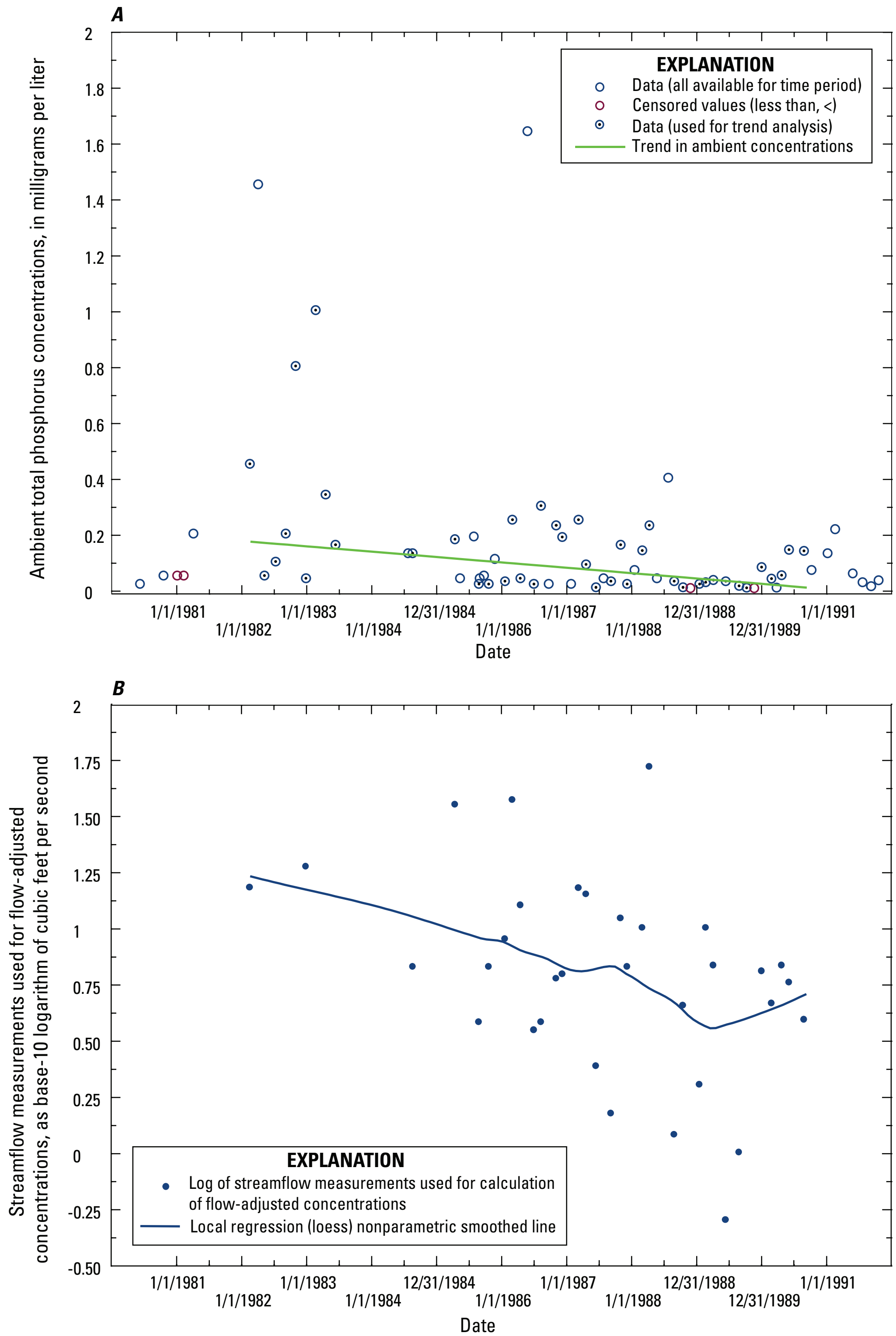
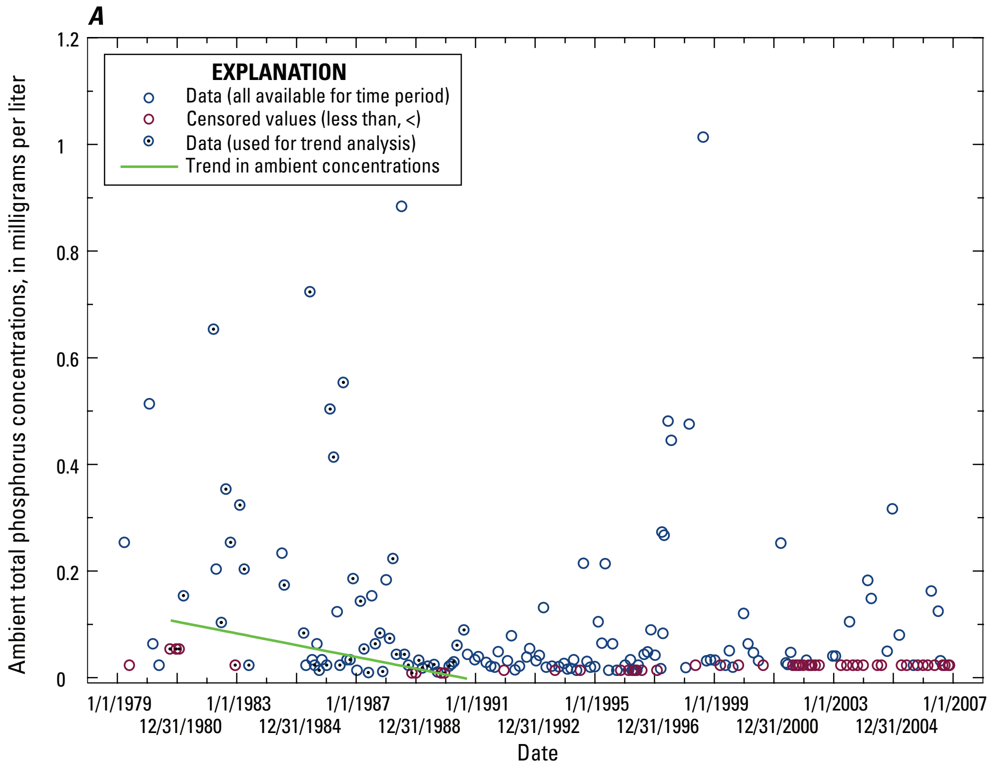


Figure 55. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 91, LaVerkin Creek at Highway 17 Bridge, Utah, downstream from Zion National Park, for water years 1981 through 1990. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 4.]



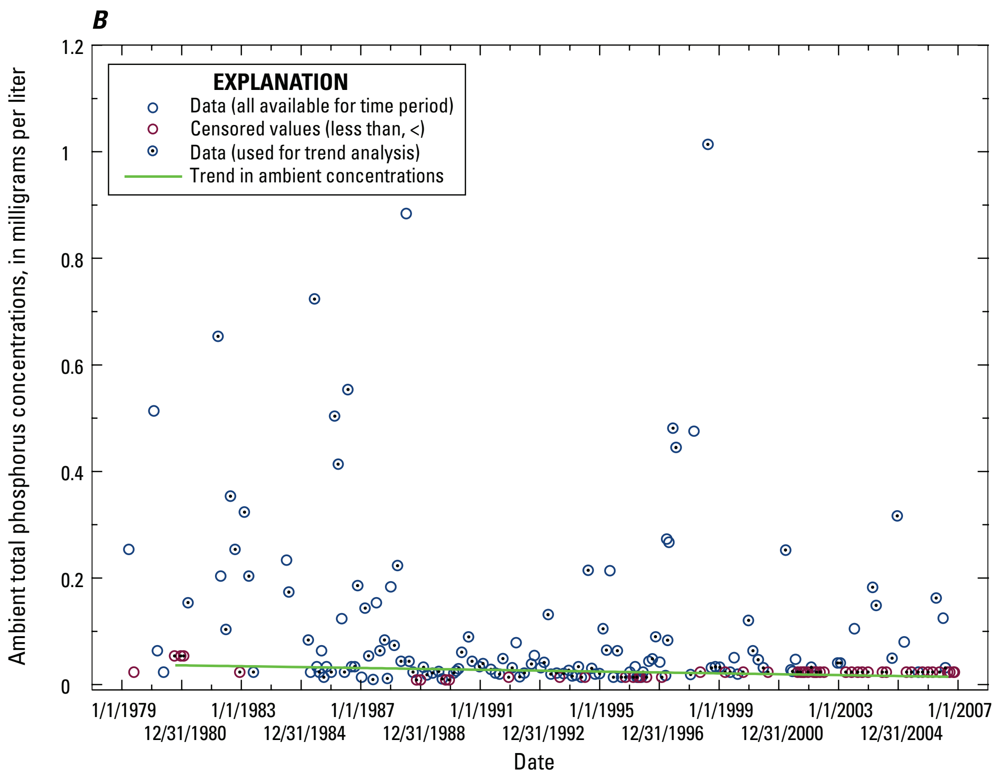


Figure 56. Trends in ambient total phosphorus concentrations for site 92, North Fork Virgin River above confluence, Utah, downstream from Zion National Park, for water years *A*, 1980 through 1990, and *B*, 1980 through 2006. [Site information in table 6. Location of site shown in fig. 4.]

