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Idaho Department of Environmental Quality

Water-Quality and Biological Conditions in Selected Tributaries of the Lower Boise River, Southwestern Idaho, Water Years 2009–12

Scientific Investigations Report 2014–5132

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

Cover: Image showing the confluence of Mason Creek with the Boise River, Idaho.
(Image provided by Google Earth™).

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U.S. Geological Survey

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

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Suggested citation:
Etheridge, A.B., MacCoy, D.E., and Weakland, R.J., 2014, Water-quality and biological conditions in selected tributaries of the Lower Boise River, southwestern Idaho, water years 2009–12: U.S. Geological Survey Scientific Investigations Report 2014-5132, 58 p., *http://dx.doi.org/10.3133/sir20145132*.

ISSN 2328-0328 (online)

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Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	640.0	acre
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound per day	0.4356	kilogram per day (kg/d)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)
	Application rate	
pounds per acre(lb/acre)	1.121	kilograms per hectare(kg/ha)

Conversion Factors, Datums, and Abbreviations and Acronyms—Continued

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
	Volume	
liter (L)	33.81	ounce, fluid (fl. oz)
milliliter (mL)	0.03381	ounce, fluid (fl. oz)
	Mass	
gram per square meter (g/m^2)	2.05×10^{-4}	pound per square foot (lb/ft^2)
microgram per kilogram (µg/kg)	1.60×10^{-8}	ounce per pound (oz/lb)
micrometer (µm)	3.937×10^{-5}	inches (in.)
milligram per square meter (mg/m^2)	2.05×10^{-7}	pound per square ft (lb/ft^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Conversion Factors, Datums, and Abbreviations and Acronyms

Abbreviations and Acronyms

BPA	bisphenol-a
CAFO	confined animal feeding operation
CFU/100mL	colony forming units per 100 milliliters
CVO	Cascades Volcano Observatory
EWI	equal-width-increment
FNU	formazin nephelometric unit
FTS	Forest Technology Systems
IBI	index-of-biotic-integrity
IDEQ	Idaho Department of Environmental Quality
IDHW	Idaho Department of Health and Welfare
SMI	Idaho Small Stream Macroinvertebrate Index
IPC	Idaho Power Company
IQR	interquartile range
LOADEST	U.S. Geological Survey LOAD ESTimator FORTRAN program
MPN	most probable number
N	nitrogen
NAWQA	National Water-Quality Assessment program
NFM	U.S. Geological Survey National Field Manual
NO_2+NO_3	nitrate plus nitrite as nitrogen
NTU	nephelometric turbidity unit
NWQL	National Water Quality Laboratory
ODEQ	Oregon Department of Environmental Quality
OP	orthophosphorus
P	phosphorus
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
RFI	rangeland fish index
RPD	relative percent difference
SFI	stream fish index
SR-HC	Snake River-Hells Canyon
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
USGS	U.S. Geological Survey
WWTP	wastewater treatment plant
WY	water year
YSI	Yellow Springs, Inc.

Water-Quality and Biological Conditions in Selected Tributaries of the Lower Boise River, Southwestern Idaho, Water Years 2009–12

By Alexandra B. Etheridge, Dorene E. MacCoy, and Rhonda J. Weakland

Abstract

Water-quality conditions were studied in selected tributaries of the lower Boise River during water years 2009–12, including Fivemile and Tenmile Creeks in 2009, Indian Creek in 2010, and Mason Creek in 2011 and 2012. Biological samples, including periphyton biomass and chlorophyll-*a*, benthic macroinvertebrates, and fish were collected in Mason Creek in October 2011. Synoptic water-quality sampling events were timed to coincide with the beginning and middle of the irrigation season as well as the non-irrigation season, and showed that land uses and irrigation practices affect water quality in the selected tributaries. Large increases in nutrient and sediment concentrations and loads occurred over relatively short stream reaches and affected nutrient and sediment concentrations downstream of those reaches. *Escherichia coli* (*E. coli)* values increased in study reaches adjacent to pastured lands or wastewater treatment plants, but increased *E. coli* values at upstream locations did not necessarily affect *E. coli* values at downstream locations. A spatial loading analysis identified source areas for nutrients, sediment, and *E. coli,* and might be useful in selecting locations for water-quality improvement projects. Effluent from wastewater treatment plants increased nutrient loads in specific reaches in Fivemile and Indian Creeks. Increased suspended-sediment loads were associated with increased discharge from irrigation returns in each of the studied tributaries. Samples collected during or shortly after storms showed that surface runoff, particularly during the winter, may be an important source of nutrients in tributary watersheds with substantial agricultural land use. Concentrations of total phosphorus, suspended sediment, and *E. coli* exceeded regulatory water-quality targets or trigger levels at one or more monitoring sites in each tributary studied, and exceedences occurred during irrigation season more often than during non-irrigation season.

As with water-quality sampling results, bottom-sediment samples analyzed for contaminants of emerging concern indicated that adjacent land uses can affect in-stream conditions. Contaminants of emerging concern were detected in four categories: urban compounds, industrial compounds, fecal steroids, and personal care products. Compounds in one or more of the four contaminant categories were detected at higher concentrations in upstream sites than in downstream sites in the tributaries and in the lower Boise River. High concentrations of compounds in upstream locations indicated that adjacent land use might be an important factor in contributing contaminants of emerging concern to the lower Boise River watershed.

Expanded monitoring at Mason Creek near the mouth included a streamgage, a continuous water-quality monitor, and monthly water-quality sample collection. Data collected during expanded monitoring efforts at Mason Creek near the mouth provided information to develop and compare water-quality models. Regression models were developed using turbidity, discharge, and seasonality as surrogates to estimate concentrations of water-quality constituents. Daily streamflow also was used in a load model to estimate daily loads of water-quality constituents. Surrogate regression models may be useful for long-term monitoring and generally performed better than other models to estimate concentrations and loads of total phosphorus, total nitrogen, and suspended sediment in Mason Creek.

Biological sampling results from Mason Creek showed low periphyton biomass and chlorophyll-*a* concentrations compared to those historically measured in the Boise River near Parma, Idaho, during October and November. The most abundant invertebrate found in Mason Creek was the highly tolerant and invasive New Zealand mudsnail (*Potamopyrgus antipodarum*). The presence of small rainbow trout (90 millimeters) may indicate salmonid spawning in Mason Creek. The rangeland-fish-index score of 58 for Mason Creek is comparable to rangeland-fish-index scores calculated for the Boise River near Middleton, indicating intermediate biotic condition.

Introduction

The lower Boise River is a 64-mi reach of river measured from the release at Lucky Peak Dam downstream to its confluence with the Snake River (figs. 1*A* and 1*B*). The lower Boise River flows through Ada and Canyon Counties and through the cities of Boise, Garden City, Eagle, Star, Middleton, Caldwell, Notus, and Parma, Idaho. The lower Boise River downstream of Lucky Peak Dam drains 1,290 mi^2 of range (48 percent), forest (1 percent), agricultural (33 percent), and developed land (16 percent) (Fry and others, 2011). Between 1990 and 2010, population increased by 91 and 110 percent in Ada and Canyon Counties, respectively (U.S. Census Bureau, 2013). With changes in demographics, agricultural land has been converted to urban or developed land in the lower Boise River watershed. The Idaho Association of Soil Conservation Districts reported a loss of 10,930 acres of agricultural land to urban or suburban development in the lower Boise River watershed between 2001 and 2005 (Scott Koberg, Idaho Soil Conservation Commission, written commun., 2013).

Land use changes in the lower Boise River watershed have affected the water quality and biological integrity of the river since the late 1800s. Starting in the late 1800s, agricultural production required construction of new dams, drains, conveyances, and diversions, but also used natural tributaries in the lower Boise River watershed. As a result, many tributaries were deepened to drain shallow groundwater. Progressive urbanization around the cities of Boise, Nampa, and Caldwell necessitated the treatment of wastewater prior to discharging it to the lower Boise River. Sewage treatment facilities constructed in the early 1950s disinfected wastewater entering the river, but introduced toxic concentrations of chlorine, which resulted in frequent fish kills (Stacy, 1993). In the late 1950s, the lower Boise River was identified as one of the three most polluted water bodies in Idaho (Osborne, 1959; Chandler and Chapman, 2001).

Section 303(d) of the Clean Water Act (U.S. Environmental Protection Agency, 2013) requires states to develop total maximum daily load (TMDL) management plans for water bodies whose beneficial uses are impaired as a result of poor water quality. The lower Boise River was added to the State of Idaho list of water-quality-limited streams in 1992. A TMDL for sediment and bacteria in the lower Boise River was completed and approved in 1999, and water-quality concentration targets were established (Idaho Department of Environmental Quality [IDEQ], 1999). In 2004, IDEQ and Oregon Department of Environmental Quality (ODEQ) approved the Snake River-Hells Canyon (SR-HC) TMDL. The SR-HC TMDL established a 0.07-mg/L total phosphorus (TP) target concentration at the mouth of the Boise River (Idaho Department of Environmental Quality and Oregon Department of Environmental Quality, 2004). In 2013, IDEQ produced a draft addendum to the 1999 lower Boise River sediment and bacteria TMDL (Idaho Department of Environmental Quality, 1999). The 2013 addendum proposed a target of 20-mg/L for the mean suspended-sediment concentration over a period of 120 days in major tributaries of the lower Boise River, including Fivemile, Tenmile, Indian, and Mason Creeks (Idaho Department of Environmental Quality, 2013). Water-quality TMDL targets for *Escherichia coli (E. coli)* bacteria in tributaries were proposed at current state-level criteria, which had changed from those in effect in 1999. Two state-level criteria for *E. coli* bacteria are considered to be action levels that trigger additional monitoring, rather than compliance targets. The action-levels for *E. coli* are expressed in terms of a single sample result and the action level is based on beneficial use. For streams with a primary-contact recreation beneficial use, the single-sample *E. coli* action level is 406 colony forming units per 100 milliliters (CFU/100mL), and for streams with a secondary-contact recreation beneficial use, the single-sample *E. coli* action level is 576 CFU/100mL. If additional sampling shows that the geometric mean of five samples collected every 3–7 days during a 30-day period is greater than 126 CFU/100mL, the *E. coli* compliance target has been exceeded. In this study, CFU/100mL was measured as most probable number [MPN]/100mL.

Water-quality and biological data collection efforts have been ongoing since the 1970s in the lower Boise River watershed. The U.S. Geological Survey (USGS) began collecting water-quality and biological data in the early 1990s in support of TMDL development and tributary subbasin assessment. Ongoing data collection efforts are conducted in cooperation with the lower Boise Watershed Council and the Idaho Department of Environmental Quality and are aimed at assessing the effectiveness of recently implemented best management practices. Through 2005, USGS studies were focused on defining conditions along the 64-mi reach of the lower Boise River and at the mouths of major tributary watersheds of the lower Boise River. Limited data existed in the tributaries upstream of their confluences with the Boise River. Information presented in this report was collected to assess and establish a baseline for water-quality and biological conditions in major tributaries of the lower Boise River. The effects from tributaries on the water quality in lower Boise River were assessed by comparing tributary concentrations and constituent loads to those in the Boise River near Parma, Idaho (USGS site No. 13213000 [B1]) (table 1; fig. 1*A*). Monitoring sites in tributary watersheds were selected based on the location of major inflows, point source discharges, and transitions between land-use types.

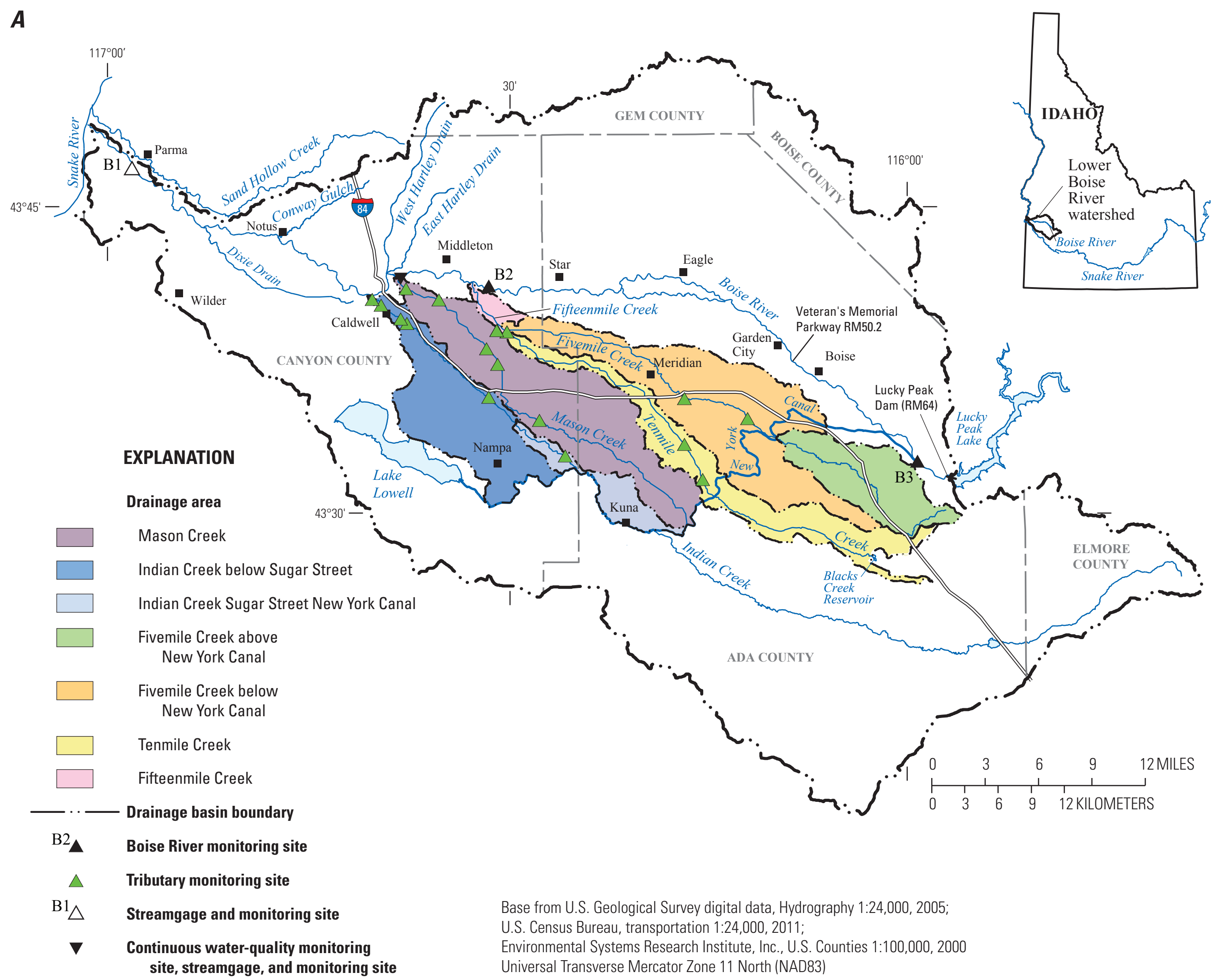

Figure 1. Locations of water-quality, biological, and bottom-sediment sampling sites in the (*A*) study area and (*B*) Mason, Indian, Fivemile, and Tenmile Creeks, and (*C*) land use changes between 1992 and 2006, lower Boise River watershed, southwestern Idaho.

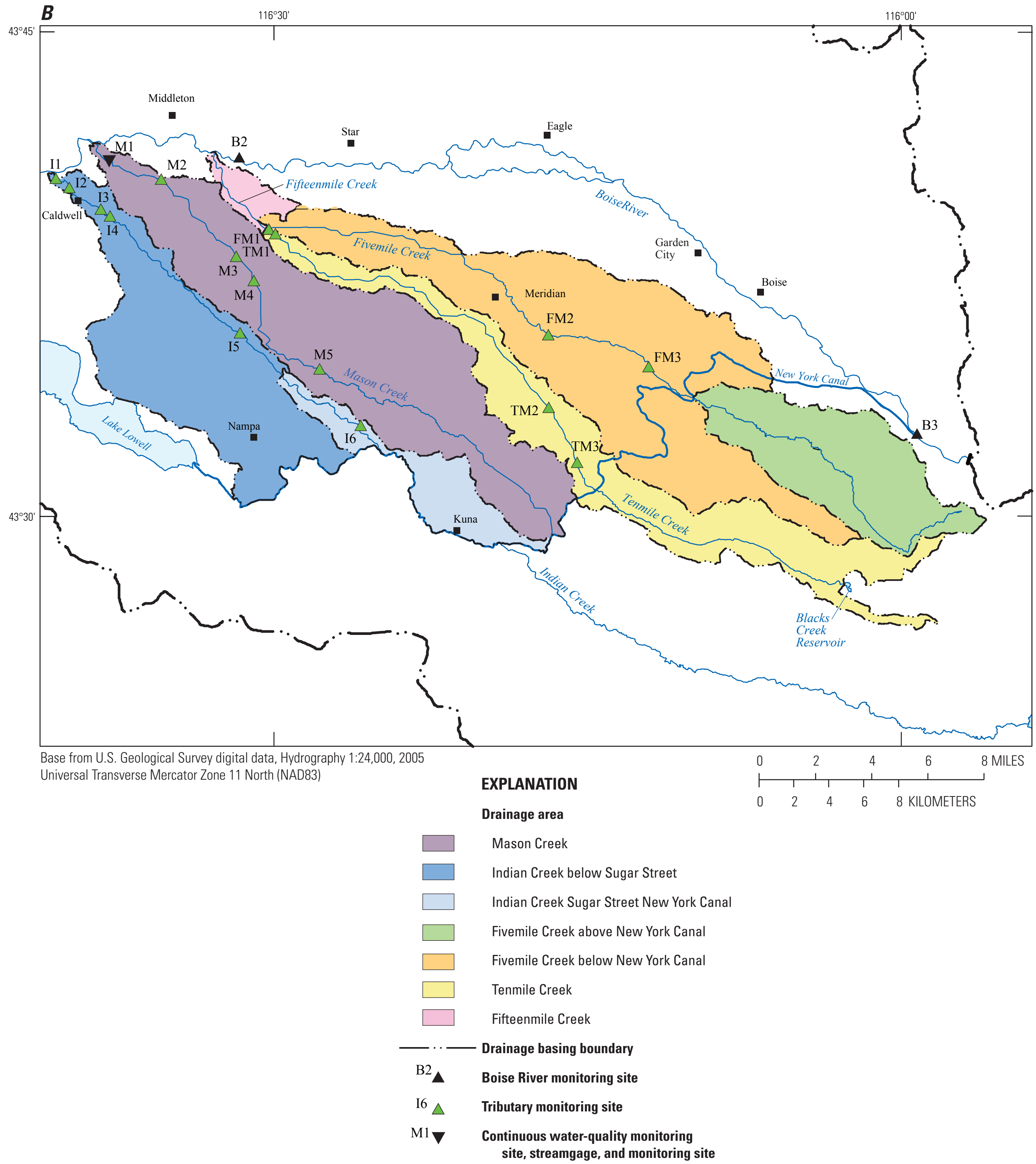

Figure 1.—Continued

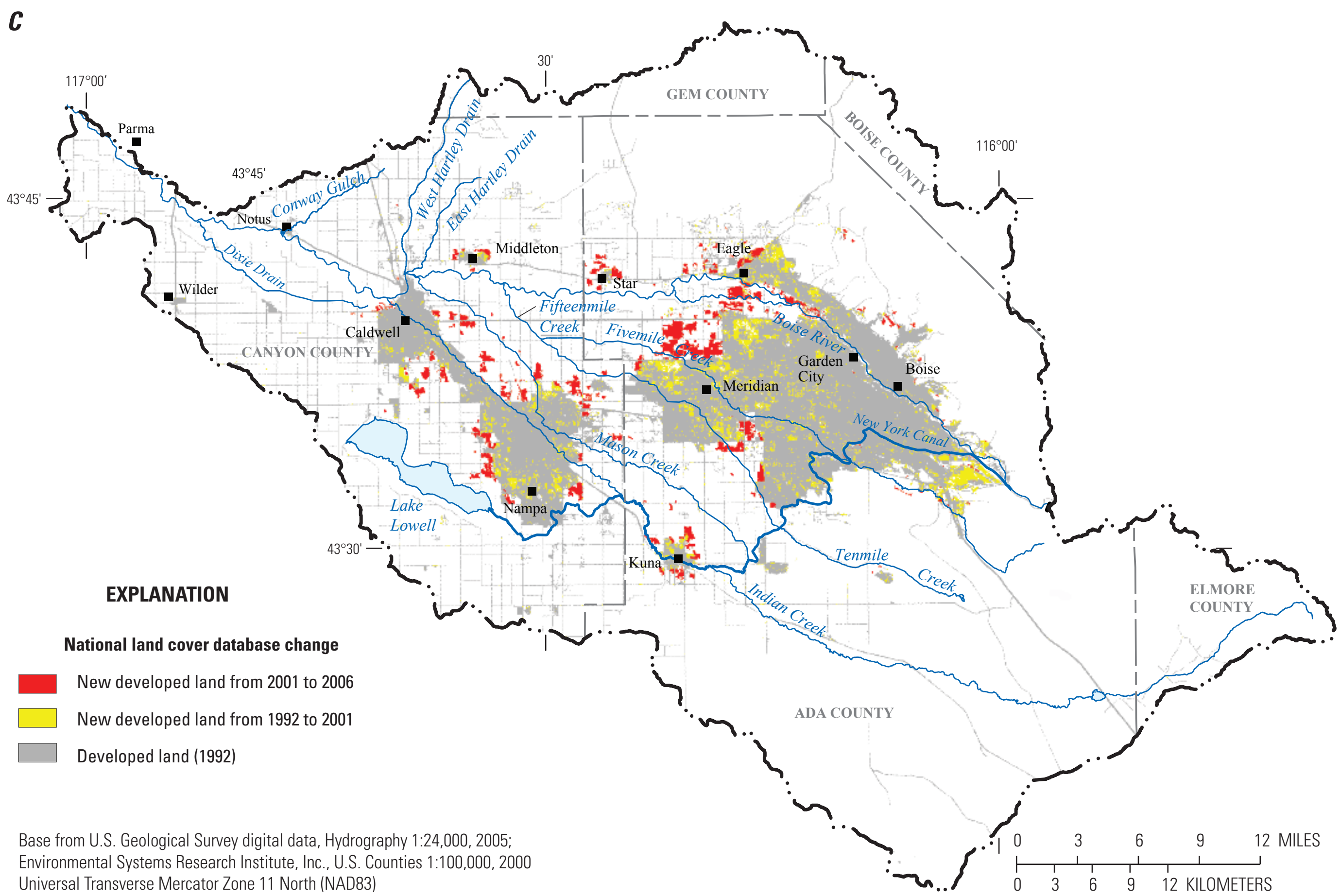

Figure 1.—Continued

Purpose and Scope

This report describes results of water-quality assessments in Fivemile and Tenmile Creeks in 2009, Indian Creek in 2010, and water-quality and biological assessments in Mason Creek in 2011 and 2012. Sampling results from each tributary are compared to results from the lower Boise River near Parma. Specific study objectives were to:

- Evaluate the status of and processes affecting water-quality and biological conditions in the Boise River and selected tributaries.
- Evaluate the effect of tributaries on the water quality in the lower Boise River.

This study was designed to repeat monitoring efforts in each tributary over a 6–7 year cycle.

Distinct seasonal and hydrologic conditions were evaluated during three water-quality sampling events. The first sampling event was completed during early irrigation season (late April or early May) to evaluate conditions during the "spring flush." The second event was completed during the middle of irrigation season in July, and the final sampling event was completed after irrigation season in late October or early November. Biological monitoring was completed in late October or early November at one site in each tributary except for Indian Creek, which was excluded because of funding limitations. The Boise River near Parma (site B1) was sampled eight times during each water year (WY) to compare tributary water-quality conditions to those in the Boise River near the downstream end of the watershed.

A short-term tributary study was completed during the weeks of August 20 and 27, 2012. The study provided 15-minute data for temperature and dissolved-oxygen concentrations over the course of at least 24 hours at six tributary sites in Indian, Mason, Fivemile, Tenmile, and Fifteenmile Creeks. Three sites were also monitored in Sand Hollow Creek, which is a tributary to the Snake River. Additionally, phosphorus (P) and suspended-sediment samples were collected and stream discharge was measured so instantaneous constituent loads could be calculated at each site.

Table 1. Monitoring sites in the lower Boise River watershed, southwestern Idaho, water years 2009–12.

[**USGS site No.:** Listed in farthest upstream to downstream order. **Abbreviated site name:** B1–B3, site reference for Boise River in figures; M1–M5, site reference for Mason Creek in figures; I1–I6, site reference for Indian Creek in figures; FM1–FM3, site reference for Fivemile Creek in figures; TM1–TM3, site reference for Tenmile Creek in figures. **Latitude** and **longitude:** Referenced to North American Datum of 1983. **Abbreviation:** USGS, U.S. Geological Survey]

USGS site No.	USGS site name	Abbreviated site name	Latitude	Longitude
13203510	Boise River below Diversion Dam, near Boise, Idaho	B3	43°32′23″	116°05′37″
13210050	Boise River near Middleton, Idaho	B2	43°41′06″	116°34′22″
13213000	Boise River near Parma, Idaho	B1	43°46′54″	116°58′22″
13210890	Mason Creek at East Powerline Road, near Nampa, Idaho	M5	43°34′32″	116°31′00″
13210965	Mason Creek at Madison Avenue, near Nampa, Idaho	M4	43°37′17″	116°33′47″
13210966	Mason Creek at Ustick Road, near Nampa, Idaho	M3	43°38′02″	116°34′31″
13210976	Mason Creek at Wells Road, near Caldwell, Idaho	M2	43°40′26″	116°37′42″
13210983	Mason Creek near Caldwell, Idaho	M1	43°41′00″	116°39′55″
13211259	Indian Creek near Robinson Road, near Nampa, Idaho	I6	43°32′47″	116°29′16″
13211307	Indian Creek at Broadmore Street, near Nampa, Idaho	I5	43°35′40″	116°34′23″
13211355	Indian Creek at Sparrow Avenue, near Caldwell, Idaho	I4	43°39′18″	116°39′53″
13211436	Indian Creek at 21st Street, at Caldwell, Idaho	I3	43°39′31″	116°40′17″
13211441	Indian Creek at Simplot Boulevard, at Caldwell, Idaho	I2	43°40′11″	116°41′37″
13211445	Indian Creek at Mouth, near Caldwell, Idaho	I1	43°40′28″	116°42′12″
13210470	Fivemile Creek at Victory Road, near Boise, Idaho	FM3	43°34′32″	116°17′00″
13210510	Fivemile Creek at Eagle Road, near Boise, Idaho	FM2	43°35′33″	116°21′15″
13210795	Fivemile Creek at Franklin Road, near Nampa, Idaho	FM1	43°38′52″	116°33′08″
13210572	Tenmile Creek at South Cloverdale Road, near Boise, Idaho	TM3	43°31′35″	116°20′04″
13210580	Tenmile Creek at Eagle Road, near Boise, Idaho	TM2	43°33′18″	116°21′16″
13210660	Tenmile Creek at Franklin Road, near Nampa, Idaho	TM1	43°38′52″	116°33′08″

Previous Investigations

Numerous Federal, state, county, and municipal monitoring programs have evaluated water quality in the lower Boise River. The Idaho Department of Health and Welfare (IDHW), Division of Environmental Quality (Idaho Department of Health and Welfare, 1989), reported that water quality in the lower Boise River deteriorated in the reach from Lucky Peak Dam to the confluence with the Snake River as a result of municipal wastewater discharges and irrigation return flows. Water quality near Parma therefore was classified as poor because of excessive bacteria, nutrients, sediment, metals, and elevated temperatures. The Boise River from Middleton to the Snake River was listed as impaired for nutrients, temperature, sediment, and bacteria, and is subject to TMDLs for sediment and *E. coli* (Idaho Department of Environmental Quality, 2011a). MacCoy (2004) evaluated water-quality data collected at multiple sites along the Boise River from 1994 to 2002 and determined that total nitrogen (TN) concentrations increased by more than eight times and TP concentrations increased by more than seven times from Lucky Peak Dam to Parma. Mullins (1998) determined that the largest point source of TP and TN to the lower Boise River was the West Boise municipal wastewater treatment plant (WWTP), and the largest nonpoint sources for suspended sediment were Dixie Drain and Mason Creek (fig. 1*A*). Donato and MacCoy (2005) reported ratios of orthophosphorus as phosphorus (OP) to TP (OP:TP) to infer likely origins of P in the lower Boise River. Higher OP:TP ratios were considered to indicate primarily urban wastewater origins of P, and low OP:TP ratios were considered to indicate primarily agricultural origins of P. The highest OP:TP ratios occurred in the lower Boise River near Parma (site B1) in November and December, and the lowest ratios in the summer. The temporal patterns in OP:TP observed by Donato and MacCoy (2005) at Parma were opposite of patterns observed in the Boise River upstream of agricultural and urban land uses. These findings suggest that most phosphorus loading downstream of Middleton (B2) is from urban sources during winter and from both urban and agricultural sources in summer. MacCoy (2004) documented the degradation of lower Boise River fish communities from flow alterations, habitat loss, and poor water quality. In particular, increased water temperatures in the lower reaches of the river have reduced successful spawning of rainbow trout, despite stocking efforts. The Idaho Department of Environmental Quality (2001) determined that nutrients originating in the Boise River watershed did not directly impair aquatic life or recreation beneficial uses in the lower Boise River, but nutrients from the lower Boise River watershed did affect beneficial uses downstream in the Snake River. However, that determination has subsequently been disputed (U.S. Environmental Protection Agency, 2009).

