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Chemical and Biological Quality of Surface Water at the U.S. Army Atterbury Reserve Forces Training Area near Edinburgh, Indiana, September 2000 through July 2001

By Martin R. Risch

Prepared in cooperation with the Indiana Army National Guard

Water-Resources Investigations Report 03-4149

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Conversion Factors, Vertical Datum, and Acronyms

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.004047	square kilometer (km^2)
gallon per minute (gal/min)	3.7856	liter per minute (L/min)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile ($ft^3/s/mi^2$)	0.01093	cubic meter per second per square kilometer ($m^3/s/km^2$)
micrometer or micron (µm)	0.000039	inch (in.)
liter (L)	0.2642	gallon (gal)
milliliter (mL)	0.03382	ounce, fluid (oz)
gram (g)	0.03527	ounce (oz)

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

$$°F = 1.8 \times °C + 32$$

Vertical Datum: In this report, vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Abbreviated concentration units used in this report (including appendixes): Chemical concentrations are given in metric units, milligram per kilogram (mg/kg), microgram per kilogram (µg/kg), milligram per liter (mg/L), or microgram per liter (µg/L). Milligram or microgram per kilogram is a unit expressing the concentration of a chemical in a solid as weight (milligram or microgram) of the chemical per unit weight (kilogram) of soil. One mg/kg is equal to 1,000 µg/kg. Milligram or microgram per liter is a unit expressing the concentration of a chemical in solution as weight (milligram or microgram) of the chemical per unit volume (liter, L) of water. For concentrations less than 7,000 mg/kg, the numerical value is the same as for concentrations in parts per million; one µg/kg is equivalent to one part per billion. Concentrations of bacteria are given in colonies per 100 milliliters (col/100 mL).

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

Nephelometric turbidity unit (NTU) is the unit of measurement for reporting turbidity that is based on use of a standard suspension of Formazin. Turbidity measured in NTU uses nephelometric methods that depend on passing light of a specific wavelength through the sample.

Radioactivity is expressed in picocurie per liter (pCi/L). A picocurie is one-trillionth (1×10^{-12}) the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second. A picocurie yields 2.22 disintegrations per minute.

Volumes of water-quality samples are given in liter (L) and milliliter (mL).

Acronyms used in this report:

Acronym	Description
EPT	Ephemeroptera, Plecoptera, Trichoptera
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
MIWB	Modified Index of Well-Being
NAWQA	National Water-Quality Assessment
QHEI	Qualitative Habitat Evaluation Index
RPD	Relative Percent Difference
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Chemical and Biological Quality of Surface Water at the U.S. Army Atterbury Reserve Forces Training Area, near Edinburgh, Indiana, September 2000 through July 2001

By Martin R. Risch

Abstract

A base-wide assessment of surface-water quality at the U.S. Army Atterbury Reserve Forces Training Area near Edinburgh, Indiana, examined short-term and long-term quality of surface water flowing into, across, and out of a 33,760-acre study area. The 30-day geometric-mean concentrations of fecal-indicator bacteria (*Escherichia coli*) in water samples from all 16 monitoring sites on streams in the study area were greater than the Indiana recreational water-quality standard. None of the bacteria concentrations in samples from four lakes exceeded the standard. Half the samples with bacteria concentrations greater than the single-sample standard contained chemical tracers potentially associated with human sewage. Increased turbidity of water samples was related statistically to increased bacteria concentration. Lead concentrations ranging from 0.5 to 2.0 micrograms per liter were detected in water samples at seven monitoring sites. Lead in one sample collected during high-streamflow conditions was greater than the calculated Indiana water-quality standard. With the exception of *Escherichia coli* and lead, 211 of 213 chemical constituents analyzed in water samples did not exceed Indiana water-quality standards. Out of 131 constituents analyzed in streambed-sediment and fish-tissue samples from three sites in the Common Impact Area for weapons training, the largest concentrations overall were detected for copper, lead, manganese, strontium, and zinc. Fish-community integrity, based on diversity and pollution tolerance, was rated poor at one of those three sites. Compared with State criteria, the fish-community data indicated 8 of 10 stream reaches in the study area could be categorized as "fully supporting" aquatic-life uses.

Introduction

The U.S. military has been obtaining assessments of water quality at its training areas nationwide. In some cases, the assessments are tied to regulatory requirements, while in other cases, they provide information about emerging or undiscovered environmental concerns. The assessments typically include a special evaluation of firing and bombing ranges for potential effects on surface-water or ground-water quality. The U.S. Geological Survey (USGS) has a history of providing water-quality investigations for the military through its Department of Defense Environmental Conservation Program.

The U.S. Army Atterbury Reserve Forces Training Area (known as Camp Atterbury) in central Indiana near Edinburgh has been used by the Army and the National Guard for more 50 years. The Indiana Army National Guard needed a baseline of information about the effects of training activities on water quality at Camp Atterbury. The Guard requested the USGS to provide an assessment of the chemical and biological quality of surface water flowing into, across, and out of Camp Atterbury, with a more extensive evaluation near the firing and bombing ranges used for weapons training of ground and air troops. This study by

the USGS during September 2000 through July 2001 was the first surface-water-quality assessment ever made at Camp Atterbury.

The objectives of the study were to

- Make a base-wide assessment of the short-term and the long-term surface-water-quality conditions;
- Evaluate potential effects of military training on surface-water quality in and near the Common Impact Area of the firing and bombing ranges;
- Monitor base-wide surface water for fecal-indicator bacteria during various flow conditions;
- Explore potential relations between fecal-indicator-bacteria concentrations, water quality, and streamflow;
- Identify water-quality constituents and locations that would aid in long-term monitoring of surface water at Camp Atterbury.

Purpose and Scope

This report presents streamflow, chemical, and biological data from USGS surface-water assessments and monitoring at Camp Atterbury during 2000 and 2001. Data were collected during three time periods. Methods, data, and interpretations in the report, however, are organized according to the type of information (streamflow, chemical, or biological) rather than chronological order or geographic location. The number and types of streamflow, chemical, and biological data for each time period follow:

(1) **September and October 2000.** Chemical and biological data were collected during low-streamflow conditions at 13 stream sites and 3 lake sites. Instantaneous streamflow was measured at the 13 stream sites. The chemical data included analyses of 16 surface-water samples, 7 streambed-sediment samples, and 10 fish-tissue samples. Analytical constituents included 9 water-quality characteristics and physical properties, 17 major ions and nutrients, 20 trace elements, 14 explosives, and 137 volatile or semivolatile organic compounds. The biological data included fish-community inventories from 10 stream reaches and 2 lakes, benthic-macroinvertebrate-community inventories at 13 stream reaches, and qualitative habitat evaluations of the same 13 stream reaches.

(2) **May and June 2001.** During a 30-day period, *Escherichia coli* (*E. coli*) concentrations, five water-quality characteristics, and instantaneous streamflow were measured five times at 16 stream sites and 4 lake sites. A total of 100 surface-water samples and 30 quality-assurance samples were analyzed for *E. coli* concentrations. A total of 23 water samples from 13 stream sites were analyzed for 66 wastewater tracers.

(3) **July 2001.** Chemical and streamflow data were collected during 2 days of high-streamflow conditions at six stream sites near and in the Common Impact Area. The chemical data included analyses of 9 water-quality characteristics and physical properties, 17 major ions and nutrients, 20 trace elements, 14 explosives, and 92 semivolatile organic compounds.

Acknowledgments

The author gratefully acknowledges the contributions of Lieutenant Colonel Richard Jones, Supervisory Environmental Protection Specialist with the Indiana Army National Guard, who provided valuable guidance and technical input for the design and implementation of this study. The author and USGS field personnel greatly appreciate the assistance of Master Sergeant Russell Reichart, Camp Atterbury Range Control Officer, who coordinated scheduling and logistics and personally assured our safety during many long days of data collection near and in the Common Impact Area. Thanks also to Art Howard, the Camp Atterbury Land Conditions Trends Analysis manager, who helped with site reconnaissance and watercraft access, and to Lara Coutinho of the Camp Atterbury Environmental Office, who helped with site reconnaissance and fish-community sampling.

Description of the Study Area

Physical setting, geology, physiography, soils, and climate of the study area are based on maps and references in Schnoebelen and others (1999) that describe the environmental setting and natural factors affecting water quality in the White River Basin, Ind. Unpublished data sets for the study area, compiled in the National Guard's geographic information system (GIS) for Camp Atterbury, supplement the descriptions of geology, soils, hydrology, and land cover in this section of the report.

History and Physical Setting

Camp Atterbury was a 40,320-acre U.S. Army installation from 1942 through 1968. The installation was a troop-training, military-hospital, and prisoner-of-war facility during World War II. The installation was deactivated from 1948 through 1950 and again in 1954 after the Korean Conflict. In 1968 and 1969, approximately 7,000 acres were sold and the remaining U.S. Army property was redesignated the Atterbury Reserve Forces Training Area. The installation then was placed under the control of the Indiana Army National Guard (Indiana National Guard, 1995).

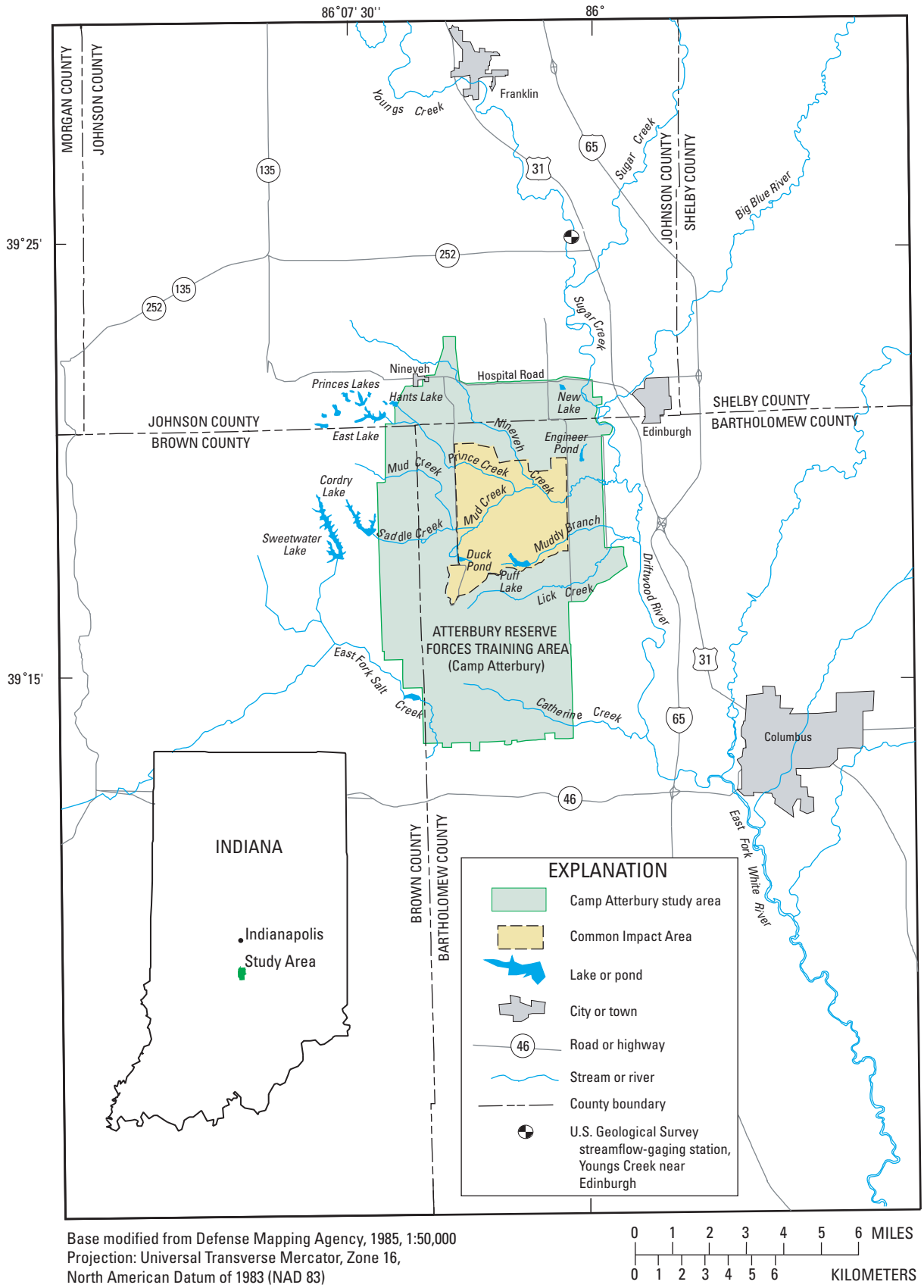
The mission of Camp Atterbury is to support individual and unit training of the National Guard, as well as training of the active and other reserve forces of the U.S. military. The year-round training areas and facilities support firing of individual and crew-served weapons, artillery, mortars, tanks, and wheeled fighting vehicles; maneuvers and qualifications for specialized units and vehicles; helicopter air-assault and parachute operations; gunnery and bombing practice for jet aircraft of the Indiana Air National Guard and Air Force Reserve; and training for emergency teams and law-enforcement officers of Federal, State, and local government.

The study area for the surface-water-quality assessment at Camp Atterbury covered approximately 33,760 acres[a], spanning about 4 to 6.5 mi by 9.5 mi (fig. 1). The central part of the study area contained the approximately 6,300-acre Common Impact Area[a] (called Impact Area in this report), that includes the weapons-firing ranges and the aerial gunnery and bombing ranges. Most of the study area is in Bartholomew County; a part of the northern boundary is in Johnson County; and a part of the western boundary is in Brown County. Nearby transportation routes include State Road 252 to the north, U.S. Highway 31 to the east, State Road 46 to the south, and State Road 135 to the west.

Camp Atterbury is in central Indiana about 30 mi south of Indianapolis (fig. 1). Nearby cities and towns include Edinburgh (population 4,505), less than 3 mi east; Nineveh, less than 1 mi northwest; Franklin (population 19,463), about 10 mi north; and Columbus (population 39,059), about 6 mi southeast (Indiana Business Research Center, 2000). Small, rural communities surround Princes Lakes, Cordry Lake, and Sweetwater Lake along the western boundary. The 1990 population density of the rural communities near Camp Atterbury was 100 to 800 people/mi^2 (Indiana Business Research Center, 2000).

Land cover in the study area was forest and woodland (53 percent), shrubland (24 percent), and grassland (15 percent); the remaining land cover was sparsely vegetated or water (unpublished data, Indiana Army National Guard, 2002, Geographic Information System [GIS] for Camp Atterbury). Developed land in the northern part of the installation included firing ranges, training areas, an airport, support facilities, and barracks; in the southwestern part of the installation was a multipurpose training range.

[a]Area computed from maps of Camp Atterbury training areas and installation boundary (unpublished data, Indiana Army National Guard, 2002, Geographic Information System for Camp Atterbury), converted from square meters to acres by multiplying with a conversion factor of 0.0002471 acres per square meter.



Base modified from Defense Mapping Agency, 1985, 1:50,000
Projection: Universal Transverse Mercator, Zone 16,
North American Datum of 1983 (NAD 83)

Figure 1. Study area and surrounding region, Camp Atterbury near Edinburgh, Indiana.

Topography, Physiography, Geology, and Soils

The surface topography of Camp Atterbury includes flat to gently rolling terrain in the north and northeast to steep, hilly terrain in the south and southwest. Terrain along Nineveh Creek and the Driftwood River in the east is lowland flanked by terraces. The land-surface altitude ranges from about 650 ft near the eastern border to 910 and 930 ft near the southwestern corner. Altitude in the central part ranges from 740 to 820 ft (Defense Mapping Agency, 1985).

The study area primarily is in the Norman Upland physiographic unit as originally defined by Malott (1922), with the northeastern part in the Scottsburg Lowland (fig. 2). The Norman Upland has westward-sloping, unglaciated upland areas with narrow ridge tops and steep slopes. The Scottsburg Lowland is an area of low relief and extremely broad, flat valleys.

The surface geology of the study area affects topography, runoff, and surface-water quality. From west to east, the surface geology (fig. 3) includes sandstone, shale, and limestone bedrock; sandy loam and loam till; and a stream corridor with alluvium and undifferentiated outwash (Gray, 1989). The advance of the Wisconsinan glaciation extended into the northern third of the study area. Thickness of the unconsolidated deposits ranges from zero to 100 ft (Gray, 1983).

Much of the study area is underlain by siltstone and limestone of the Borden Group (Gray and others, 1987). The eastern edge of the study area is underlain by the New Albany Shale, a black and greenish gray shale formation. Age of bedrock beneath the study area is shown in figure 4. The bedrock structure primarily is affected by the Illinois Basin; sedimentary strata dip westward and south-westward, with a slope of 10 to 30 ft/mi (Gutschick, 1966).

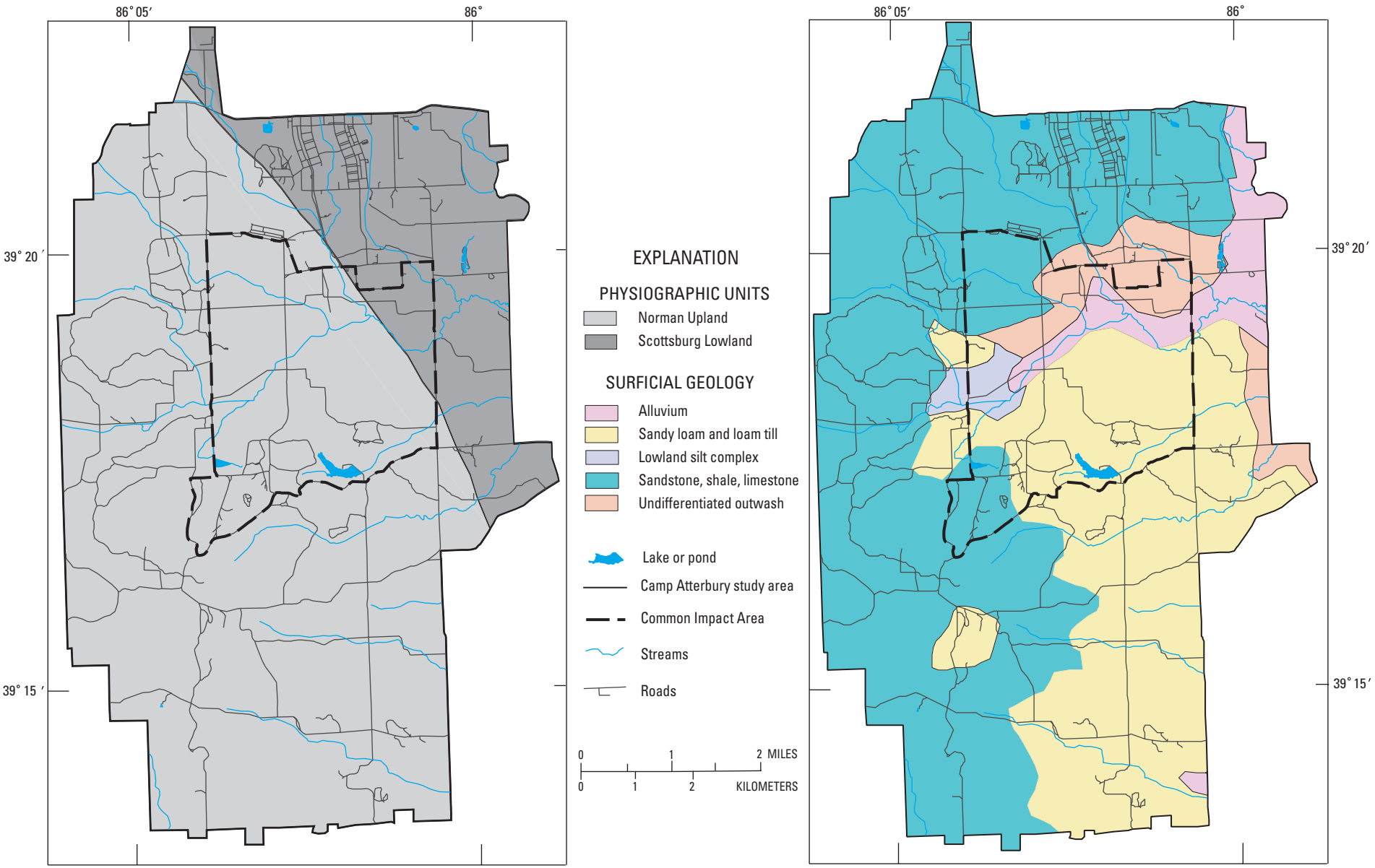
The soil regions of the study area are related to the surface geology near land surface. Six soil regions are present, classified by parent material, natural vegetation, and topography (Franzmeier and others, 1989). From west to east, the soil regions include discontinuous loess over bedrock; thin or moderately thick loess over loamy glacial till, lacustrine deposits, or weathered till; outwash; and alluvium (fig. 5).