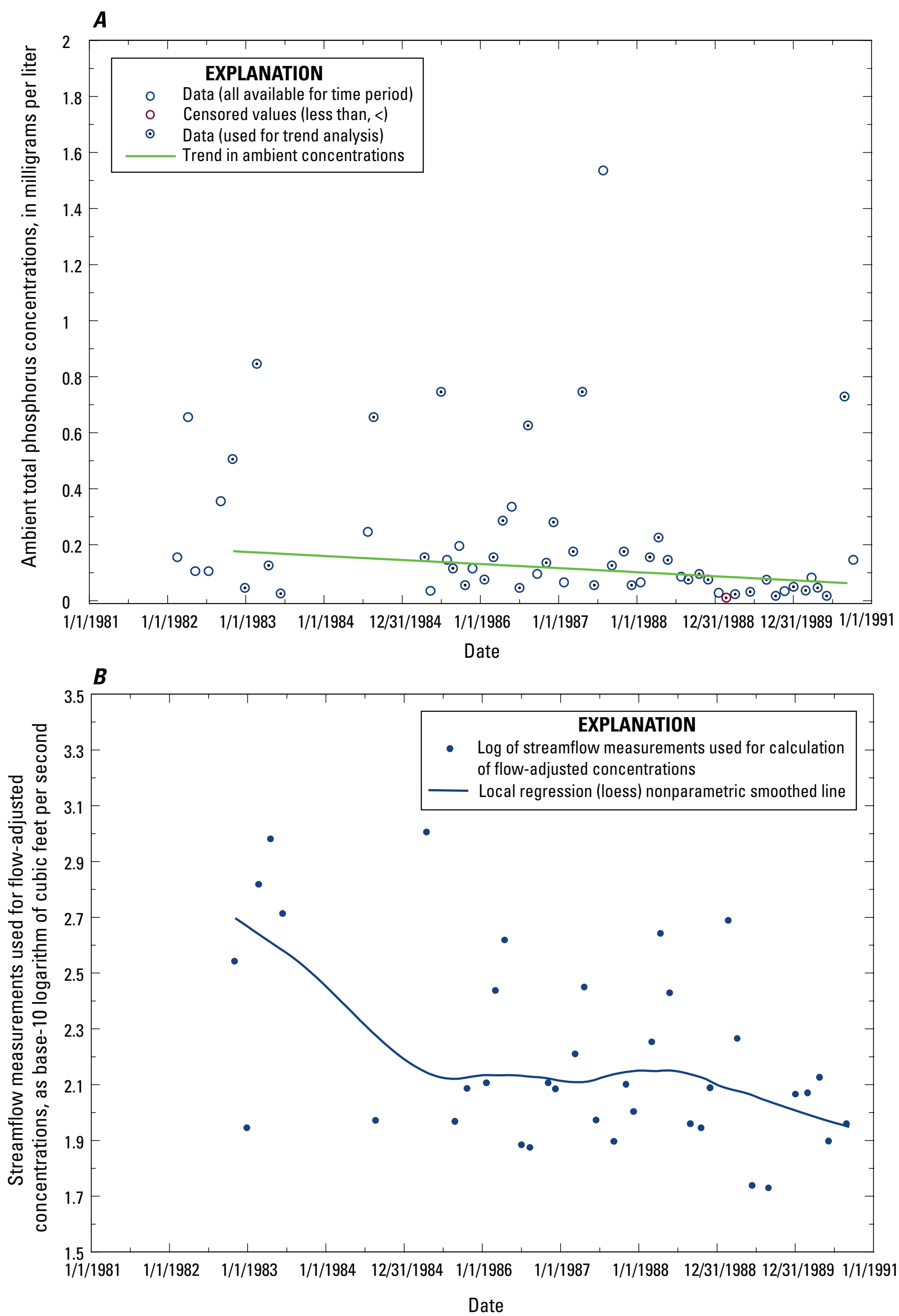


Figure 57. *A*, Trend in ambient total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 95, Virgin River one mile east of Virgin, Utah, downstream from Zion National Park, for water years 1982 through 1990. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 4.]

Trends for Sites with Variable Periods of Record

Data from 18 sites with variable periods of record evaluated for trends in ambient TP concentrations—BLCA sites 1 and 2; CURE sites 9, 17, 24, 25, and 29; DINO sites 35 and 36; ARCH sites 46 and 50; CANY site 66; HOVE site 71; CARE sites 79 and 84; and ZION sites 85, 91, and 95 (see table 6 for site names and information)—had sufficient data for evaluation of trends in flow-adjusted TP concentrations for one or more time periods. These 18 sites include alternative time periods evaluated for 4 of the 5 sites evaluated for historical, long-term trends (for water years 1977 through 1998) and 4 of the 15 sites evaluated for recent, short-term trends (for water years 2001 through 2006) in TP concentrations. The same time periods and seasons used for the analysis of trends in ambient concentrations were used for the sites evaluated for trends in FAC. The process used to determine the optimal time period evaluated for each site is described in the "Selection of Data for Trend Analysis" section of this report. These 18 sites were analyzed for trends in FAC using the uncensored Seasonal Kendall test (table 11). Fifteen of the 18 sites had contemporaneous streamflow measurements for 80 to 100 percent of the TP data, and 4 sites (including ARCH site 50, which also was evaluated for a different time period with a higher percentage of streamflow measurements) had contemporaneous streamflow measurements for between 57 and 79 percent of the TP data. The process used to determine if the streamflow data were sufficient to evaluate trends in FAC is described in the "Selection of Data for Trend Analysis" section of this report. The frequency of TP samples collected with contemporaneous streamflow measurements was highly variable as were the periods of record (fig. 16). The time periods analyzed ranged from 5 to 30 years for data collected for water years 1974 through 2007, and no site had data for the entire time span (table 11). Flow-adjusted TP concentrations for 13 of the 18 sites were analyzed using a 6-season definition; 1 site had sufficient data to evaluate 12 seasons; and 4 sites had sufficient data to use a 3- or 4-season definition. Depending on the time period and seasonal definition, sites had between 13 and 203 results used for the trend analysis. Trends in FAC were evaluated for more than one time period from three sites (ARCH site 50, HOVE site 71, and CARE site 84).

Trends in flow-adjusted TP concentrations for sites with variable periods of record for water years 1974 through 2007 are summarized in table 11. Twelve sites indicated no trends, one site indicated an upward trend, and five sites indicated downward trends. Trends in FAC were the same as the corresponding trends in ambient concentrations at six sites (CURE sites 9 and 24, ARCH site 50, CANY site 66, and CARE sites 79 and 84). Trends in FAC were different from the corresponding trends in ambient concentrations at seven sites (CURE sites 25 and 29; DINO site 35; HOVE site 71; and ZION sites 85, 91, and 95). A significant upward trend in FAC was identified for CURE site 9 (Tomichi Creek at Gunnison, Colo.) from 1995 through 2002, which also had an upward trend in ambient concentrations. For this site, the trend slope was 0.003 mg/L per year with a p-value of 0.034, which is comparable to the significant upward trend in ambient concentrations (slope 0.001 mg/L per year, p-value = 0.073) calculated for this site. The plot showing the TP data available as compared to the TP data used (based on a 6-season definition) for the trend analysis and the corresponding trend line are provided in figure 39.

In contrast, an upward trend in FAC was not identified for CURE site 29 (West Elk Creek below Forest Boundary near Sapinero, Colo.) from 1999 through 2006, but the site had an upward trend in ambient TP concentrations for this time period (trend slope = 0.003 mg/L per year, p-value = 0.056; fig. 40*A*). However, the results for trends in FAC were generally comparable (slope = 0.005 mg/L per year, p-value = 0.170) suggesting that the differences between trends for the ambient and FAC results may be an artifact of the determination of statistical significance. Streamflow measurements used for computing the FAC for site 29 are shown in figure 40*B*. No trend in streamflow was determined for site 29 from 1999 through 2006.

Corresponding significant downward trends in flow-adjusted TP concentrations were identified for five sites — CURE site 24 (Gunnison River at County Road 32 below Gunnison, Colo., from 1998 through 2006), ARCH site 50 (Moab WWTP outflow, from 1978 through 1988 and also from 1977 through 2007), CANY site 66 (Green River at Green River, Utah, from 1974 through 2000), and CARE sites 79 (Fremont River at inflow to Mill Meadow Reservoir, from 1993 through 2001), and 84 (Fremont River near Bicknell, Utah, from 1979 through 1991 and also from 1976 through 2006)—which also have significant downward trends in ambient TP concentrations. These five sites had contemporaneous streamflow measurements corresponding to between 57 and 98 percent of the TP data. Trend slopes were between -0.002 and -0.184 mg/L per year with p-values ranging from less than 0.001 to 0.064 (table 11). The trend slopes and p-values are generally comparable to the results from the analysis of trend in ambient TP concentrations. Plots showing the TP data available as compared to the TP data used (based on a 6-season definition for sites 24, 50, 79, and 84 and a 12-season definition for site 66) for the trend analysis and the corresponding FAC trend line are provided in figures 42, 48, 49, 51, and 52 for sites 24, 50, 66, 79, and 84, respectively.

In contrast, corresponding downward trends in FAC were not identified for six sites—CURE site 25 (Lake Fork Gunnison River below Gateview, Colo., from 1995 through 2005), DINO site 35 (Green River near Jensen, Utah, from 1976 through 2006), HOVE site 71 (McElmo Creek at Highway U262 crossing, Utah, from 1985 through 1990), and ZION sites 85 (East Fork Virgin River above confluence, Utah, from 1984 through 1990), 91 (LaVerkin Creek at Highway 17 Bridge, Utah, from 1981 through 1990), and 95 (Virgin River 1 mi east of Virgin, Utah, from 1982 through 1990)—identified as having downward trends in ambient TP concentrations for the same time periods (figs. 43*A*, 46*A*, 50*A*, 53*A*, 55*A*, and 57*A* for sites 25, 35, 71, 85, 91, and 95,