Contributions of sediment, nutrients, and bacteria from tributaries of the Boise River have increased since the early 1900s in association with increased agricultural production (Bureau of Reclamation, 1977). The Idaho Department of

Environmental Quality reported in 1983 that agricultural drains in the lower Boise River watershed transported large loads of nutrients (nitrogen [N] and P), sediment, and fecal bacteria (primarily from livestock), as well as organochlorine pesticides and polychlorinated biphenyls (PCBs) to the Boise River, some of which also were detected in fish tissue (Clark and Bauer, 1983).

Since 1999, numerous regulatory reports have been published in support of characterizing water-quality conditions, updating TMDLs, listing status, and assigning load allocations to the lower Boise River and its tributaries. In 2003, IDEQ completed TMDL implementation plans for the lower Boise River and its major tributaries (Idaho Department of Environmental Quality, 2003). Load allocations were assigned to each tributary for suspended sediment and *E. coli* bacteria in the 2003 implementation plan. Idaho Department of Environmental Quality published a lower Boise River implementation plan for TP in 2008 and a 5-year TMDL review for the lower Boise River in 2009 (Idaho Department of Environmental Quality, 2008, 2009). In 2013, a draft addendum to the 1999 lower Boise River sediment and bacteria TMDL (Idaho Department of Environmental Quality, 1999) proposed a suspended-sediment concentration target of a 120-day average of 20 mg/L in lower Boise River tributaries, and modified bacteria targets to conform to State of Idaho criteria for *E. coli* (Idaho Department of Environmental Quality, 2013). The 2013 addendum also proposed sediment and bacteria nonpoint-source load allocations for Mason, Indian, Fivemile, and Tenmile Creeks. The TP implementation plan (Idaho Department of Environmental Quality, 2008) establishes nonpoint-source load allocations for TP in Mason, Indian, Fivemile, and Tenmile Creeks.

Description of Lower Boise River Watershed and Selected Tributaries

Land use in the lower Boise River watershed affects water-quality and biological conditions. The amount of developed and agricultural land continues to change in the lower Boise River watershed as population grows (fig. 1*C*). Previous investigations indicate that water-quality conditions in the lower Boise River are relatively pristine from Lucky Peak Dam downstream to Veteran's Memorial Parkway in Boise (fig. 1*A*) (Mullins, 1998; MacCoy, 2004). The City of Boise's Lander and West Boise WWTPs discharge to the lower Boise River downstream of Veteran's Memorial Parkway. Several large diversions are upstream of the Boise River near Middleton (USGS site No. 13210050 [B2]), which reduce summer streamflow in the Boise River to at least the required minimum of 250 ft^3/s near Middleton (site B2). Downstream of the Idaho Power Company (IPC) streamgage near Middleton, Fifteenmile Creek discharges to the Boise River. Fifteenmile Creek is the furthest upstream major tributary to the lower Boise River that drains a large area of agricultural land (Idaho Department of Environmental Quality, 2001). Mason Creek discharges to the Boise River just upstream of Caldwell and Indian Creek discharges to the Boise River in Caldwell (fig. 1*A*). The Caldwell WWTP discharges treated effluent into the Boise River just above its confluence with Indian Creek (fig. 2). Downstream of Caldwell, major tributaries of the Boise River include Conway Gulch in Notus and Dixie Drain near Wilder (fig. 1*A*). The USGS streamgage on the Boise River near Parma (site B1) represents the downstream-most monitoring site on the Boise River. The water quality at site B1 (fig. 1*A*) represents the influence from all land uses in the lower Boise River watershed. Biological monitoring was done in a riffle on the Boise River about 1.5 mi downstream of B1. Similar to the water quality, the biological condition of the Boise River near Parma (site B1) represents influences from multiple land uses in the lower Boise River watershed.

Fivemile and Tenmile Creeks

The Fivemile Creek watershed drains 97 mi^2, consisting of about 28 percent agricultural land (Rea and Skinner, 2009). During irrigation season, New York Canal represents an artificial headwaters for Fivemile Creek. Downstream of New York Canal, Fivemile Creek drains 69 mi^2, consisting of about 14 percent agricultural land and about 67 percent developed land (Fry and others, 2011). The Tenmile Creek watershed below Blacks Creek Reservoir drains 41 mi^2, consisting of about 31 percent agricultural land (Fry and others, 2011). During irrigation season, the New York Canal system, Phyllis Canal, and Caldwell Highline Canal deliver irrigation water to pastures and croplands in the Fivemile and Tenmile Creek watersheds (fig. 2*A*). The USGS Idaho Streamstats (http://water.usgs.gov/osw/streamstats/idaho.html) program shows that the total percentage of urban or developed land increased by 30 percent in the Fivemile Creek watershed and 8 percent in the Tenmile Creek watershed between 1992 and 2001.

Fivemile and Tenmile Creeks are natural ephemeral streams upstream of their intersection with the New York Canal. However, they are perennial downstream of the New York Canal at Fivemile Creek at Franklin Road, near Nampa (USGS site No. 13210795 [FM1]) and at Tenmile Creek at South Cloverdale Road, near Boise (USGS site No. 13210572 [TM3]) (figs. 1*A* and 2; table 1). Although three samples were planned at each sampling site in Fivemile and Tenmile Creeks, Fivemile Creek at Victory Road, near Boise (USGS site No. 13210470 [FM3]) and Fivemile Creek at Eagle Road, near Boise (USGS site No. 13210510 [FM2]) were dry in November 2008. Eightmile and Threemile Creeks are ephemeral tributaries of Fivemile Creek and the confluence of Fivemile Creek with Tenmile Creek forms Fifteenmile Creek. Fifteenmile Creek discharges to the Boise River about 3 mi upstream of the city of Middleton, Idaho (fig. 1*A*).

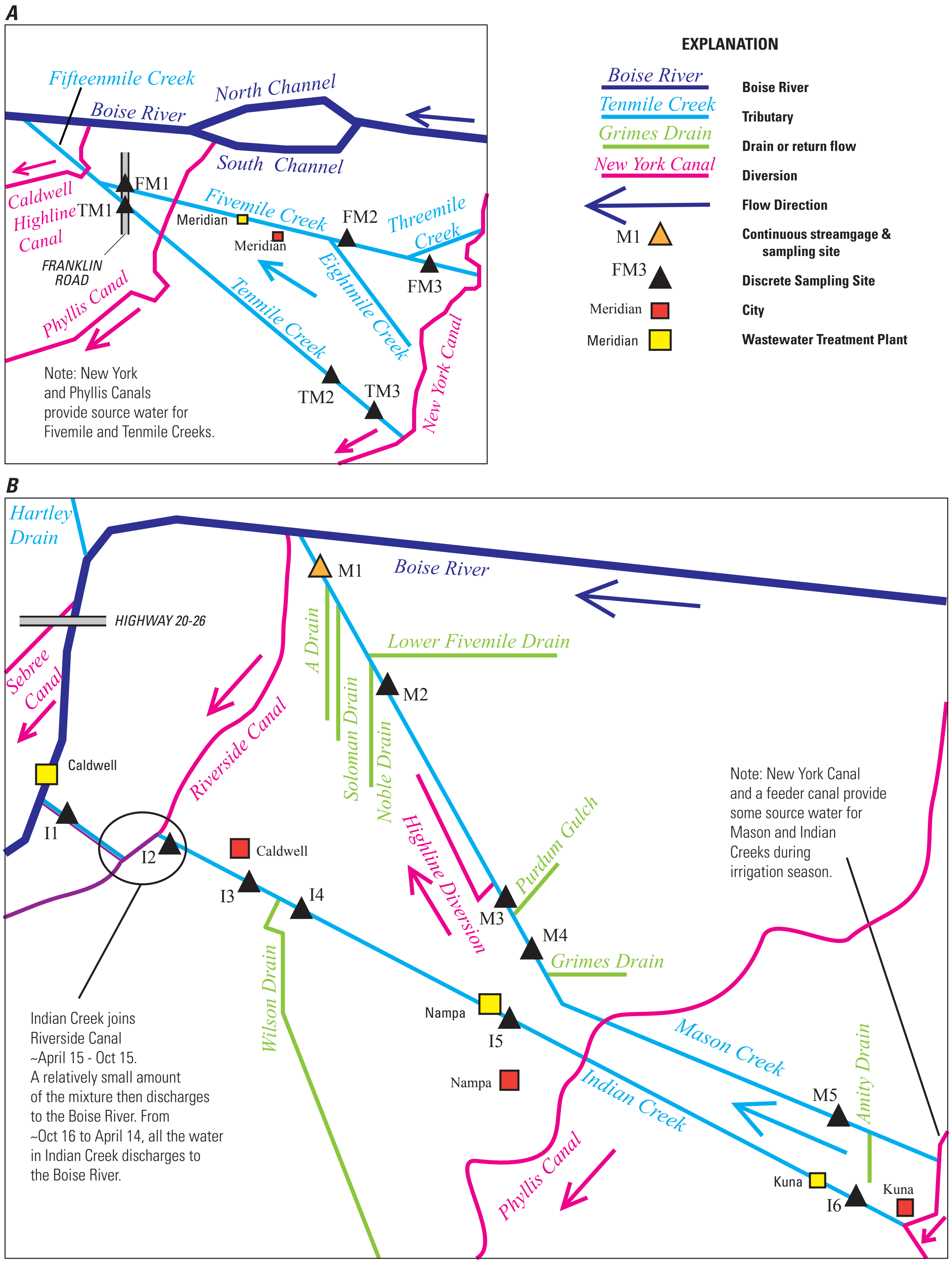

Figure 2. Fivemile, Tenmile, Mason, and Indian Creeks, lower Boise River watershed, southwestern Idaho.

The city of Meridian discharges wastewater effluent into Fivemile Creek. Nutrient concentrations are elevated in both Fivemile and Fifteenmile Creeks throughout much of the year (MacCoy, 2004).

Six sites were sampled in the Fivemile and Tenmile Creek watersheds during WY 2009 (fig. 1*B*; table 1) and are described in downstream order. The farthest upstream site was at the intersection of Tenmile Creek with South Cloverdale Road (site TM3) in a pasture. The farthest upstream site in Fivemile Creek was sampled at Victory Road, upstream of its confluence with Threemile Creek (site FM3). Samples were collected from Fivemile and Tenmile Creeks near their intersection with Eagle Road (site FM2 and site TM2), and samples were collected at site FM2 upstream of its confluence with Eightmile Creek. Sites TM3 and TM2 are adjacent to rural homes and sites FM3 and FM2 are adjacent to several commercially developed lots. Samples were collected from both creeks at their intersection with Franklin Road, just upstream of their confluence with Fifteenmile Creek (sites FM1 and TM1). Sites FM1 and TM1 are adjacent to a land-use transition from residential subdivisions to irrigated crops and samples have been collected periodically at FM1 and TM1 since 1994.

Indian Creek

The Indian Creek watershed drains 359 mi^2, 113 of which are downstream of the point where New York Canal and Indian Creek split (Rea and Skinner, 2009). The confluence of Indian Creek with New York Canal acts as artificial headwaters to Indian Creek near the city of Kuna (fig. 1*A*; fig. 2). Both Indian Creek and Wilson Drain, a tributary of Indian Creek, receive tail water from croplands and pastures in the Indian Creek watershed. In 2001, irrigated croplands totaled 20,281 acres in critical management areas adjacent to Indian Creek (Idaho Department of Environmental Quality, 2003). Indian Creek flows west/northwest through the cities of Nampa and Caldwell and intersects Riverside Canal on the western limits of the city of Caldwell (fig. 2). During irrigation season, most of the water in Indian Creek is diverted into Riverside Canal and conveyed to irrigated lands west and south of Caldwell, Idaho. During the non-irrigation season, water in Indian Creek flows through its natural drainage to the Boise River and typically is not diverted into Riverside Canal.

Both urban and rural contaminant sources have the potential to affect water quality in Indian Creek. The cities of Kuna and Nampa discharge treated wastewater effluent into Indian Creek (fig. 2). However, agricultural land uses are understood to be another major source of nutrients, pesticides, sediment, and *E. coli* in Indian Creek (MacCoy, 2004; Campbell, 2013a). As of 2010, Indian Creek was listed as impaired because of excess suspended sediment, *E. coli*, and elevated water temperature (Idaho Department of Environmental Quality, 2011a). Although not listed for nutrient impairment in 2010, P is the predominant nutrient of concern in Indian Creek.

Samples were collected at six sites in the Indian Creek watershed during 2010 (fig. 1*B*; table 1) and are described in downstream order. The farthest upstream site was Indian Creek at Robinson Road, near Nampa (USGS site No. 13211259 [I6]) and was selected as an agricultural and urban indicator site just downstream of a small dairy operation and the city of Kuna. The outfall from the city of Kuna WWTP and a larger dairy operation are between I6 and Indian Creek at Broadmore Street, near Nampa (USGS site No. 13211307 [I5]). Site I5 was selected to show changes in water quality that occurred downstream of the city of Nampa, the city of Kuna WWTP outfall, and the large dairy operation, but upstream of the Nampa WWTP. Indian Creek at Sparrow Avenue, near Caldwell (USGS site No. 13211355 [I4]) is downstream of the Nampa WWTP and upstream of Wilson Drain, a major tributary of Indian Creek (fig. 2). Wilson Drain receives effluent from the Nampa fish hatchery and tail water from irrigated agricultural land. Indian Creek at 21st Street, at Caldwell (USGS site No. 13211436 [I3]) is downstream of Wilson Drain and upstream of downtown Caldwell. Indian Creek at Simplot Boulevard, at Caldwell (USGS site No. 13211441 [I2]) represents the farthest downstream site in the Indian Creek watershed that provides unbiased water-quality information downstream of major urban and agricultural inputs.

Downstream of site I2, Riverside Canal flows into Indian Creek. Riverside Canal originates as a diversion just downstream of the Boise River confluence with Mason Creek (fig. 2). Photographic evidence (Fox and others, 2002) of a sediment plume discharging to the Boise River from Mason Creek indicates incomplete mixing in the Boise River upstream of where the river water is diverted into Riverside Canal. In Caldwell, Riverside Canal joins Indian Creek (fig. 2) and captures most of the Indian Creek streamflow during irrigation season (typically April 15–October 15). The remaining water that discharges to the Boise River at Indian Creek at mouth, near Caldwell (USGS site No. 13211445 [I1]) during irrigation season is not representative of water quality in the Indian Creek watershed because it mixes with water from Riverside Canal. During irrigation season, sediment, nutrient, and bacteria loads in Indian Creek upstream of Riverside Canal are greater than loads at the mouth of Indian Creek (site I1) because of decreased streamflow in Indian Creek downstream of Riverside Canal. Some of the streamflow in Riverside Canal is discharged to the Boise River farther downstream through Dixie Drain (fig. 1*A*). During non-irrigation season, Riverside Canal is dry and all of the streamflow in Mason and Indian Creeks is discharged directly to, and remains in the Boise River.

Mason Creek

Mason Creek is a perennial stream that originates from a feeder canal off the New York Canal, flows northwest through northeastern Nampa and continues across rural Canyon County before emptying into the Boise River near the northern city limits of Caldwell (figs. 1 and 2). The Mason Creek watershed drains 72 mi^2 (Rea and Skinner, 2009), of which 37 mi^2 (23,490) are used for agricultural production (Idaho Department of Environmental Quality, 2003). Mason Creek was dry upstream of Amity Drain (fig. 2) during non-irrigation season in 2011.

Both urban and rural contaminant sources have the potential to affect water quality in Mason Creek. However, agricultural land uses are understood to be the major source of nutrients, pesticides, sediment, and *E. coli* in Mason Creek (Fox and others, 2002; Campbell, 2009 and 2013b). A study by Mullins (1998) determined that Mason Creek was second only to Dixie Drain in sediment load contributions to the Boise River. As of 2010, Mason Creek was listed as impaired because of excess suspended sediment, *E. coli*, chlorpyrifos, “cause unknown–nutrients suspected,” and elevated water temperature (Idaho Department of Environmental Quality, 2011a). The predominant nutrient of concern in Mason Creek is P.

Five sites were sampled in the Mason Creek watershed during 2011 (figs. 1*B* and 2, table 1) and are described in downstream order. The farthest upstream site was Mason Creek at East Powerline Road, near Nampa (USGS site No. 13210890 [M5]) and was selected as an indicator of rural and agricultural land uses. Site M5 is several miles downstream of two confined animal feeding operations (CAFOs). Qualitative inspection of aerial imagery showed that relative to the watershed downstream of Nampa, the watershed immediately upstream of the site M5 drains more pastureland. Additionally, during sampling visits, site M5 a consistent manure odor was noted. The next downstream site is Mason Creek at Madison Avenue, near Nampa (USGS site No. 13210965 [M4]) and was selected as an indicator of water-quality conditions downstream of the city of Nampa and downstream of the perennial discharge from Grimes Drain (fig. 2), which flows through several subdivisions. Site M4 is at the upstream end of a land-use transition from residential, urban, and industrial land to predominantly irrigated cropland. Between site M4 and Mason Creek at Ustick Road, near Nampa (USGS site No. 13210966 [M3]), Purdum Gulch flows into Mason Creek (fig. 2). Purdum Gulch receives treated wastewater discharge from a cheese factory. Site M3 was selected as a downstream indicator of constituent contributions from the cheese factory through Purdum Gulch. Mason Creek at Wells Road, near Caldwell (USGS site No. 13210976 [M2]) characterized conditions upstream of Solomon, Noble, A, and Lower Fivemile Drains (fig. 2). Site M2 also was selected for biological sampling because it has a shallow cobble riffle. Solomon, Noble, A, and Lower Fivemile Drains discharge to Mason Creek downstream of site M2 and upstream of the farthest downstream monitoring site, Mason Creek near Caldwell (USGS site No. 13210983 [M1]). Site M1 was considered the integrator site for the Mason Creek watershed. Because it represents conditions at the downstream end of the watershed, site M1 also was selected as a streamgage and continuous water-quality monitoring site.

Study Methods

The study described in this report was conducted during WYs 2009–12. A WY is the period between October 1 and September 30 of any given calendar year. Study sites are shown in figures 1*A* and 1*B* and are listed in table 1. Sites were selected within each lower Boise River tributary watershed based on known conditions in that watershed. For example, the upstream sites in each tributary were selected based on the requirement for measureable streamflow from April to November. Downstream sites were selected to characterize land use effects, constituent loading upstream and downstream of specific return flows or diversions, and point-source discharge inputs. The Boise River near Parma (site B1) was selected as a monitoring site to assess the effects of tributaries on water quality in the Boise River at the downstream end of the watershed. Biological monitoring sites required hard substrate from which to collect periphyton and (or) invertebrate samples.

Water-Quality Sampling and Streamflow Measurement

All water-quality samples were collected, processed, and preserved according to the methods described in the USGS National Field Manual (herein referred to as the USGS NFM) (U.S. Geological Survey, variously dated). Depth- and width-integrated water samples were collected according to the equal-width-increment (EWI) method described in the USGS NFM. The EWI water-quality samples were analyzed for total and dissolved nutrients, suspended-sediment concentration, and total coliform and *E. coli* bacteria as summarized in table 2.

Equal-width-increment samples were collected with an isokinetic DH-81 sampler at wadable sites, an isokinetic DH-95 hand-line sampler at site B1 during low-flow conditions, and an isokinetic D-95 sampler deployed from a bridge crane during high-flow conditions. In accordance with the USGS NFM, the churn and sampling equipment were cleaned in soapy water, rinsed in tap water, and triple rinsed with deionized water at the start of each sampling event. A 1-L high-density polyethylene bottle and, in most cases, a 0.25-in. nozzle, were used to collect water in the sampler. Water samples were homogenized in a plastic churn splitter, which was rinsed three times with deionized water between sampling sites. Sites were sampled in downstream order starting at the farthest upstream site.

Unfiltered water samples for total nutrient analysis were acidified with sulfuric acid and chilled at 4 °C. Water samples to be analyzed for dissolved nutrients were filtered through 0.45-µm-pore-size capsule filters certified free from contamination, acidified with sulfuric acid, and chilled at 4 °C. All the nutrient samples were shipped on ice to the National Water Quality Laboratory (NWQL) for analysis. Suspended-sediment samples were shipped to the USGS Cascades Volcano Observatory (CVO) Sediment Laboratory for analysis. Unfiltered water samples to be analyzed for total coliform and *E. coli* at the IDHW, Bureau of Laboratories in Boise, Idaho, were chilled at 4 °C until delivery to the laboratory within 24 hours.

Water temperature, specific conductance, pH, turbidity, and dissolved oxygen were measured in the stream at the time of sample collection using a multi-parameter water-quality sonde calibrated according to methods described in Wagner and others (2006). Qualitative stream conditions such as odor, turbidity, and presence of debris, garbage, floating algae, suds, fish kills, and oil also were noted.

Instantaneous streamflow was measured during each sampling event at all tributary sites. From March 2011 to March 2012, the USGS operated a streamgage at Mason Creek near Caldwell, Idaho. The USGS also operates a streamgage at the Boise River near Parma, Idaho (13213000). Both streamgages provided continuous stream stage data from which a continuous record of discharge was generated using a stage-discharge relation. The streamgages were operated and discharge measurements made and processed according to methods described by Mueller and Wagner (2009) and Turnipseed and Sauer (2010). Discharge records were computed according to methods described in Rantz and others (1982).

Bottom-Sediment Sampling for Contaminants of Emerging Concern

Bottom-sediment sampling sites in the lower Boise River and its tributaries are summarized in table 2. Bottom sediments were collected, processed, and preserved according to the methods described by Radtke (2005). Bottom-sediment samples were analyzed for wastewater indicator compounds and total organic carbon as described in Burkhardt and others (2006).

Biological Sampling

Biological samples were collected at site M2 in October 2011 (table 2) to assess the relative health of the biological communities and the long-term quality of water. Periphyton, benthic macroinvertebrate (invertebrate), and fish samples were collected using protocols developed by the USGS National Water-Quality Assessment (NAWQA) Program (Moulton and others, 2002).

Periphyton samples were collected by filtering a measured portion of a composited periphyton sample through a glass-fiber filter, which was wrapped in foil and placed on dry ice or in a freezer until analyzed. Chlorophyll-*a* and ash-free dry weight were analyzed by the Bureau of Reclamation, Pacific Northwest Regional Laboratory in Boise, Idaho, using spectrophotometry (standard method 10200H; Eaton and others, 1999).

Invertebrates were collected from cobble substrates using a Slack sampler (modified Surber sampler) with a 500 µm-mesh, following the procedures in Moulton and others (2002). Samples were preserved in ethanol and shipped to Aquatic Biology Associates, Inc., in Corvallis, Oregon, for analysis. General laboratory procedures are available from U.S. Geological Survey (2014).

Water-Quality and Suspended-Sediment Analysis

Water and bottom-sediment samples were analyzed by one of three laboratories (table 2). The USGS NWQL analyzed water samples for total and dissolved nutrients. Nutrients were analyzed according to methods described in Fishman (1993) and Patton and Kryskalla (2003 and 2011) and quality-assurance and quality-control protocols described in Pritt and Raese (1995). Suspended-sediment samples were analyzed for concentration and percentage of particles less than 0.0625 mm by the CVO Sediment Laboratory using methods described in Guy (1969) and the American Society for Testing and Materials (2002) method D3977-97. The CVO Sediment Laboratory adheres to quality-control and quality-assurance measures described in Knott and others (1993). The IDHW Bureau of Laboratories in Boise, Idaho, analyzed samples for *E. coli* and total coliform according to Standard Methods number 9223B (Eaton and others, 1999).

Table 2. Summary of water-quality samples collected from the Boise River and selected tributaries, southwestern Idaho, water years 2009–12.

[**Abbreviated site name:** Complete USGS site names are provided in table 1. **Abbreviations:** USGS, U.S. Geological Survey; NWQL, National Water Quality Laboratory; CVO, Cascade Volcano Observatory Sediment Laboratory; IDHW, Idaho Department of Health and Welfare Laboratory; *E. coli*, *Escherichia coliform*; T. *coli*, total *coliform*]

Abbreviated site name	Sampling frequency	Sample type	Sampling method	Analyses	Laboratory
B1	Eight times per year, 2008–12	Water quality	Equal width increments	Total nitrogen; total phosphorus; nitrate + nitrite; ammonia; orthophosphorus; suspended sediment concentration; percent fines; *E. coli* and T. *coli*	USGS NWQL (for nutrients); USGS CVO (for suspended sediment); IDHW (for *E. coli* and T. *coli*)
M1	Monthly, March 2011–March 2012; twice a month, August and September 2011				
M5, M4, M3, M2	May, July, and November 2011				
I6, I5, I4, I3, I2, I1	May, July, and November 2010				
FM3, FM2, FM1, TM3, TM2, TM1	April and July 2009; November 2008				
B3, B2, B1	2009 (Site B1), 2011 (Site B2), 2010 (Site B3)	Bottom sediment	Composite grab	Wastewater indicator compounds and organic carbon	USGS NWQL
M5, M3, M1	July 2011				
I6, I4, I1	July 2010				
FM1, TM1	November 2008				
FM1, TM1	November 2008	Biological assessment	NAWQA	Microhabitat assessment, invertebrates	Aquatic Biology Associates, Inc. (invertebrates)
M2	October 2011			Microhabitat assessment, invertebrates, qualitative habitat assessment, fish	

Biological Analysis

Biological metrics were used to compare tributary community health to sites in the Boise River and least disturbed sites in Idaho (Maret and others, 2001; MacCoy, 2004). Metrics also can be used to assess levels of anthropogenic effects and to monitor historical trends in stream ecosystem health. The State of Idaho has developed the Idaho Small Stream Macroinvertebrate Index (SMI) (Grafe, 2002), which uses nine macroinvertebrate metrics. To distinguish between water-quality conditions at tributary sites of the lower Boise River and reference conditions, a reference, or least-disturbed site should be identified. However, because a least disturbed tributary could not be found in the lower Boise River watershed, only a broad comparison was made between the tributary SMI scores and least impacted site scores in the Basins bioregion (Snake River Plain Ecoregion) listed in appendix C of the SMI framework document (Grafe, 2002). Macroinvertebrate communities also were evaluated by functional feeding groups and tolerant and introduced taxa (Wisseman, 1996; Vieira and others, 2006; Merritt and others, 2008).

The fish community in Mason Creek was sampled using electrofishing techniques. Fish were counted, identified to species level, measured, weighed, and examined for abnormalities. Fish were identified onsite and voucher samples were submitted and verified at the Orma J. Smith Academy of Sciences museum at the College of Idaho, Caldwell, Idaho.

Mason Creek fish community data and associated sampling effort information is available in the USGS bioassessment database, at https://aquatic.biodata.usgs.gov/landing.action. The relative abundance of each species, origin (native or introduced), tolerance to pollutants (tolerant, intermediate, or sensitive), temperature preference, and trophic guilds (percentage of invertivores and piscivores, and percentage of omnivores and herbivores) also were determined.

Fish condition factors (measure of fish health) were calculated using equation 1 (Williams, 2000):

$$K = 100,000 \frac{W}{L^3} \tag{1}$$

where

- K is the condition coefficient,
- W is the weight of the fish in grams, and
- L is the standard length of the fish in millimeters.

A condition factor close to 1 indicates a balanced weight-to-length ratio. The analysis of fish condition as a measure of wellness has become a standard practice in the management of fish populations. The goal of using the condition factor equation is control for, or removal of, the confounding effects of absolute body size when comparing body mass or other measures of nutritional state (Pope and Kruse, 2007). The fish community was evaluated using an index-of-biotic-integrity (IBI) score (Mebane and others, 2003). Hatchery fish were not included in the IBI calculations. Each of 10 metrics were standardized and weighted to produce a score ranging from 0 to 100. Sites with scores between 75 and 100 exhibit high biotic integrity with minimal disturbance (Mebane and others, 2003) and possess an abundant and diverse community of native coldwater species. Sites with scores between 50 and 74 are of somewhat lower quality and are classified as having intermediate biotic integrity. Sites with scores less than 50 are considered to have poor biotic integrity with tolerant fish species predominating and sensitive species rare or absent.

A rangeland stream fish index (SFI-Range) was developed by IDEQ as another tool for smaller streams to distinguish between least disturbed and stressed fish communities (Grafe, 2002). The SFI was summarized using a spreadsheet tool developed by IDEQ (Mary Anne Nelson, Idaho Department of Environmental Quality, written commun., 2013).