According to the soil survey that includes much of Camp Atterbury (Noble and others, 1990), numerous soil types—based on texture, slope, and drainage—were mapped. The soil types were grouped into soil associations with similar characteristics. Two soil associations are present in the Impact Area. The Pekin-Chetwynd-Bartle association primarily consists of fine-textured soils on sloping terraces and steep hillsides. This soil association is characterized as poorly drained on relatively level ground to well drained on steep slopes. Surface runoff is rapid, and infiltration is low on steep slopes. The Crosby-Miami-Rensselaer association primarily consists of fine-textured soils on upland terraces to sloping hillsides. This soil association is characterized as poorly drained to very poorly drained. Infiltration is slow because of low-permeability soil texture or impermeable subsoils. This soil information indicates much of the precipitation on the Impact Area either runs off rapidly or infiltrates slowly. In some areas, the infiltration is intercepted by subsurface drains and diverted to surface water.

Climate

The study area has a humid continental climate, characterized by distinct winter and summer seasons with large annual temperature ranges. Mean monthly temperatures at Columbus, Ind., about 6 mi southeast of the study area, range from about 27°F in January to about 75°F in July. At Columbus, mean annual precipitation is 44 in., and mean monthly precipitation ranges from about 2.1 in. for December to about 4.5 in. for May and July (National Weather Service, 1997).

Midwestern Regional Climate Center (2002) precipitation data were summarized for the study area during the base-wide assessment. Rainfall in September and October 2000 was average. About 1.5 in. of rain fell September 5 through 19, 2000; no rain fell on the days of sample collection. About



Base modified from Defense Mapping Agency, 1985, 1:50,000
Projection: Universal Transverse Mercator, Zone 16,
North American Datum of 1983 (NAD 83)

Figure 2. Physiographic units of Camp Atterbury study area near Edinburgh, Indiana.

Base modified from Defense Mapping Agency, 1985, 1:50,000
Projection: Universal Transverse Mercator, Zone 16,
North American Datum of 1983 (NAD 83)

Figure 3. Surficial geology of Camp Atterbury study area near Edinburgh, Indiana.

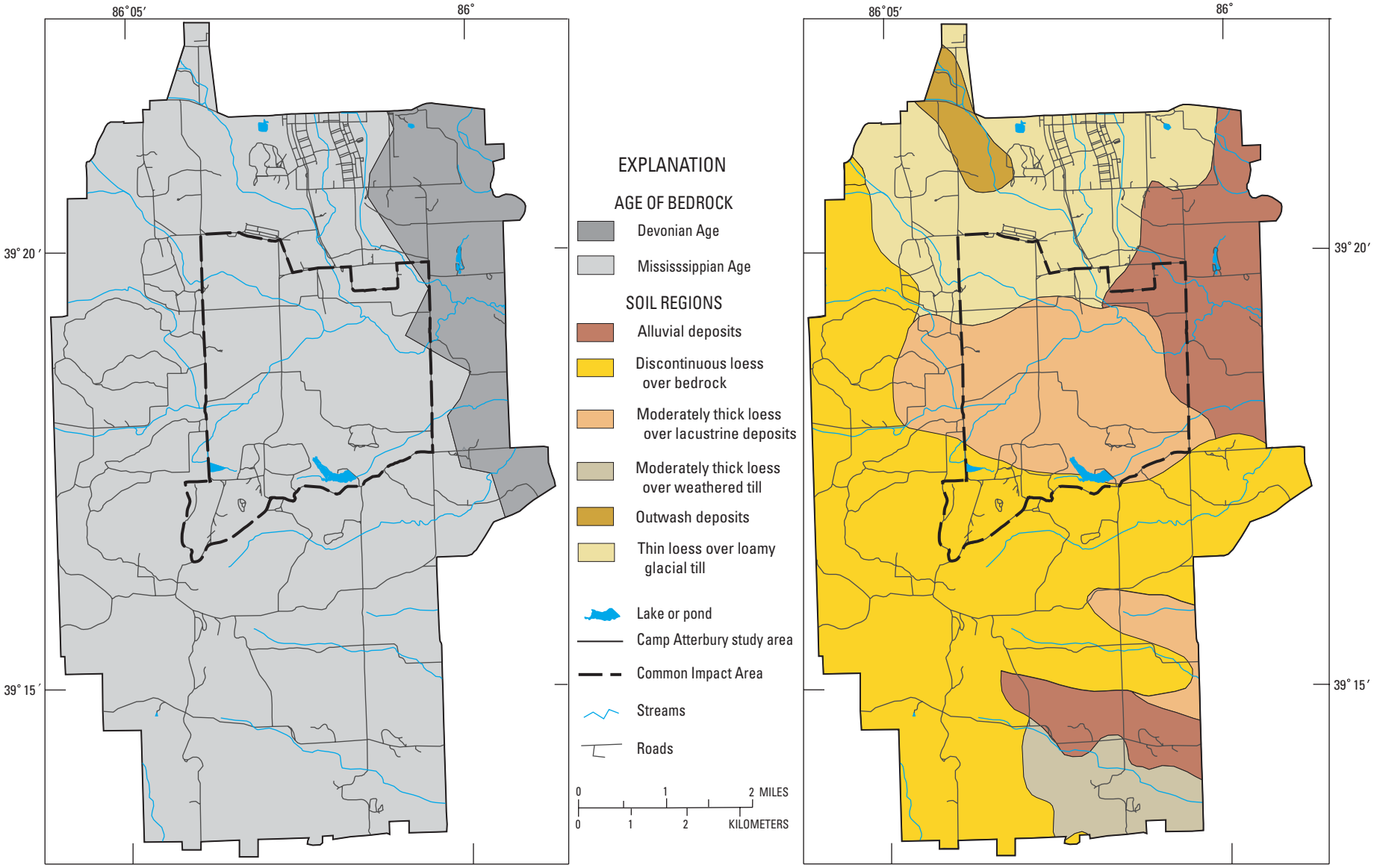


Figure 4. Age of bedrock beneath Camp Atterbury study area near Edinburgh, Indiana.

Figure 5. Soil regions of Camp Atterbury study area near Edinburgh, Indiana.

2.5 in. of rain fell in the week prior to the last sample collection in September. No rain fell on the days of data collection in October. During stream monitoring in May and June 2001, rainfall was average: about 2 in. of rain fell the second week; 1.5 in. fell the fourth week; 3 weeks were dry. During the first week of July 2001, from 2.5 to 3.0 in. of rain fell, which was 300 percent of the mean for that period.

Hydrology

The study area (fig. 1) is in the East Fork White River Basin. The drainage area of the Driftwood River near Edinburgh, Ind., is 1,060 mi^2 (Schnoebelen and others, 1999); the river is popular for boating and fishing. According to hydrologic units in the GIS for Camp Atterbury (unpublished data, Indiana Army National Guard, 2002), more than 90 percent of the study area drains eastward to the Driftwood River. Less than 10 percent of the study area, in the southwestern corner, drains to the East Fork Salt Creek. The largest stream in the study area is Nineveh Creek, with a drainage area[b] of approximately 44 mi^2. Nineveh Creek originates upstream from the study area and is joined by three tributaries inside Camp Atterbury, including Prince Creek and Mud Creek. All the streams in the study area, with the exception of Nineveh Creek, are first-order streams with drainage areas[b] less than 10 mi^2. Headwaters of Lick Creek, Muddy Branch, and Catherine Creek are inside the study area; drainage areas[b] range from 2 to 6 mi^2. Four constructed lakes in the study area are used for boating, fishing, or swimming by military personnel—Puff Lake; Duck Pond; Engineer Pond; and a new, unnamed lake called New Lake in this report. Large, constructed lakes with residential communities are upstream from the study area and include Princes Lakes, East Lake, Hants Lake, and Cordry Lake.

[b]Drainage area estimated with data from Hoggatt (1975) and U.S. Geological Survey 7.5-minute topographic maps.

During this study, the Princes Lakes wastewater-treatment facility, which serves Camp Atterbury and nearby residential communities, had a permitted outfall to the Driftwood River upstream from the confluence of Nineveh Creek and the Driftwood River. No permitted outfalls were on Nineveh Creek upstream from or inside the study area (U.S. Environmental Protection Agency, 2001). The training areas in Camp Atterbury not connected to the Princes Lakes wastewater-treatment facility were served by vault or chemical toilets. During this study, Camp Atterbury was served by the Princes Lakes public water-supply system, which obtained water from wells in the river valley northeast of the study area.

According to the Indiana Department of Environmental Management (2000), 15.8 mi of the Driftwood River and 62.3 mi of its tributaries were assessed in 1999 for support of full-body-contact recreational use and aquatic-life uses defined in the Indiana water-quality standards (Indiana Water Pollution Control Board, 2001). Data were not collected in Camp Atterbury. (The assessment methods are discussed in the Chemical and Biological Assessments section of this report.) The Driftwood River and its tributaries were rated by Indiana Department of Environmental Management (IDEM) as fully supporting aquatic-life uses. The Driftwood River was rated as partially supporting recreational use because of fecal-indicator bacteria *(E. coli)*. The tributaries were not assessed for *E. coli*.

Ground water was not directly evaluated in the study described in this report. A generalized description of the hydrogeology of the study area was based on Fenelon, Bobay, and others (1994). Three aquifer types are present in the study area—surficial sand and gravel aquifers, a weathered bedrock surface that yields small quantities of water, and a deep carbonate bedrock aquifer. Within the glaciated part of the study area, where present, the surficial sand and gravel aquifers are expected to be the most appreciable sources of ground water.

The sand and gravel aquifers usually may occur in more than one horizontal layer in glacial deposits up to 100 ft thick. Clay layers form confining units above or between aquifers. The weathered bedrock surface at depths to 150 ft can supply water at rates less than 5 gal/min. The carbonate bedrock aquifer can be found throughout the study area at depths from 100 to 500 ft and can supply water at rates of 10 to 50 gal/min. In the unglaciated part of the study area, the bedrock aquifers are expected to be the most appreciable sources of ground water.

The following discussion of ground-water and surface-water interaction is based on Schnoebelen and others (1999). Where glacial deposits more than 50 ft thick contain aquifers that discharge water to streams, these streams have a sustained base flow during dry weather. Where glacial deposits are thin or absent, more steeply sloping topography is present. The steep slopes promote surface runoff in which precipitation moves quickly over the land surface (rather than through the soil or ground water) to reach the streams. Where steep slopes, thin glacial deposits, or bedrock with a limited water-yielding capacity are present, less water is contributed to base flow during dry weather. On the basis of this discussion, in general, Nineveh Creek, Prince Creek, and Mud Creek have a greater capacity for sustained base flow in dry weather than Lick Creek, Muddy Branch, or Catherine Creek. Stream base flow sustained by discharge from aquifers may be supplemented in some parts of the study area by discharge from tile drains and seep springs.

Study Methods

This section explains the study design and selection of monitoring sites and constituents. The methods for the chemical assessment are described, including collection, analysis, and quality assurance of water, streambed-sediment, and fish-tissue samples. The methods for the biological assessment are described, including those for microbiological determinations, fish-community and benthic-macroinvertebrate-community inventories, qualitative habitat evaluations, and calculation of numerical indexes of biotic integrity.

Study Design

This study was designed to assess the base-wide quality of surface water flowing into, across, and out of Camp Atterbury, with a more extensive evaluation of water quality at the Impact Area. Monitoring sites and constituents were selected according to the study objectives.

Conceptual Model of Hydrogeology and Contaminant Transport

The study design, especially for the evaluation of the Impact Area, was based on a conceptual model of hydrogeology and contaminant transport at Camp Atterbury (fig. 6). Above ground, precipitation falls and then moves as overland runoff to streams and lakes in a watershed. Surface-water contaminants are transported in the water or adsorbed to suspended particles of inorganic or organic material in the water. Particles with adsorbed contaminants accumulate in streambed sediments or re-suspend during high streamflow. Below ground, water moves vertically from the land surface through the unsaturated zone and, where present, through low-permeability layers (confining units) to recharge water in glacial or bedrock aquifers. In some areas, shallow ground-water contaminants are transported to streams or lakes by tile drains and seep springs. Ground water moves vertically and horizontally through aquifers in a local flow system and discharges to streams or lakes. In dry weather, streamflow and lake levels are maintained by ground-water discharge. Ground-water contaminants discharge to streams or lakes through the bed sediments or they accumulate in the sediments.

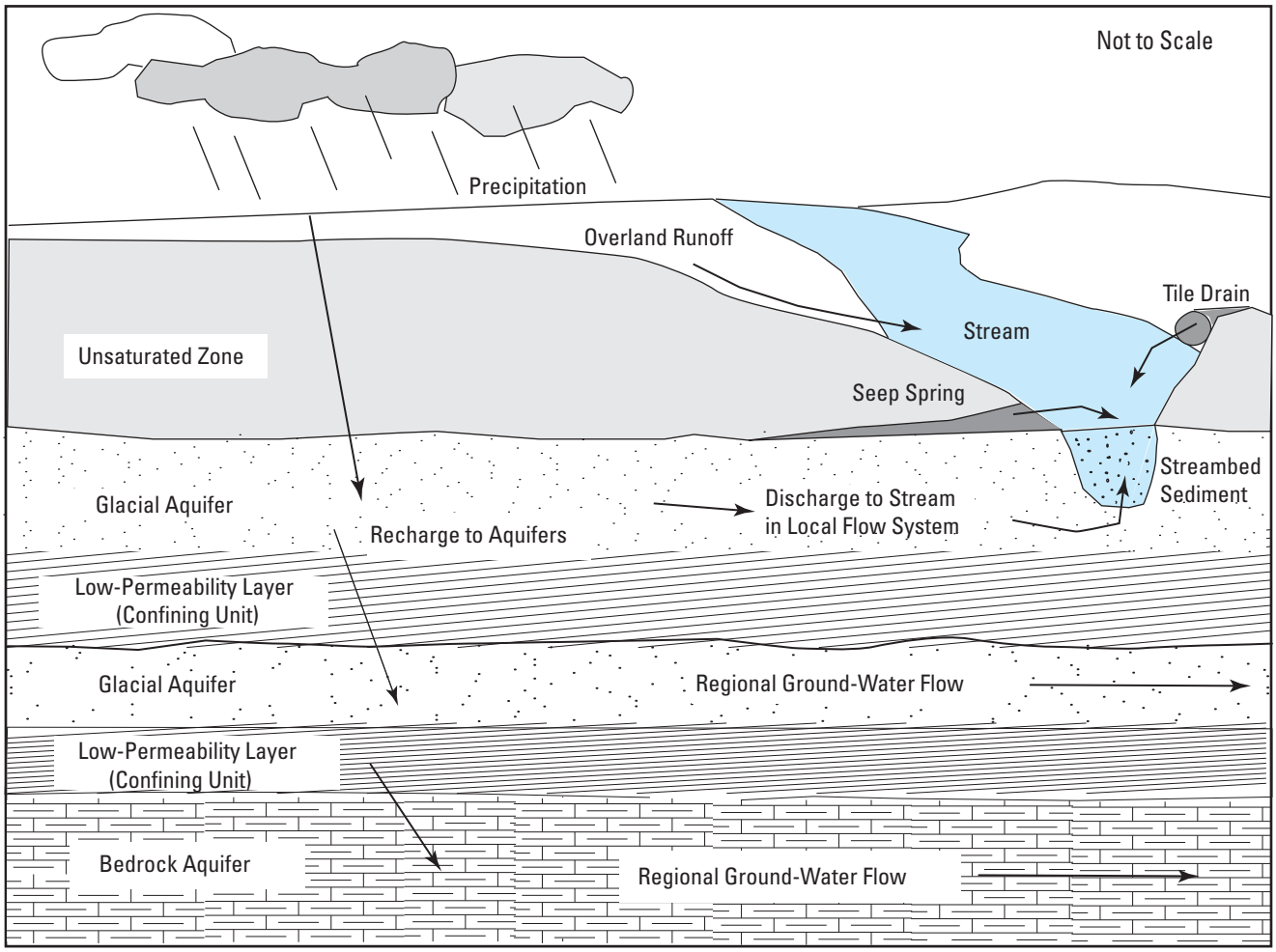


Figure 6. Cross-section diagram of conceptual model for hydrogeology and contaminant transport at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001.

Based on the conceptual model, the following assumptions were made.

- Chemical quality of surface water during low streamflow would indicate areas with substantial ground-water contamination in shallow glacial or bedrock aquifers.
- Chemical quality of surface water during high streamflow would indicate substantial contamination in overland runoff and discharge from tile drains and seep springs.
- Chemical quality of streambed sediment would indicate ground-water or surface-water contamination during a range of streamflow conditions.
- Regional ground-water-flow systems are the least likely to transport contaminants.