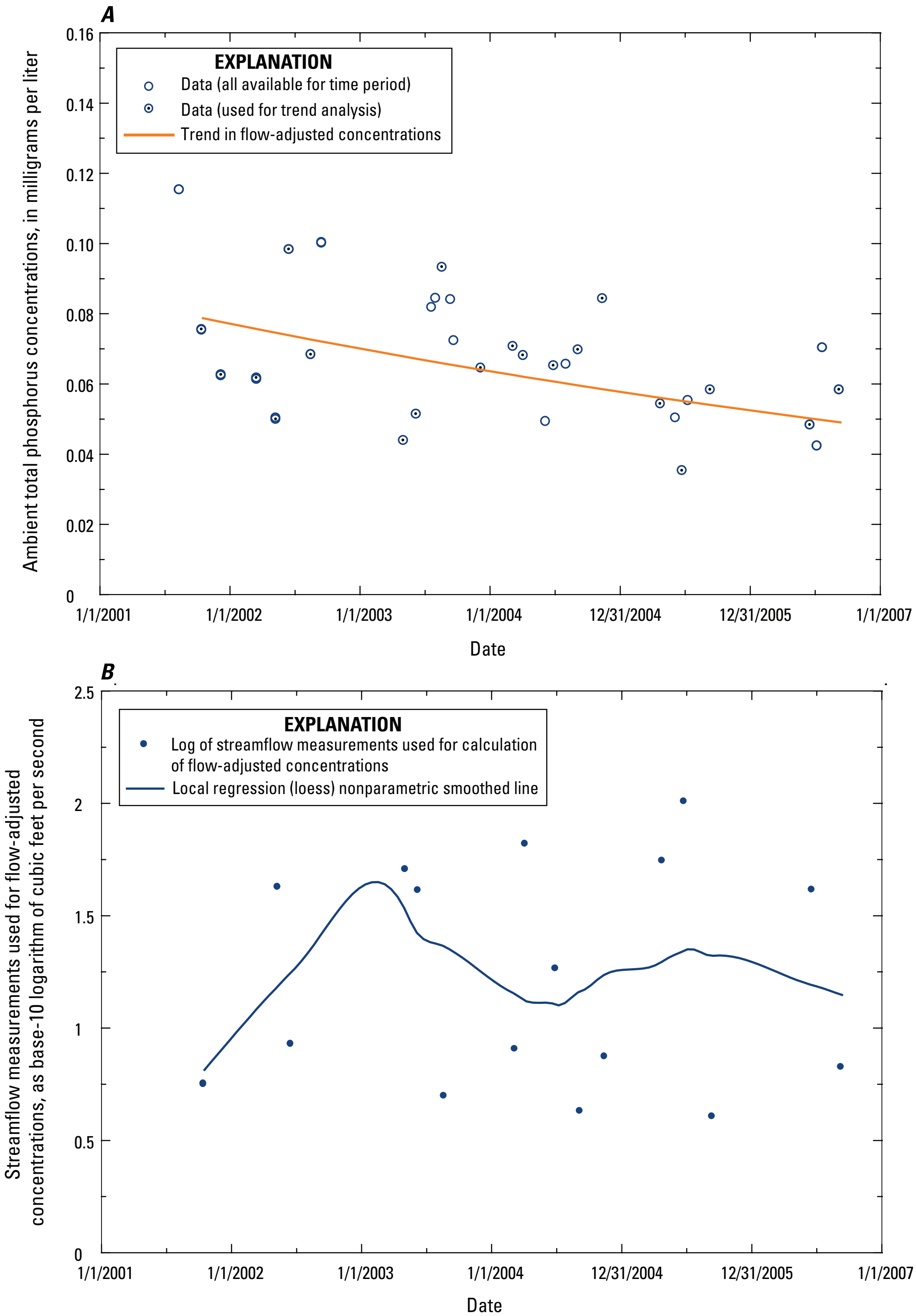


Figure 58. *A*, Trend in flow-adjusted total phosphorus concentrations, and *B*, time series of streamflow measurements used for flow-adjusted concentration calculations for site 10, Curecanti Creek near Sapinero, Colo., upstream from Curecanti National Recreation Area, for water years 2001 through 2006. [Calculated flow-adjusted concentrations not shown on figures. Site information in table 6. Location of site shown in fig. 3.]

respectively). Streamflow measurements used for computing the FAC for these six sites are shown in figure 43*B* for site 25 (no trend in streamflow), figure 46*B* for site 35 (no trend in streamflow from 1976 through 2001 with insufficient data after 2001 to test for trend), figure 50*B* for site 71 (no trend in streamflow), figure 53*B* for site 85 (no trend in streamflow), figure 55*B* for site 91 (downward trend in streamflow, p-value of 0.024 for 6-season Seasonal Kendall test from 1984 through 1991 with insufficient data prior to 1984 to test for trend), and figure 57*B* for site 95 (downward trend in streamflow, p-value of 0.014 for 6-season Seasonal Kendall test from 1982 through 1990). For site 35, the results for analysis of trend in FAC was generally comparable to the result for trend in ambient concentrations (slope -0.001 mg/L per year and p-value of 0.145 as compared to a slope of -0.002 mg/L per year and p-value of 0.002) suggesting that the differences between trends for the ambient and FAC tests for this site may be an artifact of the determination of statistical significance. Monotonic downward trends in streamflow were identified for part of or the entire trend time periods for sites 91 and 95 and possibly influenced the downward trends in ambient TP concentrations identified for these sites.

Summary and Discussion of Trends in Total Phosphorus

The significant upward or downward trends in ambient and flow-adjusted TP concentrations (p-value less than 0.10) for sites evaluated for historical long-term trends for water years 1977 through 1998 (table 9), recent, short-term trends for water years 2001 through 2006 (table 10), and(or) with variable periods of record for water years 1974 through 2007 (table 11) are summarized in table 12. Generally, these results represent temporal trend periods from the middle to late 1970s or early 1980s through the 1990s or early 2000s, although time periods varied for the sites.

Few upward trends in ambient or flow-adjusted TP concentrations were identified for the 51 and 27 sites, respectively, evaluated in and near the NCPN park units (tables 9, 10, and 11). Two sites on tributaries to the Gunnison River with significant upward trends in ambient and(or) flow-adjusted TP concentrations were identified in CURE (sites 9 on Tomichi Creek and 29 on West Elk Creek) and are summarized in table 12. These sites had short data records of between 6 and 7 years with all temporal trends identified for time periods between 1995 and 2007 suggesting more recent changes at the site or in the basin have increased TP concentrations in these tributaries. Site 9, with upward trend in ambient and FAC, suggests changes in the basin are contributing to increasing TP concentrations in Tomichi Creek. No corresponding trend in ambient TN concentrations was identified for site 9. Land cover in the Tomichi Creek basin (site 9) is primarily mixed forest and grassland although agricultural activities adjacent to the stream throughout much of the basin may be contributing phosphorus to the stream (U.S. Geological Survey, 2000; ESRI, 2011). Additionally, wastewater discharge, septic, and urban runoff may be contributing phosphorus to the stream from the town of Gunnison and surrounding areas upstream from the water-quality sampling site. In contrast, site 29, with an upward trend in ambient concentrations, did not show a corresponding trend in FAC for either time period analyzed (1999 through 2005 or 2001 through 2006) suggesting the trend at this site may be driven by change in streamflow in West Elk Creek, although no trend in streamflow was determined for either time period. Land cover in the West Elk Creek basin (site 29) is principally forested and interspersed with bare rock, shrub land, and grassland (U.S. Geological Survey, 2000). Although it is largely an undeveloped basin, some limited agricultural activity and roads are adjacent to or near the stream in the lower part of the basin (ESRI, 2011). Data were insufficient to test for a corresponding trend in TN concentrations at site 29. Nutrient water-quality monitoring at these two sites may be warranted to determine if the recent upward trends in TP concentrations at these sites are indicative of human activities in the basin that might be managed or are a result of streamflow and climate changes.

Seventeen sites with one or more significant downward trends in ambient and(or) flow-adjusted TP concentrations were identified in COLM (site 4), CURE (sites 10, 24, and 25), DINO (sites 31, 33, and 35), ARCH (sites 48 and 50), CANY (site 66), HOVE (site 71), CARE (site 79 and 84), and ZION (sites 85, 91, 92, and 95). These sites are on or tributary to the Colorado, Dolores, Fremont, Green, Gunnison, Virgin, or Yampa Rivers. More than one downward trend in ambient and flow-adjusted TP concentrations was identified at five sites (sites 50, 66, 84, 85 (no FAC results for one time period), and 92 (no FAC results)) for different time periods. The trend results from these five sites evaluated for multiple time periods were generally comparable, although sites 85 and 92 indicated an order of magnitude difference between slopes from trends of different time periods; the longer time periods indicated less change (that is, a lower slope value). Four sites (sites 25, 31, 35, and 48) evaluated for more than one trend time period indicated differing trend results between time periods; no trends were identified for the shorter time period, and significant downward trends were identified for a longer time period. Sites 4, 10, 24, 25, 71, 79, 91, and 95 had short to moderate data records of between 5 and 12 years with downward trends; sites 31, 33, 35, 48, and 66 had longer records of between 18 and 30 years with downward trends. Sites 50, 84, 85, and 92 had both moderate (6 to 12 years) and longer records (between 21 and 30 years) with downward trends. Only 1 of the 17 sites (site 10) had a downward trend in FAC without a corresponding trend in ambient concentrations. Five of the 17 sites (sites 4, 31, 33, 48, and 92) lacked sufficient streamflow measurements for analysis of FAC.

Sites with trends in flow-adjusted TP concentrations indicate the mobilization and transportation of nutrients have changed in the basin (irrespective of streamflow). Most of these trends (except for the upward trends identified at CURE sites 9 and 29) indicate changes have resulted in reduced TP concentrations in streams. These downward trends may be the result of improved wastewater treatment, which would have taken place in upstream communities and in the park units during the intervening years (late 1970s and 1980s) of these moderate and longer time periods evaluated for trend. As discussed previously, these wastewater treatment advancements were primarily driven by the CWA of 1972 (U.S. Congress 1972), the CWA of 1977 (U.S. Congress, 1977), and the Water Quality Act of 1987 (U.S. Congress, 1987). Collectively these acts facilitated the implementation of new or improved wastewater collection and treatment infrastructure, the development of best-management practices, and the establishment of nonpoint-source management and control programs. For example, TP concentrations were reduced from ARCH site 50 (Moab WWTP outflow) possibly as a result of improved wastewater treatment in Moab, Utah. It also is possible that improvements in grazing, timber harvesting, and irrigated agriculture through the implementation of best-management practices (for example, switch from flood irrigation to sprinkler irrigation or fencing off streams to livestock) have resulted in lower nutrient concentrations in and near some park units. The development and implementation of best-management practices were advanced with the passage of the Federal Land Policy and Management Act of 1976 (U.S. Congress, 1976) and the Public Rangelands Improvement Act of 1978 (U.S. Congress, 1978), which focused on inventorying and improving the management of public lands, including public rangeland conditions. However, because of the mixed land uses in most of these basins, it is possible that multiple changes have taken place upstream from these sites and influenced the downward trends in TP concentrations. For example, CANY site 66 on the Green River is downstream from the town of Green River, and farther upstream is the town of Jensen, Utah, as well as the facilities in DINO (fig. 8). Changes to improve the wastewater treatment in these towns (as a result of regulations and technology advancements) combined with reduced runoff from agricultural activities such as fertilizer applications and grazing could have resulted in the reduced TP concentrations observed at this site from 1974 through 2000 (and from 1977 through 1998).