Continuous Water-Quality Monitoring

A turbidity and temperature probe (Forest Technology Systems (2010; Sensor Model DTS-12) was installed at site M1 on April 7, 2011, and removed on March 21, 2012. The probe recorded turbidity and temperature readings at 15-minute intervals. Onsite testing of the cross-sectional variability of turbidity and temperature in Mason Creek indicated that the stream was well mixed and the continuous monitor accurately represented stream conditions. The DTS-12 turbidity and temperature probe requires factory calibration and cannot be calibrated during service visits while deployed. The DTS-12 probe was calibrated at the Forest Technology Systems factory in March 2011 prior to deployment and in April 2012 after the probe was removed from the site. Therefore, a single calibration drift correction was prorated into the turbidity record. The DTS-12 probe was cleaned according to methods described in Wagner and others (2006) during monthly service visits. A 6-series multiparameter water-quality sonde (Yellow Springs, Inc. [YSI]) with a model 6136 turbidity probe was used to obtain comparison readings during service visits for the DTS-12 probe. The YSI and the deployed DTS-12 use slightly different methods to detect turbidity. Readings from the two turbidity probes were not directly comparable, but were useful for the intended purpose, which was to determine if ambient conditions changed while the DTS-12 was cleaned. Continuous water-quality data were processed and checked according to the methods described in Wagner and others (2006).

Data Quality Assurance and Quality Control

Water-quality sample results were reviewed after receipt of the laboratory analysis. Data validation included use of a relative percent difference (RPD) to evaluate the relation between the dissolved nutrient concentrations and whole-water concentrations. RPDs were calculated using the absolute value of the difference between the result pair, divided by the mean of the result pair, multiplied by 100. Expressing precision relative to a mean concentration standardizes comparison of precision among individual constituents. Laboratory analyses were rerun and (or) verified when the dissolved fraction exceeded the whole-water fraction with an RPD greater than 10 percent. Suspended sediment and total coliform and *E. coli* results were reviewed for anomalies in relation to historical results at the same location.

Quality-control samples were collected to evaluate the quality of the analytical results, and analyzed concurrently in the laboratory with routine samples. Split replicates and blank samples were collected and submitted at a proportion equivalent to at least 10 and 5 percent of the total number of water samples, respectively.

Replicate data can be obtained in different ways to provide an assessment of precision (reproducibility) of analytical results. Replicate samples are two or more samples considered to be essentially identical in composition. Replicate samples can be obtained in the field (field replicate) by either repeating the collection process to obtain two or more independent composite samples (concurrent field replicate) or by splitting a single composite sample into two or more subsamples (split field replicate). The individual replicate samples are then analyzed separately. Likewise, a single sample can be analyzed two or more times in the laboratory to obtain a measure of analytical precision (laboratory replicate).

All replicate samples collected as part of this study were split field replicates. Analyses of split field replicates indicate the reproducibility of environmental data that are affected by the combined variability potentially introduced by field and laboratory processes. The precision of the analytical results was determined using the RPD between the environmental sample and the split replicate. An RPD of less than 20 percent for chemical analytes was considered acceptable. Split replicate samples also were analyzed for RPD with total coliform and *E. coli* bacteria samples. However, because those results are reported as a most probable number, no specific RPD acceptability value was targeted.

Blank samples identify the presence and magnitude of potential contamination that could bias analytical results. Field blanks are aliquots of deionized water that are certified as contaminant free and are processed through the sampling equipment used to collect stream samples. All blanks were collected as field blanks. Field blanks are subjected to the same processing (sample splitting, filtration, preservation, transportation, and laboratory handling) as environmental samples. Blank samples were analyzed for the same constituents as the environmental samples.

Model Development

Two types of regression models were developed to estimate nutrient and suspended-sediment loads at Mason Creek near Caldwell, Idaho (site M1, fig. 2). Regression modeling was possible at site M1 because samples were collected at least monthly and there was a continuous discharge record. The USGS LOAD ESTimator (LOADEST) FORTRAN program (Runkel and others, 2004) was used to estimate daily loads of selected water-quality constituents. Surrogate models were developed using continuous turbidity and discharge to estimate 15-minute and daily nutrient and suspended-sediment concentrations and loads. Use of surrogate regression models provides useful information on a small time scale for evaluating compliance with water-quality targets and assessing changes in the watershed in response to nutrient reduction strategies.

Load Models

Daily, monthly, and seasonal loads for March 2011 through March 2012 were estimated for TP, TN, and suspended sediment using the LOADEST program. LOADEST uses discharge data and constituent concentrations to calibrate a regression model that estimates constituent loads based on parameters of discharge and time (Runkel and others, 2004). The calibrated regression model is then used in conjunction with continuous daily mean discharge data to estimate loads over a user-specified time interval ranging between days and years.

The output regression equation from the LOADEST program takes the following general form:

$$ln(L) = a + b \times ln(Q) + c \times ln(Q^2) + d \times sin(2\pi T) + e \times cos(2\pi T) + f \times T + g \times T^2 \quad (2)$$

where

- L is the constituent load, in pounds per day,
- Q is discharge, in cubic feet per second,
- T is time, in decimal years from the beginning of the calibration period,
- a is the y-intercept or error term, and
- b, c, d, e, f, and g are regression coefficients.

LOADEST allows the user to decide between selecting the predictor variables from several predefined models or the software will automatically select the best model on the basis of the Akaike Information Criterion (Runkel and others, 2004). The selection criterion is designed to achieve a good balance between using as many predictor variables as possible to explain the variance in load and minimize the standard error of the resulting estimates. For this study, the software was allowed to select the best model. A complete discussion of the theory and principles behind the calibration and estimation methods used by the LOADEST software is given by Runkel and others (2004).

Surrogate Models

Multiple linear regression models were developed using continuously monitored water-quality parameters to estimate concentrations and loads of TP, TN, *E. coli*, and suspended sediment. The primary purpose of the surrogate models was to use continuously monitored variables to estimate constituent concentrations on a finer time scale than can be sampled. Procedures outlined in Rasmussen and others (2009) were followed when developing surrogate models for suspended sediment. Surrogate models for TP, TN, and *E. coli* were developed using stepwise linear regression analysis as described in Wood and Etheridge (2011). The functional form of the surrogate models is:

$$y = a + bx_1 + cx_2 + ... + mx_n \quad (3)$$

where

- y is the response variable,
- $b,c,...m$ are regression coefficients,
- a is the y-intercept or error term, and
- $x_1, x_2,...x_n$ are explanatory variables.

Surrogate models were calibrated using 15-minute values of continuously monitored discharge and turbidity in conjunction with laboratory analytical results for environmental samples.

Water-Quality and Biological Conditions

Existing TMDLs for the lower Boise River, the Snake River Hells-Canyon Reach, and tributaries of the Boise River have established targets for TP, suspended sediment, and *E. coli* (table 3). Water-quality results are discussed in relation to TMDL targets and tributary water-quality results are compared to results from site B1. Adjacent land uses affected water-quality conditions at many of the tributary monitoring sites. Results of bottom-sediment analysis for contaminants of emerging concern also showed that adjacent land uses could affect in-stream conditions. Biological monitoring provided additional information on the effects of water-quality and in-stream conditions on biotic integrity. Supporting information for the monitoring results is provided in appendixes. Appendix A summarizes invertebrate sampling results. Appendix B shows 360-degree photographs of each tributary monitoring site for a qualitative comparison of adjacent land uses. Appendix C includes results from a 24-hour study conducted at nine tributary sites in the Fifteenmile, Fivemile, Tenmile, Mason, Sand Hollow, and Indian Creeks.

Quality Control Sample Results

Eleven split replicate samples were collected, and 60 chemical analyte results had a mean RPD of 5.34 percent and a median RPD of 1.48 percent. Precision estimates for individual analytes in replicate samples were within the 20-percent RPD limit for 55 of 60 constituent results. Forty-one split replicate nutrient results from the NWQL averaged a 1.96-percent relative percent difference compared to routine sample results. Seven split replicate *E. coli* results from the IDHW laboratory, reported as most probable number per milliliter (MPN/mL), averaged a 25-percent RPD compared to routine sample results. Because these values are reported in units of probability, specific data-quality objectives are not required to be met except for exceeding sample hold times prior to laboratory analysis. Three of the five replicate pairs exceeding 20 percent RPDs occurred in *E. coli* results. Twelve split replicate sample results from the CVO laboratory for percent fines and suspended sediment averaged a 7.80-percent RPD compared to routine sample results. The remaining two of five replicate pairs exceeding 20 percent RPDs occurred in suspended sediment sample results. In one case the results were 3 and 4 mg/L and in the other case, the results were 78 and 96 mg/L. The second case indicates poor precision in sediment results at site B1 on July 7, 2011. No adjustments were made to analytical data on the basis of replicate analyses.

Eleven field blank samples provided 53 analyte results in which ammonia was detected four times. Although ammonia had a 36 percent detection rate in blank samples, all four detected results were estimated at concentrations less than the 0.02-mg/L laboratory reporting level; therefore, additional investigation into field equipment bias was not conducted. A field blank with constituent concentrations equal to or less than the laboratory reporting level for the analytical method indicates that the entire process of sample collection, field processing, and laboratory analysis is presumably free of contamination.

Fivemile and Tenmile Creeks

Both urban and rural contaminant sources have the potential to affect water quality in Fivemile and Tenmile Creeks. As of 2010, Tenmile Creek was listed as impaired because of excess suspended sediment and *E. coli* bacteria and Fivemile Creek was listed as impaired because of excess sediment, fecal coliform, and low flow alterations (Idaho Department of Environmental Quality, 2011a; table 3). Fivemile Creek currently is not listed as impaired for nutrients, but the city of Meridian discharges treated wastewater effluent to Fivemile Creek (fig. 2) and TP loads from a mixture of agricultural and urban land uses in the Fifteenmile Creek watershed increase TP concentrations in the Boise River during irrigation season (Etheridge, 2013).

Watershed-Scale Water-Quality Sampling Results

Environmental samples indicate that TP concentrations in Fivemile Creek decrease with flow between Fivemile Creek at Victory Road (site FM3) and Fivemile Creek at Eagle Road (site FM2) and increase by as much as 10 times between site FM2 and Fivemile Creek at Franklin Road (site FM1) (figs. 3 and 4). TP concentrations in samples collected from Fivemile Creek were greater than the 0.07-mg/L TP target established at the mouth of the Boise River, with the exception of TP concentrations in samples collected from FM2. Nearly all TP at FM1 consisted of OP on November 17, 2008, but only 58 percent consisted of OP on July 29, 2009 (table 4). This finding suggests that particulate phosphorus is a large component of TP in the downstream part of Fivemile Creek during irrigation season. The dissolved OP component at FM2 and FM3 averaged 49 percent, indicating a large amount of particulate phosphorus in the upper part of Fivemile Creek year round. The discharge of treated wastewater effluent to Fivemile Creek downstream of FM2 and upstream of FM1 may substantially increase TP concentrations in Fivemile Creek, particularly during the non-irrigation season when irrigation returns do not increase discharge in Fivemile Creek (figs. 3 and 4).

Table 3. Clean Water Act listing status for the lower Boise River and selected tributaries, southwestern Idaho, as of June 2014.

[**Abbreviated site name:** Complete USGS site names are provided in table 1. **303(d) listed constituents:** From Idaho Department of Environmental Quality (2011). **Abbreviations:** *E. Coli*, *Escherichia coli*; CFU, colony-forming unit; geomean, geometric mean of five samples collected every 3–7 days over a 30-day period; SR-HC TMDL, Snake River-Hells Canyon total maximum daily load; IDEQ, Idaho Department of Environmental Quality; mL, milliliter; mg/L, milligram per liter; °C, degrees Celsius; ton/d, ton per day; lb/d, pound per day]

Water body	Beneficial use designations	Assessment unit	303(d) listed constituents	Suggested load allocation, target, or applicable criteria
Tenmile Creek	Coldwater aquatic life, secondary contact recreation	Below Blacks Creek Reservoir	Suspended sediment	20 mg/L 120-day average[1]
			E. Coli	126 CFU/100 mL geomean[2], 576 CFU/100mL single-sample[3]
Fivemile Creek	Coldwater aquatic life, secondary contact recreation, salmonoid spawning	Fivemile Creek-3rd Order	Suspended sediment	20 mg/L 120-day average[1]
Mason Creek	Coldwater aquatic life, secondary contact recreation	Entire watershed	Water temperature	19 °C maximum daily mean; 22 °C daily maximum[3]
			Suspended sediment	20 mg/L 120-day average[1]
			E. coli	126 CFU/100 mL geomean[2], 576 CFU/100mL single-sample[3]
			Cause unknown (nutrients)	no TMDL
			Chlorpyrifos	no TMDL
Indian Creek	Coldwater aquatic life, secondary contact recreation	Below 11th Avenue in Nampa	Water temperature	19 °C maximum daily mean; 22 °C daily maximum[3]
			Suspended sediment	20 mg/L 120-day average[1]
			E. Coli	126 CFU/100 mL geomean[2], 576 CFU/100mL single-sample
Lower Boise River	Coldwater aquatic life, primary contact recreation, salmonoid spawning	Indian Creek to Mouth	Water temperature	19 °C maximum daily mean; 22 °C daily maximum; 9 °C maximum daily mean (during periods of salmonid spawning[4]); 13 °C daily maximum[3] (during periods of salmonid spawning[4])
			Suspended sediment	50 mg/L no more than 60 days; 80 mg/L no more than 14 days; 101.42 ton/d[4]
			Fecal coliform bacteria[6]	126 CFU/100 mL geomean[2], 406 CFU/100mL single-sample[3]
			Total phosphorus	0.07 mg/L; 533 lb/d[5]
			Low flow alterations	
			Substrate alterations	

[1]From Idaho Department of Environmental Quality (2013)

[2]From Idaho Department of Environmental Quality (2009)

[3]From State of Idaho (2013)

[4]From Idaho Department of Environmental Quality (1999)

[5]Idaho Department of Environmental Quality and Oregon Department of Environmental Quality (2004)

[6]Idaho Department of Environmental Quality (2003) states that compliance with the lower Boise River fecal coliform bacteria TMDL will be evaluated using applicable state water quality standards for *E. coli*.

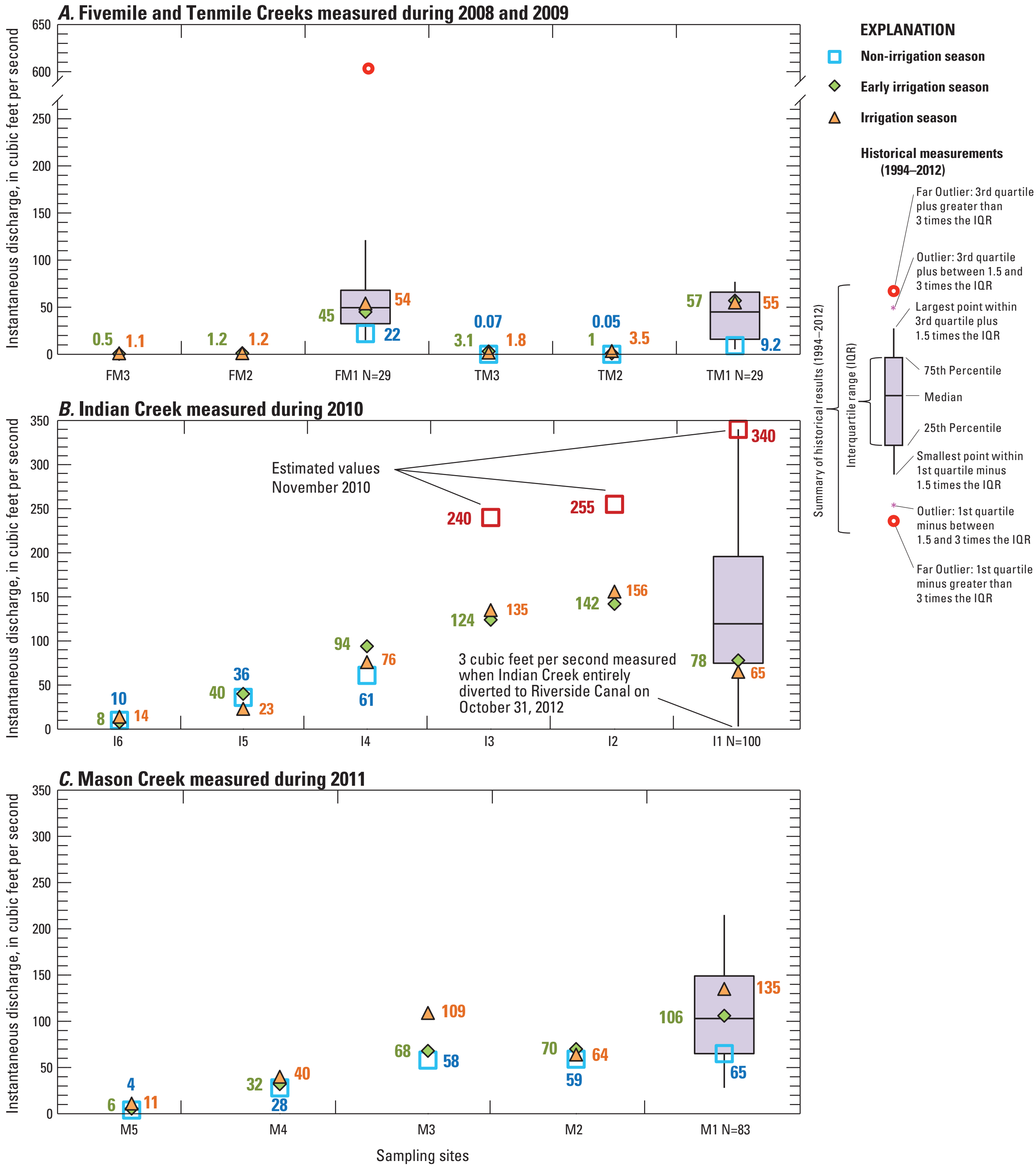

Figure 3. Instantaneous discharge from measurements in selected tributaries to the lower Boise River compared to historical discharge measurements near the mouth of each tributary (1994–2012), southwestern Idaho. (*A*) Discharge measured in Fivemile and Tenmile Creeks during 2008 and 2009 compared to historical discharge measured at sites FM1 and TM1 (1994–2012); (*B*) Discharge measured in Indian Creek during 2010 compared to historical discharge measured at site I1 (1994–2012); and (*C*) Discharge measured in Mason Creek during 2011 compared to historical discharge measured at site M1 (1994–2012). (N, number of samples).

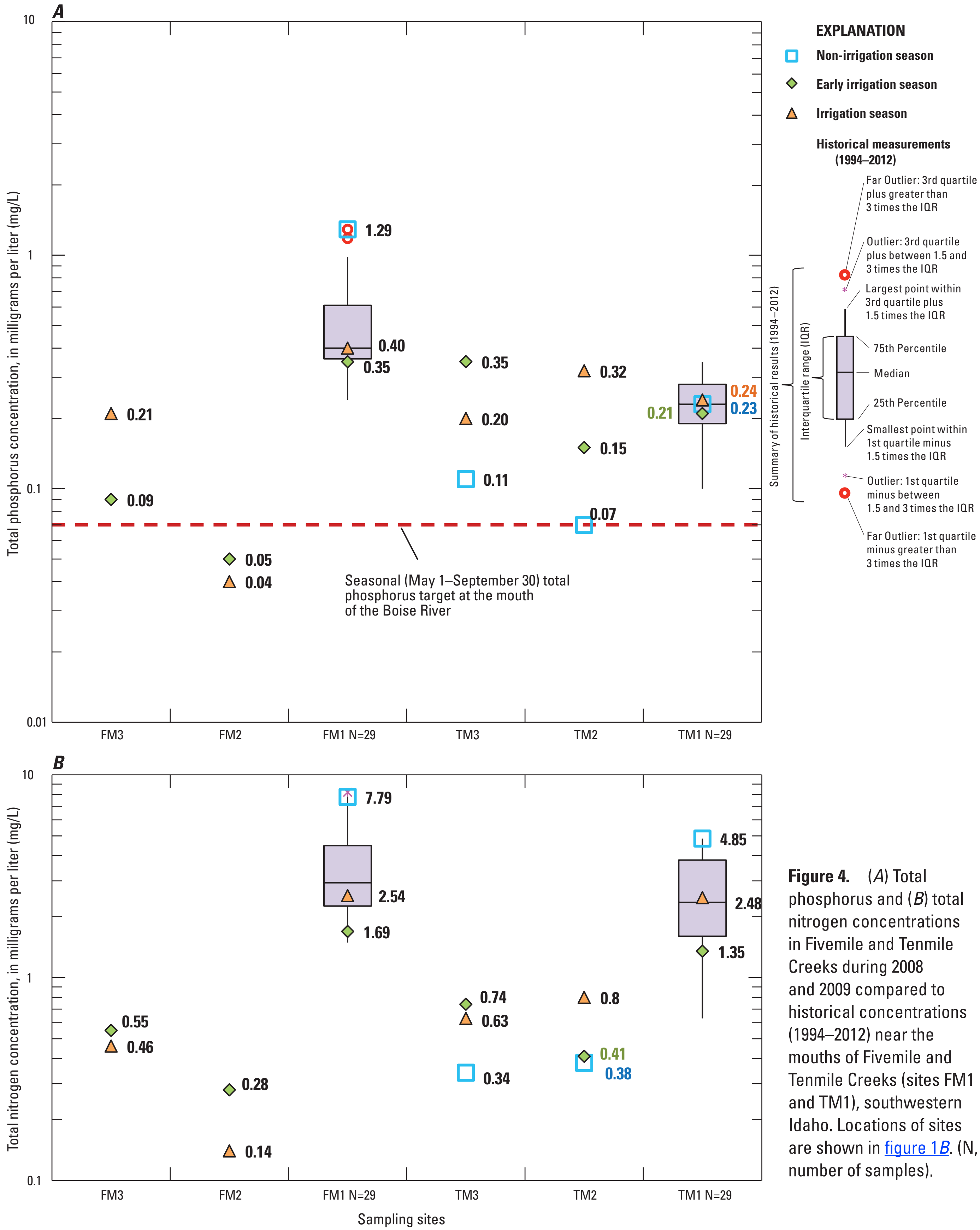

Figure 4. (*A*) Total phosphorus and (*B*) total nitrogen concentrations in Fivemile and Tenmile Creeks during 2008 and 2009 compared to historical concentrations (1994–2012) near the mouths of Fivemile and Tenmile Creeks (sites FM1 and TM1), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

Table 4. Dissolved to total phosphorus and nitrogen ratios in selected tributaries to the lower Boise River, southwestern Idaho, water years 2009–12.

[See table 1 for full list of site abbreviations and site names.]

Date	Abbreviated site name					
	FM3	FM2	FM1	TM3	TM2	TM1
	Dissolved orthophosphorus as phosphorus: Total phosphorus ratio					
04-28-09	0.56	0.26	0.76	0.98	0.94	0.64
07-29-09	0.46	0.68	0.58	0.68	0.67	0.68
11-17-08	–	–	0.98	0.78	1	1
	Dissolved inorganic nitrogen: Total nitrogen ratio					
04-28-09	0.26	0.02	0.70	0.35	0.15	0.69
07-29-09	0.09	0.08	0.78	0.09	0.15	0.86
11-17-08	–	–	0.92	0.39	0.29	0.91

Date	Abbreviated site name					
	I6	I5	I4	I3	I2	I1
	Dissolved orthophosphorus as phosphorus: Total phosphorus ratio					
05-03-10	1	0.86	1	0.96	0.97	0.89
07-27-10	1	1	0.97	0.91	0.89	0.83
11-17-10	1	1	1	1	1	1
	Dissolved inorganic nitrogen: Total nitrogen ratio					
05-03-10	0.86	0.89	0.91	0.90	0.90	0.87
07-27-10	0.83	0.97	0.95	0.91	0.91	0.84
11-17-10	0.95	0.96	0.97	0.93	0.94	0.94

Date	Abbreviated site name				
	M5	M4	M3	M2	M1
	Dissolved orthophosphorus as phosphorus: Total phosphorus ratio				
05-03-11	1	0.81	0.63	0.53	0.74
07-07-11	0.64	0.89	0.64	0.53	0.47
11-09-11	0.17	0.85	0.95	0.94	0.93
	Dissolved inorganic nitrogen: Total nitrogen ratio				
05-02-11	0.92	0.92	0.83	0.77	0.83
07-07-11	0.77	0.86	0.86	0.86	0.79
11-09-11	0.80	0.97	0.93	0.96	0.97

TP loads ranged between 0.24 and 1.25 lb/d at FM3, between 0.32 and 0.24 lb/d at FM2, and between 85 and 153 lb/d at FM1 (table 5). The TP load in Fivemile Creek increased downstream of FM3 and FM2 because of increases in TP concentration and discharge. The smallest TP load measured at FM1 was 85 lb/d during early irrigation season. The largest TP load was 153 lb/d during non-irrigation season when discharge was relatively low, but the TP concentration was the highest measured (figs. 3 and 4). Instantaneous TP loads in Fivemile Creek at Franklin Road (site FM1) represented between 7.1 and 12.6 percent of the TP load in the Boise River near Parma (site B1) (table 5). Based on data collected from 1994 to 2012, the TP load at FM1 represented a median of 72 lb/d or 4.2 percent of the median TP load in the Boise River near Parma (site B1) during the non-irrigation season, and 108 lb/d or 7.8 percent of the median TP load during irrigation season (fig. 5). TP loads in Fivemile Creek at Franklin Road (site FM1) and Fifteenmile Creek at the Mouth (USGS site No. 13210815) fluctuated during non-irrigation season in response to TP concentrations in wastewater effluent from the Meridian WWTP (Etheridge, 2013).

Total phosphorus concentrations in samples collected from Tenmile Creek did not increase as much in a downstream direction as compared to Fivemile Creek, but were greater than or equal to the 0.07-mg/L TP target established at the mouth of the Boise River. The smallest difference between seasonal concentrations in TP occurred at Tenmile Creek at Franklin Road (site TM1) (fig. 4). Tenmile Creek at Cloverdale Road (TM3) had the highest TP concentration in April 2009, whereas the downstream Tenmile Creek sites (TM2 and TM1) had the highest TP concentrations in July 2009.
Most of the TP in Tenmile Creek was dissolved OP, with the lowest average, 68 percent, occurring in July 2009 during irrigation season, and the highest average, 93 percent, occurring in November 2008 during non-irrigation season (table 4). OP represented all of the TP at sites TM2 and TM1 during non-irrigation season, and more than 90 percent of the TP at sites TM3 and TM2 in April 2009 during early irrigation season. Relative to Fivemile Creek, the higher OP:TP in Tenmile Creek suggests that groundwater may be an important source of TP to Tenmile Creek. The fact that half of the samples collected at site TM1 contained TP concentrations between 0.19 and 0.28 mg/L (the interquartile range [IQR], fig. 4) indicates a relatively consistent source of TP such as groundwater discharge.

Because the IQR of TP concentrations at Tenmile Creek at Franklin Road (site TM1) is relatively small, discharge is the most important factor influencing TP loads in Tenmile Creek. Based on historical data, the median instantaneous TP load at site TM1 during the irrigation season was 67 lb/d, representing 4.9 percent of the TP load in the Boise River near Parma (site B1). During non-irrigation season, the median load at site TM1 dropped to 9 lb/d, only 0.5 percent of the TP load in the Boise River near Parma (site B1) (fig. 5). During WY 2009, the TP load in Tenmile Creek also was greatest during irrigation season (table 5). Similar to the results from Fivemile Creek, the TP load in Tenmile Creek increased by as much as two orders of magnitude between sites TM3 and TM1 and between sites TM2 and TM1. The increase in the TP load in Fivemile Creek resulted from an increase in both discharge and TP concentration, whereas the increase in the TP load in Tenmile Creek primarily resulted from an increase in discharge (figs. 3 and 4). The combined TP load in Fivemile and Tenmile Creeks represented a maximum of 20.3 percent of the TP load in the Boise River near Parma (site B1) on July 29, 2009, during irrigation season, and a minimum of 8.8 percent on November 17, 2008 during non-irrigation season (table 5).

Concentrations of TN increased by up to 1 order of magnitude between upstream sites in Fivemile and Tenmile Creeks (sites FM3, FM2, TM3, and TM2) and downstream sites in Fivemile and Tenmile Creeks (sites FM1 and TM1) (fig. 4). Total nitrogen, although relatively low in upper Fivemile and Tenmile Creeks on average, consisted of 19 percent nitrate plus nitrite as nitrogen ($NO_2 + NO_3$). This finding suggests that organic and particulate N constitute the bulk of the TN in the upper Fivemile and Tenmile Creek watersheds. In contrast, TN consisted of an average of 81 percent $NO_2 + NO_3$ at the downstream sites (FM1 and TM1), suggesting groundwater as a source of TN in the lower Fivemile and Tenmile Creek watersheds. TN concentrations were also highest in winter at downstream sites (FM1 and TM1) and lowest in winter at upstream sites (FM3, FM2, TM3, and TM2), further indicating groundwater as the source of TN closer to the mouths of Fivemile and Tenmile Creeks (fig. 4).