Chemical and Biological Assessments

The Camp Atterbury study used chemical and biological assessments to evaluate short-term (weeks) and long-term (years) water-quality conditions. Water samples were collected for

chemical and microbiological analysis to evaluate short-term water quality during dry-weather/low-streamflow conditions and wet-weather/high-streamflow conditions. Streambed-sediment and fish-tissue samples were collected for chemical analysis to evaluate long-term water quality during a range of streamflow conditions. Fish and benthic-macroinvertebrate communities were inventoried as indicators of long-term water quality because chronic exposure to contaminants in water or sediment can affect their numbers, diversity, or health. The chemical and biological assessment in this study was consistent with the approach used by the USGS National Water-Quality Assessment Program (NAWQA) in the White River Basin, Ind., and with methods used by IDEM (2000) to determine if streams in the White River Basin, Ind., support their designated use and meet water-quality standards.

Selection of Monitoring Sites

Monitoring sites were selected to address the study objectives of base-wide assessment, evaluation of the Impact Area, and *E. coli* monitoring. Sites were located in seven watersheds in Camp Atterbury (Nineveh Creek, Prince Creek, Mud Creek, Saddle Creek, Muddy Branch, Lick Creek, and Catherine Creek) and four lakes (Puff Lake, Duck Pond, Engineer Pond, and New Lake). Sites in the watersheds were selected to characterize water quality upstream and downstream from points of stream confluence. Sites on the lakes generally were related to areas of recreational use. Locations (fig. 7) and characteristics of the 27 monitoring sites are described in tables 1 and 2.

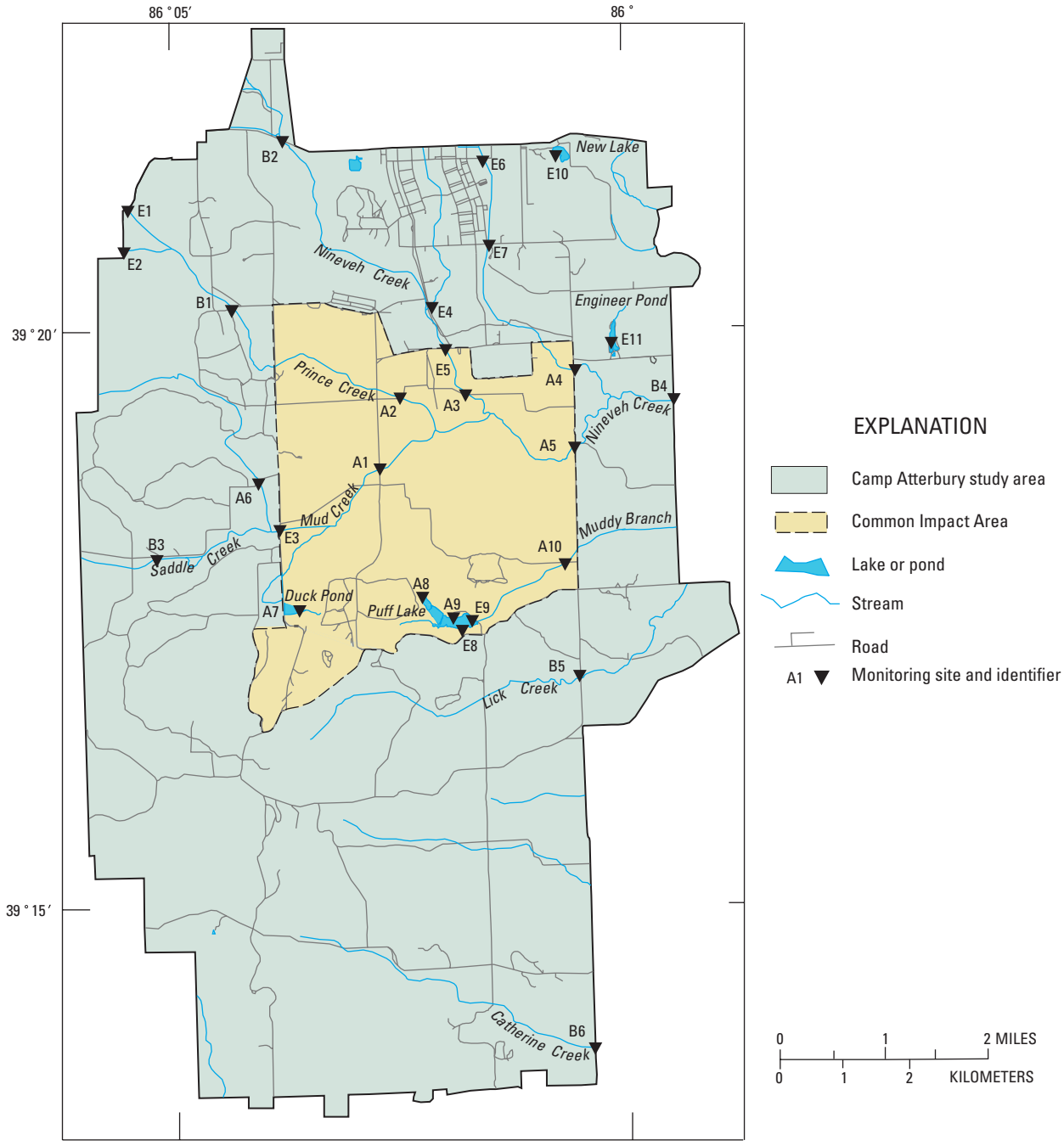
Six stream sites were selected for the base-wide assessment during September 2000—B1, B2, and B3 on the upstream side and B4, B5, and B6 on the downstream side of the study area. Seven stream sites were selected for an evaluation of the Impact Area during September 2000—sites A1, A2, and A3 inside the Impact Area; A4, A5, and A10 on the downstream side. The seventh site (A6) was on the upstream side of the Impact Area but also was the upstream site for Camp Atterbury in the Mud Creek Watershed. Two lakes were selected because they received ground-water discharge or overland runoff primarily from the Impact Area—Duck Pond (A7) and Puff Lake. The headwater pond of Puff Lake (A8) and the main body of Puff Lake (A9) were separate monitoring sites because the headwater pond was isolated from the open water of the main body by an earthen dam and by extensive aquatic vegetation. Further evaluation of the Impact Area was done at six stream sites during July 2001—B1 and E5 upstream from the Impact Area and A4, A5, A10, and B5 downstream from the Impact Area.

For *E. coli* monitoring during May through June 2001, 16 stream sites and 4 lake sites were selected. Nine of the stream sites were described previously (B1, B2, B3, B4, B5, A4, A5, A6, and A10). Among the other seven stream sites (E1 through E7), two were at the outlets of Hants Lake (E1) and East Lake (E2) at Prince Creek (fig. 1).

Sites E3, E4, and E5 were near stream confluences, and two sites (E6 and E7) were upstream and downstream from a potential sewer overflow near an unnamed tributary to Nineveh Creek. The four lake sites (selected because of the potential for full-body-contact recreation) include E8 and E9 on Puff Lake, E10 at the swimming beach on New Lake, and E11 on Engineer Pond.

Instantaneous-Streamflow Measurements

The amount of water transported in a stream can affect water quality and contaminant transport. In this report, streamflow was used to describe the volume flow rate of water in cubic feet per second. Instantaneous streamflow was reported because no continuous streamflow-record gaging stations were in the study area. Measurements were made with a current meter and methods adopted by the USGS as described in Rantz and others (1982), Carter and Davidian (1968), Buchanan and Somers (1969), Laenen (1985), and Smoot and Novak (1968). Current velocities, stream depths, and stream width were measured at a stream cross section near the monitoring sites immediately after sampling was completed. The data on current velocity, stream depth, and stream width were used to calculate the instantaneous streamflow.



Base modified from Defense Mapping Agency, 1985, 1:50,000
Projection: Universal Transverse Mercator, Zone 16,
North American Datum of 1983 (NAD 83)

Figure 7. Monitoring sites for assessment of surface-water quality at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001.

Table 1. Description of monitoring sites for assessment of surface-water quality at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001

Monitoring site (figure 7)	Site name	Scope of monitoring	Site location and purpose
B1	Prince Creek at Wilder Road	Base wide	Upstream from much of Camp Atterbury; downstream from Princes Lakes community; assess chemical and microbiological quality of water entering Impact Area
B2	Nineveh Creek at Hospital Road	Base wide	Upstream from Camp Atterbury; downstream from town of Nineveh; assess chemical and microbiological quality of water entering Camp Atterbury
B3	Saddle Creek at Mount Moriah Road	Base wide	Upstream from much of Camp Atterbury; downstream from Cordry Lake community; assess chemical and microbiological quality of water entering Camp Atterbury
B4	Nineveh Creek at Wallace Road	Base wide	Downstream from Camp Atterbury; assess chemical and microbiological quality of water leaving Camp Atterbury
B5	Lick Creek at Mauxferry Road	Base wide	Stream originates in Camp Atterbury; assess chemical and microbiological quality of water leaving Camp Atterbury
B6	Catherine Creek at Reservation Boundary Road	Base wide	Stream originates in Camp Atterbury; downstream from new multi-purpose training range; assess chemical quality of water leaving Camp Atterbury
A1	Mud Creek in Impact Area	Impact Area	Upstream from confluence with Prince Creek; assess chemical quality of water inside Impact Area
A2	Prince Creek in Impact Area	Impact Area	Upstream from confluence with Mud Creek; assess chemical quality of water inside Impact Area
A3	Nineveh Creek in Impact Area	Impact Area	Upstream from confluence with Mud Creek; assess chemical quality of water inside Impact Area
A4	Unnamed tributary to Nineveh Creek at Mauxferry Road	Impact Area	Downstream from Impact Area and developed area of Camp Atterbury; upstream from confluence with Nineveh Creek; assess effects of upstream features on chemical and microbiological quality of water
A5	Nineveh Creek at Mauxferry Road	Impact Area	Downstream from confluence with Mud Creek and downstream from Impact Area; assess chemical and microbiological quality of water leaving Impact Area
A6	Mud Creek at Mount Moriah Road	Base wide and Impact Area	Much of Mud Creek originates in Camp Atterbury; upstream from confluence with Saddle Creek; upstream from Impact Area; assess chemical and microbiological quality of water entering Impact Area
A7	Duck Pond near Lincoln Road	Impact Area	Public fishing site; water in pond originates as surface runoff or ground-water discharge from Impact Area; assess chemical quality of water at edge of Impact Area
A8	Puff Lake headwater pond	Impact Area	Part of Puff Lake isolated by small dam; water originates as surface runoff or ground-water discharge from Impact Area; assess chemical quality of ponded water in Impact Area

Table 1. Description of monitoring sites for assessment of surface-water quality at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Monitoring site (figure 7)	Site name	Scope of monitoring	Site location and purpose
A9	Puff Lake main body	Impact Area	Public fishing, boating, and recreation site; much of the water in lake originates as surface runoff or ground-water discharge from Impact Area; monitoring near the northern shore; assess chemical quality of ponded water at edge of Impact Area
A10	Muddy Branch at Bearrs Road	Base wide and Impact Area	Stream originates in Camp Atterbury; downstream from Puff Lake; inside Impact Area; assess chemical quality of water leaving Impact Area and Camp Atterbury
E1	Unnamed tributary to Prince Creek at Princes Lake Road	Base wide	Upstream from Camp Atterbury; near outlet of Hants Lake; assess microbiological quality of water entering Camp Atterbury
E2	Prince Creek at Princes Lake Road	Base wide	Upstream from Camp Atterbury; near outlet of East Lake; assess microbiological quality of water entering Camp Atterbury
E3	Mud Creek at Lincoln Road	Base wide	Downstream from confluence of Saddle Creek and Mud Creek; assess microbiological quality of water upstream from confluence with Nineveh Creek
E4	Unnamed tributary to Nineveh Creek near Kansas Cemetery	Base wide	Upstream from confluence with Nineveh Creek; assess microbiological quality of water downstream from developed area of Camp Atterbury
E5	Nineveh Creek at Range Line Road near Kansas Cemetery	Base wide	Downstream from confluence with unnamed tributary; assess microbiological quality of water downstream from unnamed tributary; assess chemical quality of water entering Impact Area
E6	Unnamed tributary to Nineveh Creek near Hospital Road	Base wide	Upstream from sewer overflow; assess microbiological quality of water entering Camp Atterbury
E7	Unnamed tributary to Nineveh Creek at County Line Road	Base wide	Downstream from sewer overflow; assess microbiological quality of water downstream from developed area of Camp Atterbury
E8	Puff Lake at Foxfire Cabin	Base wide	Near boat dock at cabin; assess microbiological quality of water near cabin
E9	Puff Lake at boat ramp	Base wide	Near shoreline at boat ramp; assess microbiological quality of water at ramp
E10	New Lake at swimming beach	Base wide	Near shoreline between cabins; assess microbiological quality of water at beach
E11	Engineer Pond western shore	Base wide	Near shoreline at potential swimming area; assess microbiological quality of water at swimming area

Table 2. Coordinates, altitude, and watershed characteristics of monitoring sites for assessment of surface-water quality at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001

[Latitude and longitude: ° , degrees, ’, minutes, ” , seconds (North American Datum of 1983); altitude (North American Vertical Datum of 1988); mi^2, square mile; n.a., not available]

Monitoring site (figure 7)	Horizontal coordinates (latitude and longitude[a])	Altitude[b] (feet)	Watershed	Stream order	Upstream drainage area[c] (mi^2)
B1	39° 20’ 12.27” 86° 04’ 30.22”	702	Prince Creek	First	5.55
B2	39° 21’ 41.77” 86° 03’ 52.46”	707	Nineveh Creek	First	8.82
B3	39° 17’ 58.55” 86° 05’ 19.34”	696	Mud Creek	First	2.95
B4	39° 19’ 10.56” 85° 59’ 25.18”	642	Nineveh Creek	Third	43.7
B5	39° 16’ 52.01” 86° 00’ 30.01”	655	Lick Creek	First	4.18
B6	39° 13’ 34.93” 86° 00’ 24.77”	635	Catherine Creek	First	6.26
A1	39° 18’ 44.35” 86° 02’ 48.30”	670	Mud Creek	Second	13.6
A2	39° 19’ 22.22” 86° 02’ 32.96”	667	Prince Creek	First	7.80
A3	39° 19’ 22.90” 86° 01’ 49.60”	660	Nineveh Creek	First	13.4
A4	39° 19’ 37.45” 86° 00’ 34.61”	655	Nineveh Creek	First	4.35
A5	39° 18’ 56.86” 86° 00’ 34.25”	655	Nineveh Creek	Second	35.3
A6	39° 18’ 38.88” 86° 04’ 11.81”	680	Mud Creek	First	4.99
A7	39° 17’ 29.89” 86° 03’ 44.71”	705	Mud Creek	Lake	.173
A8	39° 17’ 38.21” 86° 02’ 19.99”	693	Muddy Branch	Lake	n.a.
A9	39° 17’ 28.02” 86° 02’ 08.03”	685	Muddy Branch	Lake	1.45
A10	39° 17’ 53.50” 86° 00’ 44.27”	655	Muddy Branch	First	2.23
E1	39° 21’ 06.72” 86° 05’ 34.82”	740	Prince Creek	First	.266
E2	39° 20’ 43.85” 86° 05’ 52.76”	740	Prince Creek	First	2.61
E3	39° 18’ 12.74” 86° 03’ 56.21”	680	Mud Creek	Second	9.30
E4	39° 20’ 03.40” 86° 02’ 07.19”	690	Nineveh Creek	First	.953
E5	39° 19’ 50.39” 86° 02’ 04.74”	690	Nineveh Creek	First	13.0
E6	39° 21’ 29.61” 86° 01’ 34.20”	700	Nineveh Creek	First	2.18
E7	39° 20’ 43.85” 86° 01’ 31.14”	690	Nineveh Creek	First	3.22
E8	39° 17’ 19.19” 86° 01’ 51.85”	690	Muddy Branch	Lake	1.45
E9	39° 17’ 25.13” 86° 01’ 57.49”	690	Muddy Branch	Lake	1.45
E10	39° 21’ 31.58” 86° 00’ 42.48”	750	Nineveh Creek	Lake	n.a
E11	39° 19’ 49.66” 86° 07’ 07.31”	670	Nineveh Creek	Lake	n.a.

[a]Latitude, longitude, and altitude determined with differentially corrected, satellite-receiver, global-positioning-system data.

[b]Altitude at the monitoring site estimated from U.S. Geological Survey topographic map (Edinburgh, Nineveh, and New Bellesville, Ind., 7.5-minute quadrangles).

[c]Drainage area upstream from monitoring site estimated with data from Hoggatt (1975) and U.S. Geological Survey topographic maps (Edinburgh, Nineveh, and New Bellesville, Ind., 7.5-minute quadrangles).

Chemical Assessment

The chemical assessment included collection and analysis of samples of water, streambed sediment, and fish tissue. This section describes methods for selection of monitoring constituents, sample collection, field and laboratory analysis, and quality assurance.

Selection of Monitoring Constituents

Monitoring constituents were selected to address the study objectives of base-wide assessment, evaluation of the Impact Area, and *E. coli* monitoring. As many as 213 constituents were analyzed in environmental samples collected during the study. Names and laboratory reporting limits for these constituents are in appendix 1.

Monitoring constituents for water samples in the base-wide assessment were based on the USGS NAWQA guidelines in Shelton (1994). The base-wide assessment required 9 water-quality characteristics and physical properties, 17 dissolved major ions and nutrients, and 20 dissolved trace elements (table 3). These 46 base-wide monitoring constituents were determined in water samples from16 sites listed in table 1 (B1 through B6 and A1 through A10). Water samples from seven of these sites (B1 through B6 and A6) included four supplementary constituents (table 3).

To evaluate surface water in the Impact Area, the 46 base-wide monitoring constituents were required, plus constituents based on the chemical components and potential residues of munitions[c] used in the Impact Area. The components and residues of these munitions were obtained from the Munitions Items Disposition Action System (MIDAS) data base, maintained by the U.S. Army Defense Ammunition Center (2000). A list of munitions components and residues that potentially could be found in water samples affected by activities in the Impact Area was compared with available analytical methods. The monitoring constituents selected for the Impact Area evaluation included 14 explosives; 53 volatile organic compounds; 92 semivolatile organic compounds; and total recoverable lead, magnesium, potassium, and sodium (table 4). These 163 constituents were determined in water samples from 10 sites in and near the Impact Area (A1 through A10).

A further evaluation of the Impact Area was made with samples of streambed sediment from six sites (A1, A2, A3, A4, A5, and A10) and fish tissue from stream reaches near nine sites (A1, A2, A4, A5, A7, A9, A10, B4, and B5). Determinations for 131 constituents were made in streambed-sediment and fish-tissue samples, including 25 total recoverable trace elements, 14 explosives, and 92 semivolatile organic compounds (table 4).

The *E. coli* monitoring required water-quality characteristics (table 3), 66 organic chemical compounds called "wastewaters tracers" (table 5), and the *E. coli* fecal-indicator bacteria. The wastewater tracers included caffeine, cholesterol, contraceptives, detergent metabolites, fragrances, flavorings, plastics, pesticides, preservatives, and other compounds known to be present in human sewage. Wastewater tracers were used to infer whether human sewage was a potential source of *E. coli* in some samples.