Synthesis of Total Nitrogen and Total Phosphorus Trend Results

NCPN and NPS offices have an interest in the regional or national water-quality issues that may be of concern to multiple park units. To synthesize the results networkwide, the trend results from 52 sites evaluated for trends in TN (34 sites) and(or) TP (51 sites) concentrations (tables 9, 10, and 11) were plotted to correspond to the data-density plots (figs. 13–16) described earlier in "Selection of Data for Trend Analysis" section (figs. 59–62). Trend results for the 24 sites for which multiple time periods were evaluated are plotted adjacently according to the site number (for example, TN and TP trend results for site 31 are plotted at y-axis positions of 31.0 and 31.3 in figs. 59, 60, and 61). The composite trend result plots convey temporal and spatial information that can be used by the NCPN staff and individual park-resource managers to prioritize surface water of interest for additional or sustained monitoring activities.

Comparisons between the data-density plots (figs. 13–16) and the composite trend-result plots (figs. 59–62) show that a large number of sites initially considered by this study were not used for trend analysis because of high percentages of censoring, large data gaps, insufficient corresponding streamflow measurements, or insufficient or irregular sampling frequency. The absence of contemporaneous streamflow measurements restricts the ability to evaluate many of the trend results relative to changes in streamflow. Where contemporaneous streamflow records are lacking, trend analysis of corresponding precipitation records or of representative streamflow at streamgages upstream or downstream from NCPN water-quality sampling sites might yield additional insight into identified trends in ambient concentrations. Another observation from comparing these plots are that some downward trends (for example, DINO site 35 for TN) may be an artifact of lower detection limits over time resulting in more discrete low values in the more recent time period; however, many sites do not have sufficient current (or historical) records to make this determination.

Observations regarding trends in ambient and flow-adjusted TN concentrations can be made from figures 59 and 60 and tables 9–12. Trends in ambient and flow-adjusted TN concentrations were analyzed for 34 sites (45 trend analyses) and 21 sites (31 trend analyses), respectively, and for multiple time periods for 8 of these sites. Thirteen sites (38 percent) could not be evaluated for corresponding trend in FAC because of insufficient streamflow measurements or high percentages of censoring. No trends in ambient TN concentrations were identified for 24 sites (28 time periods, 62 percent), upward trends were identified for 3 sites (3 time periods, 7 percent), and downward trends were identified for 9 sites (14 time periods, 31 percent). No trends in flow-adjusted TN concentrations were identified for 16 sites (19 time periods, 61 percent), upward trends were identified for 2 sites (2 time periods, 7 percent), and downward trends were identified for 5 sites (10 time periods, 32 percent).

Two sites, DINO sites 30 and 31, had different trend results when analyzed for trends in ambient and flow-adjusted TN concentrations for different time periods. Trends in ambient and FAC for site 30 are downward for the three longer, historical time periods; the fourth more recent time period has an upward trend in ambient concentrations and no trend in FAC. Trends in ambient and FAC for site 31 are upward for the longer, historical time period and non-significant for the more recent, shorter time period.

Four sites had different trends in ambient TN concentration as compared to trends in FAC. Three of these sites (CURE site 26 and DINO sites 30 (9-year period) and 35) indicated upward or downward trends in ambient TN concentrations and no corresponding trends in FAC indicating streamflow was the

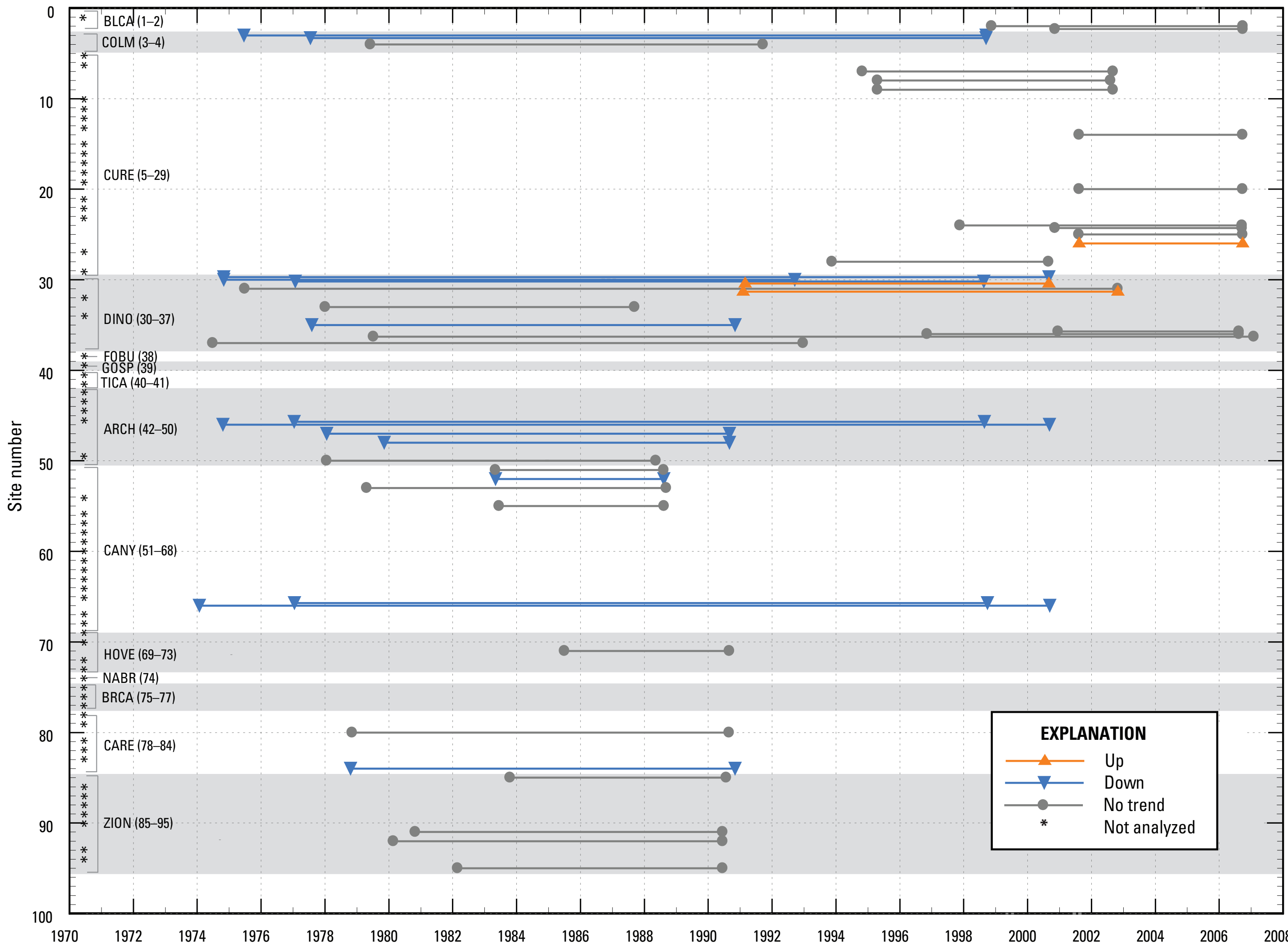


Figure 59. Summary of results of trends in ambient concentrations for total nitrogen for water-quality sampling sites in the Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–8 and 11. Numbers in parentheses following park code indicate range of site numbers for the park. See tables 9, 10, and 11 for trend results.]

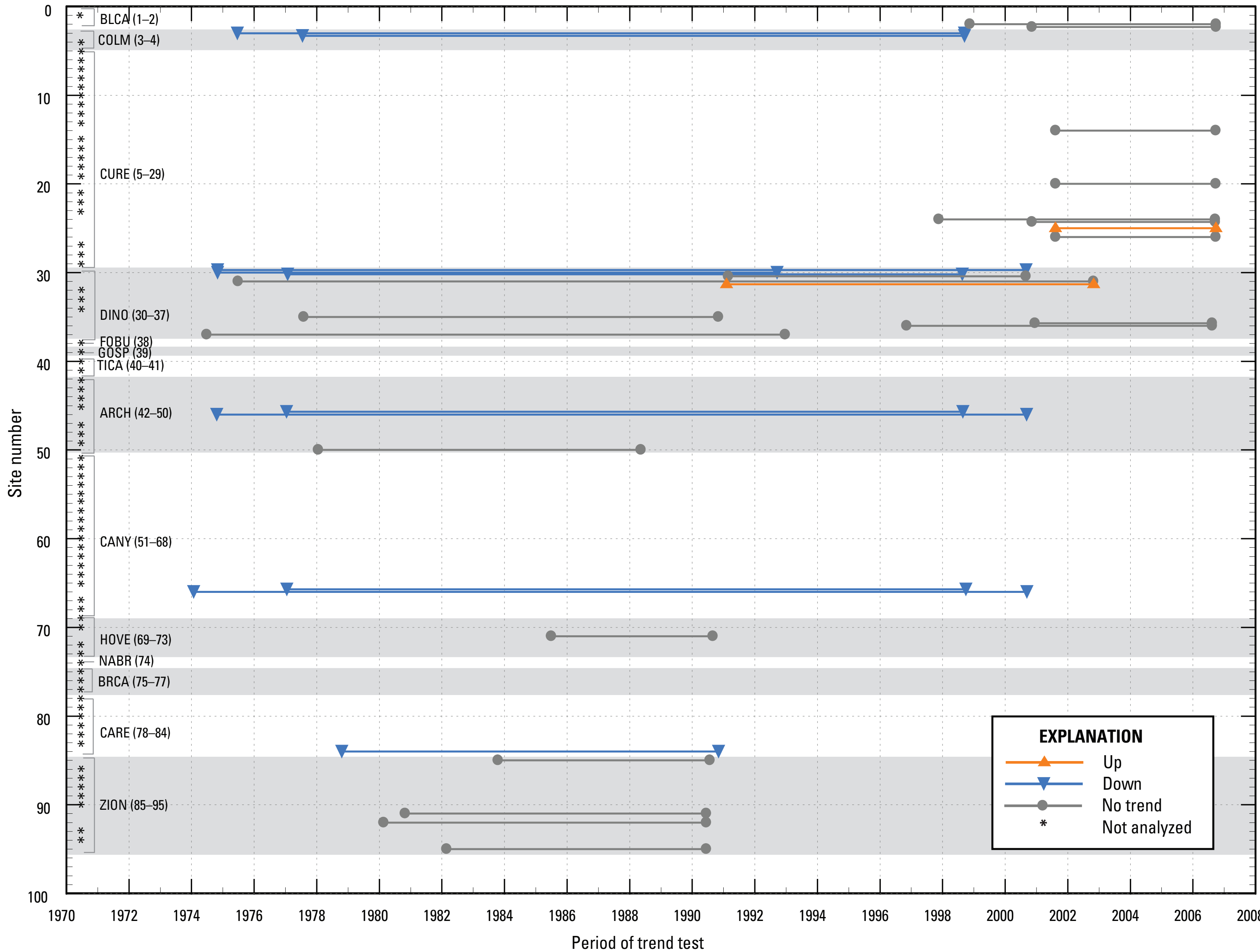


Figure 60. Summary of results of trends in flow-adjusted concentrations for total nitrogen for water-quality sampling sites in the Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–8 and 11. Numbers in parentheses following park code indicate range of site numbers for the park. See tables 9, 10, and 11 for trend results.]