Historically, TN loads in Fivemile Creek at Franklin Road (site FM1) represented a median of 0.42 ton/d or 7.6 percent of the TN load in the Boise River near Parma (site B1) during irrigation season, and 0.35 ton/d or 3.7 percent of the TN load in the Boise River near Parma during non-irrigation season (fig. 5). The TN loads in Tenmile Creek represented a median of 0.28 ton/d or 5 percent of the TN load at B1 during irrigation season and 0.09 ton/d or less than 1 percent of the TN load at site B1 during non-irrigation season. TN concentrations at sites FM1 and TM1 were highest during non-irrigation season, but flow decreases after irrigation season ended were greater at site TM1 than at site FM1 (fig. 3). As a result, TN loading in Fivemile Creek was greatest during non-irrigation season whereas TN loading in Tenmile Creek was greatest during irrigation season (table 5). The upstream areas of Fivemile and Tenmile Creeks did not contribute substantial nutrient loads to the downstream areas of Fivemile or Tenmile Creeks during any sampling event (table 5). However, gains in both discharge and dissolved N downstream of sites FM2 and TM2 contributed nearly all the TN load measured at sites FM1 and TM1.

Table 5. Summary of instantaneous total phosphorous, total nitrogen, and suspended-sediment loads measured in the Fivemile, Tenmile, Indian, and Mason Creeks, southwestern Idaho, water years 2009–12.

[**Bold** values indicate estimated instantaneous loads. **Abbreviated site name:** Complete USGS site names are provided in table 1. **Abbreviations:** lb/d, pound per day; –, no data; >, greater than; ton/d, ton per day]

Fivemile and Tenmile Creek watersheds				Indian Creek watershed				Mason Creek watershed			
Abbreviated site name	Early irrigation 04-28-09	Irrigation 07-29-09	Non-irrigation 11-17-08	Abbreviated site name	Early irrigation 05-03-10	Irrigation 07-27-10	Non-irrigation 11-17-10	Abbreviated site name	Early irrigation 05-03-11	Irrigation 07-07-11	Non-irrigation 11-09-11
Instantaneous total phosphorus load (lb/d)											
FM3	0.24	1.25	–	I6	2.63	6.95	3.78	M5	4.53	18.4	9.71
as percentage of FM1	0.29	1.07	–	as percentage of I2	0.5	1.1	0.5	as percentage of M1	3.8	5.9	15
FM2	0.32	0.24	–	I5	46.0	70.7	104	M4	19.0	30.2	16.6
as percentage of FM1	0.38	0.21	–	as percentage of I2	9.4	11	14	as percentage of M1	16	10	26
FM1	85.0	117	153	I4	499	471	467	M3	66.0	170	50.1
as percentage of B1	7.1	12.6	8.2	as percentage of I2	102	74	62	as percentage of M1	55	54	79
TM3	5.85	1.94	0.04	I3	401	496	**781**	M2	75.5	117	54.1
as percentage of TM1	9.1	2.7	0.36	as percentage of I2	82	78	>100	as percentage of M1	63	37	86
TM2	0.81	6.04	0.02	[1]I2	489	634	**756**	M1	120	313	63.1
as percentage of TM1	1.3	8.5	0.2	as percentage of B1	42	55	59	as percentage of B1	3.2	9.3	4.2
TM1	64.6	71.2	11.4	I1	198	161	**954**	B1	3,700	3,370	1,510
as percentage of B1	5.4	7.7	0.61	as percentage of B1	17	14	74				
B1	1,200	922	1,860	B1	1,170	1,150	1,290				
Instantaneous total nitrogen load (lb/d)											
FM3	1.48	2.73	–	I6	66.9	77.0	252	M5	95.2	199	135
as percentage of FM1	0.4	0.4	–	as percentage of I2	1.4	1.6	2.6	as percentage of M1	6.7	7.7	7.8
FM2	1.81	0.83	–	I5	721	674	1,460	M4	413	507	550
as percentage of FM1	0.4	0.1	–	as percentage of I2	15	14	15	as percentage of M1	29	20	32
FM1	410	740	924	I4	4,100	2,760	3,750	M3	1,060	2,000	1,360
as percentage of B1	4.4	11	4.8	as percentage of I2	87	58	39	as percentage of M1	75	78	79
TM3	12.4	6.12	0.13	I3	3,980	3,980	**9,680**	M2	997	1,160	1,430
as percentage of TM1	3.0	0.8	0.1	as percentage of I2	85	84	>100	as percentage of M1	70	45	83
TM2	2.21	15.1	0.10	[1]I2	4,690	4,760	**9,640**	M1	1,420	2,570	1,720
as percentage of TM1	0.5	2.1	<0.05	as percentage of B1	49	61	51	as percentage of B1	6.7	12	8.2
TM1	415	736	241	I1	1,580	1,160	**13,700**	B1	21,100	21,000	21,100
as percentage of B1	4.5	11	1.2	as percentage of B1	16	15	73				
B1	9,280	6,570	19,400	B1	9,650	7,840	18,800				

Table 5. Summary of instantaneous total phosphorous, total nitrogen, and suspended-sediment loads measured in the Fivemile, Tenmile, Indian, and Mason Creeks, southwestern Idaho, water years 2009–12.—Continued

[**Bold** values indicate estimated instantaneous loads. **Abbreviated site name:** Complete USGS site names are provided in table 1. **Abbreviations:** lb/d, pound per day; –, no data; >, greater than; ton/d, ton per day]

Fivemile and Tenmile Creek watersheds				Indian Creek watershed				Mason Creek watershed			
Abbreviated site name	Early irrigation 04-28-09	Irrigation 07-29-09	Non-irrigation 11-17-08	Abbreviated site name	Early irrigation 05-03-10	Irrigation 07-27-10	Non-irrigation 11-17-10	Abbreviated site name	Early irrigation 05-03-11	Irrigation 07-07-11	Non-irrigation 11-09-11
Instantaneous suspended-sediment load (ton/d)											
FM3	0.12	0.29	–	I6	1.01	2.42	0.16	M5	0.35	4.51	6.42
as percentage of FM1	1.2	2.0	–	as percentage of I2	3.1	6.2	0.4	as percentage of M1	1.2	4.0	>100
FM2	0.32	0.28	–	I5	4.21	5.58	0.49	M4	2.68	2.16	1.74
as percentage of FM1	3.1	2.0	–	as percentage of I2	13	14	1.2	as percentage of M1	9.5	1.9	99
FM1	10.4	14.3	5.52	I4	22.1	19.3	2.30	M3	12.8	43.8	1.25
as percentage of B1	7.3	20	26	as percentage of I2	68	49	5.5	as percentage of M1	45	38	71
TM3	0.72	0.43	0.01	I3	29.8	33.9	**40.8**	M2	21.1	41.4	1.91
as percentage of TM1	5.8	3.3	0.5	as percentage of I2	91	87	97	as percentage of M1	75	36	>100
TM2	0.12	0.86	0.01	[1]I2	32.6	39.1	**42.0**	M1	28.3	114	1.75
as percentage of TM1	1.0	6.5	0.5	as percentage of B1	27	31	>100	as percentage of B1	2.8	16	8.7
TM1	12.5	13.2	2.11	I1	18.7	16.5	**38.5**	B1	1,020	730	20.1
as percentage of B1	9	18	10	as percentage of B1	16	13	>100				
B1	143	72.6	20.9	B1	121	127	16.2				

[1]Loads are shown as percentage of I2 because a large diversion occurs in Indian Creek downstream of I2.

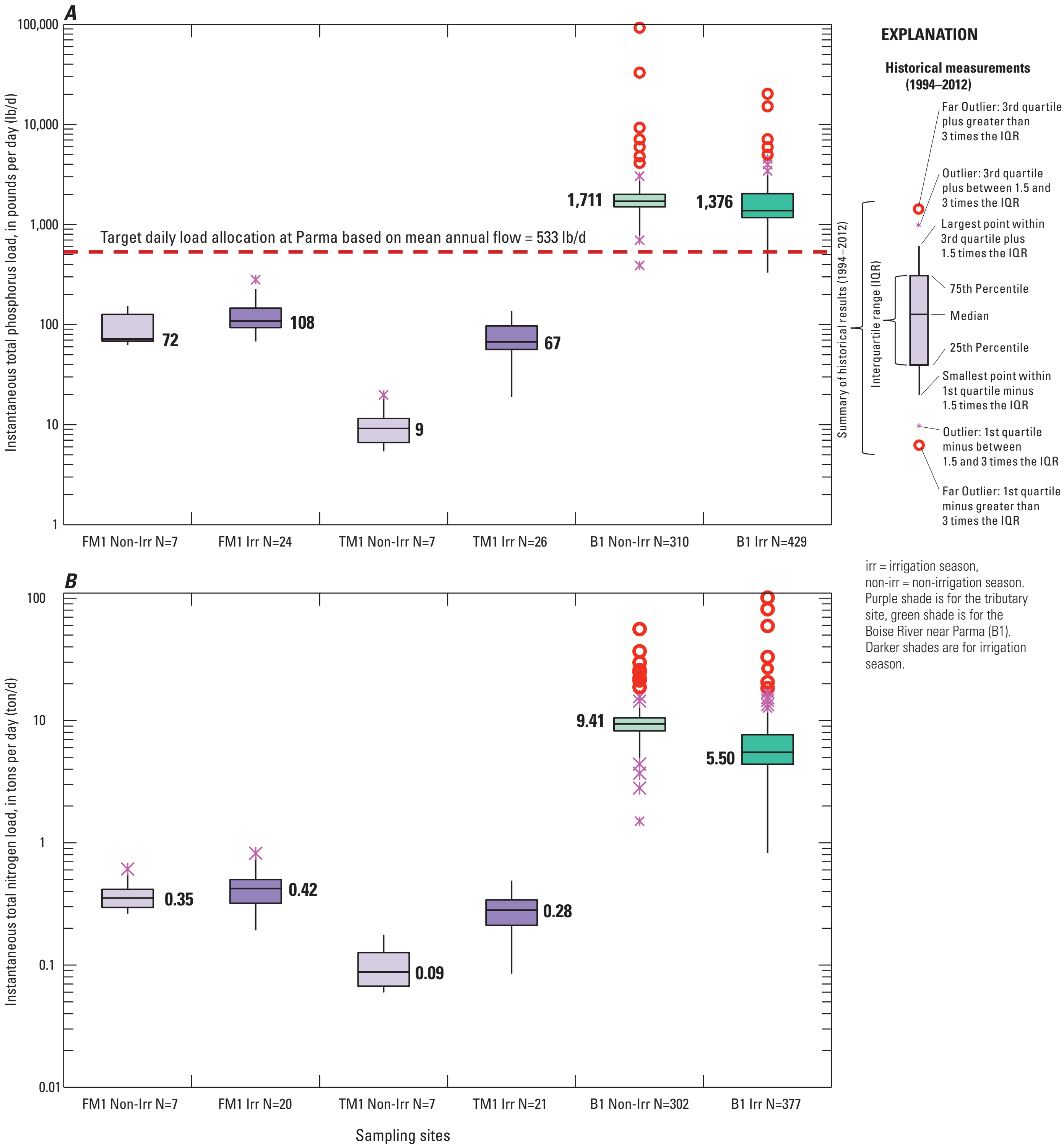

Figure 5. Historical instantaneous (*A*) total phosphorus and (*B*) total nitrogen loads in irrigation and non-irrigation seasons in Fivemile (site FM1) and Tenmile (site TM 1) Creeks (1994–2012) and the Boise River (site B1) (1969–2012), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

Increases in stream discharge are associated with increases in suspended-sediment concentrations in Fivemile and Tenmile Creeks. Discharge in both creeks did not exceed 3.5 ft^3/s at sites FM3, FM2, TM3, and TM2 and suspended-sediment concentrations generally increased with discharge downstream of sites FM2 and TM2 (figs. 3 and 6). A silty creek bottom and shallow sampling depth may have biased the suspended-sediment concentration in the sample collected at Fivemile Creek at Victory Road (site FM3) during irrigation season in July 2009 (fig. 6).The suspended-sediment target for tributaries of the Boise River is an average of 20 mg/L over a period of 120 days (table 3). Results from three sets of samples collected in late April and late July 2009, and mid-November 2008, indicate that sites FM3, FM2, TM3, and TM2 may not exceed the 20-mg/L, 120-day average suspended-sediment target. However, suspended-sediment concentrations at both Fivemile and Tenmile Creeks at Franklin Road (sites FM1 and TM1) likely exceed the 20-mg/L 120-day average target during irrigation season (fig. 6). Determination of target exceedence requires either daily or high-frequency sampling to compute daily estimates of suspended-sediment concentrations at compliance sites. Historical samples collected since 1994 indicate that suspended-sediment concentrations exceed the 20-mg/L 120-day average target more than 75 percent of the time at Fivemile Creek at Franklin Road (site FM1) and nearly 75 percent of the time at Tenmile Creek at Franklin Road (site TM1) (fig. 6). The samples collected in mid-November 2008 indicated that suspended-sediment concentrations in Fivemile and Tenmile Creeks might not exceed the 20-mg/L 120-day average suspended-sediment target during non-irrigation season.

Historically, the suspended-sediment load in Fivemile Creek at Franklin Road (site FM1) represented a median of 10 ton/d or 7.8 percent of the suspended-sediment load in the Boise River near Parma (site B1) during irrigation season and 1 ton/d or 2.0 percent of the suspended-sediment load at site B1 during non-irrigation season (fig. 7). Median suspended-sediment loads in Tenmile Creek represent 12 ton/d or 9.4 percent of the suspended-sediment load at site B1 during irrigation season and 0.12 ton/d or less than 1 percent of the suspended-sediment load at site B1 during non-irrigation season. Non-irrigation season suspended-sediment loads decreased along with decreases in discharge at upstream sites in Tenmile Creek (sites TM3 and TM2) (fig. 3; table 5). Upstream sites in Fivemile Creek were dry (sites FM3 and FM2) during non-irrigation season. Upstream sites in both Fivemile and Tenmile Creeks (sites FM3, FM2, TM3, and TM2) did not represent more than 6.5 percent of the suspended-sediment loads measured at sites FM1 and TM1 during any sampling event.

E. coli samples were not collected with a sampling frequency that matched the criterion defined in the Idaho Water Quality Standards, which is every 3–7 days over a 30-day period. The Idaho water-quality criterion for *E. coli* states that the geometric mean of 5 such samples cannot exceed 126 CFU/100 mL for waters with beneficial use designations of either primary- or secondary-contact recreation (table 3). However, all but one of the single-sample *E. coli* results exceeded the geometric mean criterion in July, and results from Tenmile Creek at Cloverdale Road (site TM3) exceeded the geometric mean criterion during all three sampling events (fig. 6). Regardless, single-sample results greater than the geometric mean criterion do not, by definition, result in an exceedence of that criterion. Idaho water-quality standards further state that if single-sample *E. coli* values exceed 576 CFU/100 mL for secondary-contact recreational use 406 CFU/100 mL for primary-contact recreational use, more frequent monitoring is necessary (table 3). Three results exceeded the secondary-contact recreational criterion in the Fivemile and Tenmile Creek watersheds. Those included the result of 580 MPN/100 mL on April 28, 2009, at Fivemile Creek at Franklin Road (site FM1), and the July 29, 2009, results of 580 MPN/100 mL at Fivemile Creek at Eagle Road (site FM2) and 1,200 MPN/100 mL at Fivemile Creek at Franklin Road (site FM1) (fig. 6).

E. coli values in the Fivemile Creek watershed increased moving downstream whereas *E. coli* values in Tenmile Creek decreased between TM3 and TM2 then increased between TM2 and TM1 (fig. 6).

The 25th percentile of all *E. coli* results in Fivemile and Tenmile Creeks (sites FM1 and TM1) during irrigation season is greater than 126 MPN/100mL (fig. 7). This suggests that *E. coli* values at sites FM1 and TM1 are greater than 126 MPN/100mL more than 75 percent of the time during irrigation season. In the Boise River near Parma (site B1), *E. coli* values exceed the 126-MPN/100mL geometric mean criterion more than 50 percent of the time during irrigation season and less than 25 percent of the time during non-irrigation season (fig. 7). Environmental samples collected during irrigation season indicate that *E. coli* values at Fivemile Creek at Franklin Road (site FM1) exceed the single-sample secondary-contact criterion slightly more than 25 percent of the time and that *E. coli* numbers at Tenmile Creek at Franklin Road (site TM1) exceed the single-sample secondary-contact criterion slightly less than 25 percent of the time.

Significant Relations Among Water-Quality Parameters

Continuous discharge or water-quality parameters have not been measured for more than 24 hours in Fivemile or Tenmile Creeks at Franklin Road (site FM1 or TM1), but since the mid-1990s, at least 25 instantaneous field measurements of discharge, water temperature, dissolved oxygen, pH, and specific conductance were collected at both sites (table 6). The instantaneous field measurements were paired with analytical results from samples collected during the same sampling event to determine if their relations were statistically significant.

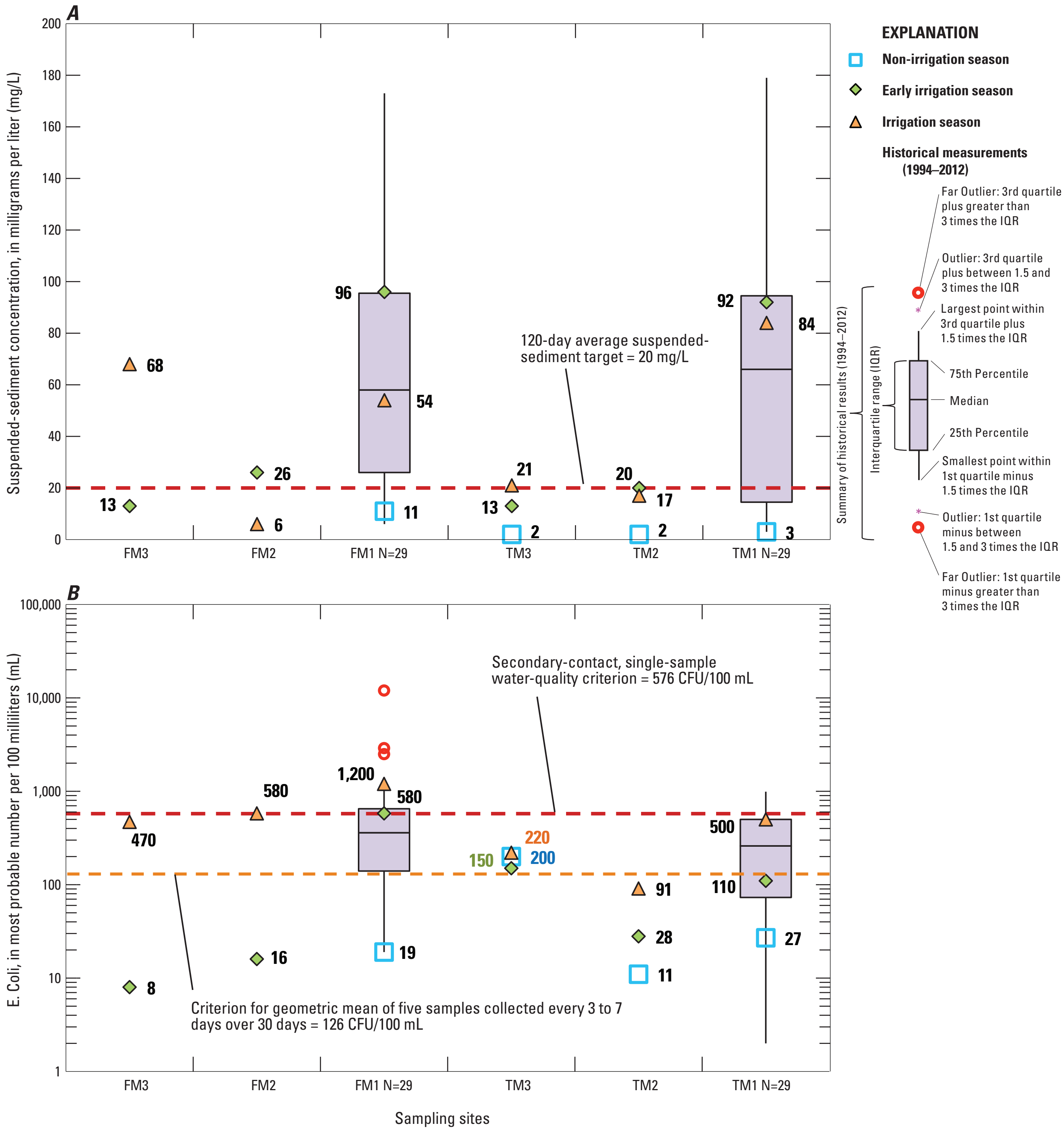

Figure 6. (*A*) Suspended-sediment concentrations and (*B*) *Escherichia coli* (*E. coli*) values in samples collected from Fivemile and Tenmile Creeks during 2008 and 2009 compared with historical results (1994–2012) from Fivemile and Tenmile Creeks at Franklin Road (sites FM1 and TM1), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

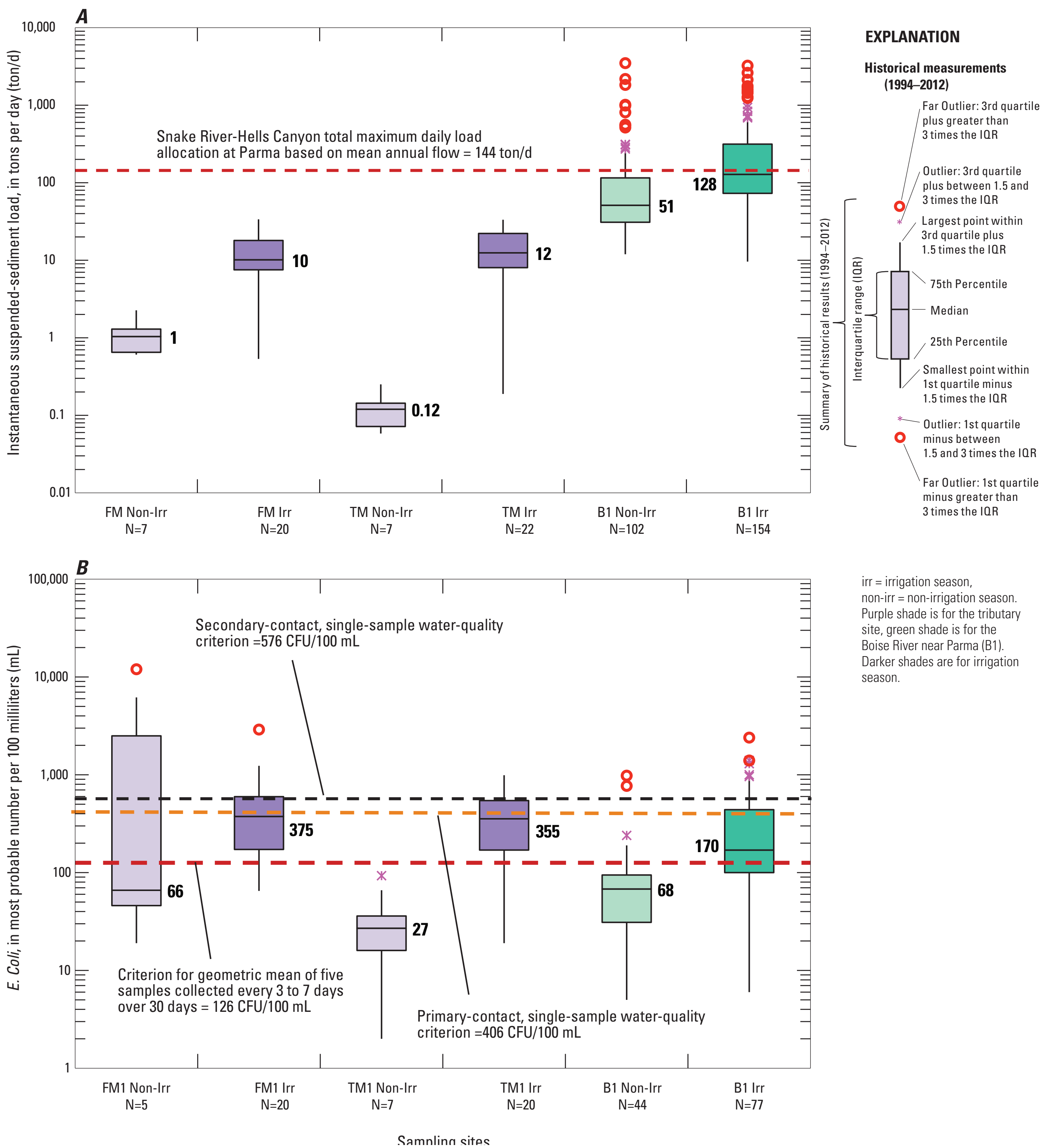

Figure 7. Historical instantaneous (*A*) suspended-sediment loads and (*B*) *Escherichia coli* (*E. coli*) values in irrigation and non-irrigation seasons in Fivemile and Tenmile Creeks (sites FM1 and TM 1) (1994–2012) and the Boise River near Parma (site B1) (1969–2012), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

Table 6. Regression analysis results using surrogates to estimate water-quality constituent concentrations in selected tributaries to the lower Boise River, southwestern Idaho.

[**Adjusted R^2**: Adjusted coefficient of determination. **RMSE:** Root mean square error; calculated according to Helsel and Hirsch (2002). **Abbreviations:** TP, total phosphorus; TN, total nitrogen; SSC, suspended-sediment concentration; OP, dissolved orthophosphorus as phosphorus; NO_3+NO_2, dissolved nitrate and nitrite as nitrogen; *E. Coli*, *Escherichia coli*; SC, specific conductance; Turb, turbidity; Q, discharge; mg/L, milligram per liter; <, less than]

Site name	Dependent variable (concentration in mg/L)	Explanatory variable(s)	Transformation	Number of samples	Adjusted R^2	Overall p-value	RMSE (mg/L)
Fivemile Creek at Franklin Road (site FM1)	TP	SC, seasonality	Natural log	32	0.63	<0.01	0.18
	TN	SC	Natural log	31	0.89	<0.01	0.84
	OP	SC, seasonality	Natural log	29	0.70	<0.01	0.18
	NO_3+NO_2	SC	Natural log	28	0.90	<0.01	0.26
	SSC	SC, seasonality	Natural log	30	0.65	<0.01	4.05
	E. coli[1]	No good model	–	28	–	–	–
Tenmile Creek at Franklin Road (site TM1)	TP	SC, Q, seasonality	None	29	0.56	<0.01	0.08
	TN	SC, Q, seasonality	Natural log	28	0.93	<0.01	0.18
	OP	SC, Q	Natural log	29	0.72	<0.01	0.08
	NO_3+NO_2	SC, Q	None	29	0.97	<0.01	0.16
	SSC	Q, seasonality	Natural log	27	0.89	<0.01	3.48
	E. coli[1]	Q, SC	Natural log	25	0.65	<0.01	[1]20
Mason Creek near Caldwell (site M1)	TP	Turb, seasonality	Natural log	17	0.75	<0.01	0.11
	TN	Turb, Q, seasonality	Natural log	17	0.75	<0.01	0.25
	OP	Turb, seasonality	Natural log	17	0.66	<0.01	0.09
	NO_3+NO_2	SC	Natural log	82	0.83	<0.01	0.24
	SSC	Turb	Natural log	17	0.87	<0.01	3.03
	E. coli[1]	Turb, Q, seasonality	Natural log	15	0.69	<0.01	[1]17
Indian Creek at Mouth (site I1)	TP	No good model	–	–	–	–	–
	TN	SC, seasonality	Natural log	70	0.92	<0.01	0.19
	OP	No good model	–	–	–	–	–
	NO_3+NO_2	SC, seasonality	Natural log	72	0.94	<0.01	0.19
	SSC	No good model	–	–	–	–	–
	E. coli[1]	No good model	–	–	–	–	–

[1]Units expressed in most probable number per 100 milliliters.

If regression analysis determined a statistically significant relation (overall p-value <0.01), water-quality parameters (surrogates) were used as explanatory variables to estimate concentrations of TP, OP, TN, nitrate plus nitrite, suspended sediment, and *E. coli* (dependent variables) in Fivemile and Tenmile Creeks at Franklin Road (sites FM1 and TM1).

Instantaneous turbidity was not measured historically in Fivemile or Tenmile Creeks, but may be useful as an explanatory variable in surrogate models for TP, TN, suspended sediment, and *E. coli*. Other parameters useful as explanatory variables included specific conductance and discharge (table 6). Regression analysis showed that statistically significant (overall p-value <0.01) surrogate models may be used to estimate concentrations of TP, OP, TN, nitrate plus nitrite, and suspended sediment at site FM1, and nitrate plus nitrite, suspended sediment, and *E. coli*, at site TM1. In addition to summarizing regression analysis on all constituents of interest, model diagnostics also are summarized in table 6, including the standard error of estimated constituent values and the amount of sample variability explained by each surrogate model using the adjusted R^2 value (R^2_a).