Collection of Surface-Water Samples

Surface-water samples were collected, using methods consistent with USGS guidelines (Wilde and Radtke, 1998) and with the USGS NAWQA Program (Shelton, 1994). Methods are described for collection of stream-water and lake-water samples during the base-wide assessment and during *E. coli* monitoring.

Stream-water samples for chemical analysis were collected during low streamflow with a technique that provided a well-mixed, representative sample with minimal disturbance of the streambed sediment. During low-flow conditions, sample sites

[c]Munitions at Camp Atterbury include, for example, small arms and artillery ammunition, mortar rounds, missiles, grenades, flares, and smoke agents (Lieutenant Colonel Richard Jones, Indiana Army National Guard, 2000, written commun.).

Table 3. Constituents and analytical methods for water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001

[UVP, ultraviolet-promoted; ICP, inductively coupled plasma; AA, atomic absorption]

Constituent group or constituent name	Type of analytical method	Type of determination
Water-quality characteristics and physical properties		
Alkalinity as calcium carbonate	Incremental titration	Temporary laboratory[a]
Dissolved oxygen	Electrometric (multimeter)	Field measurement[a]
Dissolved solids	Gravimetric	Fixed-base laboratory[b]
Gross alpha radioactivity	Scintillation counting	Fixed-base laboratory[c]
Gross beta radioactivity	Scintillation counting	Fixed-base laboratory[c]
pH	Electrometric (multimeter)	Field measurement[a]
Specific conductance	Electrometric (multimeter)	Field measurement[a]
Turbidity	Optical meter	Field measurement[a]
Water temperature	Electrometric (multimeter)	Field measurement[a]
Supplementary constituents		
Escherichia coli	Membrane filtration	Temporary laboratory[a]
Organic carbon, total and dissolved	UVP persulfate oxidation	Fixed-base laboratory[d]
Suspended sediment	Gravimetric	Fixed-base laboratory[e]
Dissolved major ions in water		
Calcium, iron, magnesium, manganese, sodium, silica	ICP atomic emission spectrometry	Fixed-base laboratory[b]
Potassium	AA flame spectrometry	Fixed-base laboratory[b]
Chloride, sulfate	Ion chromatography	Fixed-base laboratory[b]
Fluoride	Colorimetry	Fixed-base laboratory[b]
Nutrients in water		
Nitrogen, dissolved: ammonia, nitrate+nitrite, organic	Colorimetry	Fixed-base laboratory[b]
Nitrogen, total: ammonia plus organic	Colorimetry	Fixed-base laboratory[b]
Phosphorus and orthophosphate, dissolved	Colorimetry	Fixed-base laboratory[b]
Phosphorus, total	Colorimetry	Fixed-base laboratory[b]
Dissolved trace elements in water		
Aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, strontium, thallium, tin, vanadium, zinc	ICP atomic-emission spectrometry	Fixed-base laboratory[f]

[a]Field measurement or determination at the temporary laboratory with methods from Wilde and Radtke (1998).

[b]U.S. Geological Survey laboratory determination with methods from Fishman and Friedman (1989).

[c]U.S. Geological Survey laboratory determination with methods from Thatcher and others (1977).

[d]U.S. Geological Survey laboratory determination with methods from Brenton and Arnett (1993).

[e]U.S. Geological Survey laboratory determination with methods from Sholar and Shreve (1998).

[f]Laboratory determination by use of method SW6010B from U.S. Environmental Protection Agency (1986).

Table 4. Constituent groups and analytical methods for water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001

[AA, atomic absorption USGS, U.S. Geological Survey; ICP, inductively coupled plasma; USEPA, U.S. Environmental Protection Agency]

Constituent groups	Type of method	Analytical method
Total recoverable lead in water	AA graphite-furnace spectrometry	USGS method[a]
Total recoverable magnesium in water[b]	Colorimetry	USGS method[a]
Total recoverable potassium in water[b]	AA flame spectrometry	USGS method[a]
Total recoverable sodium in water[b]	ICP atomic-emission spectrometry	USGS method[a]
25 Total recoverable trace elements[c] in sediment or fish tissue	ICP atomic-emission spectrometry	USEPA method SW6010B[d]
53 Volatile organic compounds[c] in water	Gas chromatography/mass spectrometry	USEPA method SW8260[d]
92 Semivolatile organic compounds[c] in water, sediment or fish tissue	Gas chromatography/mass spectrometry	USEPA method SW8270C[d]
14 Explosives[c] in water, sediment or fish tissue	High-performance liquid chromatography[e]	USEPA method SW8330[d]

[a]U.S. Geological Survey laboratory determination with methods from Fishman and Friedman (1989).

[b]Constituent analyzed in water samples from September 2000 only.

[c]A list of the individual elements or compounds is in appendix 1.

[d]Laboratory determination by use of methods from U.S. Environmental Protection Agency (1986).

[e]Prior to analysis, water samples were prepared with solid-phase extraction; sediment and tissue samples were extracted by sonification.

Table 5. Wastewater tracers analyzed in water samples collected at Camp Atterbury near Edinburgh, Indiana, May 14 through June 14, 2001

Wastewater tracer		
Acetophenone	1,4-dichlorobenzene	2,6-dimethylnapthalene
Acetyl hexamethyl tetra-hydronaphthalene	Dichlorvos	Naphthalene
Anthracene	*d*-limonene	*Para*-cresol
9,10-anthraquinone	Equilenin	Diethoxynonyl phenol (total)
Benzo(a)pyrene	17-*alpha*-ethynyl estradiol	Diethoxyoctyl phenol
Benzophenone	17-*beta*-estradiol	Monoethoxyoctyl phenol
5-methyl-1H-benzotriazole	Estrone	*Para*-nonyl phenol (total)
3-*beta*-coprostanol	Ethanol,2-butoxy-phosphate	Pentachlorophenol
Beta-sitosterol	Ethyl citrate (triethyl citrate)	4-cumylphenol
3-*tert*-butyl-4-hydroxyanisole (BHA)	Fluoranthene	4-*n*-octylphenol
Bisphenol A	Hexahydro hexamethyl cyclopenta benzopyran	4-*tert*-octylphenol
Bromacil	Indole	Phenol
Bromoform	Isoborneol	Phenanthrene
Caffeine	Isophorone	Prometon
Camphor	Isoquinoline	Pyrene
Carbaryl	Menthol	Skatol(3-methyl-1H-indole)
Carbazole	Metalaxyl	Stigmastanol
Chlorpyrifos	Methyl salicylate	Tetrachloroethylene
Cholesterol	Metolachlor	Tri(2-chloroethyl)phosphate
Cotinine	N,N-diethyl-meta-toluamide	Tri(dichlorisopropyl)phosphate
Cumene (isopropylbenzene)	1-methylnapthalene	Tributylphosphate
Diazinon	2-methylnapthalene	Triclosan

at some first-order streams had well-mixed flow regimes in water less than 1 ft deep. To collect samples, a location was selected where the streamflow effectively integrated water from the full width and depth of the stream. A Teflon hose was fixed in the horizontal and vertical center of flow and connected to a peristaltic pump on a platform on the streambank. Another Teflon hose was connected to the outlet of the pump and clamped in a stand. The Teflon hose was flushed with stream water before sample containers were filled with water that did not require filtration. Next, the hose was connected to a 0.45-µm filter clamped in the stand and the remaining sample containers were filled.

Stream-water samples for chemical analysis were collected during high streamflow by personnel while wading, using an equal-width increment technique. A 3-L Teflon bottle with an isokinetic nozzle, attached to a wading rod, was used to composite a water sample from a minimum of 10 vertical sections. Each vertical section was sampled by lowering the bottle with the rod at the same transit rate. Each vertical section was in the center of an increment of equal width across the stream channel. A peristaltic pump and Teflon hose were used to transfer aliquots from the 3-L sample bottle into individual sample containers. The 3-L bottle was shaken between each aliquot.

Lake-water samples for chemical analysis were collected by personnel in a boat, using a depth-integrated technique to obtain a 3-L composite sample from three locations per lake (sites A7, A8, and A9). At each location, depth to the lake bottom was measured with a weighted tape and the distance divided into two or three equal increments. A Teflon hose connected to a peristaltic pump was lowered to the middle of each increment with a pole. An equal portion (0.5 or 0.33 L) was pumped from each increment at a location; the three 1-L samples were combined in a 3-L Teflon bottle. A peristaltic pump and Teflon hose were used to transfer aliquots from the 3-L sample bottle into individual sample containers. The 3-L bottle was shaken between each aliquot.

Samples for chemical analysis were preserved in the field, chilled, and shipped by overnight freight to the USGS laboratories in Colorado. Samples for suspended-sediment analysis were shipped as a group to the USGS Sediment Laboratory in Kentucky.

Stream-water samples for *E. coli* monitoring were collected by personnel while wading, using an equal-width increment technique (Wilde and Radtke, 1998) to obtain a composite sample throughout the water column across the stream. Water samples from lakes also were collected by personnel while wading and were depth-integrated from three locations to obtain a composite sample. Water samples were collected in 300-mL glass bottles. Prior to use, the bottles were washed and then sterilized by autoclaving. Samples were kept on ice until processed.

For the chemical analysis of wastewater tracers during the *E. coli* monitoring, a grab sample of stream water was collected in the center of flow with a new, 1-L, amber glass bottle. The sample was kept refrigerated until the microbiological analysis was completed. Selected samples for chemical analysis were shipped on ice by overnight freight to the laboratory for analysis within 30 days of collection.

Collection of Streambed-Sediment Samples

Streambed-sediment samples were collected at six monitoring sites (A1 through A5, and A10) and processed with methods adapted from Shelton and Capel (1994) and Renn (1998). At each monitoring site, a composite sample of streambed sediment was collected for analysis. Areas with slow water (less than 0.2 ft^3/s) and accumulation of fine-grained sediments were targeted for sampling. Sediment samples were collected approximately 30 ft or less from where water samples were collected. To obtain the composite sample, approximately 10 subsamples were collected with a 250-mL glass beaker from the top 4 to 6 in. of

streambed sediment. The subsamples were combined and mixed in a glass dish; 500 mL of the unprocessed, mixed sediment were removed for particle-size analysis. The remaining sediment was processed through a 200-µm screen-size sieve to obtain a 500-mL composite sample containing clay, silt, and fine sand for chemical analysis. For total recoverable trace-elements analysis, a polypropylene sieve was used; for explosives and semivolatile organic compound analysis, a stainless-steel sieve was used. Sediment samples were placed in new glass jars, chilled, and shipped by overnight freight to the USGS laboratory in Colorado. Analysis of particle-size distribution was done at the USGS Indianapolis office by drying, sieving, and weighing the 500 mL of unprocessed sediment.

Collection of Fish-Tissue Samples

Fish-tissue samples were collected in stream reaches near seven monitoring sites inside of and downstream from the Impact Area (A1, A2, A4, A5, A10, B4, and B5) and in Puff Lake and Duck Pond near the Impact Area. Creek chub (*Semotilus atromaculatus*) were targeted as the primary species for collection in first-order streams, consistent with guidelines for a sentinel species of environmental contamination used in Indiana (Stahl and Sobat, 2000). When creek chub were absent, such as in second-order streams or lakes, species targeted were largemouth bass (*Micropterus salmoides*) or spotted bass (*Micropterus punctulatus*), consistent with USGS NAWQA Program guidelines (Crawford and Luoma, 1993) and with previous NAWQA fish-community data for the White River Basin in Indiana (Baker and Frey, 1997). Samples were collected in late summer through early fall to minimize seasonal physiological changes in the target fish species that could affect organic-compound concentrations. (The lipid content of fish increases prior to spawning, accompanied by a temporary increase in hydrophobic organic compounds.)

Fish were collected with backpack, barge-mounted, or boat-mounted electroshocking equipment. Electroshocking is described in the Fish-Community Inventories section of this report. Fish collection for tissue analysis was done as part of fish-community inventories at five sites downstream from the Impact Area. At three sites inside the Impact Area, fish collection was done specifically for tissue samples. If the required number and total weight of a targeted species were obtained in the 450-ft reach of the fish-community inventories outside the Impact Area, no further fish collection was done. If additional fish were needed, another reach downstream from the community inventory was electroshocked. Inside the Impact Area, a reach upstream and downstream from the monitoring site was electroshocked.

Once fish were collected in a reach, individuals were selected and tissue samples were prepared. For creek chub, at least nine of the largest (assumed to be the oldest) individuals from the electroshocking were selected to obtain a minimum 300-g, whole-fish, composite sample. For largemouth bass or spotted bass, at least four of the largest individuals from the electroshocking were selected to obtain a minimum 300-g composite sample composed of at least eight skin-on, scaleless fillets (including belly flap). Tissue samples were wrapped in aluminum foil, placed in a labelled plastic bag, and quickly frozen on dry ice for overnight shipment to the USGS laboratory in Colorado. At the laboratory, fish-tissue samples were kept frozen until all samples had arrived; then, the samples were thawed, processed, and analyzed as a group.

Analytical Methods

Four water-quality characteristics (pH, specific conductance, dissolved oxygen, and water temperature) were determined in the field with an electronic multimeter to evaluate the mixing or stratification of the water column at the monitoring sites. Turbidity was determined in the field with an optical turbidimeter. Alkalinity was determined in a mobile-laboratory van by incremental titration (Wilde and Radtke, 1998).

Water samples were analyzed at the USGS National Water Quality Laboratory in Colorado for three physical properties, organic carbon, total recoverable trace elements, major ions, and nutrients by analytical methods listed in tables 3 and 4. Chemical analysis of wastewater tracers (table 5) was done by the USGS National Water Quality Laboratory, where the method was developed. Samples were processed through continuous liquid-liquid extraction and analyzed with selected-ion-monitor gas chromatography/mass spectrometry. Water, streambed-sediment, and fish-tissue samples were analyzed for trace elements, explosives, volatile organic compounds, and semivolatile organic compounds at the USGS laboratory in Colorado for the Department of Defense Environmental Conservation Program. Samples were analyzed by USEPA methods listed in table 4. Names and laboratory reporting limits for the constituents in tables 3, 4, and 5 are listed in appendix 1. Suspended-sediment analysis of water samples was done by the USGS Sediment Laboratory in Kentucky.

Quality-Assurance Program

A quality-assurance program was implemented for sampling equipment and supplies used in the chemical assessment. The multimeter, turbidimeter, and pH meter (for alkalinity determinations) were checked with laboratory-grade standard solutions each day before use, following manufacturer's procedures and USGS methods in Wilde and Radtke (1998). Water-sampling equipment was cleaned before each use by pumping a dilute solution of phosphate-free detergent, followed by a deionized-water rinse, a nitric-acid rinse (to remove inorganics), and a methanol rinse (to remove organics). Streambed-sediment sampling and fish-tissue filleting equipment were cleaned before each use with a deionized-water rinse followed by a nitric-acid rinse and a methanol rinse. Field blanks to assess whether equipment cleaning was adequate were prepared by pumping deionized, carbon-filtered water (obtained from the USGS Indianapolis office laboratory) through the Teflon tubing into the sample containers. Trip-blank samples consisting of organic-free water from the analytical laboratory were transported with empty and filled sample containers to assess whether volatile organic compounds were introduced during storage and transport.

The USGS laboratories provided quality-assurance data with the analytical data. Matrix-spike duplicate samples consisting of two extra sets of water samples were collected at one site and submitted to the laboratory. At the laboratory, the samples were spiked with known amounts of selected constituents to determine if the sample matrix interfered with the analysis. Laboratory quality assurance included control samples to assess analytical accuracy, duplicate samples to assess analytical precision, and method blanks to assess sample representativeness. USGS personnel used the quality-assurance data to validate and qualify analytical results presented in the Chemical Quality section of this report.

Biological Assessment

This section explains the biological-assessment methods. Included are microbiological analysis of water samples, inventories of benthic-macroinvertebrate and fish communities, calculation of numeric indexes for the benthic-macroinvertebrate and fish communities, and calculation of a numeric index for stream habitat quality.

Microbiological Analysis of Water

The microbiological analysis of water samples determined the concentrations of *E. coli* in colonies per 100 mL of sample (col/100 mL). This section describes how the water samples were collected and analyzed and how quality assurance was provided. These methods were used by the USGS for *E. coli* monitoring throughout Indiana in a project with IDEM (Silcox and others, 2000, 2001, 2002).

Sample processing and microbiological analysis was done by USGS Indianapolis office personnel within 6 hours or less of sample collection, according to methods in Wilde and Radtke (1998). Prior to use, all sample-processing equipment was washed and then sterilized with an ultraviolet lamp. Membrane filters, sterile buffer solution, sterile dilution water, and petri dishes were quality assured by the USGS Water-Quality Service Unit. Agar media kits were quality assured by the USGS Ohio District Microbiological Laboratory.

Sample processing involved filtering the water, plating the filters on growth media, and incubating the filter plates. Five to seven different sample volumes were filtered to obtain dilutions of 1:1 to 1:100. Dilutions of 1:10 and 1:100 were filtered if the extent of possible *E. coli* concentrations was unknown. This approach assured at least one sample volume would produce an *E. coli* colony count in the ideal range of 20 to 80 colonies per filter plate. Sample dilutions were made with sterile water. Sterile, disposable pipets or graduated cylinders were used to measure and deliver sample volumes. A stainless-steel filter-funnel system attached to a vacuum pump was used to process the sample volume through a 0.45-µm filter designed to capture *E. coli* for incubation and quantification. After filtering the sample, a sterile saline buffer solution was used to rinse the graduated cylinder and filter funnel, and the rinseate was filtered. Fresh, membrane-filter thermotolerant agar in labeled petri dishes was used to encourage growth of *E. coli* colonies on the prepared filters. The filter plates were placed for 2 hours in a pre-heated incubator set at 35.0°C and then placed for 22 to 24 hours in a pre-heated incubator set at 44.5°C.

Microbiological analysis involved counting the colonies on each filter plate (fig. 8) and calculating the *E. coli* concentration for each site. After the second incubation, the filter was transferred to a filter pad saturated with urea/phenol red reagent solution. After 15 minutes at room temperature, the yellow to yellow-brown *E. coli* colonies were counted. If the colony count on the filter plate was the ideal range (20 to 80), verification was made by recounting. *E. coli* concentrations were reported, using one of three methods:

(1) If a single filter plate had a colony count in the ideal range, the concentration was calculated as the colony count, multiplied by 100, and the product divided by the sample volume.

(2) If multiple filter plates had colony counts in the ideal range, the counts were summed, multiplied by 100, and the product divided by the sum of the sample volumes.

(3) If no filter plates had a colony count in the ideal range, the concentration was calculated with all the filter plates that had colonies; this was done in a manner similar to the multiple-filter-plate method in (2) above, and the result was noted as an estimate.