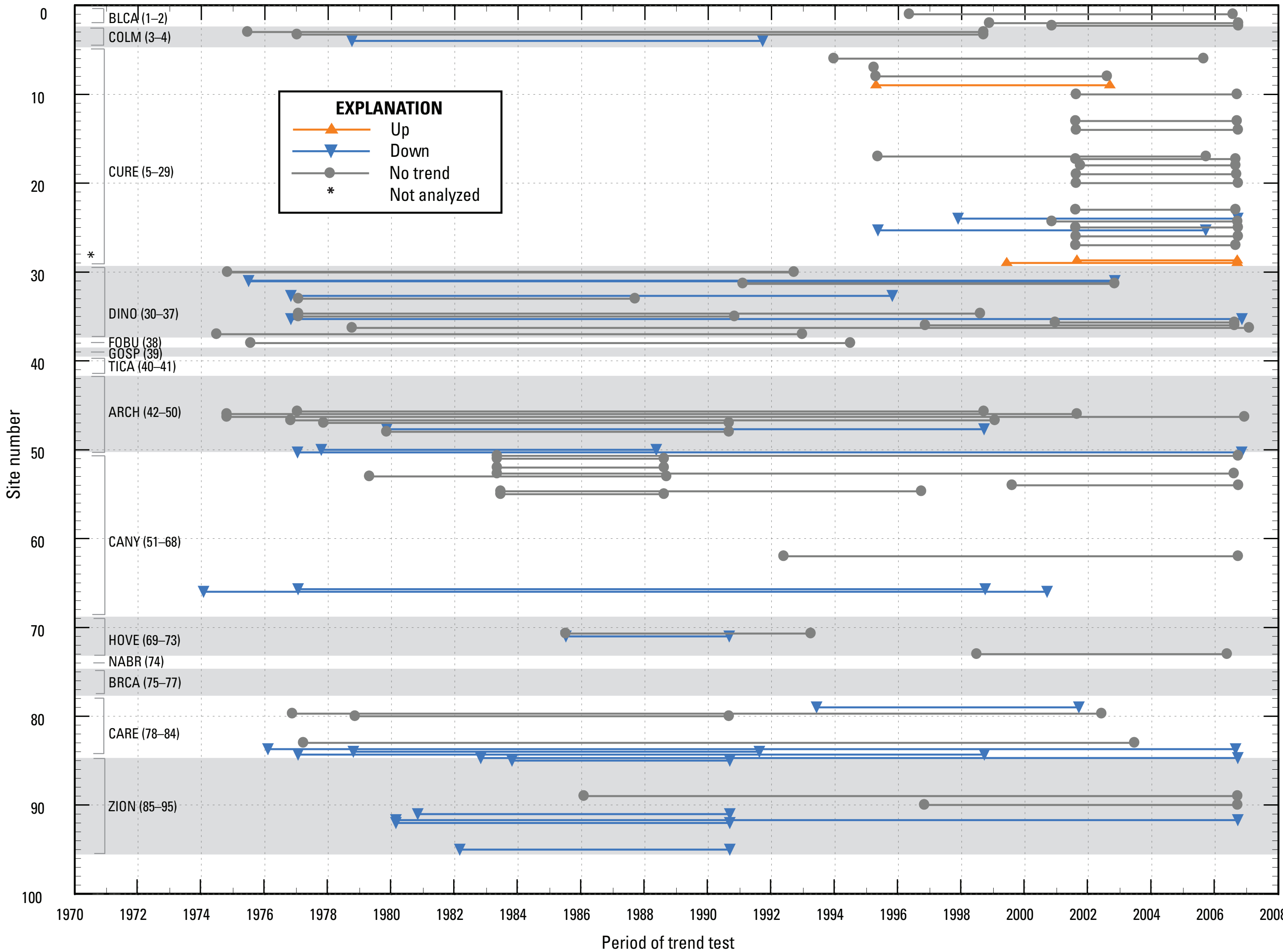


Figure 61. Summary of results of trends in ambient concentrations for total phosphorus for water-quality sampling sites in the Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–9 and 11. Numbers in parentheses following park code indicate range of site numbers for the park. See tables 9, 10, and 11 for trend results.]

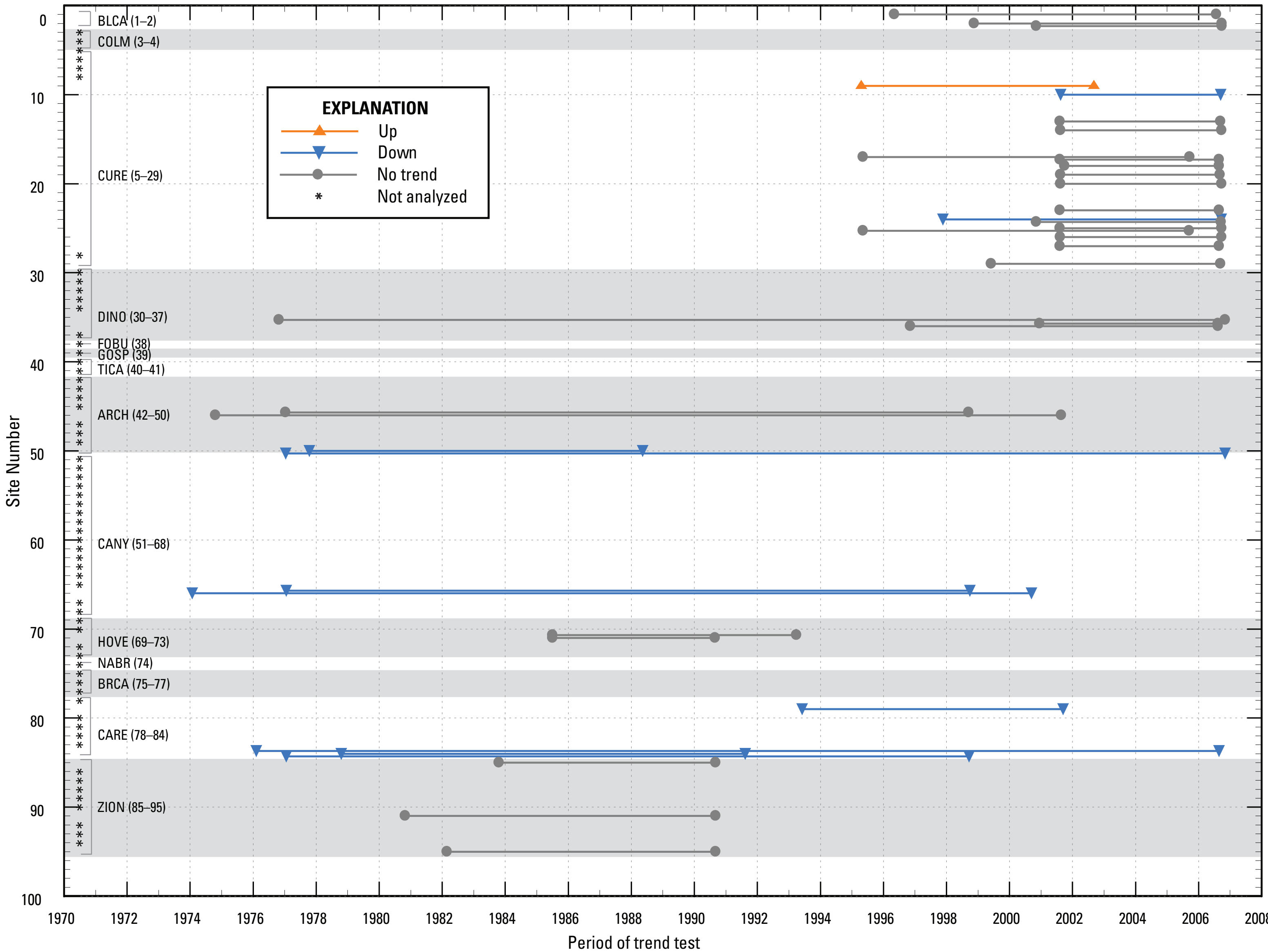


Figure 62. Summary of results of trends in flow-adjusted concentrations for total phosphorus for water-quality sampling sites in the Northern Colorado Plateau Network, for water years 1974 through 2007. [Park codes explained in table 1. Sites described in table 6 and shown in figs. 2–8 and 11. Numbers in parentheses following park code indicate range of site numbers for the park. See tables 9, 10, and 11 for trend results.]

driving factor in the trends identified at these sites. The fourth site (CURE site 25) had no trend in ambient TN concentrations but an upward trend in FAC; however, this difference in trend also may be an artifact of the determination of statistical significance.

Upward trends in ambient and(or) flow-adjusted TN concentrations were identified at three sites (CURE site 26 and DINO sites 30 and 31) and two sites (CURE site 25 and DINO site 31), respectively, and only for shorter time periods beginning in the early 1990s or early 2000s.