Indian Creek

Water-quality sampling results suggested that discharge from the Kuna and Nampa WWTPs, Wilson Drain, Riverside Canal, and groundwater are the primary influences on constituent concentrations and loads in Indian Creek. Discharge steadily increases in the downstream direction between Indian Creek at Robinson Road (site I6) and Indian Creek at Sparrow Avenue (site I4) (fig. 3). Because increases in discharge remain steady in the downstream direction during non-irrigation season, groundwater may contribute substantial base flow to Indian Creek upstream of its confluence with Wilson Drain (fig. 2). Major return flows and diversions do not occur upstream of Wilson Drain in the Indian Creek watershed.

Watershed-Scale Water-Quality Sampling Results

Except for the May 3, 2010 TP result in Indian Creek at Robinson Road (site I6), every TP result from samples collected in the Indian Creek watershed exceeded the 0.07-mg/L target concentration for TP in the lower Boise River at the mouth (fig. 8). Concentrations of TP and OP increased substantially between Indian Creek at Robinson Road (site I6) and Indian Creek at Broadmore Way (site I5). A small dairy operation is adjacent to site I6, and a large dairy operation is located between sites I6 and I5. The city of Kuna WWTP also discharges to Indian Creek between sites I6 and I5. TP concentrations increased from 0.06 mg/L at site I6 to 0.21 mg/L at site I5 on May 3, 2010. TP concentrations increased from 0.09 and 0.07 mg/L at site I6 to 0.57 and 0.54 mg/L at site I5 in samples collected in July and November 2010, respectively. Land use transitions from agricultural upstream of site I5 to urban in the city of Nampa downstream of site I5. Between Indian Creek at Broadmore Way (site I5) and Indian Creek at Sparrow Avenue (site I4), TP concentrations at least doubled to concentrations ranging between 0.98 and 1.42 mg/L with the addition of wastewater effluent from Nampa WWTP (fig. 8). High flows during the May 3, 2010 sampling event, meant to capture conditions during “spring flush,” may have lowered TP concentrations at sites I5 and I4 during the May 2010 sampling event (figs. 3 and 8). Downstream of site I4, TP concentrations decreased to values just slightly higher than at site I5, ranging between 0.60 and 0.75 mg/L at 21st Street (site I3) and Simplot Boulevard (site I2), with the highest TP concentrations measured during the middle of irrigation season on July 27, 2010. It is not known if TP concentrations decreased as a result of dilution from Wilson Drain because no samples were collected from Wilson Drain. TP concentrations decreased further in Indian Creek near the mouth (site I1). A mixture of Riverside Canal water, diverted from the Boise River upstream of Caldwell, and Indian Creek water likely resulted in lower TP concentrations near the mouth of Indian Creek (site I1) during irrigation season than during non-irrigation season. A decrease in TP concentrations between sites I2 and I1 also was noted on November 17, 2010, when Riverside Canal was inactive (fig. 8).

Ratios of OP:TP were high throughout the Indian Creek watershed (table 4). High OP:TP ratios at site I6, which is upstream of the Kuna and Nampa WWTPs, suggest that groundwater is a source of P. High OP:TP ratios downstream of site I6 are typical of streams receiving effluent from WWTPs. During irrigation season, OP:TP ratios decreased in Indian Creek downstream of the confluence with Wilson Drain (downstream of site I4), suggesting that agricultural sources of particulate P may exist in Wilson Drain and Riverside Canal (fig. 2). In November 2010, the TP concentration increased from 0.07 mg/L at site I6 to 0.54 mg/L at site I5 and consisted entirely of OP, suggesting that effluent from Kuna WWTP increases TP concentrations between sites I6 and I5.

As with TP concentrations, TP loads increased substantially between both sites I6 and I5 and between sites I5 and I4. However, because discharge increased downstream of site I4, TP loads remained greater than 400 lb/d even though TP concentrations decreased downstream of I4 (table 5; fig. 8). Total phosphorus loads increased by at least 10 times between I6 and I5, and by at least four times between I5 and I4 over the course of the three sampling events in 2010 (table 5). Between sites I4 and I3, TP loads did not change considerably, except for loads measured in November 2010. Because of rainfall just prior to sampling on November 17, 2010, the three downstream monitoring sites in the Indian Creek watershed were not wadeable. Therefore, discharge was estimated at all three sites downstream of the confluence with Wilson Drain (sites I3, I2, and I1). Because discharge was estimated, instantaneous loads for November 17, 2010, also were estimated at the three downstream sites. Although instantaneous loads were estimated for November 17, 2010, TP loads were considered to be higher than normal and may be indicative of increased discharge in Wilson Drain (between sites I4 and I3) rather than increased nutrient concentrations in Indian Creek (figs. 3 and 8).

The TP loads in Indian Creek near the mouth (site I1) represent a large amount of the TP load measured in the Boise River near Parma (site B1) in samples collected during non-irrigation season (fig. 9). The median instantaneous TP load in Indian Creek at the mouth (site I1) during non-irrigation season is 629 lb/d or 37 percent of the 1,711-lb/d median instantaneous TP load in the Boise River near Parma (site B1). Riverside Canal captures most of the TP load in Indian Creek during irrigation season, so table 5 compares instantaneous TP loads measured in Indian Creek at Simplot Boulevard (site I2) to instantaneous TP loads measured in the Boise River near Parma (site B1). The irrigation-season loads at site I2 represented 42 and 55 percent of the TP load at site B1 on May 3 and July 27, 2010, respectively (table 5). Effluent from the Kuna WWTP between sites I6 and I5 and effluent from the Nampa WWTP upstream of site I4 represent substantial sources of TP loading to Indian Creek and the lower Boise River. Wilson Drain also might have the potential to nearly double the TP load in Indian Creek during winter rain events with increases in discharge rather than increases in TP concentrations.

Total nitrogen concentrations increased downstream of the outfall for the Kuna WWTP (downstream of site I6) and further increased downstream of the Nampa WWTP in samples collected from Indian Creek at Sparrow Avenue (site I4) (fig. 8). Most TN in the Indian Creek watershed consisted of dissolved inorganic N in the form of nitrate plus nitrite (table 4). The lowest TN concentrations were measured during irrigation season and the highest were measured in November 2010. Total nitrogen concentrations in the five most downstream sites (sites I5–I1) were 7 mg/L or greater on November 17, 2010. On July 27, 2010, TN concentrations were 5 mg/L or greater between sites I5 and I2. Rather than acting as a nonpoint source of TN, Wilson Drain diluted TN concentrations in Indian Creek between I4 and I3 (fig. 8).

The median instantaneous TN load in Indian Creek at the mouth (site I1) during non-irrigation season is 4.12 ton/d or 44 percent of the median load of 9.41 ton/d measured at Parma (site B1) (fig. 9*B*). During irrigation season, instantaneous TN loads measured in Indian Creek at Simplot Boulevard (site I2) represent a better estimate of the contribution of TN from Indian Creek to the lower Boise River watershed. In May and July 2010, instantaneous loads measured at site I2 represented 49 and 61 percent of the TN load measured at Parma (site B1), respectively. TN loads generally increased by at least five times between sites I6 and I5 downstream of the Kuna WWTP outfall and at least doubled between sites I5 and I4 downstream of the Nampa WWTP outfall (table 5). TN loading in Indian Creek suggests that urban land use associated with point-source discharges contributes most of the TN load to Indian Creek.

The suspended-sediment target for tributaries of the Boise River is an average of 20 mg/L over a period of 120 days (table 3). Except for the suspended-sediment concentration in Indian Creek at Broadmore Way (site I5) on July 27, 2010, all suspended-sediment concentrations downstream of site I6 were greater than 20 mg/L when samples were collected during irrigation season (fig. 10). Downstream of the confluence of Indian Creek with Wilson Drain (sites I3–I1), suspended-sediment concentrations were greater than 20 mg/L in all samples collected during 2010. Higher suspended-sediment concentrations downstream of site I5 (sites I4–I1) in the July 27, 2010 samples indicated that agricultural sources of sediment may exist downstream of Nampa. Increases in suspended-sediment concentrations downstream of the confluence with Wilson Drain (sites I3–I1) during non-irrigation season suggest that Wilson Drain is a year-round source of sediment in the Indian Creek watershed (fig. 10).

The median instantaneous suspended-sediment load measured during non-irrigation season in Indian Creek at the mouth (site I1) was 21 ton/d or 41 percent of the median of 51 ton/d measured during non-irrigation season in the Boise River near Parma (site B1) (fig. 11). In contrast, median suspended-sediment loads at site I1 represented 10.9 percent of the median suspended-sediment load measured at site B1 during irrigation season. Measured instantaneous loads upstream of the confluence of Indian Creek with Riverside Canal at Simplot Boulevard (site I2) in May and July 2010 showed that the Indian Creek watershed contributes between 27 and 31 percent of the suspended-sediment load in the lower Boise River watershed during irrigation season. It is not known if the loads measured at site I1 during irrigation season ultimately flow to the Boise River from Riverside Canal. Because discharge measurements were estimated on November 17, 2010, at 21st Street, Simplot Boulevard, and the mouth of Indian Creek (sites I3–I1), instantaneous loads measured at sites I3, I2, and I1 on November 17, 2010, are not the best measure of instantaneous suspended-sediment loads during non-irrigation season.

All but one of the single-sample *E. coli* numbers downstream of Robinson Road (sites I5–I1) exceeded the 126-CFU/100mL geometric mean *E. coli* criterion (table 3) on May 3 and July 27, 2010 (fig. 10). *E. coli* numbers at Sparrow Avenue (site I4) and 21st Street (site I3) exceeded 126 MPN/100mL in all three samples collected in 2010. Indian Creek has a beneficial use designation that includes secondary-contact recreation (table 3). State of Idaho water-quality standards state that a single-sample *E. coli* result that exceeds 576 CFU/100mL triggers additional sampling. State criteria are stated in units of CFU/100mL whereas results from samples collected as part of this study are expressed in similar units of MPN/100mL. Two *E. coli* results on July 27, 2010, exceeded 576 MPN/100mL. The *E. coli* count was 690 MPN/100mL at Indian Creek at Broadmore Way (site I5) and 580 MPN/100mL at Indian Creek at the mouth (site I1).

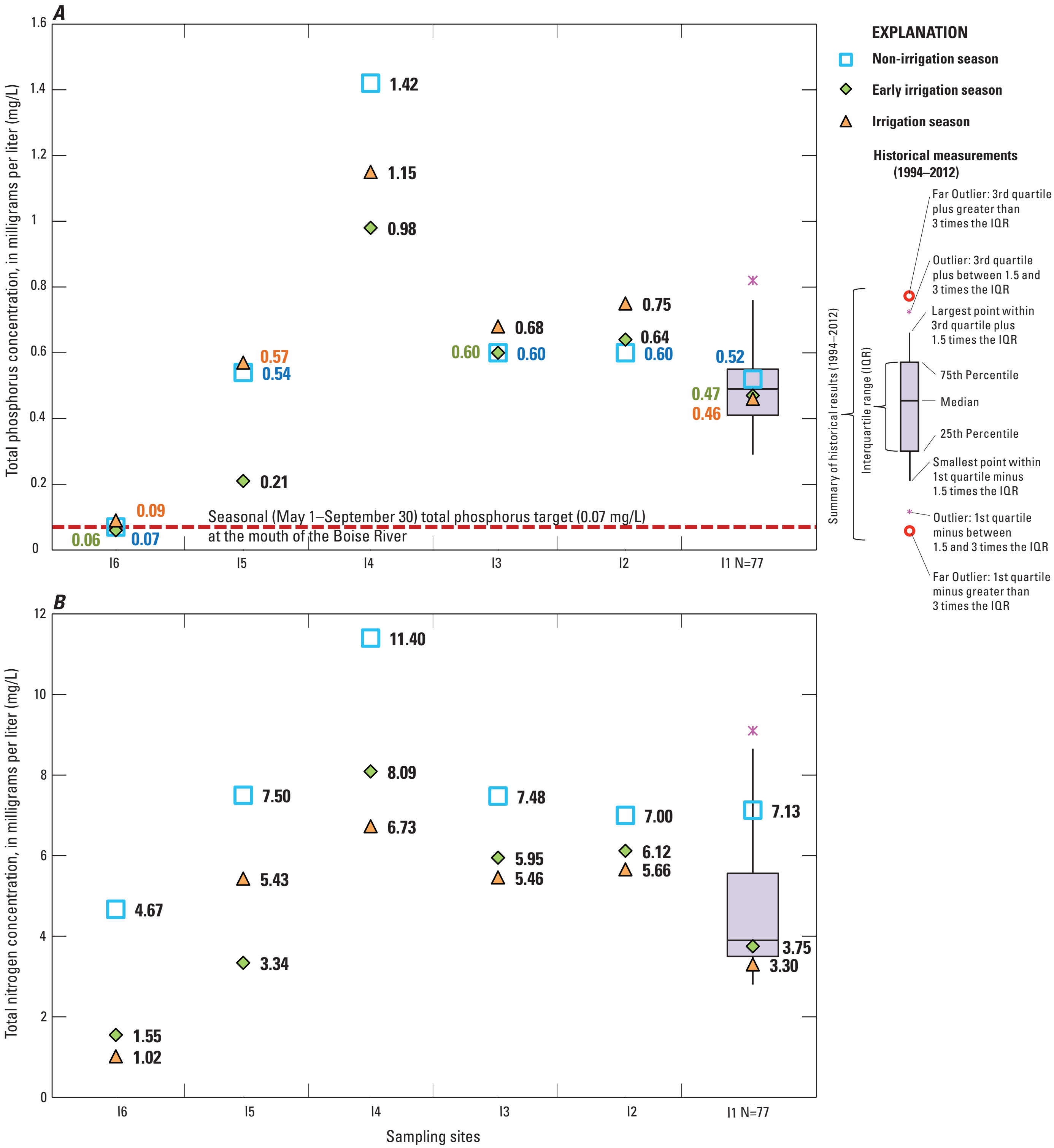

Figure 8. (*A*) Total phosphorus and (*B*) total nitrogen concentrations in samples collected from Indian Creek during 2010 compared with historical concentrations (1994–2012) in Indian Creek at the mouth (site I1), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

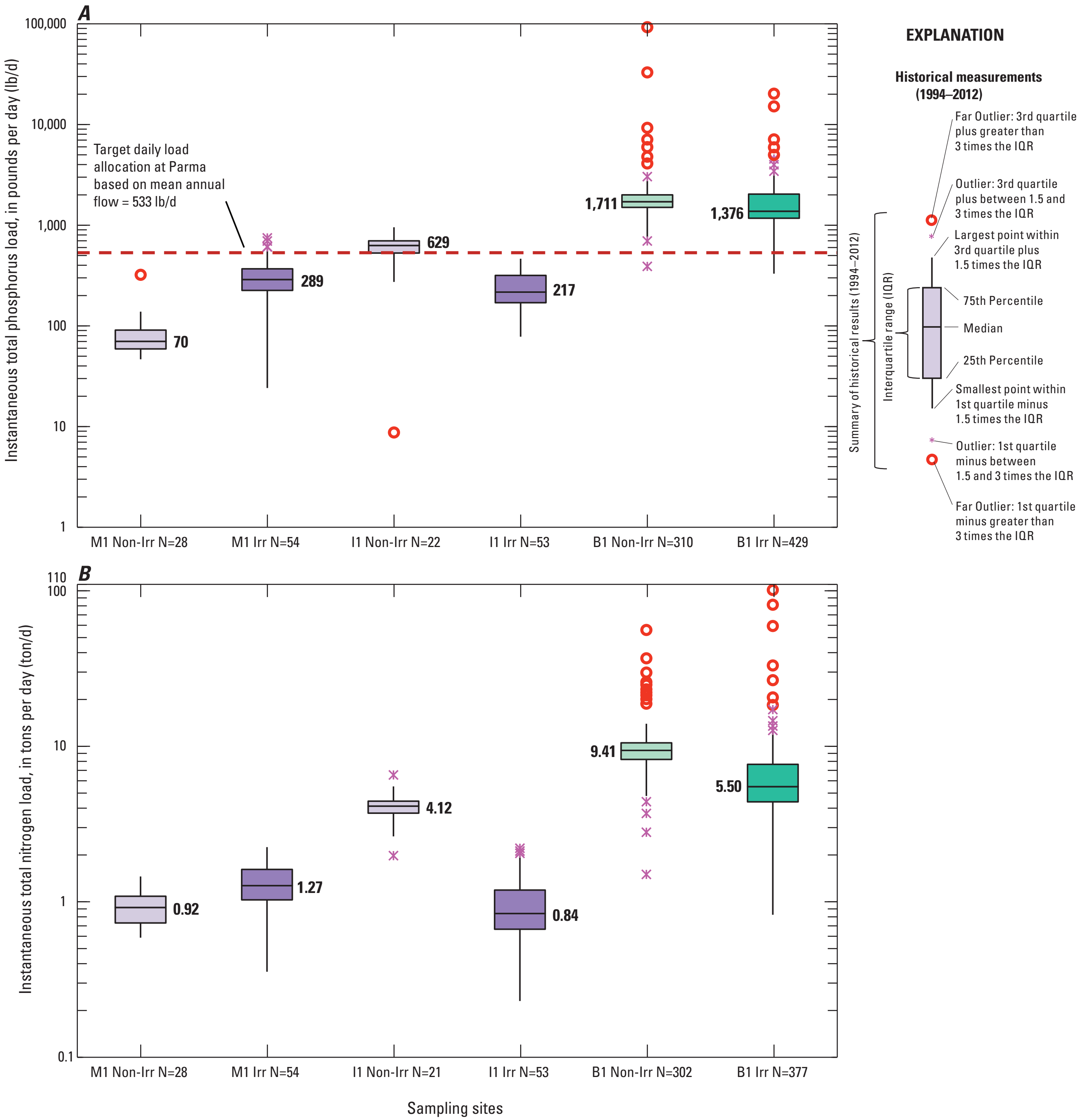

Figure 9. Historical instantaneous (*A*) total phosphorus and (*B*) total nitrogen loads in irrigation and non-irrigation seasons in Mason and Indian Creeks (sites M1 and I1) (1994–2012) and the Boise River near Parma (site B1) (1969–2012), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

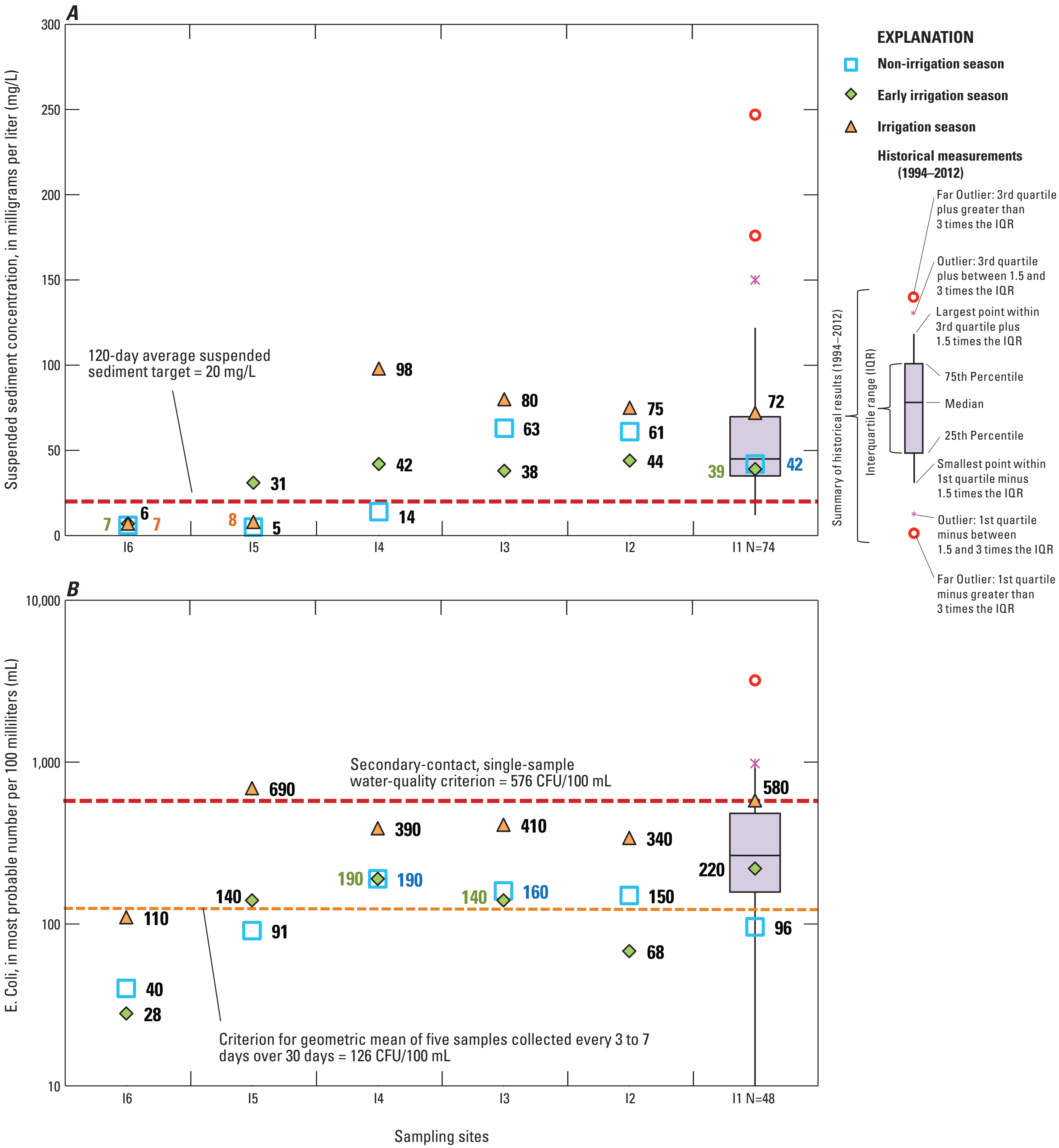

Figure 10. (*A*) Suspended-sediment concentrations and (*B*) *Escherichia coli (E. Coli*) values in samples collected from Indian Creek during 2010 compared with historical results (1994–2012) from Indian Creek at the mouth (site I1), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

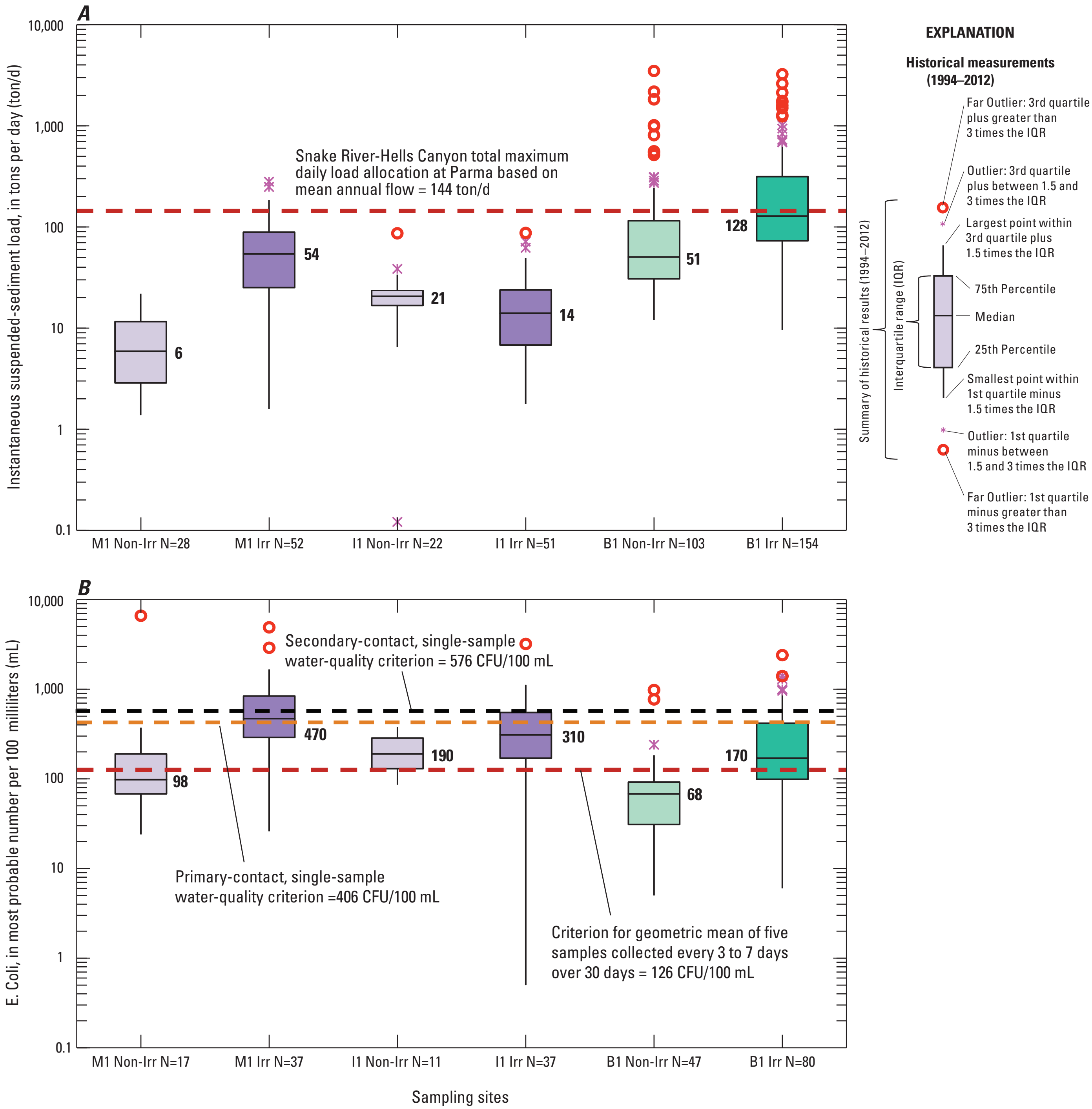

Figure 11. Historical instantaneous (*A*) suspended-sediment loads and (*B*) *Escherichia coli* (*E. coli*) values in irrigation and non-irrigation seasons in Mason and Indian Creeks (sites M1 and I1) (1994–2012) and the Boise River near Parma (site B1) (1969–2012), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

Sample results from the mouth of Indian Creek (site I1) indicate that mixing of water from Riverside Canal with Indian Creek water in irrigation season may not have influenced *E. coli* values in Indian Creek at the mouth (fig. 10).

E. coli results throughout the Indian Creek watershed displayed the same general spatial pattern during all three sampling periods. *E. coli* values increased downstream of Robinson Road (site I6) and remained relatively high at monitoring sites downstream of Robinson Road (sites I5–I1) (fig. 10). A longer-term dataset consisting of 37 samples collected during irrigation season shows that Indian Creek at the mouth (site I1) exceeds the 126-MPN/100mL geometric mean criterion at least 75 percent of the time and exceeds the 576-MPN/100mL single-sample criterion as much as 25 percent of the time (fig. 11). *E. coli* values at site I1 generally are higher than those measured in the Boise River near Parma (site B1) year round.

Significant Relations Among Water-Quality Parameters

At least 70 instantaneous field measurements of discharge, water temperature, dissolved oxygen, pH, and specific conductance have been made during sampling events at Indian Creek at the mouth (site I1) since the mid-1990s. Instantaneous field measurements were paired with analytical results from samples collected during the same sampling event to determine if their relations were statistically significant. If regression analysis determined a statistically significant relation (overall p-value <0.01), water-quality parameters (surrogates) were used to estimate concentrations of TP, OP, TN, NO_2+NO_3, suspended sediment, and *E. coli* in Indian Creek at the mouth (site I1) (table 6).

Because Indian Creek mixes with water from Riverside Canal just upstream of the monitoring location at the mouth, statistical relations between water-quality constituents and water-quality parameters generally were insignificant. If more extensive monitoring had been done in a location upstream of the confluence of Indian Creek with Riverside Canal, statistical relations between water-quality constituents and water-quality parameters may have been significant (table 6). TN and NO_2+NO_3 showed a statistically significant relation with specific conductance and seasonality likely because groundwater is a source of N throughout the lower Boise River watershed (Dallas and others, 2007). Most N in Indian Creek is dissolved (table 4) and N concentrations predictably increase during non-irrigation season when water in Indian Creek consists of more groundwater discharge than irrigation runoff (Berenbrock, 1999).

Mason Creek

Water-quality monitoring was expanded in Mason Creek during 2011 and 2012 to include a streamgage, a continuous water-quality monitor, and more frequent sampling near the mouth (site M1). Water-quality samples were collected throughout the watershed (sites M5–M1) during three discrete sampling events in 2011, and were collected at least monthly at Mason Creek near Caldwell (site M1). In addition to results from three discrete sampling events at sites M5–M1, this section describes continuous water-quality and streamflow data, modeling results, and statistical analyses of data collected from Mason Creek near the mouth (sites M1). Results from more frequent sampling events at site M1 are described in context with modeling results. Historically, water-quality data have been collected at two sites near the mouth of Mason Creek. Monthly data were collected for this study at Mason Creek near Caldwell (USGS site No. 13210983; table 1; fig. 1*B*). Samples have been collected at Mason Creek at Mouth near Caldwell, Idaho (USGS site No. 13210985) historically to characterize conditions in Mason Creek just upstream of its confluence with the Boise River. Results from both sites near the mouth have been combined for evaluation of historical conditions near the mouth of Mason Creek.