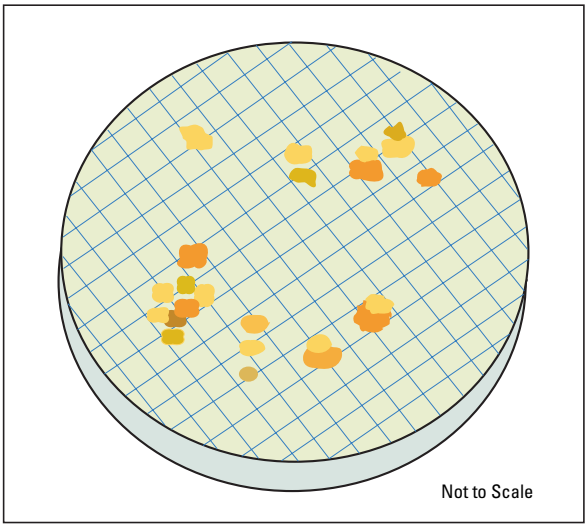


Figure 8. Illustration of filter plate with *Escherichia coli* colonies.

At each monitoring site, five water samples were collected in a 30-day period for determination of *E. coli* concentrations. For comparison with the Indiana water-quality standards, both the single-sample and geometric-mean concentrations were required. The 30-day geometric mean concentration was calculated as the fifth root of the product of the five-sample concentrations, using the following equation.

$$GM = \sqrt[5]{S_1 \times S_2 \times S_3 \times S_4 \times S_5} \quad ,$$

where,

GM is the geometric mean, and

Si is the concentration of *E. coli* measured in each of the five samples.

For quality assurance, filter blanks, process blanks, field blanks, and duplicate samples were analyzed. Filter blanks were processed before every set of samples to determine if the processing equipment was clean. Process blanks were made after the last sample each day by filtering saline buffer solution through the equipment onto a fresh filter. Process blanks determined if the rinses following each sample were complete. Field blanks consisted of saline buffer solution poured into a sample bottle and kept with the samples collected in a day. Analysis of field blanks determined adequate sterilization of sample bottles and potential contamination during sample transport. Duplicate samples were collected concurrently with the environmental samples at selected sites and processed like the environmental samples. Duplicate samples were used to evaluate the natural variability in the samples.

Fish-Community Inventories

Fish-community inventories were made in stream reaches near 10 monitoring sites (B1 through B6, A4 through A6, A10) in a manner consistent with guidelines for the USGS NAWQA Program (Meador and others, 1993). Fish were collected by a USGS biologist using pulsed Direct Current electroshocking techniques. Backpack or barge-mounted shocking equipment was used by wading personnel at all stream sites—a Smith-Root 12-A 400-watt Backpack Electrofisher or a Smith-Root SR-6 Electrofisher Tote Barge powered by a 2.5-GPP Electrofisher generator. (Electroshocking for fish-tissue sample collection in Puff Lake and Duck Pond was done from a flat-bottomed boat with a 110-V AC generator powering a Coffelt VVP-2E Electrofisher.)

Stream reaches that averaged 450 ft in length were electroshocked in two passes, the first pass starting at the monitoring site and proceeding upstream to a natural fish barrier, such as a riffle. The second pass was made downstream to the starting point. Electrofishing temporarily stunned the fish so they could be collected with dipnets and accumulated in baskets in the stream. Upon collection, the fish were sorted by species, their length and weight were measured, and the fish then were released alive (fig. 9). Fish were taxonomically identified to species level in the field by a USGS biologist. For quality assurance, some voucher specimens were photographed or preserved from each sampling reach for later identification by an icthyologist at Ohio Northern University. Identifications were based on taxonomic keys by Pflieger (1975), Trautman (1981), Robinson and Buchanan (1992), and Page (1983). Taxonomic nomenclature followed Robins and others (1991).

Two numeric indexes (the Index of Biotic Integrity and the Modified Index of Well-Being) were used to evaluate and compare long-term water-quality conditions at the stream reaches where fish-community inventories were made.

(1) The Index of Biotic Integrity (IBI), developed by Karr and others (1986), was adapted to specific conditions in the Eastern Corn Belt Plains ecoregion of Indiana by Simon and Dufour (1998). The IBI uses 11 fish-community concepts called "metrics" to obtain a single numeric score. The following metrics have three general categories—species composition, trophic composition, and fish condition:

- Total number of species
- Number of darter/madtom/sculpin species
- Percent headwater species
- Number of minnow species

Figure 9. Fish sorting, weighing, and measuring during a fish-community inventory at Camp Atterbury near Edinburgh, Indiana, October 2000.

- Number of sensitive species
- Percent omnivore individuals
- Percent insectivore individuals
- Percent pioneer species
- Catch per unit effort
- Percent simple lithophil individuals
- Percent of individuals with deformities, eroded fins, lesions, and tumors.

The fish-community-inventory data from a stream reach was compared to graphs in Simon and Dufour (1998) to obtain metric scores. Different graphs were consulted for headwater streams (less than 20-mi^2 drainage area; eight reaches in the study area) and for wadeable rivers (20- to 1,000-mi^2 drainage area; two reaches in the study area). The individual metric scores were summed to provide an IBI composite score for the fish inventory in a stream reach.

(2) The Modified Index of Well-Being (MIWB) is based on the Index of Well-Being (IWB), developed by Gammon (1976). The IWB is a numeric value that incorporates these measures of a fish community—number of individuals, biomass (weight), and diversity based on number and weight. The IWB was modified by the Ohio Environmental Protection Agency (Yoder, 1987) to create the MIWB. The MIWB retained the same computational formula as the conventional IWB. The difference was that any of 13 highly pollution-tollerant

species, exotic species, and hybrid species were eliminated from the numbers of individuals and biomass components of the calculation.

To calculate the MIWB for a stream reach, the number of individuals and weight of individuals per species were converted to "relative abundance" by dividing the numbers and weights by 450 ft, the standard distance for electroshocking. The MIWB composite score for a stream reach was calculated with the equation

$$MIWB = 0.5 \ln N + 0.5 \ln B + H_{number} + H_{weight} ,$$

where,

$MIWB$ = Modified Index of Well-Being composite score;

ln = the natural logarithm;

N = total numbers of individuals of all species;

B = total weight of individuals of all species;

H_{number} = Shannon Diversity Index for number of individuals; and

H_{weight} = Shannon Diversity Index for weight of individuals.

The Shannon Diversity Index was calculated twice for the previous equation, once with the number of individuals of each species and once with the weight of individuals of each species. The two calculations of the index were made with the following equation

$$H = \sum_{1}^{i} \left(\frac{n_i}{N} \ln \frac{n_i}{N} \right) ,$$

where,

H = the Shannon Diversity Index for number of individuals (H_{number}) or the Shannon Diversity Index for weight of individuals (H_{weight});

n_i = the numbers of individuals of the i th species or weight of individuals of the i th species;

N = the total number of individuals or total weight of individuals;

ln = the natural logarithm.

Benthic-Macroinvertebrate-Community Inventories

Benthic-macroinvertebrate-community inventories were made in stream reaches near 13 monitoring sites (B1 through B6, A1 through A6, and A10) in a manner generally consistent with guidelines for the USGS NAWQA Program (Cuffney and others, 1993). Macroinvertebrate samples were submitted to the USGS National Water Quality Laboratory Biological Group in Colorado for taxonomic identification and estimation of abundance.

In this study, richest habitats of streambed were targeted for semi-quantitative sampling—primarily large rocks and cobbles in main-channel riffle areas at three locations per reach. (Near site A10 on Muddy Branch, no rocks or cobbles were in the streambed, so woody debris piles were targeted.) A Surber sampler, consisting of a 1-ft^2 sampling frame and 210-µm mesh collection net[d], was used to collect benthic-macroinvertebrate samples. When the sampling frame was placed on the streambed, all the enclosed rocks, cobbles, and stones were collected into a bucket (fig. 10). As the rocks were gathered, organisms that were floating, detached from the rocks, or released from the streambed were caught in the collection net. The rocks in the bucket were scrubbed gently to remove attached organisms. The contents of the bucket were strained through a 212-µm sieve. Contents of the collection net were removed with stream water in the bucket and strained through the sieve. Gravel and debris were picked from the sieve and the benthic-macroinvertebrate sample was placed in a 1-L sample bottle and fixed with a 10-percent Formalin solution.

Benthic macroinvertebrates were identified by the USGS National Water Quality Laboratory Biological Group with the quantitative method described in Moulton and others (2000). The objective of the quantitative method was to estimate the

[d]This mesh size was consistent with a macroinvertebrate study in the White River Basin in Indianapolis (Voelker and Renn, 2000); Cuffney and others (1993) list a 455-µm mesh collection net for semi-quantitative sampling.

Figure 10. Surber sampler in use for collection of benthic-macroinvertebrate sample at Camp Atterbury near Edinburgh, Indiana, September 2000.

abundance of each taxon sorted from a sample. The method was an enhancement of the fixed-count approach described in the USEPA Standard Taxonomic Assessment (Barbour and others, 1999) and achieved the lowest taxonomic level consistent with the USGS NAWQA Program.

In general, insects, mollusks, and crustaceans were identified to either genus or species; aquatic worms were identified to family; and flatworms and nematodes were identified to class or phylum. Insect life stages (adult, pupae, or larvae) were recorded for each insect taxon.

The quantitative method was done by two personnel from the USGS Biological Group. The first person sorted organisms by taxa, using a fixed-count approach that targeted a minimum count of 300 organisms from randomly selected grids of a subsampling frame. The second person sorted the rest of the subsampling frame for at least 10 percent of the time used by the first person and searched for large or rare organisms not likely represented in the randomly selected grids. The sorted benthic macroinvertebrates were identified and enumerated, relative abundances were calculated for each sample, and data were quality assured.

For each monitoring site, a numeric index of biotic integrity was calculated with a method developed by Hilsenhoff (1987) to interpret relative abundance and diversity of benthic macroinvertebrates in the phylum Arthropoda, such as insects. Each taxon was assigned a numeric value from zero to 10 that indicated the organism's tolerance to organic pollution; zero was the least tolerant and 10 was the most tolerant. These "tolerance values," taken from Hilsenhoff (1987 and 1978) and supplemented by Bode and others (1996), were based on thousands of benthic-macroinvertebrate samples that were compared with chemical and physical measurements of organic water pollution. In some samples from the study area, incomplete specimens were identified to the family level and not assigned

a tolerance value. For calculation of the numeric index, these family-level taxa assumed the tolerance value of the most abundant taxon in the sample from that family. Indistinct taxa (such as identifications based on incomplete specimens) were assumed to include clearly identified taxa, where present.

To calculate the Hilsenhoff Biotic Index (HBI), the number of organisms within a taxon was multiplied by the tolerance value for that taxon. These products were summed for all the taxa identified in the sample, and the sum was divided by the total number of arthropods with tolerance values in the sample. The calculation resulted in an HBI between 1 and 10, which was compared with a ranking scale for severity of organic water pollution (Hilsenhoff, 1987).

For each monitoring site, a numeric index of pollution-intolerant insect taxa was calculated, following a method previously used by the USGS for the White River in Indianapolis (Voelker and Renn, 2000). The EPT Richness Index (Lenat and Penrose, 1996) represents the number of distinct taxa in the pollution-sensitive insect orders Ephemeroptera, Plecoptera, and Tricoptera (EPT) (fig. 11). EPT taxa are more intolerant of large concentrations of metals or organic compounds than are other orders of benthic macroinvertebrates.

Thus, a high EPT Richness Index reflected a diverse community of pollution-intolerant taxa at a site, indicating good water quality and abundant habitat. The EPT Richness Index was expressed as an integer and used to compare benthic-macroinvertebrate data from monitoring sites.

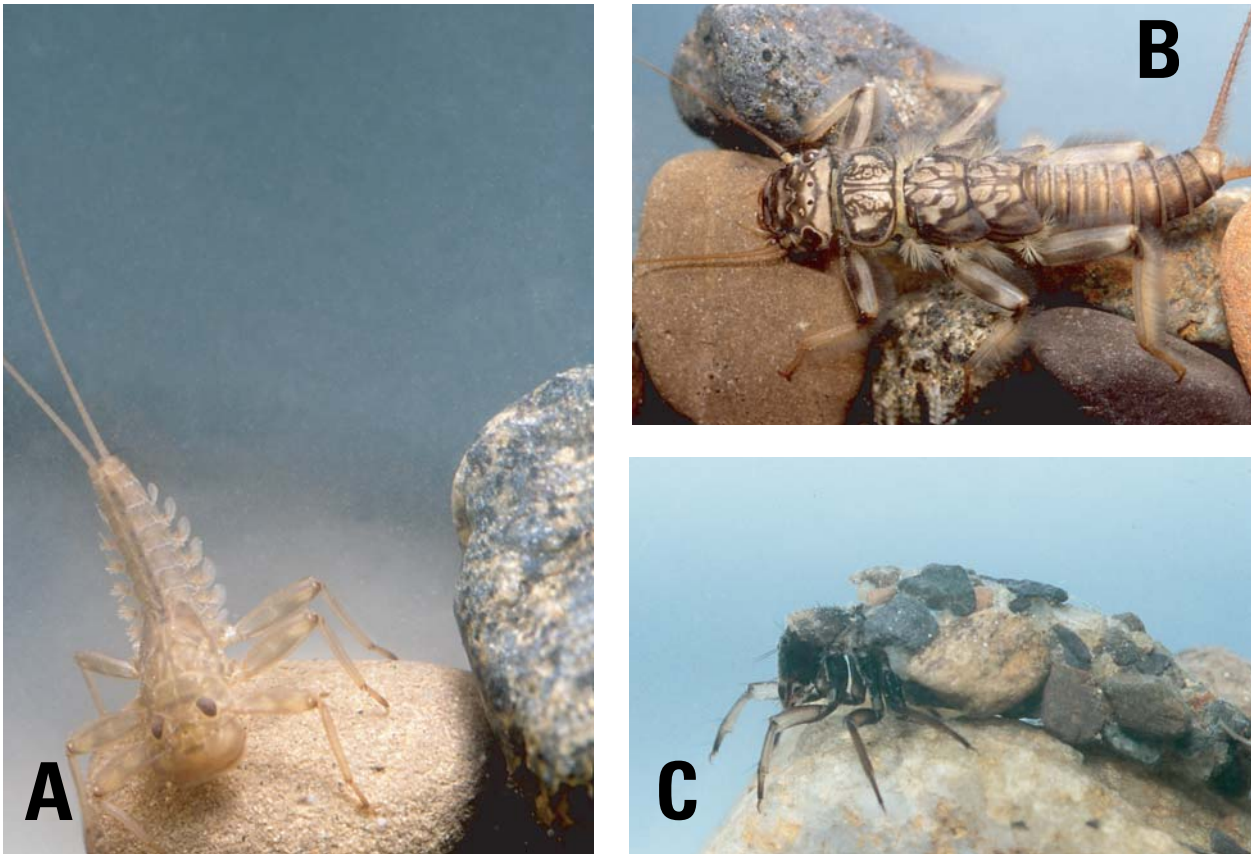


Figure 11. Aquatic insects of the orders Ephemeroptera (A), Plecoptera (B), and Trichoptera (C), typical of pollution-intolerant benthic macroinvertebrates. (Photographs modified from Moulton and others, 2000, courtesy of Steven V. Fend and James L. Carter, National Research Program, U.S. Geological Survey, Menlo Park, California, and Saelon Renkes, freelance photographer.)

Qualitative Habitat Evaluation

The Qualitative Habitat Evaluation Index (QHEI) was used to compute a numeric index for the physical habitats at the stream sites for the fish-community and benthic-macroinvertebrate community inventories. Developed by the Ohio Environmental Protection Agency and documented by Rankin (1989), the QHEI has been used by the USGS and IDEM. To calculate the QHEI, six stream-habitat metrics were scored individually and a total was summed: (1) substrate type, origin, and quality; (2) instream cover; (3) channel morphology; (4) riparian zone and bank erosion; (5) pool and riffle-run quality; and (6) stream gradient and drainage area. A field sheet with each metric divided into smaller components for standard scoring was used to calculate the QHEI score for each site.

Surface-Water Quality

Streamflow conditions during the water-quality study are discussed in the following section. Chemical data are presented from analysis and quality assurance of water, streambed-sediment, and fish-tissue samples. Biological data are presented from bacteria monitoring and inventories of fish and benthic macroinvertebrates. The chemical and biological data are discussed with regard to base-wide water quality, sources of contaminants, the Impact Area, and uncertainties of interpretation.

Streamflow Conditions

Typically, streamflow information is obtained as a continuous record from USGS streamflow-gaging stations, but no stations were operated in the study area. Historical and daily streamflow data from a nearby USGS streamflow-gaging station were used to identify low-streamflow and high-streamflow conditions for this study (Stewart and others, 2001, 2002; Fowler and Wilson, 1996).

USGS streamflow-gaging station 03362000 on Youngs Creek near Edinburgh (fig. 1) is about 4 mi north of the study area. The station on Youngs Creek is below a drainage area of 107 mi^2 with surface geology (till, alluvium, and outwash), bedrock geology (shale and limestone), and physiography (Scottsburg Lowland) similar to most of the Nineveh Creek Watershed (fig. 2). Land use in the Youngs Creek Watershed is primarily agricultural, compared with forestland for much of the Nineveh Creek Watershed (Schnoebelen and others, 1999). The period of record for the Youngs Creek gaging station is 1942 through the years of this study.

Streamflow conditions in the study area during the base-wide assessment were evaluated with the Youngs Creek gaging-station data in three ways. First, the streamflow hydrograph for August 2000 through August 2001 (fig. 12) indicates two of the three water-sampling periods in September 2000 were during relatively low to moderate streamflow (less than 50 ft^3/s); one sampling period in September 2000 was during average streamflow (less than 100 ft^3/s but more than 50 ft^3/s); and the water sampling period in July 2001 was during a recession from relatively high streamflow (more than 250 ft^3/s). Water sampling in May and June 2001 was during streamflow conditions that ranged from low to high.

Second, the daily mean streamflow values and instantaneous streamflow values for September 2000 were divided by the drainage areas so that the streamflow from watersheds in the study area with drainage areas different from the Youngs Creek drainage area could be compared to the Youngs Creek streamflow. The resulting units for the area-adjusted streamflow values were $ft^3/s/mi^2$. The area-adjusted daily mean streamflow from the Youngs Creek gaging station was plotted with area-adjusted instantaneous streamflow from the study's monitoring sites on the dates of sampling (fig. 13, p. 30). The graph indicates instantaneous streamflows in the study area on the September 2000 sampling dates were less than the annual mean streamflow at the Youngs Creek gaging station. Most streamflows in the study area were less than 50 percent of the streamflow values for the Youngs Creek gaging station from 1942 through 2000.