The downward trends in ambient and flow-adjusted TN concentrations were during earlier historical periods (generally starting in the 1970s or early 1980s and ending in the 1990s or 2000s). Sites (COLM site 3, DINO site 30, ARCH site 46, and CANY site 66) evaluated for historical, long-term trends from 1977 through 1998 or similar time periods of 20 or more years starting in the mid- to late 1970s and ending in the mid- to late 1990s or early 2000s consistently show downward trends in ambient TN concentrations. These four sites are on the Colorado, Green, or Gunnison Rivers and reflect larger basins influenced by various upstream human activities, including large reservoir systems, numerous cities and towns, and various agricultural activities. The long-term downward trends suggest that at least at these sites nutrient water quality is improving. In contrast, DINO sites 31 and 36 (Yampa River upstream from the monument boundary) show no trend during this historical, long-term period despite multiple upstream human influences (for example, municipalities and numerous grazing allotments and related agricultural activities), although there are no large reservoirs upstream from these sites.

Other sites with shorter historical records of between 6 and 12 years and ending in the late 1980s or early 1990s from COLM, DINO, ARCH, CANY, HOVE, CARE, and ZION show a mix of no trend and downward trend results. No recent, short-term downward trends in ambient or flow-adjusted TN concentrations were identified for any NCPN sites. Several sites within or near the BLCA and CURE park units provide the most recent short-term datasets for trend analysis, but they lacked historical TN data (before the early 1990s). Nearly all sites in and near NCPN park units (except sites in or near BLCA and CURE, DINO site 36, and the other long-term sites noted above) were unable to be evaluated for trends in ambient or flow-adjusted TN concentrations after the early 1990s. For example, sites in and near ARCH (except site 46), CANY (except site 66), HOVE, CARE, and ZION had insufficient TN data after the early 1990s for any recent trend analysis. Sites in and near FOBU, GOSP, TICA, NABR, and BRCA had insufficient TN data to be evaluated for any trend analysis.

Furthermore, observations regarding trends in ambient and flow-adjusted TP concentrations can be made from figures 61 and 62 and tables 9-12. Trends in ambient and flow-adjusted TP concentrations were analyzed for 51 (78 trend analyses) and 27 sites (39 trend analyses), respectively, and for multiple time periods for 23 of these sites (11 FAC sites). Twenty-four sites (47 percent) could not be evaluated for corresponding trends in FAC because of insufficient streamflow measurements or high percentages of censoring. No trends in ambient TP concentrations were identified for 40 sites (53 time periods, 68 percent); upward trends were identified for 2 sites (3 time periods, 4 percent); and downward trends were identified for 16 sites (22 time periods, 28 percent). No trends in flow-adjusted TP concentrations were identified for 21 sites (28 time periods, 72 percent); an upward trend was identified for 1 site (1 time period, 2 percent); and downward trends were identified for 6 sites (10 time periods, 26 percent).

Seven sites analyzed for trends in ambient or flow-adjusted TP concentrations for more than one time period (CURE sites 24 and 25; DINO sites 31, 33, and 35; ARCH site 48; and HOVE site 71) had different trend results for multiple time periods.

Eight sites had different trends in ambient TP concentration as compared to trends in FAC. Seven of these sites (CURE sites 25 and 29; DINO site 35; HOVE site 71; and ZION sites 85, 91, and 95) indicated upward or downward trends in ambient TP concentrations and no corresponding trends in FAC indicating streamflow was the driving factor in the trends identified at these sites. The eighth site (CURE site 10) had no trend in ambient TP concentrations but a downward trend in FAC.

Upward trends in ambient and(or) flow-adjusted TP concentrations were identified at two sites, CURE sites 9 and 29, respectively, and only since the mid- to late 1990s or early 2000s.

Most of the downward ambient and flow-adjusted TP concentrations were during earlier historical periods (generally starting in the 1970s or early 1980s and ending in the 1990s or 2000s). Several sites (DINO sites 31, 33, and 35 (for time period ending in 2006); ARCH sites 48 and 50; CANY site 66; CARE site 84; and ZION sites 85 and 92) evaluated for historical, long-term trends from 1977 through 1998 or similar time periods of 18 or more years starting in the late 1970s or early 1980s and ending in the mid- to late 1990s or early 2000s consistently show downward trends in ambient TP concentrations. These nine sites are on the Dolores, Green, Virgin, or Yampa Rivers and reflect a mix of smaller and larger basins influenced by various upstream human influences (for example, recreation, resource-extraction activities, grazing and irrigated agriculture, and WWTP discharges), and geology. The long-term downward trends suggest that at least at these sites nutrient water quality is improving. In contrast, eight sites (COLM site 3, DINO sites 35 (for time periods ending in the early and late 1990s) and 36, ARCH sites 46 and 47, CANY site 51, and CARE sites 80 and 83) show no trends during this historical, long-term period despite similar upstream human influences.

Other sites with shorter historical records of between 6 and 12 years and ending in the late 1980s or early to mid-1990s from COLM, DINO, ARCH, CANY, HOVE, CARE, and ZION show a mix of no trend and downward trend results. Unlike the TN results, a few recent, short-term downward trends in ambient or flow-adjusted TP concentrations were identified (CURE sites 10 (FAC), 24, and 25). Several sites within or near the BLCA and CURE park units and a few sites in or near DINO, CANY, HOVE, and ZION provide the most recent short-term datasets for trend analysis, although most sites lacked historical TP data (before the early 1990s). Sites in and near GOSP, TICA, NABR, and BRCA had insufficient TP data to be evaluated for any trend analysis.

Generally, trends in TN and TP concentrations at water-quality sampling sites in the NCPN have remained unchanged or have resulted in lower nutrient concentrations over time at most sites. Similarities between trends in ambient and flow-adjusted TN and TP concentrations can be identified by comparing figures 59 and 61 and figures 60 and 62 and the results in table 12. Typically, more data for a longer time period and from more sites were available for evaluation of TP trends in ambient concentrations than for TN; a higher percentage (35 percent for TN as compared to 47 percent for TP) of sites with TP data were unable to be evaluated for corresponding trends in FAC. Five sites (BLCA site 1; CURE sites 14, 20, and 24; and DINO site 36) indicated ‘no trend’ for TN and TP data evaluated for trends in ambient and FAC for the same time periods, and eight sites only analyzed for trends in ambient concentrations (CURE sites 7 and 8; DINO sites 33 and 36; CANY sites 51, 53, and 55; and CARE site 80) indicated ‘no trend’ for TN and TP data evaluated for the same time periods. Two of these 13 sites (BLCA site 2 and DINO site 36) were evaluated for multiple time periods with the same ‘no trend’ result. Few upward trends were identified in TN or TP concentrations; the upward trends in TN or TP concentrations have all taken place since the 1990s. These findings suggest that recent changes at the site (for trends in ambient concentrations) or in the basin (for trends in FAC) may be leading to increasing concentrations—even for sites that indicated downward trends or no trends for a longer historical time period (DINO sites 30 and 31 for TN). The lack of a historical data record limits the ability to interpret the recent short-term upward trends for other sites (CURE sites 9, 25, 26, and 29). No sites indicated upward trends for both constituents. Only two sites (CANY site 66 on the Green River and CARE site 84 on the Fremont River) indicated downward trends in ambient and FAC concentrations for both TN and TP suggesting that changes in these basins have contributed to an overall reduced nutrient loading to these streams. Overall, either long-term downward trends or no trends in concentrations from about the early 1970s through the early 2000s were identified. Shorter-term period data within this time period indicated similar results. A few upward trends were identified either in CURE or DINO for the more recent time periods (1990s to 2000s and early to mid-2000s). These trends could be an artifact of the shorter time periods used for the analysis or of recent changes in the basin.

Comparison of trends in ambient TN and TP concentrations and their corresponding trends in FAC indicate that climatic variations (represented by changes in streamflow) have had limited impact on trend identification—neither masking trends in FAC nor creating ambient concentration trends at most sites. Differences between ambient and FAC trend results were observed more often for TP trends (30 percent) than for TN trends (23 percent).

Quantification of trends in streamflow and(or) loads, and precipitation, as well as collection and evaluation of ancillary data, such as dissolved oxygen, macroinvertebrates, and algal community composition and structure for ongoing water-quality monitoring sites could provide additional insight into the nutrient status in these streams. It may be helpful to consider and quantify (for example, through a multiple-regression analysis) these results within the context of each water-quality sampling site’s basin, including the dominant geology, land cover, and land uses. The overall sampling period of record, the seasonal sampling frequency, and the simultaneous measurement of streamflow and analysis of related constituents are all key considerations when designing and implementing water-quality sampling programs.

Synthesis of Total Nitrogen and Total Phosphorus Exceedance and Trend Results

In order to better understand nutrients in surface water flowing in and through NCPN park units, summary results from the exceedance and trend analyses were collectively evaluated. Although results for sites in table 8 (exceedances summary) and in table 12 (summary of significant upward or downward trends) are not directly comparable because of differing time periods and analytical criteria, evaluation of these two summaries provides insight into NCPN sites with high percentages of exceedances (85-percent exceedance or greater) and with significant upward or downward trends. Analyses of trends in TN and(or) TP concentrations were completed for 52 of 93 sites evaluated for exceedances (56 percent). Generally, most sites had TN and(or) TP exceedances (89 of 93) and few sites had upward (4 for TN and 2 for TP) or downward (9 for TN and 16 for TP) trends in concentrations.

Exceedances ranged from 51 to 100 percent for the four sites with significant upward trends in TN concentrations (CURE sites 25 and 26 and DINO sites 30 (recent time period only) and 31). Two of the four sites had exceedances greater than 85 percent. Exceedances were 85 and 100 percent, respectively, for the two sites with significant upward trends in TP concentrations (CURE sites 9 and 29). These results suggest the percentage of TN or TP exceedances may increase at these sites if upward trends in concentration are sustained.

Exceedances ranged from 85 to 100 percent for the nine sites with significant downward trends in TN concentrations (COLM site 3, DINO sites 30 (long-term time period) and 35, ARCH sites 46-48, CANY sites 52 and 66, and CARE site 84). Exceedances ranged from 25 to 100 percent for the 16 sites with significant downward trends in TP concentrations (COLM site 4; CURE sites 10 and 24; DINO sites 31, 33, and

35; ARCH sites 48 and 50; CANY site 66; HOVE site 71; CARE sites 79 and 84; and ZION sites 85, 91, 92, and 95). Five of the 16 sites had exceedances greater than 85 percent. These results suggest the percentage of TN or TP exceedances may decrease at these sites if downward trends in concentration are sustained.