Watershed-Scale Water-Quality Sampling Results

Sampling results indicate land use is a consistent factor affecting the timing and magnitude of constituent concentrations and loads. Nutrient, suspended-sediment, and *E. coli* concentrations generally were lowest at Mason Creek at Madison Avenue (site M4) during all three sampling periods, indicating agricultural land use downstream of site M4 affects water-quality more than urban and residential land use upstream of site M4.

All sampling results from 2011 for TP and OP in the Mason Creek watershed were greater than the TP TMDL target of 0.07 mg/L at the mouth of the Boise River. Total phosphorus concentrations did not increase substantially downstream of site M4 in early May or early November 2011, but did increase downstream of site M4 in July 2011 (fig. 12). However, TP concentrations were consistently higher at the farthest upstream site (site M5) relative to the next site downstream (site M4). Site M5 also exhibited the highest TP concentration measured in the Mason Creek watershed in November 2011. Ratios of OP:TP indicate that particulate phosphorus constitutes a large part of TP loads in the Mason Creek watershed.

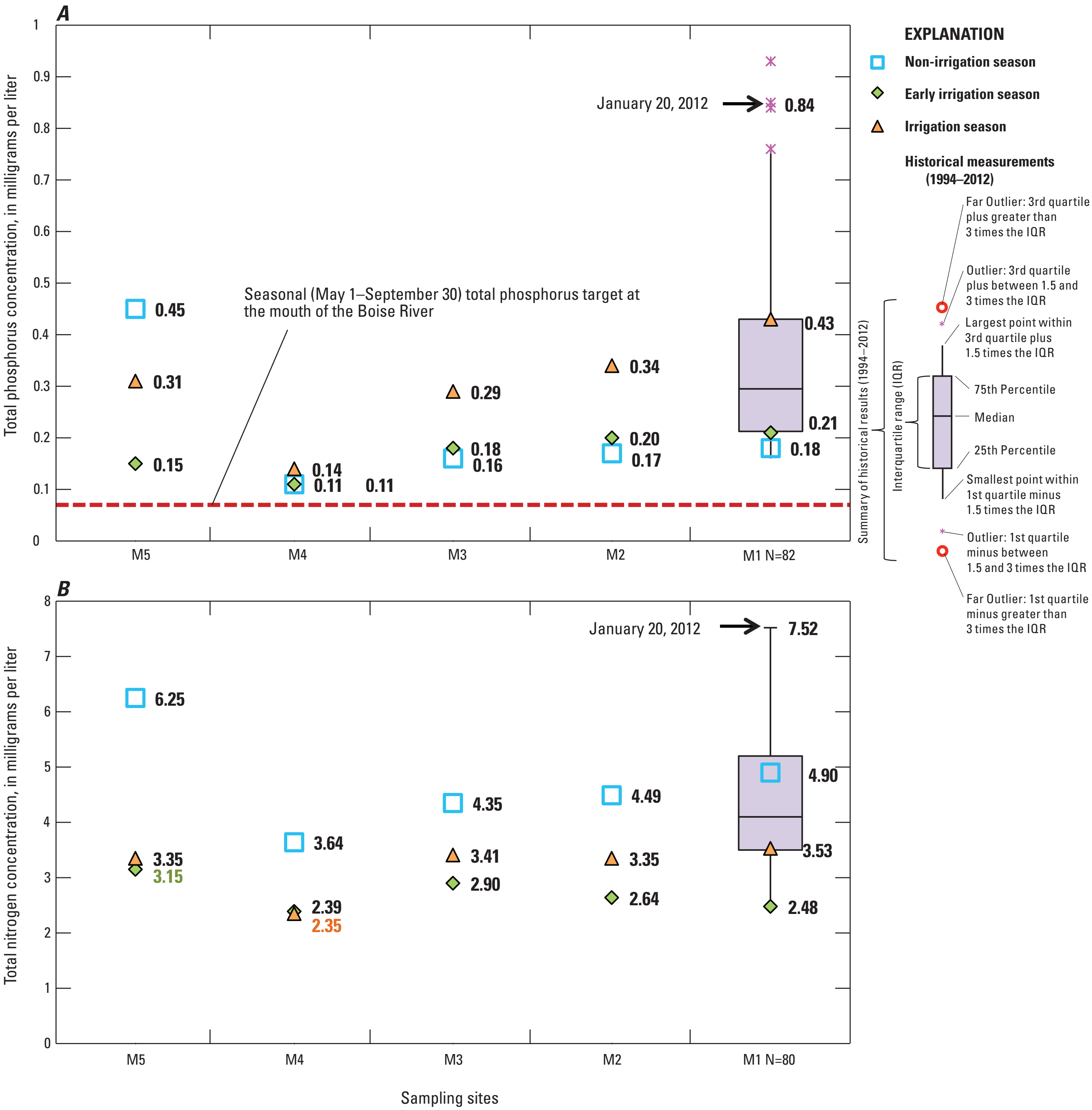

Figure 12. (*A*) Total phosphorus and (*B*) total nitrogen concentrations in samples collected from Mason Creek during 2011, compared with historical concentrations (1994–2012) from Mason Creek near Caldwell (site M1), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

Generally, OP:TP ratios decreased between sites M4 and M1 during irrigation season (table 4), indicating increasing effects from surface runoff and irrigation return flows. The site at Powerline Road (site M5) showed a decreasing OP:TP ratio between May and November 2011, with the lowest ratio of 0.17 occurring on November 9, 2011 (table 4). In contrast, TP ratios at downstream sites (sites M4–M1) were between 0.85 and 0.95 on November 9, 2011. The lower OP:TP ratio at site M5 is consistent with effects from particulate phosphorus runoff from pastured land and the higher OP:TP ratios downstream of site M5 are consistent with TP contributions from groundwater during non-irrigation season (Fox and others, 2002).

In November 2011, TP loads at upstream sites generally represented a higher percentage of the TP load at site M1 than during irrigation season because flow decreased at site M1 during non-irrigation season and flows at the upstream sites remained similar year round (fig. 3; table 5). The TP load at site M5 represented 15 percent of the TP load at site M1 in November, and the TP load at site M4 represented 26 percent of the TP load at site M1 in November. However, TP loads at Ustick Road (site M3) represented 79 percent of the TP load at site M1 in November because discharge more than doubled between sites M4 and M3 (fig. 3). Most of the TP loading in Mason Creek delivered to the Boise River during the non-irrigation season sampling event probably is from groundwater discharge (Fox and others, 2002) downstream of site M4.

When diversions and return flows operate during irrigation season, loading dynamics change in the Mason Creek watershed. The TP load at site M5 represented between 3.8 and 5.9 percent of the TP load in samples collected at site M1 during irrigation season, and the TP load at site M4 represented between 10 and 16 percent of the TP load in samples collected at site M1 during irrigation season. The TP load at site M3 increased by more than three times compared to the TP load at site M4. Purdum Gulch discharges to Mason Creek between sites M4 and M3 (fig. 2) and receives treated wastewater discharge from a cheese factory with lower TP concentrations than those at site M4 (T. Smith, IDEQ, oral commun., 2013). Surface-water runoff or agricultural returns to Purdum Gulch are more likely to be sources of TP between Mason Creek at Madison Avenue (site M4) and Mason Creek at Ustick Road (site M3) during irrigation season. The total phosphorus loads at site M3 represented 55 and 54 percent of the TP load measured at M1 in May and July 2011, respectively. The Highline diversion is located downstream of Mason Creek at Ustick Road (site M3), and reduced the instantaneous TP load in Mason Creek at Wells Road (site M2) on July 7, 2011. Site M2 is just upstream of four return flows known as Lower Fivemile, Noble, Solomon, and A Drains (fig. 2). The return flows between site M2 and the Mason Creek streamgage (site M1) accounted for 37 and 63 percent of the TP load at site M1 during the May and July 2011 sampling events, respectively (table 5).

Based on historical sampling results, the median instantaneous TP load at site M1 is 70 lb/d or 4 percent of the TP load at the Boise River near Parma (site B1) during non-irrigation season, and 289 lb/d or 21 percent to the TP load at site B1 during irrigation season (fig. 9). Based on photographic evidence (Fox and others, 2002), water from Mason Creek flows along the left bank of the Boise River and is partially captured by the diversion for Riverside Canal, which removes about 100 to 300 ft^3/s from the left bank of the Boise River during irrigation season. The quantity of the Mason Creek TP load reaching the Boise River near Parma (site B1) depends on how irrigation water in Riverside Canal is ultimately used, consumed by crops, and spilled into other canals and drains, including Dixie Drain (figs. 1*A* and 2).

The highest TN concentrations occurred throughout the Mason Creek watershed in November 2011 (fig. 12). Total nitrogen concentrations generally did not increase moving downstream in May and July 2011 when irrigation returns increase flows in Mason Creek moving downstream, but did increase moving downstream of Madison Avenue (site M4) in November when groundwater is the primary source of flow in Mason Creek (Fox and others, 2002). This suggests that groundwater is higher in N than irrigation return flows. Lower TN results during the “first flush” of surface water irrigation through the Mason Creek watershed further indicate groundwater as a source of N. Between 93 and 97 percent of the N measured at sites downstream of Powerline Road (sites M4–M1) was dissolved inorganic N, indicating a groundwater source (table 4). As with TP concentrations, TN concentrations were higher in Mason Creek at Powerline Road (site M5) than at Madison Avenue (site M4). The TN concentration in November 2011 at site M5 was the highest in the watershed and consisted of more organic and (or) particulate N than the other samples collected in November, suggesting a source of TN in surface runoff from pastured land upstream. Particulate and (or) organic N were also present in larger percentages in all samples collected during irrigation season (table 4).

Total nitrogen loading showed little difference between irrigation season and non-irrigation season. The lack of change in TN loading between irrigation and non-irrigation seasons suggests that additional flow from irrigation supply and return water may dilute a more concentrated source of TN in the base flow component of surface-water discharge. Diversions between sites M3 and M2 remove some of the TN load from Mason Creek and return flows nearly double the TN loads between sites M2 and M1 during irrigation season (fig. 2; table 5). Return flows between sites M2 and M1 contributed between 30 and 55 percent of the TN load at site M1 during irrigation-season in 2011. Most of the TN loading that ultimately influences water quality in the Boise River takes place downstream of site M4 during both irrigation and non-irrigation seasons. Based on historical sampling results, the median instantaneous TN load at site M1 represents 0.92 ton/d or 9.7 percent of the TN load at Parma (site B1) during non-irrigation season, and 1.27 ton/d or 23 percent of the TN load at Parma during irrigation season (fig. 9).

Land use changes and return flow contributions affected suspended-sediment concentrations and loads throughout the Mason Creek watershed. The suspended-sediment target for major tributaries of the Boise River is an average of 20 mg/L over a period of 120 days (table 3). Except for results from sites M3, M2, and M1 in early November 2011, all suspended-sediment concentrations in the Mason Creek watershed exceeded 20 mg/L during the study period (fig. 13). In early May and July 2011, suspended-sediment concentrations increased downstream of Madison Avenue (site M4) with a slight decrease measured between sites M2 and M1. The suspended-sediment concentration at site M5 increased to 595 mg/L in November 2011 when large decreases in suspended-sediment concentrations were measured at downstream sites (sites M4–M1). This result is close to the highest concentration (629 mg/L) in 80 samples collected over 9 years at site M1. All four historical results greater than 500 mg/L at site M1 were measured during irrigation season. The fact that the highest suspended-sediment concentration measured at site M5 occurred during non-irrigation season may be a consequence of different land uses influencing water quality in Mason Creek at site M5. The high suspended-sediment concentration at site M5 in November 2011 coincides with lower percentages of dissolved nutrients and higher nutrient concentrations compared to the other two samples collected at site M5.

The spatial pattern of sediment loading changed during each of the three sampling events in the Mason Creek watershed. Loads increased in a downstream direction in May 2011 and decreased in a downstream direction in November 2011. In July 2011, part of the sediment load was diverted downstream of site M3 through Highline Diversion (fig. 2) and 64 percent of the suspended-sediment load measured at site M1 entered Mason Creek downstream of site M2 through Lower Fivemile, Noble, Solomon, and A Drains. In November 2011, site M5 likely was the source of sediment loading to Mason Creek, and the sediment load decreased in a downstream direction except for site M2 where a relatively high stream velocity (3.2 ft/s compared with 1.8 ft/s at site M1) likely suspended more sediment in the water column.

The suspended-sediment TMDL for the lower Boise River (Idaho Department of Environmental Quality, 1999) is 101.42-ton/d at the mouth of the Boise River. The median instantaneous suspended-sediment load at site M1 during irrigation season was 54 ton/d based on 52 historical samples. The median instantaneous suspended-sediment load at Parma (site B1) during irrigation season was 128 ton/d based on 154 historical samples (fig. 11). Disregarding plumbing and irrigation practices, 54 ton/day represents 42 percent of the median instantaneous suspended-sediment load at Parma (site B1) during irrigation season and 53 percent of the suspended-sediment load allocation at the mouth of the Boise River. During non-irrigation season, the suspended-sediment load at site M1 was 6 ton/d or 12 percent of the 51 ton/d median load at site B1 (fig. 11).

All single-sample *E. coli* results in Mason Creek exceeded the 126-MPN/100mL geometric mean criterion in July 2011. *E. coli* results from site M5 exceeded the geometric mean criterion during all three sampling events (fig. 13). The result of 650 MPN/100mL at Powerline Road (site M5) on July 7, 2011, was the only *E. coli* result that exceeded the applicable single-sample *E. coli* criterion.

E. coli results throughout the Mason Creek watershed displayed the same general spatial pattern during all three sampling events. *E. coli* values were highest at site M5, decreased in a downstream direction to the lowest result at either site M4 (in July), site M3 (in early May), or site M2 (in November), and then increased slightly at site M1. This pattern suggests that *E. coli* values were highest in areas where agriculture is a substantial or the predominant land use.

Historically, the *E. coli* values at site M1 exceeded 126 MPN/100mL more than 75 percent of the time during irrigation season and between 25 and 50 percent of the time during non-irrigation season (fig. 11). In the Boise River near Parma (site B1), *E. coli* values exceeded the geometric mean criterion between 50 and 75 percent of the time during irrigation season and less than 25 percent of the time during non-irrigation season. Mason Creek has a secondary-contact recreation beneficial use designation, whereas the Boise River near Parma has a primary-contact recreation beneficial use designation. Single-sample *E. coli* water-quality criteria for primary-contact and secondary-contact recreational uses are 406 and 576 CFU/100mL, respectively (table 3). Sampling results indicate that *E. coli* values near the mouth of Mason Creek exceed the single-sample secondary-contact criterion between 25 and 50 percent of the time during irrigation season. *E. coli* values exceeded the single-sample primary-contact criterion less than 25 percent of the time at the Boise River near Parma (site B1) (fig. 11).

Significant Relations Among Water-Quality Parameters

The continuous record at Mason Creek near Caldwell (site M1) consists of discharge, turbidity, and water temperature data from March 2011 to March 2012. At least 80 instantaneous field measurements of discharge, water temperature, dissolved oxygen, pH, and specific conductance have been made since the mid-1990s. Each instantaneous water-quality parameter was paired with analytical results from the same sampling event. Statistically significant relations between field measurements and constituent concentrations were determined using regression analysis (table 6). Water-quality parameters with significant relations to water-quality constituents could be used as explanatory variables (surrogates) for estimation of constituent concentrations including TP, OP, TN, NO_2+NO_3, *E.coli*, and suspended sediment.

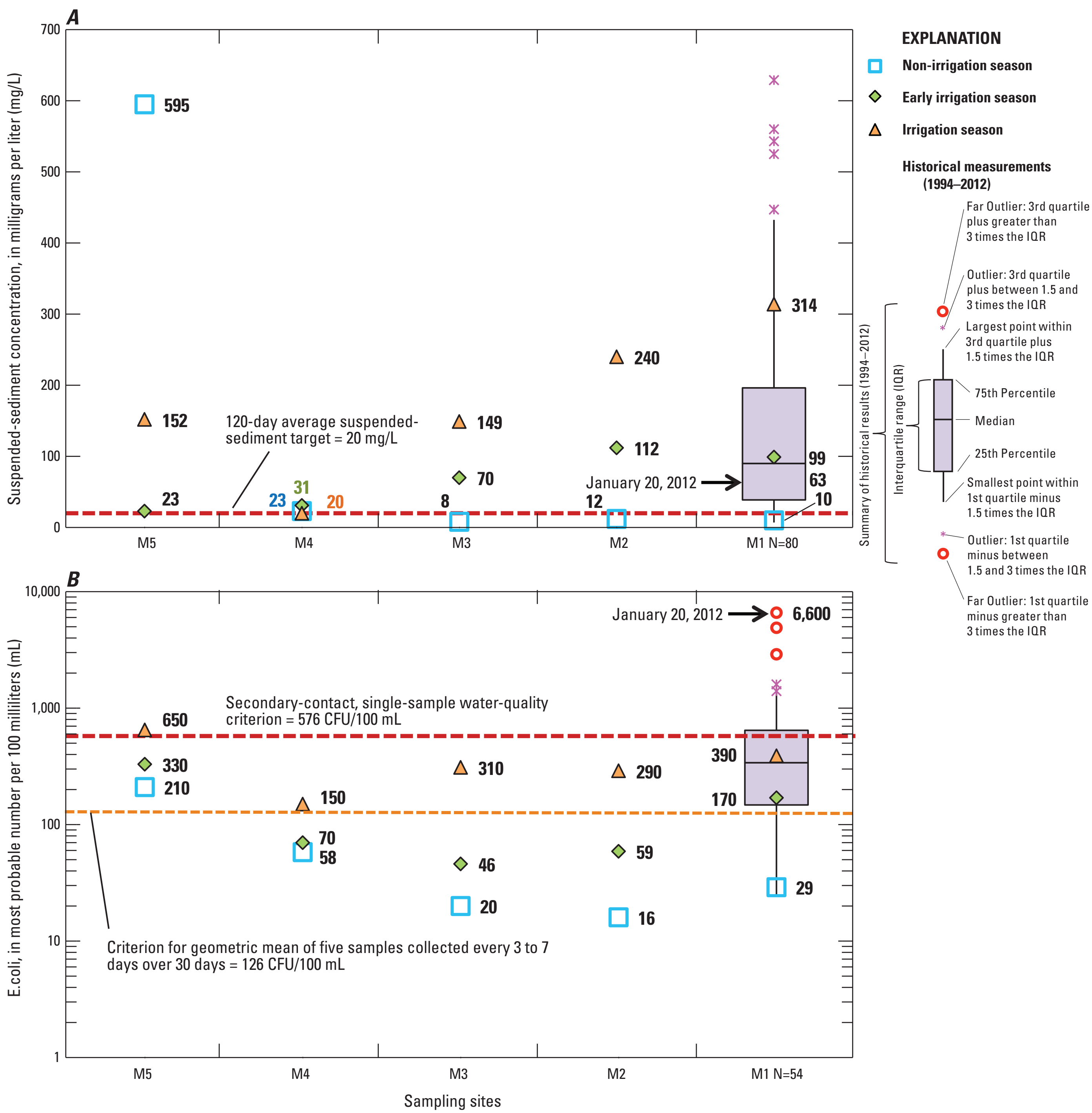

Figure 13. (*A*) Suspended-sediment concentrations and (*B*) *Escherichia coli* (*E. coli*) values in samples collected from Mason Creek during 2011, compared with historical results (1994–2012) from Mason Creek near Caldwell (site M1), southwestern Idaho. Locations of sites are shown in figure 1*B*. (N, number of samples).

Regression analysis indicates that continuous turbidity, discharge, and specific conductance are good surrogates for TP, OP, TN, *E.coli*, and suspended sediment at site M1. Specific conductance, which is not available in the continuous record at site M1, accounted for 83 percent of sample variability in 82 NO_2+NO_3 results (table 6). Because continuous discharge and turbidity are available from March 2011 to March 2012, surrogate models were developed to estimate real-time concentrations of TP, TN, suspended sediment, and *E. coli* at site M1.

If a streamgage is re-established at site M1, the potential for backwater conditions should be addressed with either an index velocity meter or more frequent discharge measurements. Backwater conditions are likely at site M1 when discharge in the Boise River near Parma exceeds 5,000 ft^3/s.

Continuous Data

From March 10, 2011, to March 21, 2012, a streamgage was operated at Mason Creek near Caldwell (site M1). On April 7, 2011, a turbidity and temperature sensor was installed at the streamgage and operated through March 21, 2012. A stage-discharge rating was developed using 11 discharge measurements collected over a range of flow conditions. The streamgage provided 15-minute readings for gage height, discharge, temperature, and turbidity.

Discharge

During irrigation season, discharge at site M1 consists of discharge at site M2 plus return water from Solomon, Noble, A, and Lower Fivemile Drains. When irrigation season ends, the water table is elevated near site M1 because of percolation of applied irrigation water on adjacent fields and inflow from the adjacent shallow aquifer (Fox and others, 2002). As non-irrigation season progresses, discharge steadily decreases in the creek as the water table in the aquifer adjacent to the creek declines (Fox and others, 2002). Discharge response at site M1 to periods of rainfall in the watershed is more pronounced during non-irrigation season compared to irrigation season (fig. 14). Monthly sampling at site M1 included a winter storm on January 20, 2012, and resulted in extremely high concentrations for most water-quality constituents.

Discharge at site M1 was measured continuously from March 2011 through March 2012 (fig. 14). Discharge increased from 49 ft^3/s on April 7 to 80 ft^3/s on April 10, and 104 ft^3/s on April 21, 2011. The increase in discharge took place as irrigation canals, diversions, and returns were flushed with water at the beginning of a new irrigation season. Turbidity values increased from 40 formazin nephelometric units (FNUs) to more than 100 FNUs on April 8, associated with the first flush of irrigation water through the Mason Creek watershed.

As irrigation water began to flow through the Mason Creek watershed, discharge in the Boise River increased from 3,800 to 5,000 ft^3/s on April 6 and to 6,800 ft^3/s on April 9, 2011, at Parma (site B1). Discharge measurements at site M1 on April 7 and May 3, 2011, confirm that the streamgage was under the influence of backwater from the Boise River. Comparison of hydrographs from sites M1 and B1 also confirms that site M1 was under the influence of backwater from April 6 to June 8, 2011. On June 9, a discharge measurement confirmed that Mason Creek was no longer under the influence of backwater as discharge at site B1 decreased to 5,800 ft^3/s, and remained less than 5,000 ft^3/s for the rest of the study period. The discharge record at site M1 between April 6 and June 8 was qualified as “poor” and can be used with the understanding that computed discharge during that period is associated with at least an 8 percent uncertainty.

Monthly mean discharge at site M1 ranged from a low of 51 ft^3/s in February and March to a high of 147 ft^3/s in September 2011. During irrigation season in 2011, monthly mean discharge ranged from 82 ft^3/s in April to 147 ft^3/s in September, with monthly mean discharge during May, June, and July fluctuating within plus or minus 6 ft^3/s of 130 ft^3/s. When irrigation season ended in October, monthly mean discharge steadily decreased from 94 ft^3/s in October to 51 ft^3/s in February and March 2012.

Continuous Water Temperature

Water temperature has an important effect on the density of water, the solubility of constituents in water, specific conductance, pH, the rate of chemical reactions, and biological activity in water (Wilde, 2006). High water temperatures are of primary concern with respect to beneficial uses for coldwater aquatic biota. Mason Creek is designated with the coldwater aquatic biota beneficial use and therefore requires that stream temperatures do not exceed a maximum of 22 °C or a maximum daily mean of 19 °C (table 3). Daily mean temperature at the Mason Creek streamgage exceeded 19 °C on 25 days between June 23 and August 29, 2011, (7 percent of the April 2011–March 2012 study period [fig. 14]). During the study period, 15-minute temperature data exceeded 22 °C less than 1 percent of the time (fig. 15).

Turbidity

Turbidity is caused by suspended and dissolved matter such as clay, silt, finely divided organic matter, sestonic algae and other microscopic organisms, organic acids, and dyes in the water column (Anderson, 2005). Turbidity is affected by the amount of precipitation and runoff, intensity and duration of storms, slope of the river channel, geomorphic structure of the channel, origin of the water including point and nonpoint sources, and time of travel from the point of origin to the point of measurement. Biological activity, such as algal blooms, also

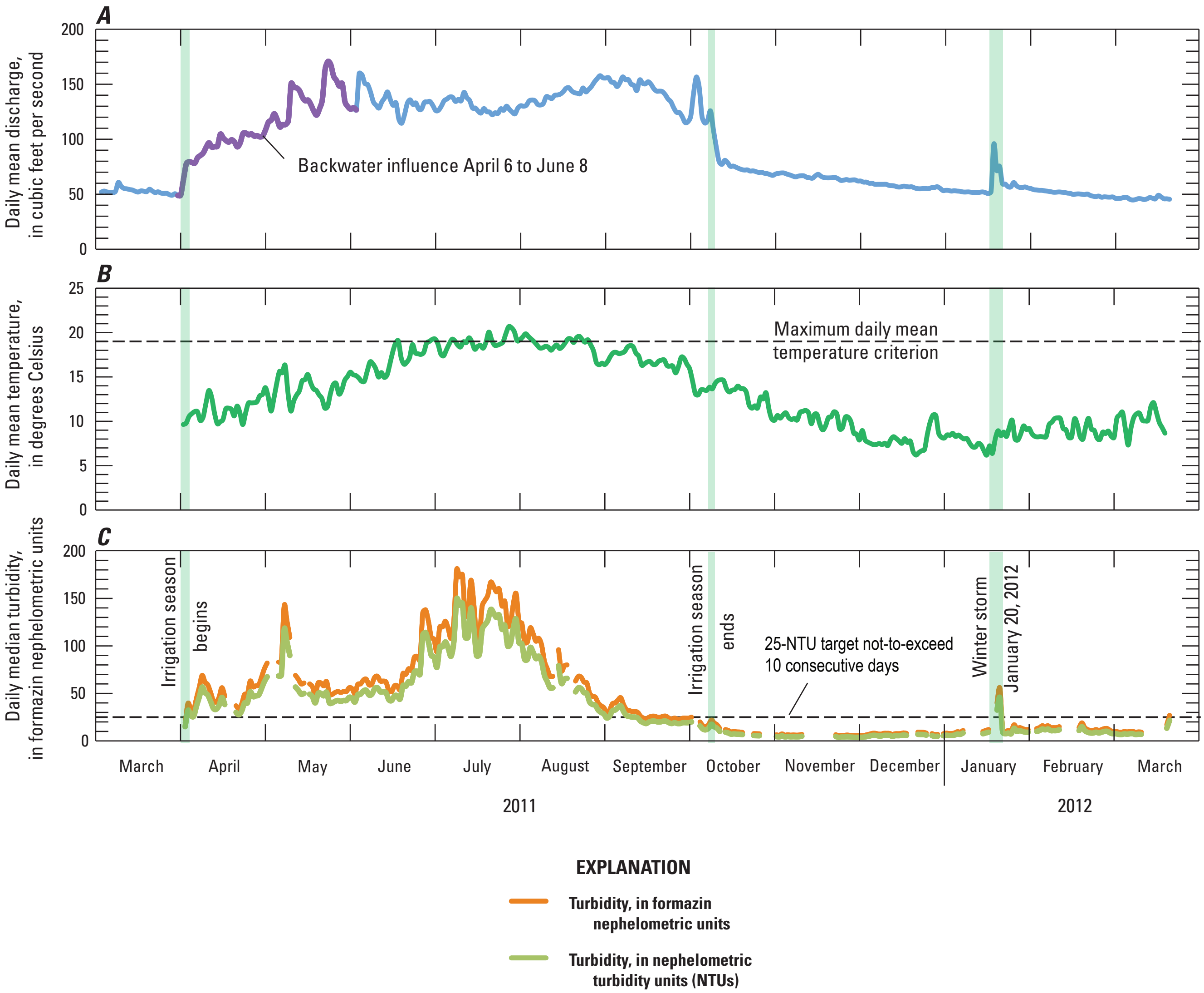

Figure 14. Daily mean values for computed (*A*) discharge and (*B*) water temperature, and daily median values for (*C*) turbidity at Mason Creek near Caldwell, Idaho, March 2011–March 2012..

can increase turbidity. Particulates in water provide attachment sites for nutrients, pesticides, indicator bacteria, and other potential contaminants. Increased turbidity reduces light penetration and photosynthesis, affecting benthic habitats, and interferes with feeding habits of aquatic organisms. High values of turbidity for short periods may be less harmful than lower, but persistently elevated, values (Wetzel, 2001).