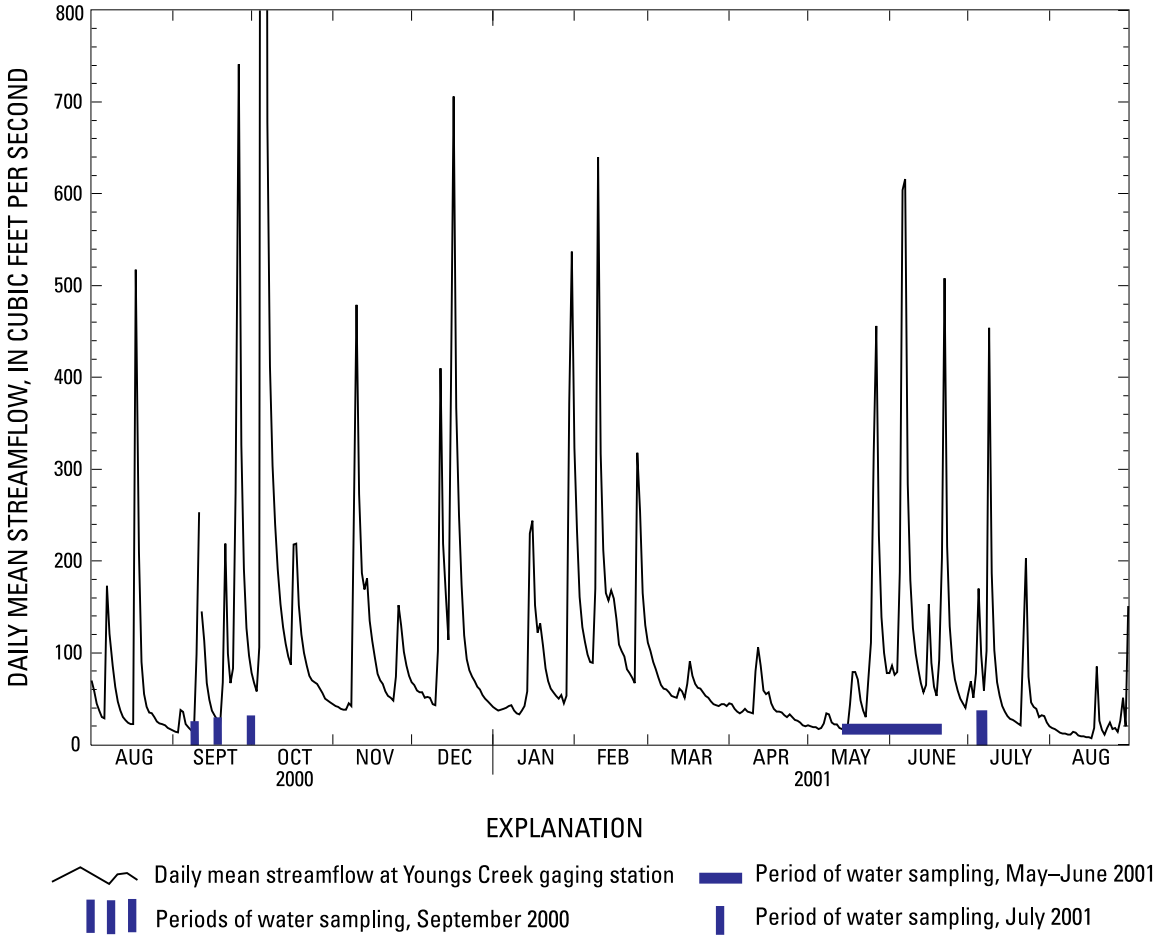


Figure 12. Daily mean streamflow at U.S. Geological Survey streamflow-gaging station 03362000 on Youngs Creek near Edinburgh, Indiana, August 1, 2000, through August 31, 2001, with period of water sampling at Camp Atterbury near Edinburgh, Indiana.

Third, the daily mean streamflow at the Youngs Creek gaging station on the September 2000 and July 2001 sampling dates in the study area (Stewart and others, 2001, 2002) were compared with historical streamflow characteristics (Fowler and Wilson, 1996) to classify the probable streamflow conditions in the study area. Area-adjusted daily mean streamflow at Youngs Creek and area-adjusted instantaneous streamflow from the study area were classified by comparison with historical streamflow characteristics for the Youngs Creek gaging station. The comparison (table 6, p. 31) indicates most of the streamflow conditions in the study area on sampling dates in September 2000 probably were low to moderate. The sample at site B1 on September 5, 2000, and the sample at site A1 on September 28, 2000, probably were collected during average to slightly above-average conditions. The comparison also indicates the streamflow conditions in the study area on sample dates in July 2001 probably were high. The three preceding evaluations of streamflow support a generalization about streamflow conditions for the water-quality-sampling results described in the following section. For comparison, the periods of water sampling during September 2000 will be called low-streamflow conditions (less than 0.5 $ft^3/s/mi^2$) and the periods of water sampling during July 2001 will be called high-streamflow conditions (more than 3 $ft^3/s/mi^2$).

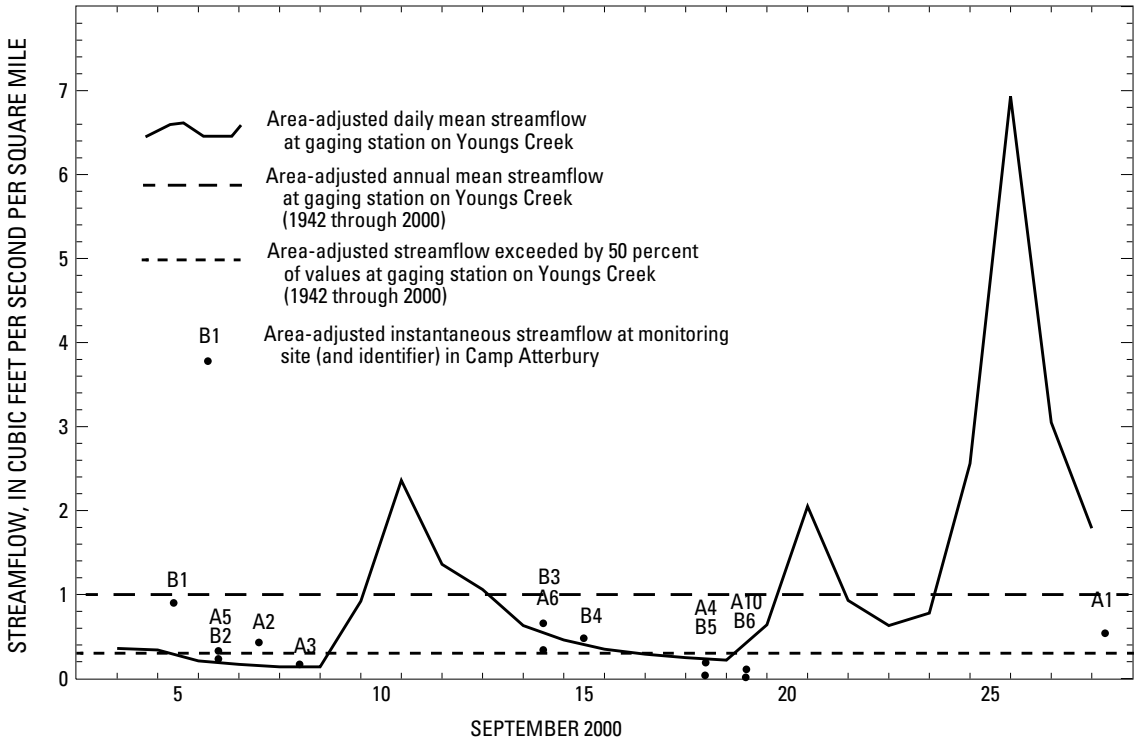


Figure 13. Daily mean streamflow at U.S. Geological Survey streamflow-gaging station 03362000 on Youngs Creek near Edinburgh, Indiana, and instantaneous streamflow from monitoring sites at Camp Atterbury near Edinburgh, Indiana, September 2000 (adjusted to drainage area).

Chemical Quality

Chemical data were used to evaluate base-wide water quality and to examine potential effects on water quality, streambed sediment, and fish tissue inside of and downstream from the Impact Area. This section summarizes chemical data for water, streambed-sediment, and fish-tissue samples collected during September and October 2000. Chemical data for water samples collected in July 2001 also are included.

Water-Sample Analysis and Quality Assurance

Sixteen water samples were collected from streams and lakes, September 9 through September 28, 2000, during low-streamflow conditions; six samples were collected July 5 and 6, 2001, during high-streamflow conditions. Explosives, volatile organic compounds, and semivolatile organic compounds (table 4 and appendix 1) were not detected in any of the samples. The following narrative discusses constituents that were detected—water-quality characteristics, physical properties, major ions, nutrients, and trace elements.

Water-quality characteristics and physical properties of the samples are summarized in table 7 (p. 32); all the data are in appendix 2. Generally, water from streams in the study area contained dissolved-oxygen concentrations at more than 80 percent of saturation at low and high streamflow (median 8.8 and 7.0 mg/L); water samples had slightly alkaline pH (median 7.8 standard units) at low streamflow that increased at high streamflow (median 8.3 standard units). Suspended sediment and turbidity at low streamflow were small (median 7.7 mg/L and 5.0 NTUs) but increased by about eight times at high streamflow (median 64 mg/L

Table 6. Daily mean streamflow at U.S. Geological Survey streamflow-gaging station 03362000 on Youngs Creek near Edinburgh, Indiana, and instantaneous streamflow on water-sampling dates at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

[ft^3/s, cubic foot per second; $ft^3/s/mi^2$, cubic foot per second per square mile; mi^2, square mile; avg., average]

	Youngs Creek gaging station 03362000			Camp Atterbury monitoring sites				
Date	Daily mean streamflow[a] (ft^3/s)	Type of streamflow condition[b]	Area-adjusted daily mean streamflow[c] ($ft^3/s/mi^2$)	Monitoring site (figure 7)	Instantaneous streamflow (ft^3/s)	Drainage area (mi^2)	Area-adjusted instantaneous streamflow ($ft^3/s/mi^2$)	Probable type of streamflow condition
9/05/2000	36	Moderate	0.34	B1	4.99	5.55	0.90	Above avg.
9/06/2000	22	Low	.21	B2	2.70	8.82	.31	Moderate
9/07/2000	18	Low	.17	A2	3.37	7.80	.43	Moderate
9/08/2000	15	Low	.14	A3	2.25	13.4	.17	Low
9/14/2000	67	Average	.63	A6	1.71	4.99	.34	Moderate
9/15/2000	49	Moderate	.46	B4	21.1	43.7	.48	Moderate
9/18/2000	27	Moderate	.25	A4	.84	4.35	.19	Low
9/19/2000	24	Moderate	.22	A10	.24	2.23	.11	Low
9/28/2000	191	Above avg.	1.8	A1	7.41	13.6	.54	Average
7/05/2001	170	Above avg.	1.6	A10	14.0	2.23	6.3	High
7/05/2001	170	Above avg.	1.6	A4	31.0	4.35	7.1	High
7/06/2001	98	Average	.92	B1	16.0	5.55	2.9	High
7/06/2001	98	Average	.92	A5	110	35.3	3.1	High

[a]Stewart and others (2001, 2002).

[b]Type of streamflow conditions based on percent of time daily mean was equaled or exceeded for the period of record (1942 through 1995) in Fowler and Wilson (1996), with area-adjusted streamflow: very low, 99 to 80 (0.02 to 0.07 $ft^3/s/mi^2$); low, 80 to 60 (0.07 to 0.2 $ft^3/s/mi^2$); moderate, 60 to 40 (0.2 to 0.5 $ft^3/s/mi^2$); average, 40 to 20 (0.5 to 1.2 $ft^3/s/mi^2$); above average (above avg.), 20 to 10 (1.2 to 2.3 $ft^3/s/mi^2$); high, 10 to 2 (2.3 to 7.5 $ft^3/s/mi^2$); very high, less than 2 percent (more than 7.5 to $ft^3/s/mi^2$).

[c]Streamflow divided by 107-square-mile drainage area.

and median 38 NTUs). Values for specific conductance and dissolved-solids concentrations were slightly larger at high streamflow (median 357 µS/cm and 204 mg/L) than at low streamflow (median 316 µS/cm and 193 mg/L). Organic-carbon concentrations at low flow were small (median 4.0 mg/L total; 3.4 mg/L dissolved). Water from two lake samples (A7 on Duck Pond and A9 on Puff Lake) in September 2000 indicated neutral pH, similar turbidity, and generally less specific conductance and dissolved solids than did the stream samples. Dissolved oxygen was less than 20 percent of saturation in the headwaters and near the shore in Puff Lake (A8, 1.8 mg/L, and A9, 2.1 mg/L) but was more than 80 percent of saturation in Duck Pond (7.8 mg/L).

Radiological determinations (table 8, p. 33) of gross alpha radioactivity at sites B2 (3.2 pCi/L) and B3 (3.6 pCi/L) were greater than the Indiana water-quality standard of 3 pCi/L. The confidence interval for these measurements of gross alpha radioactivity included values for sites B2 and B3 that are less than the standard. Additional data to verify these gross alpha radioactivity values were not obtained as part of this study. Gross beta radioactivity reported in samples from sites B2, B3, A3, and A5 were less than the Indiana water-quality standard of 1,000 pCi/L.

Concentrations of dissolved major ions and total nutrients in the 16 water samples from September 2000 and 6 samples from July 2001 are

Table 7. Summary statistics for water-quality characteristics and physical properties of water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

[pH, log of hydrogen-ion concentration; s.u., standard unit; µS/cm, microsiemen per centimeter; °C, degree, Celsius; mg/L, milligram per liter; Std. Dev., standard deviation; NTU, nephelometric turbidity unit; TOC, total organic carbon; DOC, dissolved organic carbon]

Samples from streams (13 during low streamflow and 6 during high streamflow)

	pH (s.u.)		Specific conductance (µS/cm)		Water temperature (°C)		Dissolved oxygen (mg/L)	
Streamflow	Low	High	Low	High	Low	High	Low	High
Mean	7.6	8.2	293	330	17.5	21.9	8.6	7.1
Median	7.8	8.3	316	357	16.9	21.2	8.8	7.0
Std. Dev.	.37	.2	132	120	2.7	2.6	.94	.80
Minimum	6.9	7.9	109	175	14.4	18.7	5.9	6.3
Maximum	8.0	8.4	568	480	22.9	25.8	9.6	8.3

	Dissolved solids (mg/L)		Turbidity (NTU)		Suspended sediment (mg/L)		TOC (mg/L)	DOC (mg/L)
Streamflow	Low	High	Low	High	Low	High	Low	Low
Mean	185	196	6.5	46	11	57	3.9	3.2
Median	193	204	5.0	38	7.7	64	4.0	3.4
Std. Dev.	79.9	63.6	4.8	38	9.4	18	1.2	.84
Minimum	90	122	2.0	12	2.7	25	2.3	1.9
Maximum	346	278	16	120	29	73	5.8	4.3

Samples from lakes (3 during low streamflow and zero during high streamflow)

	pH (s.u.)	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Dissolved solids (mg/L)	Turbidity (NTU)
Mean	7.1	113	22.2	3.9	82.7	11
Median	6.5	129	22.9	2.0	86.0	7.0
Std. Dev.	1.4	38.6	1.8	3.4	7.6	8.0
Minimum	6.1	73.0	20.2	1.8	74.0	5.0
Maximum	8.7	147	23.5	7.8	88	20

Table 8. Radiological determinations for water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000

[Gross alpha activity reported as thorium-230; pCi/L, picocurie per liter; gross beta activity reported as cesium-137; <, less than reporting limit listed]

	Gross alpha radioactivity			Gross beta radioactivity		
Monitoring site (figure 7)	Reported concentration[a] (pCi/L)	Confidence interval (pCi/L)	Range of possible values[b] (pCi/L)	Reported concentration[a] (pCi/L)	Confidence interval (pCi/L)	Range of possible values[b] (pCi/L)
B1	<3.0	1.10	2.4–3.0	<4.0	2.06	2.0–4.0
B2	3.2	1.91	2.3–4.2	7.5	3.18	5.9–9.1
B3	3.6	2.94	2.1–5.1	4.6	4.20	2.5–6.7
B4	<3.0	1.30	2.3–3.0	<4.0	2.43	1.8–4.0
B5	<3.0	.69	2.7–3.0	<4.0	1.00	2.5–4.0
B6	<3.0	1.44	2.3–3.0	<4.0	2.12	1.9–4.0
A1	<3.0	.61	2.7–3.0	<4.0	1.17	2.4–4.0
A2	<3.0	.55	2.7–3.0	<4.0	1.69	2.2–4.0
A3	<3.0	.85	2.6–3.0	4.6	2.57	1.7–5.8
A4	<3.0	2.22	1.9–3.0	<4.0	3.87	1.1–4.0
A5	<3.0	1.35	2.3–3.0	4.2	2.42	1.8–5.4
A6	<3.0	.58	2.7–3.0	<4.0	1.23	2.4–4.0
A7	<3.0	.54	2.7–3.0	<4.0	1.01	2.5–4.0
A8	<3.0	1.51	2.2–3.0	<4.0	3.75	1.1–4.0
A9	<3.0	.43	2.8–3.0	<4.0	.98	2.5–4.0
A10	<3.0	.93	2.5–3.0	<4.0	1.52	2.2–4.0

[a]Standards for "water quality for public water supply at the point at which water is withdrawn for treatment" are gross alpha radioactivity, 3 picocuries per liter, and gross beta radioactivity, 1,000 picocuries per liter (Indiana Water Pollution Control Board, 2001).

[b]Range of possible values calculated by subtracting or adding half of the confidence interval to the reported value. If the gross alpha or beta radioactivity was less than the reporting limit, the upper limit in the range of possible values was the reporting limit.

summarized in table 9; all the data are in appendix 3. Water samples collected during September 2000 at 10 monitoring sites in and near the Impact Area (A1 through A10) were analyzed for total recoverable and dissolved concentrations of magnesium, potassium, and sodium. A substantial difference between the total recoverable and dissolved concentrations was not reported (appendix 3), so dissolved concentrations of magnesium, potassium, and sodium are listed in table 9. Generally, concentrations of major ions in streams were similar during low and high streamflow. Streams and lakes were predominantly a calcium-magnesium-bicarbonate water type. Total organic nitrogen and ammonia concentrations (table 9) during high streamflow were two times the concentration during low streamflow but were less than 1 mg/L. Total phosphorus concentrations (table 9) were about the same during high and low streamflow (less than 0.1 mg/L).

Concentrations of nine trace elements detected in at least one surface-water sample are summarized in table 10; all trace-element data are in appendix 4. Antimony, arsenic, chromium, nickel, silver, thallium, vanadium, and zinc were not detected in any sample. Cadmium, copper, and molybdenum were detected in water samples from streams but not from lakes (sites A7, A8, and A9). Cobalt, selenium, and tin were detected in water samples from lakes but not from streams (appendix 4).