Many sites with high percentages of exceedances did not have significant trends in concentration; although, upward trends in concentrations may be observed in the future. For example, even though DINO site 30 (fig. 8) had three long-term downward trends in ambient and flow-adjusted TN concentrations (from 1974 through 1992, from 1974 through 2000, and from 1977 through 1998), a recent upward trend (1991 through 2000) in ambient TN concentrations also was identified (with a correspondingly weak upward trend in FAC). Additionally, this site had TN exceedances 98 percent of the time from 1974 through 2000. These results suggest this site may be susceptible to an upward trend in TN concentrations and increasing elevated concentrations if recent conditions continue or worsen. Some sites had high percentages of exceedances and had significant upward trends in TN or TP concentrations, including CURE sites 9, 25, and 29 and DINO sites 30 (recent period only) and 31. These sites may warrant new or sustained monitoring to determine if conditions are improving or degrading in these basins.

A broad temporal and spatial perspective is required for understanding the factors affecting nutrient contributions to water-quality sampling sites in larger streams such as the Colorado and Green Rivers, which encompass large basin areas and concomitantly a vast range of climatic, human, and landscape factors. As described above, some of the NCPN sites show elevated nutrient concentrations and(or) a high percentage of exceedances but downward trends in TN or TP concentrations (for example, ARCH site 46 for TN and CARE site 84 for TN and TP). Other sites show low percentages of exceedances and low median concentrations and correspondingly downward trends in TN or TP concentrations (for example, DINO site 33 for TP). Individual elevated concentrations (that is, exceedances) at a site might result from geology, which can be influenced by factors affecting runoff including land cover, land use, road projects, and recreational activities. Elevated nutrient concentrations also may result from individual, household septic and community wastewater discharges, which are influenced by development patterns, recreation activities in areas susceptible to contamination by human waste, precipitation events leading to stormwater runoff and sewer overflows, age and extent of infrastructure, and availability of appropriate waste-treatment technology. Additionally, agricultural activities, which are influenced by seasonal climate fluctuations, irrigation intensity, crop type, grazing intensity, and use of best-management practices, may contribute to elevated concentrations. All these factors can vary considerably over time and space.

In contrast, upward or downward trends in concentrations over time suggest a sustained temporal pattern of change related to these factors. For example, an upward trend could be the result of increasing population density (and consequently increasing nutrient concentrations in wastewater discharge), increased road density, new or increased resource-extraction activities, or increased recreational activities in areas with marginal land cover susceptible to erosion and contamination by human wastes. Likewise, a downward trend could be the result of technological improvements or management approaches such as advanced wastewater treatment and expanded infrastructure, implementation of best-management practices, reduced grazing density, or restricted access for recreation. These types of improvements and management approaches have likely influenced the long-term downward trends identified on the larger streams flowing in and through NCPN parks, including the Colorado, Fremont, Green, Gunnison, Virgin, and Yampa Rivers.

Additional investigation of particular NCPN sites may be warranted to determine the specific factors driving nutrient conditions at a site. For example, COLM site 3 (Gunnison River near Grand Junction, Colo.; fig. 7) indicates generally elevated TN concentrations (median 1.40 mg/L), a high percentage of TN and TP exceedances (98- and 82-percent exceedance, respectively), a historical (1975 through 1998) downward trend in TN concentrations, but no trend in TP concentrations. Review of upstream sites in and near BLCA and CURE (fig. 3) indicates one site (BLCA site 1, Red Rock Canyon at mouth near Montrose, Colo.) also had elevated median TN concentration (1.31 mg/L based on a limited dataset collected from 2001 through 2004), which suggests closer evaluation of this tributary and the surrounding area may be warranted to determine if natural factors or human activities in this basin may be contributing nitrogen to the lower Gunnison River downstream from BLCA. Additionally, other factors may be contributing to the downward trend in TN concentrations at this site, which also may warrant closer evaluation. Although some sites farther upstream in the basin had elevated maximum TN concentrations (for example, CURE sites 24 and 25 had maximum values of 7.30 and 3.48 mg/L, respectively), a median TN concentration of 0.200 mg/L at CURE site 2 (Gunnison River below Gunnison Tunnel, Colo.) suggests TN concentrations are generally low upstream from this site. This type of investigation may be warranted for other NCPN sites with elevated nutrient concentrations or with upward trends in concentrations.

Although the exceedance and trend results are not directly comparable between most sites and a regional trend analysis was not part of this study, the trend results suggest the nutrient reduction observed across much of the NCPN may be a function of large-scale environmental factors such as nationally mandated changes to improve municipal wastewater treatment, address nonpoint-source pollution, improve management of public land, and implement agricultural best-management practices such as improvements in fertilizer and manure application to help minimize erosion and nutrient runoff. The large numbers of exceedances for many surface-water sites across the NCPN suggest the concentrations are elevated regardless of trends. Although few significant upward trends in TN or TP concentrations were identified in the NCPN data, sites with exceedances of the State of Utah phosphorus standard or USEPA recommended nutrient water-quality criteria and(or) sites with elevated median concentrations may indicate problem areas in surface water that warrant closer evaluation and continued or renewed water-quality sampling. The NCPN and individual park units may benefit from continued or additional collaboration with other organizations and agencies monitoring and analyzing data collected from integrator sites upstream and downstream from the streams flowing through the NCPN park units, including the Colorado, Fremont, Green, Gunnison, Virgin, and Yampa Rivers. Follow-up evaluation of exceedances and trends using more recently collected nutrient data will aid in documenting, quantifying, and understanding the current water-quality changes taking place in NCPN basins.

Summary

Nutrient impairment is documented by the U.S. Environmental Protection Agency (USEPA) as a primary cause of degradation in lakes and reservoirs, and nutrients are related to organic enrichment and oxygen depletion, which is the third most important cause of degradation in streams after pathogens and habitat alterations. Recently (2011), an effort to develop State-based numeric nutrient criteria has resulted in renewed emphasis on nutrients in surface water throughout the Nation. In response to this renewed emphasis and to investigate nutrient water quality for Northern Colorado Plateau Network (NCPN) streams, the U.S. Geological Survey (USGS), in cooperation with the National Park Service, assessed total nitrogen (TN) and total phosphorus (TP) concentration data for 93 sites in or near 14 National Park units for the time period 1972 through 2007. The TN and(or) TP concentrations for these 93 sites were compared to applicable State of Utah water-quality standards or U.S. Environmental Protection Agency recommended nutrient criteria for aggregated Ecoregions II (forested mountains) and III (xeric west), and descriptive statistics were compiled for each site. Notable exceedances and median concentrations from water-quality sampling sites on the Colorado, Fremont, Green, Gunnison (and tributaries), Virgin, and Yampa Rivers were described. In addition, TN and(or) TP data from 52 of the 93 sites, in or near 12 National Park units, were evaluated for temporal, monotonic trends in ambient measured concentrations and flow-adjusted measured concentrations. Ambient measured concentrations (hereafter referred to as “ambient concentrations”) are unadjusted concentrations measured from samples collected in the stream. Flow-adjusted measured concentrations (hereafter referred to as “flow-adjusted concentrations” or “FAC”) are concentrations measured in samples collected in the stream and subsequently adjusted to remove the effects of streamflow. Exceedances of standards and trends were evaluated to provide a more complete understanding of historical and current nutrient water-quality conditions throughout the NCPN.

The purpose of this study was to improve the understanding of nutrients (specifically, TN and TP) and surface-water quality in the NCPN, to provide information for network and park natural-resource managers to inform future monitoring decisions, and to identify potential nutrient sources and influences on water quality in park units in the NCPN.

The results for water-quality exceedances were variable. Generally, there were large numbers of exceedances identified for many NCPN sites, many sites had high percentages (greater than 85 percent) of exceedances, and many of these exceedances have been occurring for a long time period. Sixty-two of 65 sites for TN and 92 of 93 sites for TP had data that exceeded an applicable standard or criterion, and exceedances ranged from 2 to 100 percent of nutrient samples collected from 1972 through 2007. The average frequency of exceedance for TN for all 65 sites was 74 percent and for TP for all 93 sites the average frequency of exceedance was 61 percent. Exceedances were widespread spatially and temporally throughout the NCPN and many sites had exceedances over most or all of their available record. Of the 65 sites evaluated for TN exceedances, 29 (45 percent) of them had exceedances greater than or equal to 85 percent of samples. Of these, 13 sites (in 7 NCPN park units) had TN exceedances equal to 100 percent of samples. Of the 93 sites evaluated for TP exceedances, 33 (35 percent) of them had exceedances greater than or equal to 85 percent of samples. Of these, 16 sites (all in CURE) had TP exceedances equal to 100 percent of samples. Data from sites in the xeric ecoregion had, on average, 76 percent (TN) and 57 percent (TP) exceedances; data from sites in the mountain ecoregion had, on average, 70-percent exceedances for both TN and TP. The Colorado, Fremont, Green, Gunnison (and tributaries), Virgin, and Yampa Rivers show large variability and, in some cases, relatively high numbers and(or) percentages of TN and TP exceedances. Networkwide, the higher frequency and percentage of exceedance for TN than for TP and the lower sample-collection frequency for TN indicates greater monitoring and management attention may be warranted for TN. However, because of current [2011] nutrient-criteria development activities in states with NCPN park units continued monitoring of both constituents is warranted in order to make comparisons to updated standards or criteria in the future.

Throughout the NCPN, median TN concentrations ranged from 0.106 to 2.42 milligrams per liter (mg/L) and median TP concentrations ranged from 0.006 to 0.367 mg/L for data from all sites, excluding data from the one wastewater treatment plant included in the dataset. Median TN concentrations are low for CURE and BRCA sites as compared to most other NCPN sites; most concentrations, however, were still greater than the USEPA TN criterion for mountain ecoregions (0.12 mg/L). Median TN concentrations also were low for a few other sites in BLCA, CANY, NABR, and ZION; however, some of these sites had a very limited data record. Median concentrations were equal to or less than the applicable

standard or criterion for data from 8 TN (12 percent) and 35 TP (38 percent) sites. The averages of median TN and TP concentrations at xeric ecoregion sites (1.40 and 0.201 mg/L, respectively) were higher than the averages of median TN and TP concentrations at mountain ecoregion sites (0.281 and 0.069 mg/L, respectively). Throughout the NCPN park units, higher median TN concentrations generally did not correspond with higher median concentrations of TP. This observation suggests that particular natural or human factors taking place in some areas result in concentrations of one nutrient that are higher than the other. In contrast, some lower median TN concentrations compared well to lower median concentrations of TP, suggesting these sites are downstream from areas with limited natural or human factors affecting nutrient concentrations. Both natural (that is, geologic) and human factors are likely contributing to elevated TN and(or) TP concentrations and frequent exceedances in streams near to and downstream from human activities such as agriculture, mining, and development.