The State of Idaho general (not water-body specific) water-quality criteria state that instantaneous turbidity cannot exceed 50 nephelometric turbidity units (NTUs) above background instantaneously or 25 NTU for more than 10 consecutive days. The instrument technology used in this study measures turbidity in FNUs. Although similar to NTUs, turbidity measured in FNUs is not directly comparable to turbidity measured in NTUs (Anderson, 2005). Continuous turbidity meters commonly measure turbidity in FNU. Measuring turbidity in FNU overcomes numerous factors that have the potential to bias turbidity measurements. These include the changes in color of particles or dissolved matter and the presence of predominantly small particles in the matrix (Anderson, 2005). Future comparisons of turbidity at Mason Creek should be conducted using the same instrumentation because turbidity probes of differing models will not provide comparable results.

Nine comparison readings between the deployed turbidity probe and a bench-top turbidity meter were made at the Mason Creek streamgage between August 2011 and March 2012. The bench-top turbidity meter provided readings in NTUs, whereas the deployed probe provided readings in FNUs. The data comparison was used to compute a site-specific relation

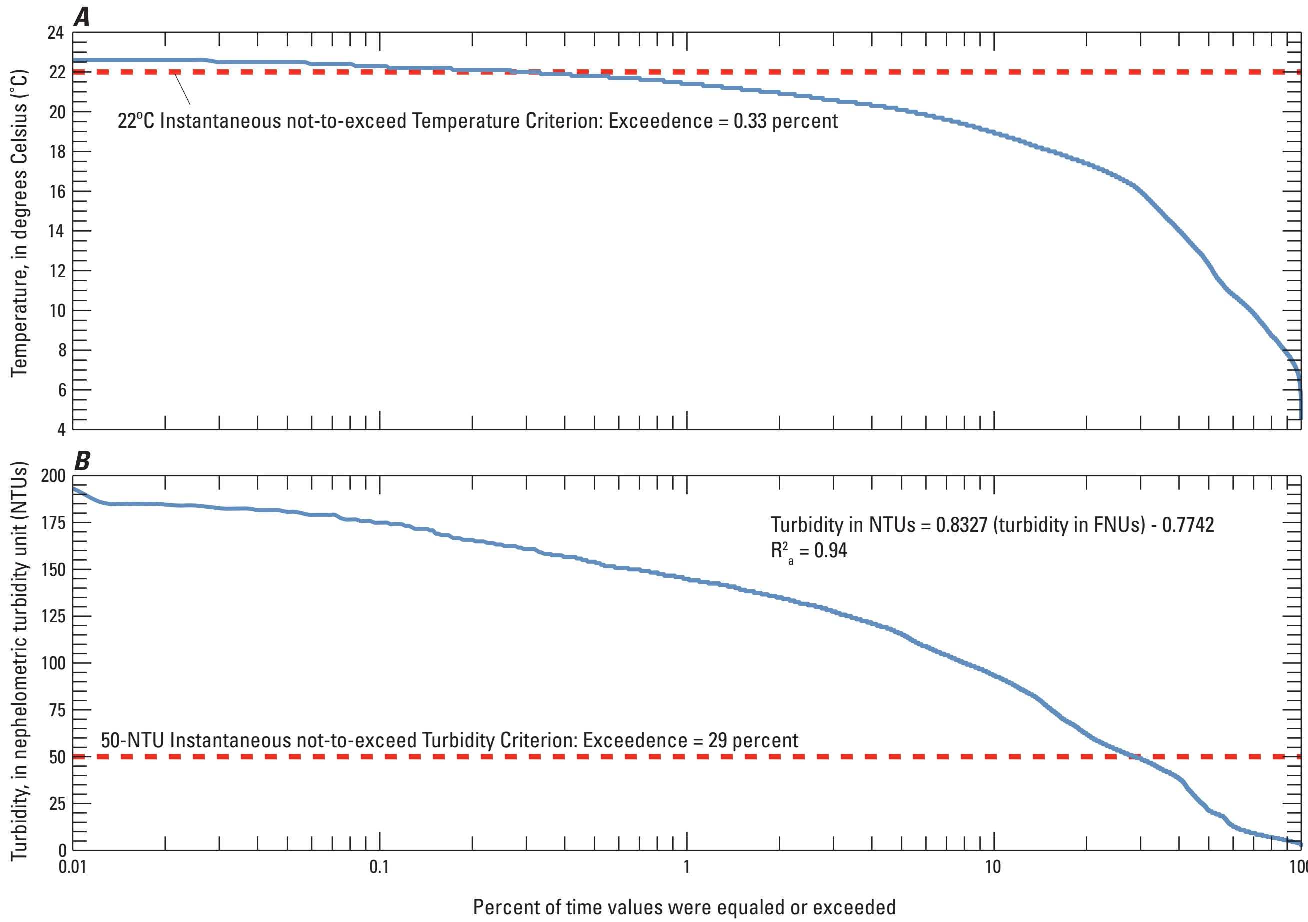

Figure 15. Exceedence curves for 15-minute values of (*A*) temperature and (*B*) turbidity in Mason Creek near Caldwell, Idaho, April 2011–March 2012.

between the two instruments. The offset and slope from the relation were used to convert the FNU turbidity record into an NTU turbidity record. Turbidity likely exceeded the 25-NTU consecutive-day criterion for 147 days from April 9 to September 3, 2011, and 9 days from September 5 to September 14, 2011 (fig. 14). The 50-NTU criterion was exceeded 29 percent of the time during the study (fig. 15).

Monthly Water-Quality Sampling Results and Surrogate Models

Total phosphorus concentrations in Mason Creek near Caldwell (site M1) generally were lower during non-irrigation season than during irrigation season, but always were greater than the 0.07-mg/L TMDL target for the mouth of the Boise River (fig. 16; table 3). From October to May (excluding January) 2011, TP concentrations ranged from 0.18 to 0.21 mg/L. In June and late September 2011, TP concentrations were 0.26 and 0.23 mg/L, respectively. Four samples collected between July and early September 2011 ranged from 0.30 to 0.43 mg/L. A sample collected during a winter storm on January 20, 2012 had a TP concentration of 0.84 mg/L, which was higher than any of the 82 historical samples for TP at M1 (figs. 12 and 16). The January 2012 result indicates that surface runoff may be a significant source of TP during winter storms. Manure typically is applied to crops in winter (Schmitt and Rehm, 2002) and therefore is more prone to surface runoff when cold temperatures freeze soil surfaces.

Unlike TP concentrations, which tend to be larger in the summer, OP concentrations ranged between 0.14 and 0.21 mg/L all year with the exception of the 0.65-mg/L OP concentration in the sample collected during the January storm (fig. 16*A*). The OP:TP ratios of less than 0.66 between June and September indicate that particulate phosphorus from irrigation returns probably plays an important role in phosphorus loading to Mason Creek at site M1. This observation coupled with the reliably seasonal fluctuation of TP at site M1 confirms that turbidity and seasonality are the best explanatory variables for estimating TP concentrations in Mason Creek.

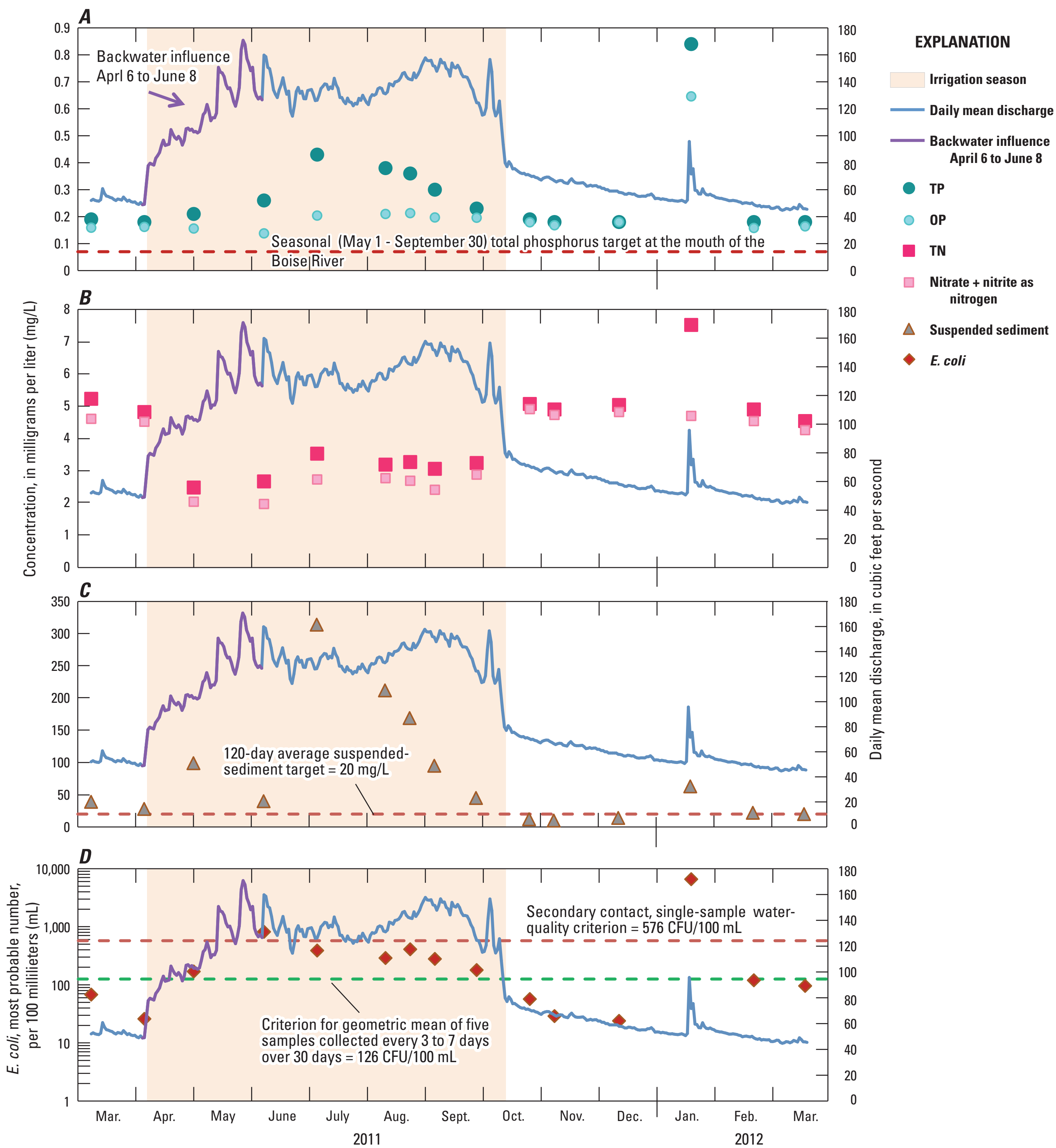

Figure 16. Concentrations of (*A*) phosphorus, (*B*) nitrogen, (*C*) suspended sediment, and (*D*) *Escherichia coli* (*E. coli*) in samples collected from Mason Creek near Caldwell (site M1), Idaho, March 2011–March 2012.

The surrogate model using turbidity and seasonality explained 75 percent of the variability in measured TP concentrations in Mason Creek (table 6, fig. 17). Streamflow and specific conductance were statistically insignificant as surrogates for TP concentrations. Use of surrogate modeling for concentrations of OP did not produce acceptable results (table 6). The TP surrogate model underestimated the TP concentration during the January 2012 storm (fig. 17). If the surrogate model is to be used for estimating TP concentrations during future storms, additional samples should be collected during storms to verify the model results.

In contrast to TP, concentrations of TN generally were higher during non-irrigation season and lower during irrigation season (fig. 16). The sample collected at site M1 in May 2011 represented the "first flush" of the irrigation system and had a concentration of 2.48 mg/L, the lowest measured concentration in samples collected during the study. Groundwater is the primary source of discharge to Mason Creek during the winter (Fox and others, 2002), and seasonal variations in the TN concentration at site M1 indicate that groundwater also is the primary source of TN and NO_2+NO_3.

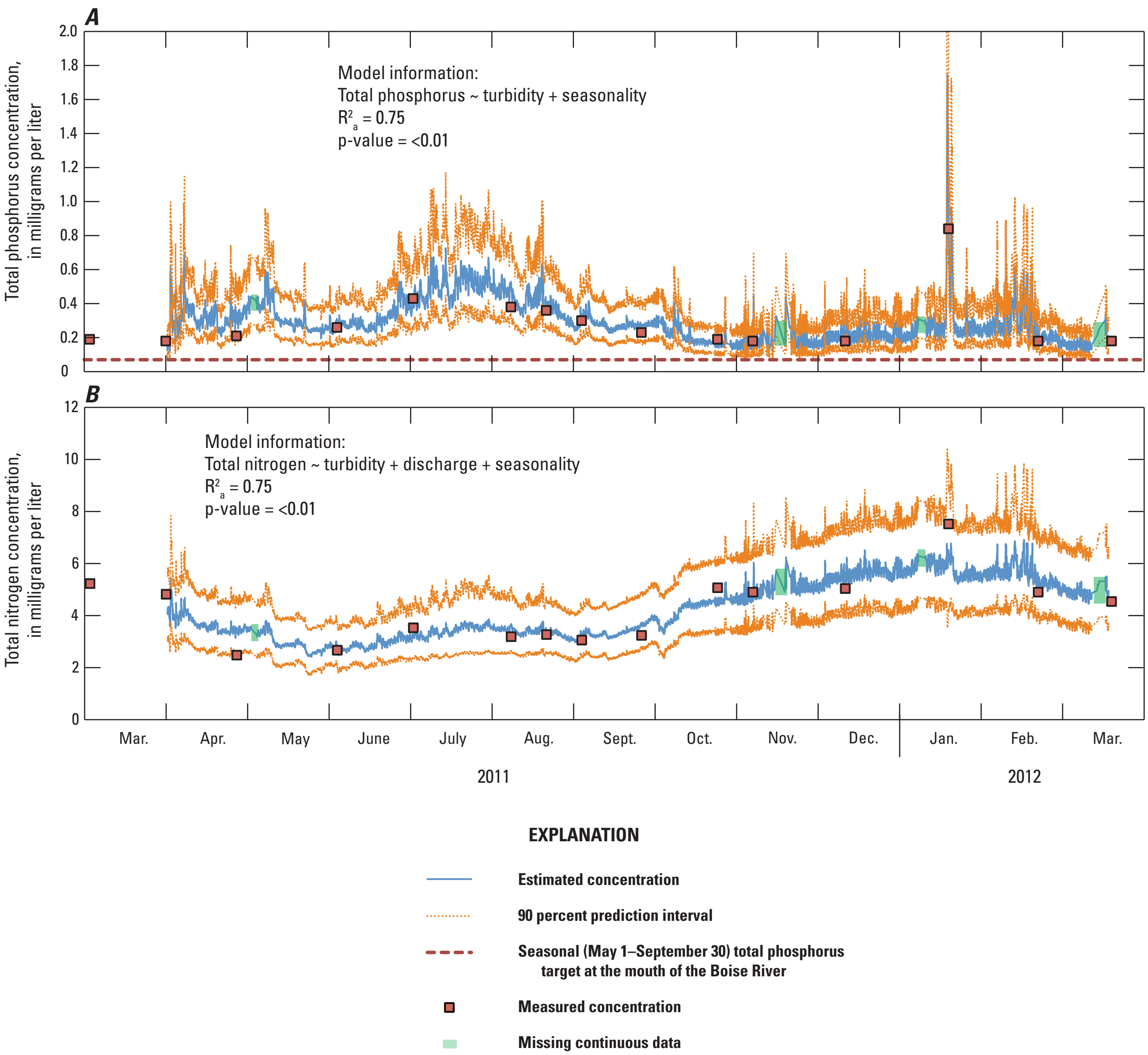

Figure 17. Estimated (*A*) total phosphorus and (*B*) total nitrogen concentrations based on surrogate models developed for Mason Creek near Caldwell (site M1), Idaho, March 2011–March 2012.

From May to late September, TN concentrations at site M1 ranged from 2.48 to 3.53 mg/L, whereas TN concentrations in April 2011 and from late October 2011 to late March 2012 (excluding January) ranged from 4.54 to 5.23 mg/L. The TN concentration measured on January 20, 2012, was 7.52 mg/L, indicative of surface runoff during a winter storm.

Except for the January 2012 concentration, NO_2+NO_3 concentrations at site M1 were slightly lower than TN concentrations with a similar seasonal pattern. From May to September 2011, the NO_2+NO_3 concentration at M1 ranged from 1.97 to 2.88 mg/L. From late October 2011 through April 2012, the NO_2+NO_3 concentration ranged from 4.26 to 4.91 mg/L. The NO_2+NO_3 concentration in the sample collected during the January 2012 storm was not higher than NO_2+NO_3 concentrations in other winter samples (fig. 16), indicating that groundwater may be the primary source of NO_2+NO_3 to Mason Creek.

The presence of a seasonal fluctuation in the TN concentrations at site M1 indicates that seasonality may be a useful explanatory variable for modeling TN (fig. 16). Significant negative correlations between discharge at site M1 and TN and between turbidity and TN support their use as additional explanatory variables in the surrogate model for TN. Specific conductance was statistically insignificant as a surrogate for TN in Mason Creek.

The best TN surrogate model (R^2_a = 0.75) for Mason Creek used discharge, seasonality, and turbidity as explanatory variables. Like the TP model, the TN model underestimated the TN concentration in Mason Creek during the January 2012 storm. Additional data collected during storms would help to refine the TN model. Based on the discrete samples collected from site M1, specific conductance was the best explanatory variable for estimating NO_2+NO_3 concentrations. However, because a continuous record of specific conductance was not available for Mason Creek, a regression model for NO_2+NO_3 based on surrogate data could not be developed.

Suspended-sediment concentrations in Mason Creek generally were higher during irrigation season than during non-irrigation season (fig. 16). Backwater conditions resulting in a decrease in the stream velocity may have biased suspended-sediment concentrations low on April 7, May 3, and June 9, 2011 (fig. 16). Historical information based on 25 samples indicates that, on average, 86 percent of the suspended sediment in Mason Creek near the mouth is silt and (or) clay (smaller than 0.0625 mm). Turbidity is an especially useful surrogate for estimating suspended-sediment concentrations when the sediment is primarily comprised of fine-grained material (Gray and Gartner, 2006; Rasmussen and others, 2009).

Although sampling results were likely biased low during backwater conditions on April 7, May 3, and June 9, a surrogate model using only turbidity to estimate suspended-sediment concentrations explained 87 percent of the variability in the calibration dataset (fig. 18). Discharge in Mason Creek was not a significant explanatory variable. More variability in the turbidity data resulted in a wider prediction interval during the non-irrigation season (fig. 18). A 120-day moving average computed using the surrogate model indicates that the suspended-sediment target in Mason Creek (not to exceed a 20-mg/L average over 120 days) was rarely if ever achieved during the study period.

As with TP and suspended-sediment concentrations, *E. coli* values were higher during irrigation season. Total phosphorus, OP, TN, and to a lesser degree, suspended-sediment concentrations each spiked during the winter storm on January 20, 2012. The *E. coli* count of 6,600 MPN/100 mL in the sample collected on January 20, 2012, was the highest value in the 54-sample historical *E. coli* data set collected at site M1 (fig. 13). Unlike nutrients and sediment, *E. coli* sample results also were higher following lower-magnitude periods of rainfall in February 2012, and in March of both 2011 and 2012 (fig. 16).

Relative to nutrients and sediment, *E. coli* values are more variable in a given season. Continuous turbidity and discharge generally correlate with *E. coli* values at site M1, but surrogate model diagnostics were not favorable for the model using both of these explanatory variables (table 6). Adding seasonality as an explanatory variable in the model improved the R^2_a from 0.38 to 0.69, but the 90 percent prediction interval around the estimated value was more than 1,000 MPN/100mL during the summer months. If the January 20, 2012, result is included, the *E. coli* model becomes statistically insignificant. A statistically significant seasonal model probably could be developed if data from backwater periods and winter storms are not used. Precipitation data may provide a significant explanatory variable; however, precipitation data were not available.

Surrogate and LOADEST Model Comparisons

Surrogate models developed for Mason Creek near Caldwell (site M1) were used to compute continuous loads and compare those loads to load estimates computed using LOADEST. LOADEST models were developed for TP, TN, and suspended sediment (table 7).

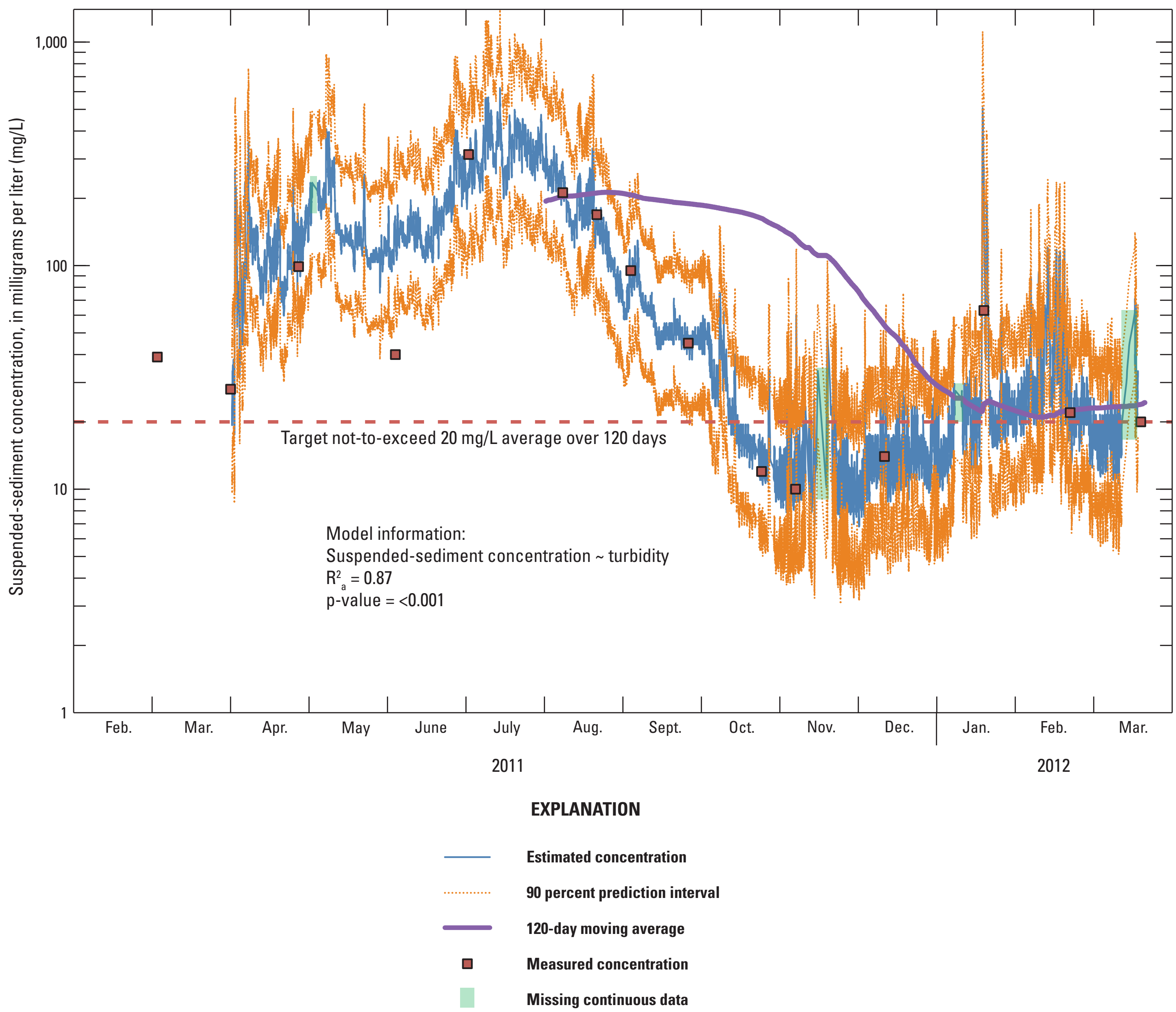

Figure 18. Estimated suspended-sediment concentrations based on a surrogate model developed for Mason Creek near Caldwell (site M1), Idaho, March 2011–March 2012.

Instantaneous loads of TP based on field data were compared to estimated daily loads computed using a surrogate model and a LOADEST model (fig. 19). Because the surrogate model for TP included turbidity as an explanatory variable, the calibration dataset consisted of 17 sample pairs from data collected during this study. In contrast, the LOADEST model included discharge and seasonality as explanatory variables, and was calibrated with 82 samples from historical and recent discharge data (table 8). A LOADEST model also was developed using only the 17-sample calibration dataset as was used in the surrogate model. The resulting LOADEST model using only 17 samples performed poorly as compared to the LOADEST model using the historical record of 82 samples. The surrogate model performed better than both LOADEST models during the January 2012 storm, and overall explained 89 percent of the variability in measured instantaneous loads of TP, and 75 percent of the variability in measured concentrations of TP (table 8). The LOADEST model incorporating historical data explained 83 percent of the variability in measured instantaneous loads of TP and 49 percent of the variability in measured concentrations of TP. Additional samples collected during storms would be useful for calibrating both the TP LOADEST and surrogate models.

Table 7. LOAD ESTimator (LOADEST) and surrogate regression equations developed to estimate loads and concentrations of constituents of concern in Mason Creek near Caldwell (site M1), Idaho, water years 2011–12.

[**LOADEST regression equation for constituent load:** Unbiased results are provided by the LOADEST model and bias correction factors are accounted for in the regression coefficients. **Regression variable coefficients:** The intercept term (a) in LOADEST models is in units of pounds per day. The model as presented will output estimates of load of pounds per day. **Duan's BCF**: From Duan (1983). **Abbreviations:** RPD, relative percent difference; BCF, bias correction factor; PRESS, PRediction Error Sum of Squares statistic; TP, total phosphorus; TN, total nitrogen; SSC, suspended-sediment concentration; Q, discharge; ln, natural log; cos2π and sin2π, seasonality terms; lb/d, pound per day; mg/L, milligram per liter]

Constituent	LOADEST regression equation for constituent load (lb/d)	Regression variable coefficients							Median RPD
		a	b	c	d	e	f	g	
TP	$\ln Load = a + b \times \ln Q + c \times \ln Q^2 + d \times \sin(2\pi\, dtime) + e \times \cos(2\pi\, dtime) + f \times dtime + g \times dtime^2$	9.711	1.184	-0.411	0.232	0.235	-0.006	-0.004	16.4
TN	$\ln Load = a + b \times \ln Q + c \times \sin(2\pi\, dtime) + c \times \cos(2\pi\, dtime) + d \times dtime$	14.914	0.806	0.024	0.273				7.2
SSC	$\ln Load = a + b \times \ln Q + c \times \ln Q^2 + d \times \sin(2\pi\, dtime) + e \times \cos(2\pi\, dtime) + f \times dtime$	21.547	1.926	-0.738	-0.241	0.901	-0.025		75.4

Constituent	Surrogate regression equation for constituent concentration (mg/L)	Regression variable coefficients					Duan's BCF	PRESS	Median RPD
		a	b	c	d	e			
TP	$\ln TP = a + b \times \ln Turbidity + c \times \sin(2\pi\, dtime) + d \times \cos(2\pi\, dtime)$	-3.575	0.681	-0.101	0.557		1.019	2.3	9.5
TN	$\ln TN = a + b \times \ln Turbidity + c \times \ln Q + d \times \sin(2\pi\, dtime) + e \times \cos(2\pi\, dtime)$	2.839	0.161	-0.440	-0.080	0.312	1.007	0.91	15.3
SSC	$\ln SSC = a + b \times \ln Turbidity$	0.230	1.118				1.059	2.7	15.7

Table 8. Comparison of U.S. Geological Survey LOAD ESTimator (LOADEST) and surrogate regression models for nutrients and suspended sediment at Mason Creek near Caldwell, Idaho, water years 2011–12.

[Adjusted R^2: Adjusted coefficient of determination. **Abbreviations:** TP, total phosphorus; TN, total nitrogen; SSC, suspended-sediment concentration; mg/L, milligram per liter; ton/d, tons per day; lb/acre, pounds per acre]

Loads	LOADEST			Surrogate		
	TP	TN	SSC	TP	TN	SSC
Number of samples	82	17	80	17	17	17
Adjusted R^2, load model	0.83	0.76	0.79	0.89	0.78	0.87
Adjusted R^2, concentration model	0.49	0.76	0.66	0.75	0.75	0.87
Annual load (tons)	29.9	358	9,950	30.7	367	12,100
Irrigation season load (tons)	24.5	235	9,010	23.1	218	10,700
Irrigation season runoff[1] (lb/acre)	2.09	20.0	768	1.96	18.5	911
Average daily load (ton/d)—irrigation season	0.13	1.23	47.2	0.12	1.17	56.0
Average daily load (ton/d)—non-irrigation season	0.03	0.76	6.12	0.04	0.82	3.74
Annual Flow-weighted concentration (mg/L)	0.32	3.82	106	0.33	3.93	129

[1]Irrigated acreage obtained from Idaho Department of Environmental Quality (2003). Irrigation season runoff estimate assumes all runoff comes from irrigated land.