These data indicate detections of lead (appendix 4) in water samples downstream from the Impact Area and adjacent training areas. During low streamflow, an estimated concentration of 1.5-µg/L dissolved lead was reported in the sample from site A3 on Nineveh Creek, downstream from firing ranges in the Impact Area. Estimated concentrations of total lead (0.55 µg/L) were reported in water samples from sites B5 and B6 downstream from training areas with artillery-firing points and practice ranges (Defense Mapping Agency, 1985) and at site A8 in the Puff Lake headwaters adjacent to the Impact Area. During high streamflow, total lead concentrations were 0.7 µg/L at site E5 upstream from the Impact Area; 0.5 to 1 µg/L at sites A4, A5, and A10 downstream from the Impact Area; and 2.0 µg/L at site B5 on Lick Creek. Dissolved lead in these samples during high streamflow was not detected at a reporting limit of 3 µg/L.

The Indiana water-quality standard for protection of aquatic life against chronic toxicity from total lead in water is calculated with the calcium-carbonate hardness of the water sample[e]. The calculated water-quality standard for lead of 1.4 µg/L was exceeded by the 2.0-µg/L total lead concentration in the water sample from site B5, based on the calcium-carbonate hardness concentration of 50 mg/L (appendix 3). Other water samples with lead detections (from sites A3, A4, A5, A8, A10, E5, and B6) did not exceed their calculated water-quality standards for lead.

Indiana water-quality standards were unavailable for iron, manganese, and strontium, but substantial concentrations were reported in samples from six monitoring sites (appendixes 3 and 4). Concentrations of dissolved iron increased substantially from low to high streamflow at four monitoring sites downstream from the Impact Area. The increase in iron was more than tenfold, from 6.8 to 71 µg/L at site A4 and from 7.2 to 120 µg/L at site A10; iron concentrations more than doubled at sites A5 and B5. The largest concentrations of dissolved manganese were in water samples from site A3 in the Impact Area (636 µg/L) and site B6 downstream from training areas with artillery-firing points and a practice range (582 µg/L). These manganese concentrations were about 20 times the median value of 30 µg/L for all streams during low

[e]The Indiana water-quality standard for total lead is calculated with the calcium-carbonate hardness concentration in the sample and the following equation from Indiana Water Pollution Control Board (2001) subsection 327 IAC 2-1-6(a)(3)2.

$$e^{1.273\,[\ln \text{hardness}] - 4.705},$$

where,

e is the base of the natural logarithm,
ln is the natural logarithm, and
hardness is the calcium-carbonate hardness concentration in milligrams per liter.

Table 9. Summary statistics for dissolved major ions and nutrients in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

[All concentrations in milligram per liter; low-streamflow samples in September 2000; high-streamflow samples in July 2001; Std. Dev., standard deviation; -- , no data; < ; less than reporting limit]

Samples from streams (13 during low streamflow and 6 during high streamflow)

	Calcium		Magnesium		Potassium		Sodium		Nitrogen (total)[a]	
Streamflow	Low	High	Low	High	Low	High	Low	High	Low	High
Mean	39	40	13	13	1.9	1.7	5.5	4.4	0.25	0.46
Median	38	42	13	14	2.0	1.9	5.4	4.4	.25	.44
Std. Dev.	21	16	6.5	5.3	.61	.50	1.6	1.7	.07	.13
Minimum	14	18	6.3	7.0	.95	.90	3.0	2.2	.11	.29
Maximum	85	59	27	21	3.0	2.3	9.2	7.3	.34	.61

	Hardness (as calcium carbonate)		Chloride		Silica (as silicon dioxide)		Sulfate		Phosphorus (total)	
Streamflow	Low	High	Low	High	Low	High	Low	High	Low[b]	High[b]
Mean	140	104	5.9	5.3	7.8	7.6	19	17	0.06	0.06
Median	130	109	5.1	4.9	6.4	7.9	15	17	.03	.05
Std. Dev.	78	61	3.3	4.2	2.4	2.6	8.8	3.9	.05	.03
Minimum	48	22	.75	1.2	5.1	4.0	4.9	12	.03	.04
Maximum	290	180	10	12	13	11	42	24	.12	.11

Samples from lakes (3 during low streamflow and zero during high streamflow)

	Calcium	Magnesium	Potassium	Sodium	Nitrogen (total)[a]	Hardness[c]	Chloride	Silica	Sulfate	Phosphorus (total)
Mean	15	5.6	0.94	2.5	0.30	52	0.83	5.0	10	--
Median	14	5.7	.93	2.1	.30	54	.88	3.7	5.9	--
Std. Dev.	4.0	2.2	.03	.70	.10	19	.14	4.5	8.8	--
Minimum	11	3.3	.91	2.0	.30	33	.67	1.3	4.0	<.05
Maximum	19	7.7	.97	3.3	.40	70	.93	10	20	<.05

[a]Total organic nitrogen and ammonia.

[b]Total phosphorus detected in 3 of 13 low-streamflow samples and 5 of 6 high-streamflow samples.

[c]Hardness as calcium carbonate.

Table 10. Summary statistics for trace elements in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

[All concentrations in microgram per liter; all concentrations for dissolved trace elements unless noted; Std. Dev., standard deviation; -- , no data; E, estimated concentration less than reporting limit; < , less than reporting limit listed]

Samples from streams

	Barium		Boron		Cadmium		Copper		Iron	
Streamflow	Low	High	Low	High	Low	High	Low	High	Low	High
Samples	13	6	13	6	13	6	13	6	13	6
Detections	13	6	13	6	0	5	6	5	13	6
Mean	34	36	29E	27E	--	.47	2.7E	4.6E	14	60
Median	28	33	31E	28E	--	.47	2.6E	3.5E	12	60
Std. Dev.	13	12	5.6	6.0	--	.04	.46	2.5	9.3	41
Minimum	18	22	17E	18E	<.6	.41	2.3E	3.0E	5.6	11
Maximum	58	50	34E	34E	<.6	.51	3.3E	9.1E	35	120

	Lead		Lead (total)		Manganese		Molybdenum		Strontium	
Streamflow	Low	High	Low	High	Low	High	Low	High	Low	High
Samples	13	6	13	6	13	6	13	6	13	6
Detections	1	0	2	5	13	6	2	4	13	6
Mean	1.5E	--	.55E	1.5	130	53	2.6E	2.1E	97	84
Median	1.5E	--	.55E	1.5	30	39	2.6E	2.1E	79	67
Std. Dev.	0	--	.02	.70	220	33	.60	.10	48	37
Minimum	<3.0	<3.0	.54E	.70E	15	18	2.3E	2.0E	52	58
Maximum	1.5E	<3.0	.56E	2.0	640	100	2.9E	2.2E	192	151

Samples from lakes

	Barium	Boron	Cadmium	Copper	Iron	Lead	Lead (total)	Manganese	Molybdenum	Strontium
Samples	3	3	3	3	3	3	3	3	3	3
Detections	3	3	0	0	3	0	1	3	0	3
Mean	16	26E	--	--	110	--	.55	150	--	43
Median	15	23E	--	--	26	--	.55	58	--	45
Std. Dev.	7.9	7.3	--	--	160	--	0	210	--	7.4
Minimum	6.6	19E	<.6	<10	17	<3.0	.55	6.9	<20	33
Maximum	26	36E	<.6	<10	290	<3.0	.55	400	<20	50

flow (table 10). Manganese concentrations did not increase substantially from low to high streamflow; an exception is site A10 downstream from the Impact Area where the manganese concentration doubled from 56 to 100 µg/L. Strontium concentrations in water samples from three sites on Nineveh Creek were more than twice the median (table 10). In downstream order, strontium concentrations were 176 µg/L at B2, 151 µg/L at E5, and 192 µg/L at A3.

Quality assurance included laboratory-control samples and method blanks, along with field duplicates, matrix-spike duplicates, field blanks, and trip blanks. Laboratory-control samples with percent recoveries outside the laboratory-control limits resulted in associated water samples being re-extracted (if appropriate) and re-analyzed. Results from re-analysis are listed in tables and appendixes of this report. Aluminum was detected in some laboratory method blanks at approximately the same concentration as some samples; therefore, aluminum was not reported with the trace elements in table 10. Cyclohexane and acetone, volatile organic compounds, were detected in some laboratory method blanks at approximately the same concentration as some samples; therefore, these compounds were not listed as detections.

Concentrations of constituents in sequentially collected, field-duplicate samples were evaluated with the relative percent difference (RPD)[f]. In four pairs of duplicates, the RPD for physical properties, cations, anions, and trace elements was less than or equal to 10 percent, an indication of low natural variability of the sampled waters. (The RPD was greater than 10 percent for total lead and dissolved molybdenum in a pair of duplicates collected during high streamflow; however, the RPD was based on estimated concentrations less than 1.0 µg/L.) Matrix-spike duplicates had percent recoveries of spike constituents and RPD between duplicates that were within established laboratory-control limits. These data indicate analytical results were not biased by interferences in the water samples. Constituents were not detected in the field blanks or trip blanks, which indicated cleaning of sampling equipment and sample storage did not bias the analytical results.

[f]Relative percent difference is the difference of the two concentrations divided by the average of the sum of the concentrations, expressed as percent.

Chemical Analysis of Streambed-Sediment Samples

Seven streambed-sediment samples were collected at six monitoring sites inside of and downstream from the Impact Area in September 2000. Samples were sieved to remove particles larger than 200 µm (fine sand) and dried before chemical analysis. Streambed sediment before processing was variable in particle-size distribution and ranged from 0.6 to 11.2 percent silt and clay, 46.7 to 93.2 percent sand, and about 4.6 to 51.6 percent gravel (table 11). The largest proportion of fine-grained silt and clay particles were in samples from sites A1 and A4. Chemical analysis included trace elements, semivolatile organic compounds, and explosives. Quality-assurance data indicated the RPD between duplicate samples was less than 10 percent for all detected trace elements, with the exception of tin and vanadium. Small concentrations of five trace elements were detected in method blanks but were less than 1 percent of concentrations in the sediment samples.

Explosives, target semivolatile organic compounds, and three trace elements (antimony, silver, and thallium) were not detected. Concentrations of 22 trace elements were detected (table 12). The largest concentrations of nine trace elements were measured in sediment samples from sites A2 and A4 (arsenic, copper, iron, lead, magnesium, potassium, strontium, vanadium, and zinc.) Indiana does not have regulatory standards for chemicals in streambed sediment. For comparison, concentrations of six of the nine trace elements in streambed-sediment samples from the study area were compared with fresh-water-sediment-quality criteria for protection of aquatic life (Canadian Council of Ministers of the Environment, 1995 and 1999).

Table 11. Physical properties of streambed-sediment samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000

Monitoring site (figure 7)	Percent sand[a]	Percent gravel[b]	Percent silt and clay[c]	Percent moisture[d]
A1	80.4	13.5	6.1	11.0
A2	46.7	51.6	1.7	20.9
A3	92.2	6.8	1.0	18.6
A4	83.8	5.0	11.2	33.2
A5	80.6	18.8	.6	16.0
A10	93.2	4.6	2.2	23.2

[a]Particle size 63 to 2,000 micrometers.

[b]Particle size greater than 2,000 micrometers.

[c]Particle size less than 63 micrometers.

[d]Percent moisture determined for the processed sediment sample submitted for chemical analysis; other physical properties determined for the unprocessed sediment sample.

Table 12. Concentrations of trace elements detected in streambed-sediment samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000

[Concentrations in milligram per kilogram; < , not detected at less than reporting limit concentration; E, estimated concentration is less than reporting limit; concentrations of antimony, silver, and thallium were not detected in all samples]

Monitoring site (figure 7)	Aluminum	Arsenic	Barium	Beryllium	Boron	Calcium	Chromium	Cobalt
A1	2,010	2.0	11.0	0.28E	1.0E	2,730	5.4	3.4
A2	2,290	5.0	13.7	.27E	2.3E	42,300	6.8	2.8
A3	1,170	2.4	11.8	<.61	1.7E	47,900	3.5	1.6
A4	2,420	3.9	19.5	<.75	2.6E	64,200	5.1	2.3
A5	1,530	2.2	13.6	.18E	1.9	41,200	6.6	2.0
A10	1,170	3.8	13.8	<.65	<13	294	5.6	2.1

Monitoring site	Copper	Iron	Lead	Magnesium	Manganese	Molybdenum	Nickel	Potassium
A1	2.1	5,000	2.4	2,190	92.5	<2.2	6.0	183E
A2	19	7,800	4.7	15,400	249	.65E	6.8	311E
A3	2.2E	4,410	2.7	15,100	150	.38E	3.9E	167E
A4	5.8	6,790	4.6	26,300	245	<3.0	5.4E	282E
A5	2.5	5,490	3.1	14,700	203	.49E	5.2	220E
A10	1.9E	5,380	2.9	227	318	<2.6	2.8E	95E

Monitoring site	Selenium	Sodium	Tin	Strontium	Vanadium	Zinc	Number detected
A1	<1.5	<562	0.56E	3.20	6.2	11.9	19
A2	<1.6	<632	.54E	30.5	8.4	15.2	20
A3	<1.6	<615	.55E	29.4	5.0	9.40	19
A4	<1.9	<1,748	<15	36.2	8.8	17.5	17
A5	.64E	<595	.64E	26.7	7.7	10.9	21
A10	<1.7	165E	<13	1.20E	8.1	6.70	17

These criteria are used by the USGS NAWQA Program for comparison of trace-element concentrations in streambed sediments. Concentrations of arsenic, chromium, copper, lead, nickel, and zinc were less than 50 percent of the NAWQA criteria, except for arsenic and copper in the sample from site A2. In the sample from A2, arsenic was 5.0 mg/kg, compared with a criteria of 5.9 mg/kg; copper was 19 mg/kg, compared with a criteria of 35.7 mg/kg. Criteria were not available for 16 detected trace elements.

The mean, median, minimum, and maximum concentrations for eight trace elements detected in the six streambed-sediment samples collected in the study area in September 2000 (table 13) were compared with streambed-sediment data for 18 sites sampled in 1992 throughout the White River Basin in Indiana (Rice, 1999) and for 33 sites sampled from 1994 through 1996 on the White River and its tributaries in the Indianapolis area (Voelker and Renn, 2000). These two sets of streambed-sediment data include rural and urban environments, forest and agricultural land use, and watersheds generally larger than most of those at Camp Atterbury. The comparison indicates that concentrations of aluminum, arsenic, chromium, copper, iron, lead, nickel, and zinc in the study area were less than the concentrations throughout the White River Basin. The mean, median, and maximum concentrations of aluminum, arsenic, and iron in the study area were similar to the White River and its tributaries near Indianapolis; concentrations of chromium, copper, lead, nickel, and zinc were less than those from the White River and its tributaries near Indianapolis.

Chemical Analysis of Fish-Tissue Samples

Ten fish-tissue samples were collected from seven stream reaches and two lakes in October 2000 (table 14, p. 41). Site A3 in the Impact Area is not listed in table 14 because the minimum number of fish from the target species were not collected. Whole-fish samples of creek chub (*Semotilus atromaculatus*) were obtained from four stream reaches. Fish-fillet samples of spotted bass (*Micropterus punctulatus*) were obtained from three stream reaches. Fish-fillet samples of largemouth bass (*Micropterus salmoides*) were obtained from two lakes. At Puff Lake, two composite samples were prepared—one with seven small, immature fish; the other with two large, mature fish.

Nineteen trace elements were detected in the 10 fish-tissue samples (table 15, p. 42). Detections of aluminum in five samples and lead in four samples may be laboratory artifacts because the difference between sample concentrations and method-blank concentrations was less than 50 percent. Explosives or semivolatile organic compounds were not detected. An exception was one semivolatile organic compound, the plasticizer di(2-ethylhexyl) phthalate, reported in five of the six fish-fillet samples. Concentrations in four of the six samples were estimated to be less than the 1.0-mg/L reporting limit; at least these four detections could be potential artifacts of sample preparation, but no data were available to confirm the source of the compound.

Concentrations of the following eight trace elements were larger in whole-fish samples than in fish-fillet samples: barium, calcium, copper, iron, lead, manganese, strontium, and zinc (table 15). The difference may be because of the livers in whole-fish samples (trace elements tend to concentrate in the liver). Overall, the largest concentrations of barium, calcium, copper, lead, magnesium, manganese, strontium, and zinc were in fish-tissue samples from stream sites in the Impact Area (sites A2, A4, or A10). By comparison, the largest concentrations of aluminum, boron, copper, iron, lead, magnesium, strontium, vanadium, and zinc were in streambed-sediment samples (table 12) from sites A2 and A4 in the Impact Area. Fish-tissue samples from largemouth bass in Puff Lake (A9) appeared to have similar numbers and concentrations of trace elements, whether the samples were from small, immature fish or large, mature fish.

State or federal regulatory standards or assessment criteria were not available for the trace elements detected in the fish-tissue samples. Guidance from the U.S. Food and Drug Administration (1993) lists “levels of concern” in shellfish for

Table 13. Comparative statistics for concentrations of selected trace elements detected in streambed-sediment samples collected at Camp Atterbury, Indiana, September 2000, and from the White River Basin, Indiana, 1992 and 1994–96

[mg/kg, milligram per kilogram; 10,000 mg/kg is 1 percent; < , not detected at less than reporting-limit concentration]

Location	Comparative statistics	Aluminum (percent)	Arsenic (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)
6 sites in Camp Atterbury	Mean	0.18	3.2	5.5	5.6
	Median	.18	3.1	5.5	2.4
	Minimum	.12	2.0	3.5	1.9
	Maximum	.24	5.0	6.8	19
18 sites in White River Basin[a]	Mean	5.3	8.1	77	38
	Median	5.3	7.9	56	25
	Minimum	4.6	4.7	47	15
	Maximum	5.7	11	270	120
33 sites on White River and tributaries near Indianapolis[b]	Mean	.18	3.3	8.5	22
	Median	.13	3.0	6.0	10
	Minimum	.01	2.0	1.0	10
	Maximum	.48	9.0	70	97

Location	Comparative statistics	Iron (percent)	Lead (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)
6 sites in Camp Atterbury	Mean	0.58	3.4	5.0	12
	Median	.54	3.0	5.3	11
	Minimum	.44	2.4	2.8	6.7
	Maximum	.78	4.7	6.8	17
18 sites in White River Basin[a]	Mean	2.8	54	35	140
	Median	2.8	29	29	100
	Minimum	2.1	18	23	72
	Maximum	3.2	280	77	360
33 sites on White River and tributaries near Indianapolis[b]	Mean	.56	31	15	40
	Median	.56	20	10	30
	Minimum	.04	<10	<10	5
	Maximum	1.7	140	30	190

[a]Rice, 1999.

[b]Voelker and Renn, 2000.