Trends in ambient concentrations (34 TN sites and 51 TP sites) and FAC (22 TN sites and 27 TP sites) were determined for 52 of the 93 sites with sufficient data, and relations between trends and changes in nutrient sources and streamflow were explored. Not all sites had TN and(or) TP data available for comparison. Analysis of data for trends in concentrations of TN and TP was completed for two groups of sites, each having similar periods of record: 6 sites (4 TN and 5 TP) with nutrient data from 1977 to 1998 (historical long-term period) and 15 sites (7 TN and 15 TP) with nutrient data from 2001 to 2006 (recent short-term period). Additionally, trend analysis of TN and(or) TP concentrations was completed for data from 30 and 42 sites, respectively, having variable periods of record collected from 1974 through 2007 using time periods specific and optimal for each site. Some sites were evaluated for more than one time period. The nonparametric Seasonal Kendall test for uncensored data or the corresponding Seasonal Kendall test for censored data was used for the trend analysis. Comparisons of trends between data from water-quality sampling sites generally were limited because of differences in periods of record, data gaps, and data density. Many sites evaluated for trends in ambient concentrations could not be evaluated for trends in FAC because of insufficient contemporaneous streamflow measurements or a high percentage of censoring.

The trend results for TN were variable depending on the site, constituent, and time period evaluated. Data from the four sites (in or near COLM, DINO, ARCH, and CANY) evaluated for historical long-term (1977–1998) trends indicated downward trends in ambient and flow-adjusted TN concentrations. These sampling sites are on streams with long-term water-quality monitoring activities (sites 3 on the Gunnison River, 30 and 66 on the Green River, and 46 on the Colorado River). Upward trends in ambient or flow-adjusted TN concentrations were identified for two (CURE sites 25 and 26) of seven sites evaluated for recent short-term (2001–2006) trends. These two sampling sites are on tributaries, Lake Fork Gunnison River and Pine Creek, which flow into the Gunnison River and through CURE and BLCA. Data from 30 sites with variable periods of record were evaluated for trends in ambient TN concentrations. Data from 17 of these 30 sites had sufficient contemporaneous streamflow measurements to be evaluated for trends in TN FAC. Most sites with variable periods of record indicated no trends (21 ambient and 13 FAC sites) or downward trends (9 ambient and 5 FAC sites) in TN concentrations; only two sites (DINO sites 30 on the Green River (recent time period) and 31 on the Yampa River) indicated upward trends in ambient and(or) flow-adjusted TN concentrations. The sites with downward trends are distributed throughout five park units in the NCPN (COLM, DINO, ARCH, CANY, and CARE) on the Colorado, Fremont, Green, Gunnison, or Yampa Rivers. Of all the 34 sites evaluated for trends in ambient and flow-adjusted TN concentrations, three TN sites (CURE site 26 and DINO sites 30 and 35) indicated upward or downward trends in ambient TN concentrations and no corresponding trend in FAC indicating streamflow was the driving factor in the trends identified at these sites; two sites (CURE site 25 and DINO site 31) indicated upward trend in FAC and no corresponding trend in ambient TN concentrations.

The trend results for phosphorus were similarly variable depending on the site, constituent, and time period evaluated. Data from two of five sites in or near COLM, DINO, ARCH, CANY, and CARE (CANY site 66 on the Green River and CARE site 84 on the Fremont River) evaluated for historical long-term (1977–1998) trends indicated downward trends in ambient and flow-adjusted TP concentrations. Only one (CURE site 29 on West Elk Creek) of 15 sites evaluated for recent short-term trends in TP indicated an upward trend in ambient concentrations; data from one site (CURE site 10 on Curecanti Creek) indicated a downward trend in FAC. These sites were on tributaries that flow into the Gunnison River and through CURE and BLCA. Data from 42 sites with variable periods of record were evaluated for trends in ambient TP concentrations. Data from 18 of these 42 sites had sufficient contemporaneous streamflow measurements to be evaluated for trends in flow-adjusted TP concentrations. Most sites with variable periods of record indicated no trends (29 ambient and 12 FAC sites) or downward trends (16 ambient and 5 FAC sites) in TP concentrations; only two sites (CURE sites 9 on Tomichi Creek and 29 on West Elk Creek) indicated upward trends in ambient and(or) flow-adjusted TP concentrations. The sites with downward trends were distributed throughout eight park units in the NCPN. The two sites with upward trends also were on tributaries that flow into the Gunnison River. Of all the 51 sites evaluated for trends in ambient and flow-adjusted TP concentrations, seven TP sites (CURE sites 25 and 29, DINO site 35, HOVE site 71, and ZION sites 85, 91, and 95) indicated upward or downward trends in ambient TP concentrations and no corresponding trend in FAC indicating streamflow was the driving factor in the trends identified at these sites; only one site (CURE site 9) indicated upward trends in ambient and flow-adjusted TP concentrations.

Comparison of trends in ambient TN and TP concentrations and their corresponding trends in FAC indicates that climatic variations (represented by changes in streamflow) had limited impact on trend identification—neither masking trends in FAC nor only creating ambient concentration trends at most sites.

Most of the downward trends in ambient and flow-adjusted TN or TP concentrations were during earlier historical periods (generally starting in the 1970s or early 1980s and ending in the 1990s or 2000s). Notably, many of the sites whose data indicated historical long-term downward trends in TN and(or) TP were on larger streams, including the Colorado, Dolores, Fremont, Green, Gunnison, Virgin, and Yampa Rivers and one of the sites was a wastewater treatment plant outflow. The long-term downward trends suggest that at least at these sites nutrient water quality is improving. These results suggest that nutrient reduction observed on these larger streams in the NCPN may be a function of large-scale environmental factors such as nationally mandated changes to improve municipal wastewater treatment, address nonpoint-source pollution, enhance management of public land, and guide the agriculture industry's implementation of best-management practices such as improvements in fertilizer or manure application to help minimize erosion and nutrient runoff. Only two sites (CANY site 66 on the Green River and CARE site 84 on the Fremont River) indicated downward trends in ambient and FAC concentrations for both TN and TP, suggesting that changes in these basins have contributed to an overall reduced nutrient loading to these streams.

In contrast, the few upward trends in ambient and flow-adjusted TN or TP concentrations identified were during more recent sampling periods (1990s to 2000s and early to mid-2000s). Upward trends in TN or TP were identified at two large-river sites in DINO (sites 30 and 31 on the Green and Yampa Rivers, respectively) and at four sites on tributaries to the Gunnison River in CURE (sites 9 on Tomichi Creek, 25 on Lake Fork Gunnison River, 26 on Pine Creek, and 29 on West Elk Creek). These trends could be an artifact of the shorter time periods used for the analysis or of recent changes in the basin. The lack of a historical data record limits the ability to interpret the recent short-term upward trends for these sites.

Exceedances ranged from 51 to 100 percent for the four sites with significant upward trends in TN concentrations (CURE sites 25 and 26 and DINO sites 30 (recent time period only) and 31). Exceedances were 85 and 100 percent, respectively, for the two sites with significant upward trends in TP concentrations (CURE sites 9 and 29). These results suggest that the percentage of TN or TP exceedances may increase at these sites if upward trends in concentration are sustained.

Exceedances ranged from 85 to 100 percent for the nine sites with significant downward trends in TN concentrations (COLM site 3, DINO sites 30 (long-term time period) and 35, ARCH sites 46-48, CANY sites 52 and 66, and CARE site 84). Exceedances ranged from 25 to 100 percent for the 16 sites with significant downward trends in TP concentrations (COLM site 4; CURE sites 10 and 24; DINO sites 31, 33, and 35; ARCH sites 48 and 50; CANY site 66; HOVE site 71; CARE sites 79 and 84; and ZION sites 85, 91, 92, and 95). Five of the 16 sites had exceedances greater than 85 percent. These results suggest that the percentage of TN or TP exceedances may decrease at these sites if downward trends in concentration are sustained. Many sites with high percentages of exceedances did not have significant trends in concentration.

Although few significant upward trends in TN or TP concentrations were identified in the NCPN data, exceedances of the State of Utah phosphorus standard or USEPA recommended nutrient water-quality criteria may indicate problem areas in surface water that warrant closer evaluation and continued water-quality sampling. Sites with a high number of exceedances, elevated median concentrations, or upward trends in concentrations merit continued or renewed monitoring and assessment to evaluate future changes in nutrient concentrations that could result in nutrient enrichment and eutrophication.

Results evaluated in this report represent conditions for different periods of record and thus may not always represent basin conditions through time. This highlights the need to maintain long-term water-quality and streamflow sampling programs at key reference and integrator sites throughout the network so that, in the future, statistically based comparisons between upstream and downstream sites can be made. In some cases, observations in this report were based on data collected only in the 1970s and 1980s, which provided insight into historical conditions, but information on current conditions was unavailable. Future water-quality monitoring activities may benefit from sustained data-collection efforts with attention to site-specific issues and consideration of basin characteristics that affect source, transport, and fate of nutrients in aquatic systems. Follow-up evaluation of exceedances and trends using more recently collected nutrient data will aid in documenting, quantifying, and understanding the current water-quality changes taking place in NCPN basins. Quantification of trends in streamflow and(or) loads and precipitation, as well as collection and evaluation of ancillary data, such as dissolved oxygen, macroinvertebrates, and algal community composition and structure for these sites, could provide additional insight into nutrient status in these streams. It also may be helpful to consider and quantify (for example, through a multiple regression analysis) these results within the context of the basin of each water-quality sampling site, including the dominant geology, land cover, and land uses. The overall sampling period of record, the seasonal sampling frequency, and the simultaneous measurement of streamflow and analysis of related constituents are all key considerations when designing and implementing water-quality sampling programs.

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