The TN surrogate model performed better than the LOADEST model during the January 2012 winter storm and explained 78 percent of the variability in measured instantaneous loads and 75 percent or the variability in sampled TN concentrations (fig. 19, table 8). Additional samples collected during storms may indicate which modeling approach is best for estimating TN at site M1.

Turbidity was used as the only explanatory variable in the surrogate model for suspended sediment (table 7). Flow and seasonality were used as explanatory variables for the LOADEST model, which was developed from a calibration dataset of 80 historical suspended sediment sample pairs (table 8). The LOADEST model developed using only the 17-sample dataset worked as well as the LOADEST model developed using the 80-sample data set. Although the LOADEST model more closely estimated the suspended-sediment load during the January 2012 storm, overall it underestimated the suspended-sediment load for most of the irrigation season and thus, diminished its usefulness with respect to long-term monitoring (fig. 19). The surrogate model over-estimated the sediment load during the January storm, but overall explained 87 percent of the variability in measured instantaneous load and sampled suspended-sediment concentration. Using 80 samples, the LOADEST model explained 79 percent of the variability in the measured instantaneous load and 66 percent of the variability in the sampled suspended-sediment concentration. Additional storm samples would help calibrate the surrogate model and could provide greater accuracy for estimating suspended-sediment loads and concentrations during storms.

Biological Monitoring Results

The periphyton biomass and chlorophyll-*a* concentration in periphyton in Mason Creek at Wells Road (site M2) were low relative to those at Boise River near the mouth, 5 g/m^2 and 26 mg/m^2, respectively. The chlorophyll-*a* concentration in periphyton at the Boise River near the mouth (downstream of site B1) was 152 mg/m^2 measured during the same week in late October 2011.

Invertebrate densities and associated traits for the sample collected from Mason Creek at Wells Road (site M2) (fig. 1*B*) in 2011 are shown in appendix A. The invertebrate taxa richness (number of discrete taxa in a sample) for Mason Creek was 19, which is low compared to forested sites in Idaho (average of 36 taxa; Maret and others, 2001) and least-disturbed sites in the Snake River Basin (average of about 27; Grafe, 2002). Metrics (qualities of an invertebrate community) that tend to decrease with increasing perturbation, such as Ephemeroptera, Plecoptera, and Trichoptera taxa, also were low in Mason Creek (6) compared to least disturbed basin streams in Idaho (average of about 15, see Grafe, 2002, appendix A). The most abundant invertebrate in Mason Creek was the highly tolerant and invasive *Potamopyrgus antipodarum* (New Zealand mudsnail). This species can dominate a benthic community by attrition and may be another reason for low taxa richness and abundance in Mason Creek. The sediment tolerant mayfly *Tricorythodes minutus* was also found in Mason Creek. This species is common in the lower Boise River, especially in the downstream reaches (MacCoy, 2004). The thermal preference of all the species in Mason Creek was Cool/Warm as defined in Vieira and others (2006). An SMI score of 26 out of 100 was calculated for the Mason Creek invertebrate population (Jason Pappani, Idaho Department of Environmental Quality, written commun., 2013). This compares to a median SMI score of 64 for least impacted streams in the Basins bioregion (Grafe and others, 2002). An SMI score less than 33 is considered poor and is below the minimum threshold for considering a water body to meet aquatic life beneficial uses (Grafe and others, 2002), indicating degraded water-quality conditions and is in the lowest 25th percentile of least impacted streams in the Basins bioregion.

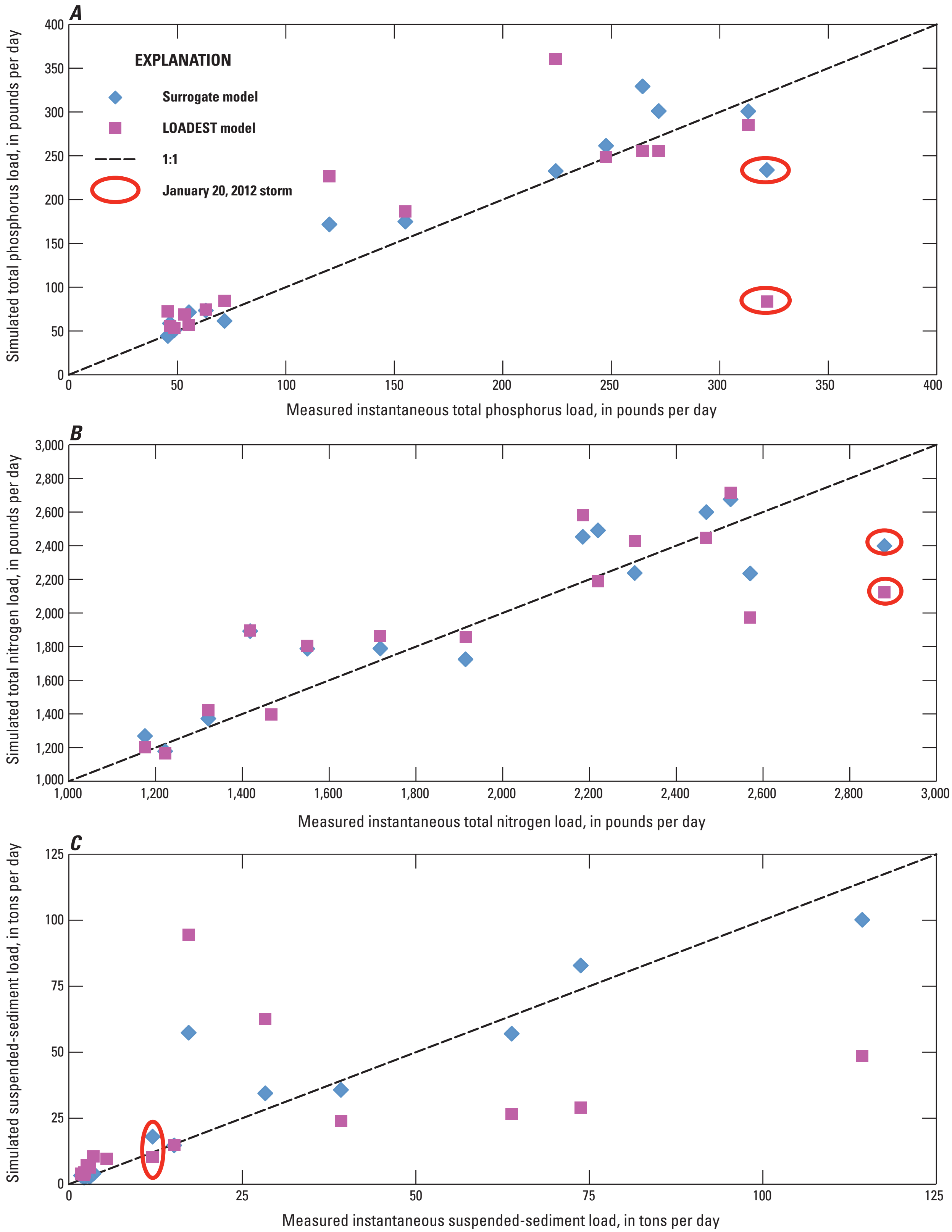

Figure 19. Measured instantaneous loads of (*A*) total phosphorus, (*B*) total nitrogen, and (*C*) suspended sediment compared with estimated loads using U.S. Geological Survey LOAD ESTimator (LOADEST) and surrogate models, Mason Creek near Caldwell (site M1), Idaho, March 2011–March 2012.

Mason Creek at Wells Road (site M2) also was evaluated for the quality of the fish community. Twenty-six individual fish (2 Cobitidae [loaches], 4 Cyprinidae [minnows], 13 Catostomidae [suckers], and 7 Salmonidae [trout]) were found in a 160-m reach of Mason Creek at Wells Road (site M2) (table 9). All the fish collected had condition factors close to 1 except for the introduced Oriental Weatherfish (loaches) that have a snake-like appearance and a weight-to-length ratio smaller than for other fish. All the fish species except for the loach were native, cool or coldwater species, and categorized as sensitive or intolerant to pollution; some species considered tolerant of some forms of pollution also were present (Bridgelip Sucker, Largescale Sucker, Northern Pikeminnow, and Oriental Weatherfish) (table 9). The adult trophic or feeding guilds ranged from herbivore to piscivore, indicating a variety of food sources supporting the fish population. Rainbow trout ranged in length from 90 to 275 mm, indicating at least three age classes. The presence of smaller sized rainbow trout (90 mm) indicates possible salmonid spawning in Mason Creek.

The RFI score of 58 for Mason Creek is comparable to RFI scores calculated for the Boise River reach near Middleton, indicating intermediate biotic integrity (MacCoy, 2006). The lack of sculpin, which is a heavily weighted metric for the RFI, and the presence of invasive and tolerant species in Mason Creek at Wells Road (site M2) probably influenced the lower intermediate score.

Table 9. Fish species and abundance at Mason Creek at Wells Road, near Caldwell (site M2), Idaho (USGS site No. 13210976), October 27, 2011.

[Data can be accessed at https://aquatic.biodata.usgs.gov. **Origin:** N, native; I, introduced. **Tolerance:** T, tolerant; I, intermediate; S, sensitive. **Adult trophic guild:** Classification of species from Zaroban and others, 1999; herb, herbivore; omni, onmivore; inv, invertivore; pisc, piscivore. **Abbreviations:** mm, millimeter; g, gram]

Common name	Length (mm)	Weight (g)	Abundance	Condition factor	Origin	Tolerance	Temperature preference	Adult trophic guild
Bridgelip sucker	161	43	1	1.03	N	T	Cool	herb
Largescale sucker	260	158	1	0.90	N	T	Cool	omni
Largescale sucker	305	283	1	1.00	N	T	Cool	omni
Longnose dace	71	5	1	1.40	N	I	Cool	herb
Mountain sucker	190	71	1	1.04	N	I	Cool	herb
Mountain sucker	200	79	1	0.99	N	I	Cool	herb
Mountain sucker	150	33	1	0.98	N	I	Cool	herb
Mountain sucker	185	75	1	1.18	N	I	Cool	herb
Mountain sucker	204	75	1	0.88	N	I	Cool	herb
Mountain sucker	193	104	1	1.45	N	I	Cool	herb
Mountain sucker	115	19	1	1.25	N	I	Cool	herb
Mountain sucker	65	4	1	1.46	N	I	Cool	herb
Mountain sucker	163	62	1	1.43	N	I	Cool	herb
Mountain sucker	164	53	1	1.20	N	I	Cool	herb
Northern pikeminnow	168	51	1	1.08	N	T	Cool	inv/pisc
Oriental weatherfish	165	34	1	0.76	I	T	Warm	omni
Oriental weatherfish	140	19	1	0.69	I	T	Warm	omni
Rainbow trout	270	193	1	0.98	N	S	Cold	inv/pisc
Rainbow trout	275	188	1	0.90	N	S	Cold	inv/pisc
Rainbow trout	170	44	1	0.90	N	S	Cold	inv/pisc
Rainbow trout	235	122	1	0.94	N	S	Cold	inv/pisc
Rainbow trout	155	37	1	0.99	N	S	Cold	inv/pisc
Rainbow trout	90	10	1	1.37	N	S	Cold	inv/pisc
Rainbow Cutthroat	285	246	1	1.06	N	S	Cold	inv/pisc
Redside shiner	142	39	1	1.36	N	I	Cool	inv
Umatilla dace	83	8	1	1.40	N	I	Cool	inv

Contaminants of Emerging Concern in the Lower Boise River Watershed

As part of ongoing USGS monitoring in the lower Boise River watershed, bottom-sediment samples were collected from each of the Boise River tributaries and from three sites on the main stem of the Boise River (table 10). Bottom-sediment samples were analyzed for 61 organic wastewater indicator compounds or contaminants of emerging concern. The 27 compounds that were detected were grouped into four categories: (1) urban, (2) industrial, (3) fecal steroids, and (4) personal care products. Agricultural pesticides also were part of the analytical suite, but were not detected in the bottom sediment from any of the monitoring sites. Total organic carbon content for the bottom-sediment samples also was determined. Bottom-sediment sample results were used to evaluate if adjacent land uses can influence in-stream water-quality and biological conditions. Regulatory thresholds have not been established for any of the organic wastewater indicator compounds detected in the sediment samples collected during this study. However, the findings from this study may provide valuable baseline information for future comparisons.

Bottom-sediment sample sites were selected to capture the effects of land use adjacent to the river or creek and in the contributing watershed. For example, results from the Boise River below Diversion Dam (site B3) represent relatively unaffected conditions with minimal effects from urban and agricultural development. Results from the Boise River near Middleton (site B2) represent the influence of urban land use. The Boise River near Parma (site B1) integrates all land uses in the entire lower Boise River watershed. Upstream tributary sites represent influences from land uses adjacent to each site and tributary sites sampled near the mouth provide results indicative of all land uses in the tributary watershed.

The number of detected compounds ranged from 7 at Indian Creek near the mouth (site I1) to 17 at Tenmile Creek at Franklin Road (site TM1). Detected urban compounds were exclusively poly-aromatic hydrocarbons (PAHs). Detected compounds in the industrial category included placticizers, industrial PAHs, solvents, disinfectants, and detergent metabolites. Detected steroids indicated the presence of fecal material from omnivores, ruminants (livestock), and carnivores. Detected personal care products included fragrances and household cleaners.

Urban Compounds

All the detected urban compounds were PAHs associated with fuels and fuel additives. The detected PAHs are classified as urban compounds because they are associated with urban motor vehicle traffic. The highest concentrations of urban compounds were in sediments from the Boise River near Parma (site B1) and the Boise River near Middleton (site B2). Sites with the most frequent detections included Tenmile Creek at Franklin Road (site TM1) (five compounds); and the Boise River near Middleton (site B2), Fivemile Creek at Franklin Road (site FM1), and Indian Creek at Sparrow Avenue (site I4) (four compounds each). Urban compounds were not detected in sediment collected from the Boise River below Diversion Dam (site B3). The compound 2,6-dimethylnaphthalene was detected in sediment from all 10 of the remaining sampling sites, indicating that it may be a good overall indicator of upstream urban land use.

Industrial Compounds

Detections of industrial compounds were less frequent than detections of fecal steroids. The highest detected concentration for industrial compounds was for phenol in bottom sediment collected from Indian Creek at Robinson Road (site I6) (table 10). The presence of phenol, an industrial disinfectant, at a concentration of 3,130 µg/kg in the sediment from Indian Creek indicates an influence from adjacent land use. The phenol concentration in the sediment from site I6 is higher than the median concentration of 2,180-µg/kg in nine samples of treated biosolids from nine WWTPs reported by Kinney and others (2006). The sample from Indian Creek at Sparrow Avenue (site I4) contained the highest concentrations of bisphenol *a* and carbazole, an industrial plasticizer and a polyaromatic hydrocarbon, respectively. Bisphenol *a*, commonly known as BPA, has been implicated as a potential endocrine-disrupting compound (Teeguarden and others, 2013). Site I4 is in the city of Caldwell and downstream of the Nampa WWTP. The industrial disinfectant, para-cresol, was detected at relatively high concentrations in sediment from the Boise River near Parma (site B1) and Fivemile Creek at Franklin Road (site FM1). Para-cresol was the most frequently detected industrial compound, with detections at 9 of 11 sites. Industrial compounds were not detected in sediment collected from the Boise River below Diversion Dam (site B3).

Fecal Steroids

Fecal steroids were detected in all of the bottom-sediment samples. Bottom sediment from Mason Creek at Powerline Road (site M5), situated downstream of two dairy operations, contained the highest concentrations of two of the four steroids detected in the lower Boise River watershed. The presence of fecal steroids in bottom sediment from site M5, the farthest upstream monitoring site in the Mason Creek watershed, indicates that adjacent land use may be a more important contributor of those compounds to streams as compared to watershed-wide land uses. The highest concentrations of the other two fecal steroids detected were in sediment from Mason Creek at Ustick Road (site M3) and Indian Creek at Sparrow Avenue (site I4). Site I4 is several miles downstream of the Nampa WWTP and site M3 is adjacent to several fields of cultivated crops and a pasture. Three of the four detected fecal steroid concentrations also were relatively high in sediments from the Boise River near Middleton (site B2), downstream of both city of Boise WWTPs (table 10).

Table 10. Summary of wastewater indicator compounds detected in bottom-sediment samples collected in the lower Boise River and selected tributaries, southwestern Idaho, water years 2009–11.

[**Abbreviated site name:** Complete USGS site names are provided in table 1. **Compound name:** Analytical methods for many compounds are under development. In other cases, concentrations are estimated because the result is less than the laboratory reporting level. **Bold** values are highest concentration estimated or reported for constituent. **CASRN:** Chemical abstracts service registry number. **Compound use:** PAH-U, polycyclic aromatic hydrocarbons in fuels and asphalt; Pla, plasticizers and resins; PAH-I, polycyclic aromatic hydrocarbons in dyes and explosives; Sol, solvent; Dis-I, industrial use disinfectant; DM-I, industrial detergent metabolite; St, steroids indicating biophysicochemical breakdown of animal waste; Dis-P, disinfectant; Fr, fragrances and flavors in foods, lotions, soaps, and sprays; DM, detergent metabolite; HC, home cleaning products. **Toxicity information:** Reported lethal aqueous concentration with 50 percent mortality. Source is U.S. Environmental Protection Agency (2007). **Abbreviations:** TM, Tenmile Creek; FM, Fivemile Creek; BR, Boise River; IC, Indian Creek; MC, Mason Creek; E, concentration estimated due to analytical uncertainty; µg/kg, microgram per kilogram; mg/L, milligram per liter; –, not detected]

Classification	Compound name	CASRN	Reporting level (µg/kg)	Detection frequency (percent)	Wastewater indicator compounds detected at study sites (µg/kg) TM1 2009	FM1 2009	M5 2011	M3 2011	M1 2011	I6 2010	I4 2010	I1 2010	B3 2010	B2 2011	B1 2009	Compound use	Toxicity information (mg/L)
Urban	2,6-dimethylnaphthalene	581-42-0	50	91	E28.8	E28.4	46.7	E14.3	27.9	63.3	E36.2	E6.18	–	23.3	**91.6**	PAH-U	
	anthracene	120-12-7	50	9	–	–	–	–	–	–	–	–	–	**25**	–	PAH-U	
	fluoranthene	206-44-0	50	27	E14.2	E7.03	–	–	–	–	**E16.6**	–	–	–	–	PAH-U	[1]74
	benzo[a]pyrene	50-32-8	50	55	**E5.94**	E4.62	3.00	5.80	3.00	–	–	–	–	–	E5.37	PAH-U	[2]1.5
	phenanthrene	85-01-8	50	27	E9.81	–	–	–	–	–	E14.5	–	–	**78.6**	–	PAH-U	[2]590
	pyrene	129-00-0	50	45	E13.2	E9.49	–	–	–	–	E15.9	–	–	**58.1**	E10.5	PAH-U	[2]90.9
Industrial	bisphenol *a*	80-05-7	50	27	E9.09	–	–	E7.6	–	–	**E14.7**	–	–	–	–	Pla	[1]3,600, [3]50
	carbazole	86-74-8	50	45	–	–	5.6	7.9	4.3	–	**E11.5**	–	–	5.3		PAH-I	[1]0.93–1.50
	isophorone	78-59-1	50	45	–	–	**E6.7**	–	E2.6	–	–	E4.03	–	E2.5	E5.11	Sol	[1]145–319
	para-cresol	106-44-5	250	82	E76.2	343	128	120	41	E256	E165	–	–	E35	**545**	Dis-I	[2]1,400
	para-nonylphenol (total)	84852-15-3	250	9	–	–	E231	–	–	–	–	–	–	–	–	DM-I	
	phenol	108-95-2	50	45	E311	E123	E180	–	–	**E3,130**	–	–	–	–	E151	Dis-I	[4]4,000
Fecal steroids	beta-sitosterol	83-46-5	500	82	E3,160	E2,000	**E8,210**	E2,970	E2,220	E3,720	–	–	<355	E6,720	E2,280	St	
	beta-stigmastanol	19466-47-8	500	91	E567	E379	**E1,710**	E732	E438	E592	E377	E269	–	E659	E496	St	
	3-beta-coprostanol	360-68-9	500	73	E282	E101	E407	E167	E160		**E809**		–	E532	E427	St	
	cholesterol	57-88-5	250	100	E2,470	E854	E3,310	**E3,940**	E2,850	E1,140	E1,060	E473	E500	E500	E3,410	St	
Personal care products	triclosan	3380-34-5	50	9	–	–	–	–	–	–	–	–	E88.3	–	–	Dis-P	[1]180
	3-methyl-1h-indole (skatol)	83-34-1	50	100	E18.7	E32.1	12	11.8	4.8	E25.9	**E37.6**	E7.07	E1.49	E5	E15.2	Fr	[1]8.84
	4-nonylpheno monoethoxylate- (total, np1eo)	104-35-8	500	18	**E264**	–	–	–	–	–	–	–	E72.7	–	–	DM	
	4-octylphenol monoethoxylate-(opeo1)	2315-67-5	250	18	**E48.5**	–	–	–	–	–	–	–	E13.7	–	–	DM	
	acetophenone	96-86-2	150	27	–	–	–	–	–	**E60.3**	E51.6	E50.1	–	–	–	Fr	
	acetyl-hexamethyl-tetrahydronaphthalene (AHTN)	21145-77-7	50	9	–	–	–	–	–	–	**E6.83**	–	–	–	–	Fr	
	benzophenone	119-61-9	50	9	–	–	–	–	–	–	**E16.0**	–	–	–	–	Fr	[1]14.2–15.3
	d-limonene	5989-27-5	50	9	–	–	**E40.3**	–	–	–	–	–	–	–	–	HC	[1]0.7
	hexahydrohexamethyl-cyclo-pentabenzopyran (HHCB)	122-05-5	50	27	–	–	–	–	–	–	**E25.4**	–	E12.7	E8.5	–	Fr	
	indole	120-72-9	100	100	**E373**	266	94.9	197	97.4	194	283	E45.7	E18.0	150	E238	Fr	[2]1.00
	nonylphenol, diethoxy- (total,npeo2)	9062-77-5	1,000	27	**E1,200**	–	–	–	–	–	–	–	E272	–	E409	DM	
			Number of detections		17	12	14	11	11	9	16	7	9	14	13	–	
			Total organic carbon content (percent)		2.2	1.9	2.3	3.3	1.1	2.9	2.3	0.5	0.1	1.2	2.0	–	

[1]*pimephales promelas* (fathead minnow) with 96 hour exposure.

[2]*daphnia magna* (water flea) with 48 hour exposure.

[3]U.S. Environmental Protection Agency maximum concentration limit in µg/kg.

[4]*oncorhynchu mykiss* (rainbow trout) with 96 hour exposure.

Personal Care Products

The personal care product skatol, or 3-methyl-1h-indole, was detected in sediment samples from all sites and may be a good indicator of domestic or recreational human effects. Except for the Boise River near Middleton (site B2), skatol concentrations were highest (>30 µg/kg) at sites downstream of municipal WWTPs (sites FM1 and I4). The sediment sample collected from the Boise River below Diversion Dam (site B3), indicative of background conditions, contained seven detections of personal care products. The sediment sample collected from site B3 was the only sample that contained a detectable concentration of triclosan, a personal bactericide and potential endocrine disruptor (Veldhoen and others, 2006). Indian Creek at Sparrow Ave (site I4) contained detectable concentrations of six personal care products, and Tenmile Creek at Franklin Road (site TM1) contained five (table 10).

Summary

Between water years 2009 and 2012, water-quality and bottom-sediment samples were collected in four lower Boise River tributary watersheds including Fivemile, Tenmile, Indian, and Mason Creeks. Three water-quality samples were collected at five to six sampling sites in each tributary during a given year, and were timed to coincide with the beginning of irrigation season, the middle of irrigation season, and the beginning of non-irrigation season. Water-quality samples also were collected at least eight times a year at the Boise River near Parma streamgage. The Boise River near Parma streamgage is near the mouth of the Boise River and serves as a downstream comparison site for water-quality and biological conditions in tributaries. Bottom-sediment samples were analyzed for contaminants of emerging concern and were collected at selected tributary sites and at one of three sites in the lower Boise River on an annual rotation. Water-quality monitoring was expanded at Mason Creek near the mouth during 2011 and 2012 to include a streamgage, a continuous temperature and turbidity monitor, and monthly sample collection. Expanded monitoring efforts in Mason Creek near the mouth provided data necessary to complete regression analysis of water-quality parameters (surrogates) and their relation to constituents of interest including total nutrients and suspended sediment. Surrogate regression models were used to estimate concentrations and loads of constituents of interest at 15-minute and daily time-scales.

Watershed-wide water-quality sample results from each tributary showed that most constituent loading can occur over relatively short reaches in the watershed and that irrigation practices influence load distribution and discharge in specific reaches. The addition of point-source wastewater treatment effluent substantially increased nutrient concentrations and loads in Indian and Fivemile Creeks, whereas nonpoint-source return flows increased nutrient and suspended-sediment loads in Mason Creek.

The expanded dataset and resulting surrogate regression models from Mason Creek showed that daily variability in estimated concentrations of total nitrogen, total phosphorus, and suspended sediment cannot be captured using discrete monthly sampling events. The suspended sediment regression model was also useful for evaluating compliance with a 120-day average suspended-sediment target of 20 milligrams per liter. Surrogate regression models generally performed better than other models when estimating constituent concentrations.

Biological samples for periphyton biomass and chlorophyll-*a*, benthic macroinvertebrates, and fish were collected in Mason Creek once during non-irrigation season in 2011. Mason Creek sampling results showed low periphyton biomass and chlorophyll-*a* concentrations compared to those historically measured in the Boise River near Parma during October and November. The invertebrate community at Mason Creek was dominated by the invasive New Zealand mudsnail (*Potamopyrgus antipodarum*). Three age classes of rainbow trout were found in Mason Creek at Wells Road. Most of the fish species collected are native, cool or coldwater species and categorized as sensitive or intolerant to pollution; however, other species collected are considered warm-water and pollution tolerant species including suckers, a minnow, and a loach.

Bottom-sediment samples were collected from selected tributary and lower Boise River sites and analyzed for 61 organic wastewater compounds. Detected compounds were grouped into four categories: urban, industrial, fecal steroids, and personal care products. Agricultural pesticides were not detected in the bottom-sediment samples. Pesticides used in urban pest control and personal repellents, which are under the urban and personal care product categories, also were not detected. Relatively high concentrations of compounds in one or more of the four categories were detected at upstream sites in sampled tributaries and the lower Boise River, indicating that adjacent land use may be an important factor determining concentrations of wastewater indicator compounds in bottom sediment. The Boise River near Parma integrates influences from land uses in the entire Boise River watershed. Concentrations from bottom-sediment samples collected near Parma were not as high as some upstream sites.

Acknowledgments

The authors thank the Boise Field Office staff and data management staff of the USGS Idaho Water Science Center for assistance with fieldwork and data compilation over the duration of the study. Special thanks go to Mark Hardy, Christopher Mebane, and Gregory Clark for their technical advice throughout the data analysis and writing of this report, and to Dorene MacCoy, who managed the lower Boise River studies in previous years.

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Appendixes

Appendixes A–C are available for download at http://pubs.usgs.gov/sir/2014/5132.

Appendix A. Aquatic Macroinvertebrate Density, Traits, and Community Metrics for Mason Creek, Southwest Idaho

Appendix A contains Stream Macroinvertebrate Index (SMI) scores, invertebrate densities, and associated traits for the macroinvertebrate sample collected from Mason Creek at Wells Road (site M2). Scores are not provided for Fivemile or Tenmile Creeks because invertebrate samples were not representative of conditions when the stream was actively flowing.

Appendix B. Tributary Monitoring Site Photographs

Appendix B includes 360-degree panoramic photographs taken at each tributary monitoring site in Fivemile, Tenmile, Indian, and Mason Creeks.

Appendix C. Continuous 24-Hour Water-Quality Monitoring, Water-Quality, and Biological Samples Collected During a 24-Hour Period in Selected Tributaries, August 2012

Appendix C provides results of a short-term study completed at nine tributary sites in August 2012. A continuous water-quality monitor was installed at each site and set up to log 15-minute readings of temperature and dissolved oxygen for 24 hours. Figures show a time-series plot of temperature and dissolved oxygen over the 24-hour monitoring period. Stream discharge was measured and water-quality and biological samples were collected at each site. Water-quality samples were analyzed for total phosphorus, total dissolved phosphorus, dissolved orthophosphorus as phosphorus, suspended sediment, and percentage of fine-grained suspended sediment. Biological samples were analyzed for chlorophyll-*a* in periphyton and periphyton biomass. The chlorophyll-*a* extraction method also provided results for pheophytin-*a* in periphyton. Instantaneous loads were calculated for total phosphorus, total dissolved phosphorus, dissolved orthophosphorus as phosphorus, and suspended sediment.

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

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Ethereidge and others—**Water-Quality and Biological Conditions in Selected Tributaries, Lower Boise River, Southwestern Idaho, Water Years 2009–12**—Scientific Investigations Report 2014–5132

ISSN 2328-0328 (online)
http://dx.doi.org/10.3133/sir20145132