Table 14. Characteristics of fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, October 2000

[Creek chub, *Semotilus atromaculatus*; spotted bass, *Micropterus punctulatus*; largemouth bass, *Micropterus salmoides*]

Monitoring site (figure 7) near stream reach	Sample location	Type of sample	Total weight of sample (grams)	Number of individuals and species	Minimum total length (centimeters)	Maximum total length (centimeters)
A2	Prince Creek	Whole fish	307	15 Creek chub	11.0	14.0
A4	Unnamed tributary	Whole fish	303	9 Creek chub	12.6	16.8
A10	Muddy Branch	Whole fish	313	10 Creek chub	13.2	17.5
B5	Lick Creek	Whole fish	310	10 Creek chub	12.0	15.5
A1	Mud Creek	Fish fillet	388	4 Spotted bass	26.9	29.8
A5	Nineveh Creek	Fish fillet	311	4 Spotted bass	22.0	25.0
B4	Nineveh Creek	Fish fillet	323	4 Spotted bass	19.2	33.7
A7	Duck Pond	Fish fillet	339	6 Largemouth bass	21.1	30.1
A9	Puff Lake	Fish fillet	238	7 Largemouth bass	17.0	24.6
A9	Puff Lake	Fish fillet	289	2 Largemouth bass	32.2	34.4

three trace elements; concentrations in fish-tissue samples were less than those three levels of concern—arsenic (86 mg/kg), cadmium (3.7 mg/kg), and lead (1.7 mg/kg).

Biological Quality

The data from the biological assessment are presented in this section and are compared with evaluative criteria. The data are from microbiological analyses in 2000 and 2001 and from fish-community inventories, benthic-macroinvertebrate inventories, and qualitative habitat evaluations in 2000. Interpretations of these data are in the Short-Term and Long-Term Conditions section of this report.

Microbiological Data

Typically, *E. coli* in water is direct evidence of the presence of fecal contamination from warm-blooded animals and indicates the possible presence of pathogens. *E. coli* is one of the two preferred indicator bacteria used by the USEPA and IDEM to determine the suitability of surface water for recreational use. The Indiana water-quality standard[g] for full-body-contact recreational use requires the *E. coli* concentration to be less than the single-sample standard of 235 col/100 mL and less than the geometric mean of 125 col/100 mL computed from five samples collected within a 30-day period.

As part of the base-wide assessment in September 2000, six stream-water samples were analyzed for *E. coli*, and four of the six samples exceeded the single-sample standard (table 16, p. 43). The presence of these fecal-indicator bacteria in water flowing into the study area (sites B1 on Prince Creek and B2 on Nineveh Creek) and in water flowing out of the study area (sites B4 on Nineveh Creek and B5 on Lick Creek) prompted the *E. coli* monitoring during May and June 2001.

[g]Indiana Water Pollution Control Board, 2001, subsection 327 IAC 2-1-6.

Table 15. Concentrations of trace elements detected in fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, October 2000

[Concentrations in milligram per kilogram; < , not detected at less than reporting-limit concentration; E, estimated concentration is less than reporting limit; B, difference between sample concentration and laboratory method blank is less than 50 percent of the method-blank concentration (indicating sample concentration could be biased high)]

Monitoring site (figure 7)	Trace elements detected[a]	Aluminum	Antimony	Arsenic	Barium	Calcium	Cadmium	Cobalt
Stream site (whole fish)								
A2	12	<10	<1.0	<1.0	2.4	12,500	<0.5	<1.0
A4	13	4.0 E,B	.38 E	<1.0	1.5	4,650	<.5	<1.0
A10	13	4.1 E,B	.47 E	<1.0	2.2	12,700	<.5	<1.0
B5	13	5.6 E,B	.42 E	<1.0	1.4	8,660	<.5	<1.0
Stream site (fish fillet)								
A1	11	<10	<1.0	<1.0	.18 E,B	1,310	<.5	<1.0
A5	14	3.8 E,B	<1.0	.54 E	.46 E	3,150	<.5	.49 E
B4	12	<10	<1.0	<1.0	.52 E	3,540	<.5	<1.0
Lake site (fish fillet)								
A7	13	<10	<1.0	<1.0	.21 E	1,270	<.5	<1.0
A9 (small[b])	11	<10	.38 E	<1.0	.18 E,B	1,390	.1 E	<1.0
A9 (large[b])	12	3.7 E,B	.58 E	<1.0	.14 E,B	881	<.5	<1.0

Monitoring site	Copper	Iron	Lead	Magnesium	Manganese	Potassium	Sodium	Selenium
Stream site (whole fish)								
A2	1.7 E	14	0.25 E,B	439	4.5	2,850	964	0.63 E
A4	1.4 E	20	.32 E,B	316	2.3	2,970	895	.69 E
A10	1.3 E	17	.40 E,B	432	6.2	2,840	1,230	.68 E
B5	.95 E	24 E	<.8	371	1.9	2,720	991	.51 E
Stream site (fish fillet)								
A1	.42 E	3.4	<.8	283	.25 E	3,560	617	.76 E
A5	<2.0	6.6 E	<.8	436	.49 E	3,730	772	.79 E
B4	.44 E	4.4	<.8	403	.33 E	3,830	775	.80 E
Lake site (fish fillet)								
A7	<2.0	3.7	<.8	368	.47 E	3,510	725	1.0 E
A9 (small[b])	.33 E	<10	<.8	344	.36 E	4,070	627	<1.3
A9 (large[b])	<2.0	4.5 E	.34 E,B	328	.22 E	3,830	569	.50 E

Table 15. Concentrations of trace elements detected in fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, October 2000—Continued

Monitoring site (figure 7)	Strontium	Tin	Thallium	Zinc
Stream site (whole fish)				
A2	14	1.2 E	<1.2	23
A4	3.2	1.4 E	<1.2	21
A10	9.3	1.5 E	<1.2	27
B5	5.7	1.0 E	<1.2	23
Stream site (fish fillet)				
A1	.91	1.0 E	<1.2	8.5
A5	4.7	.92 E	<1.2	9.4
B4	4.8	.79 E	<1.2	12
Lake site (fish fillet)				
A7	3.2	.71 E	.46 E	10
A9 (small[b])	.89 E	1.3 E	<1.2	12
A9 (large[b])	.57 E	1.4 E	<1.2	6.4

[a]Number does not include trace elements with a B qualifier.

[b]Lake site A9 fish fillets from small (immature) or large (mature) fish.

In May and June 2001, 100 samples from 20 monitoring sites at Camp Atterbury were analyzed for *E. coli*. The number and location of monitoring sites and the 30-day sampling period were intended to examine a greater range of streamflow conditions and more stream reaches than were examined in September 2000. Four of the monitoring sites were at lakes that could be used by Camp Atterbury personnel for full-body-contact recreation. Each week in this 30-day period, five water-quality characteristics[h] were determined at the 20 sites and instantaneous streamflow was measured at the 16 sites on streams.

[h]pH, specific conductance, water temperature, dissolved oxygen, and turbidity.

Table 16. Concentrations of *Escherichia coli* in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000

[*E. coli*, *Escherichia coli*, concentration in colonies per 100 milliliters; concentrations in **bold** are greater than the single-sample Indiana water-quality standard for full-body-contact recreation (235 colonies per 100 milliliters)]

Monitoring site (figure 7)	Watershed and location	*E. coli* concentration
B1	Prince Creek, upstream	**640**
B2	Nineveh Creek, upstream	**390**
B3	Mud Creek, Saddle Creek	110
B4	Nineveh Creek, downstream	**280**
B5	Lick Creek, downstream	**270**
B6	Catherine Creek, downstream	100

For quality assurance, 30 samples were analyzed along with the 80 stream and 20 lake samples. Quality-assurance data indicated the sterilization of sample bottles and sample-processing equipment was effective, the final rinses of filtering equipment were adequate, and the difference in concentrations of duplicate samples was small.

The *E. coli* concentrations for each site for each week and the 30-day (five-sample) geometric mean are listed in table 17. The monitoring sites and the 30-day geometric-mean concentrations for samples collected at each site are shown in figure 14 (p. 45). None of the lake samples exceeded the Indiana single-sample standard. Each week, from 4 to 11 of the 16 stream samples exceeded the single-sample standard. The 30-day geometric-mean concentrations at all 16 monitoring sites on streams exceeded the Indiana standard for recreational use. The weekly *E. coli* concentrations, instantaneous-streamflow, and water-quality-characteristics data for these 16 sites are listed in appendix 5.

Table 17. Concentrations of *Escherichia coli* in water samples collected at Camp Atterbury near Edinburgh, Indiana, May 14 through June 14, 2001

[*E. coli*, *Escherichia coli*, concentrations in colonies per 100 milliliters; concentrations in **bold** are greater than the single-sample Indiana water-quality standard for full-body-contact recreation (235 colonies per 100 milliliters); concentrations in ***underlined bold italics*** are greater than the 30-day (five-sample) geometric mean Indiana water-quality standard for full-body-contact recreation (125 colonies per 100 milliliters)]

Monitoring site (figure 7)	Watershed and location	*E. coli* concentrations in single weekly samples					30-day geometric mean[a]
		May 14 through May 17	May 21 through May 24	May 29 through June 1	June 4 through June 7	June 11 through June 14	
E1	Prince Creek, Hants Lake	215	**470**	143	**530**	188	***268***
E2	Prince Creek, East Lake	**480**	**380**	93	**1,400**	68	***276***
E3	Mud Creek, upstream	**490**	**2,650**	93	230	200	***353***
E4	Nineveh Creek tributary	90	**360**	72	**500**	**1,100**	***264***
E5	Nineveh Creek	67	147	41	**1,233**	117	***143***
E6	Nineveh Creek tributary	203	172	**967**	**2,000**	**500**	***505***
E7	Nineveh Creek tributary	21	170	**440**	**866**	**670**	***247***
B1	Prince Creek, upstream	187	210	123	**477**	200	***215***
B2	Nineveh Creek, upstream	153	**240**	**250**	**2,767**	**610**	***434***
B3	Mud Creek, Saddle Creek	**900**	**2,225**	43	70	100	***226***
B4	Nineveh Creek, downstream	54	170	110	**2,325**	82	***180***
B5	Lick Creek, downstream	200	**862**	**400**	110	110	***211***
A4	Nineveh Creek tributary	122	132	73	**2,225**	210	***221***
A5	Nineveh Creek, downstream	137	230	132	177	180	***168***
A6	Mud Creek, upstream	**510**	**5,500**	100	**28**	**240**	***285***
A10	Muddy Branch, downstream	128	147	113	**1,800**	120	***215***
E8	Puff Lake Foxfire Cabin	1[b]	4	77	4	4	6
E9	Puff Lake boat ramp	6.7	2	12	3	3	5
E10	New Lake	12	16	1[b]	140	1[b]	30
E11	Engineer Pond	3	10	3	10	1[b]	6

[a]The 30-day (five-sample) geometric mean was calculated with the equation

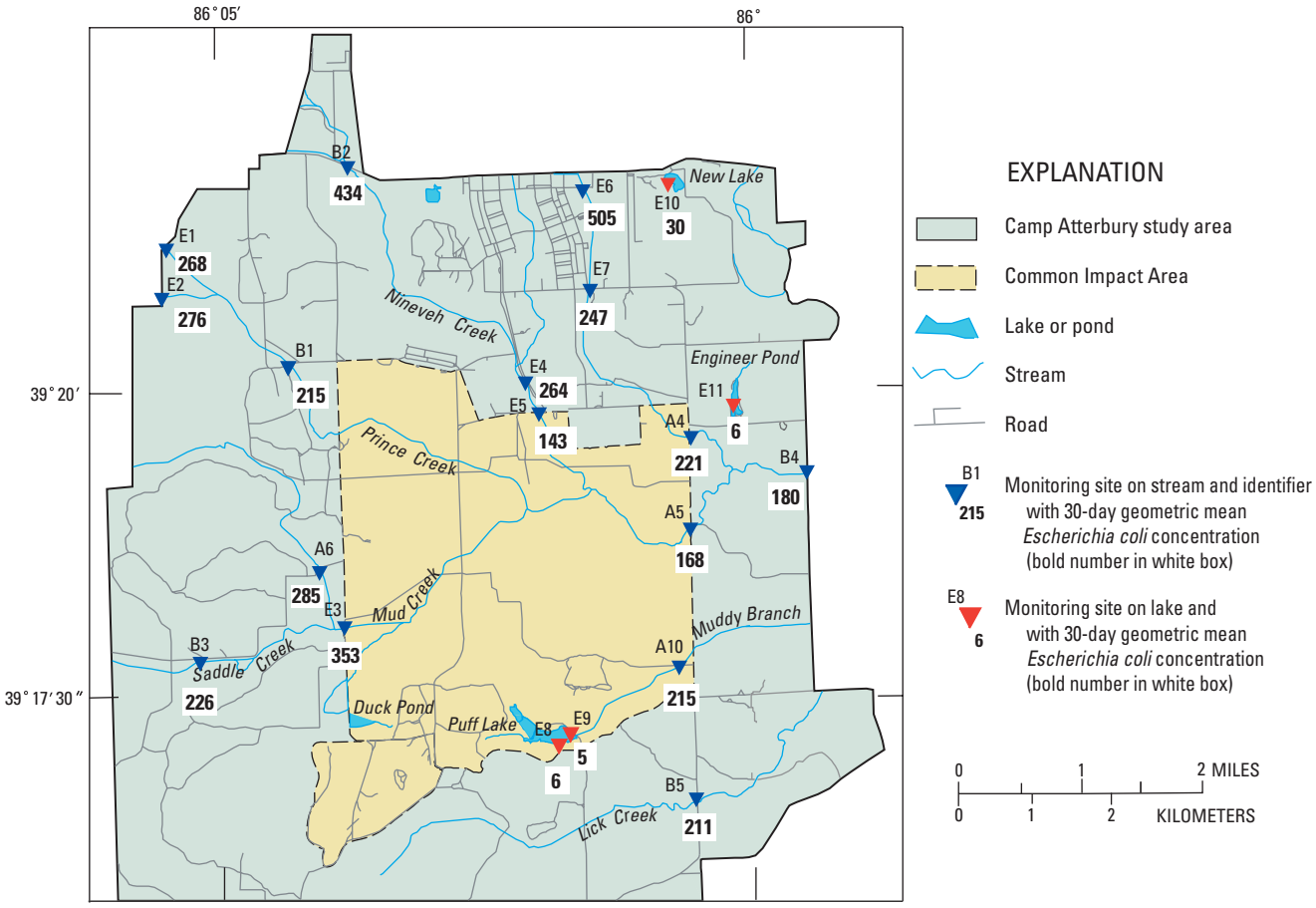
$$GM = \sqrt[5]{S_1 \times S_2 \times S_3 \times S_4 \times S_5}$$

where,

GM is the geometric mean, and

Si is the concentration of *E. coli* measured in each of the five samples.

[b]Concentration of zero was adjusted to 1 for calculation of 30-day geometric mean.



Base modified from Defense Mapping Agency, 1985, 1:50,000
Projection: Universal Transverse Mercator, Zone 16,
North American Datum of 1983 (NAD 83)

Figure 14. Monitoring sites and 30-day geometric mean *Escherichia coli* concentrations in water samples collected at Camp Atterbury near Edinburgh, Indiana, May 14 through June 14, 2001.

Among the 80 water samples collected from streams during May and June 2001, the *E. coli* concentrations ranged from 21 to 5,500 col/100 mL. The boxplot of the distribution of the concentrations (fig. 15) shows that the median concentration was 195 col/100 mL. As the boxplot indicates, the data distribution was skewed, with half of the data values between 195 and 5,500 col/100 mL and half between 21 and 195 col/100 mL.

The stream data were grouped and statistical analysis was done to determine if the *E. coli* concentrations were related to instantaneous streamflow, specific conductance (a measure of dissolved solids), or turbidity (a measure of suspended solids). Data for the 16 stream samples from each of the 5 weeks were statistically analyzed, as were the data for all 80 water samples from streams. Kendall's Tau correlation coefficients (Helsel and Hirsch, 1995, p. 212) were calculated to determine the significance of these potential relations. Kendall's Tau is a rank-based procedure that is resistant to outliers and measures linear and nonlinear correlations, even for small sample sizes. At the 5-percent level of significance (α=0.05), *E. coli* concentration and instantaneous streamflow were not related for each of the 5 weeks and for the 80 stream samples. At the 5-percent level of significance, *E. coli* concentration and specific

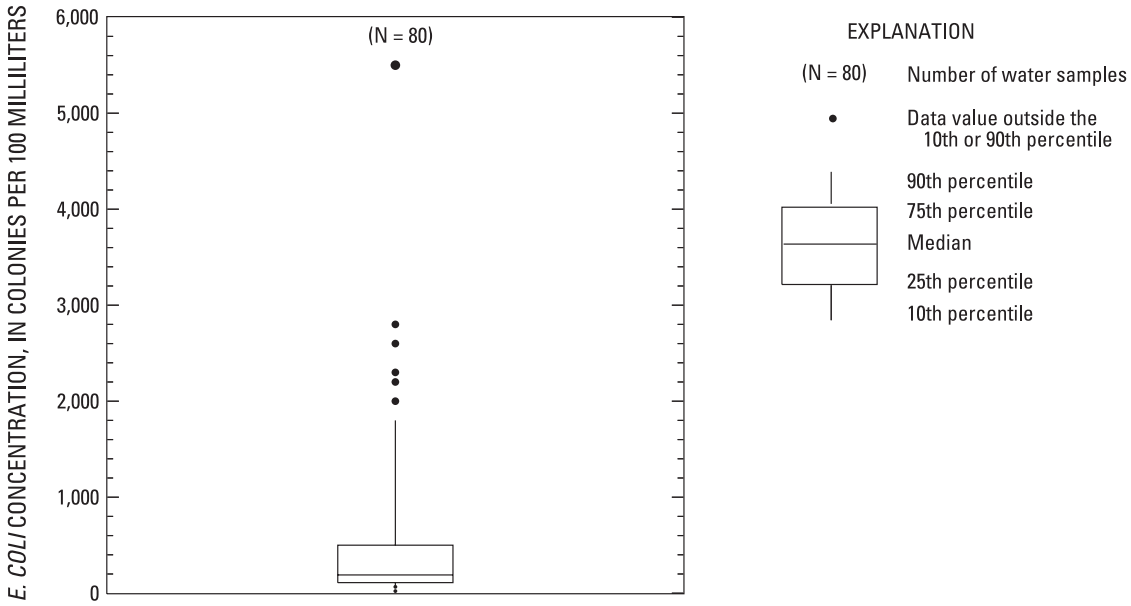


Figure 15. Boxplot of *Escherichia coli* (*E. coli*) concentrations in water samples collected from 16 monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May 14 through June 14, 2001.

conductance were not related for the 80 stream samples. During 2 of the 5 weeks, *E. coli* concentration increased as specific conductance decreased ($p = 0.01$)[i]. A statistically significant correlation was shown between *E. coli* concentration and turbidity for the 80 stream samples ($p = 0.0005$), whereby increased turbidity indicated increased *E. coli*. A similar correlation between *E. coli* concentration and turbidity ($p = 0.001$) has been reported for the Wabash, Kankakee, and Ohio River Watersheds in Indiana in 1998, 1999, and 2000 (Silcox and others, 2002).

Fish-Community Inventories

During October 2000, USGS personnel electroshocked nine stream reaches at Camp Atterbury, using the technique described in the Study Methods section of this report. During September 2000, personnel from the Indiana Department of Natural Resources (IDNR) Division of Fish and Wildlife and the Camp Atterbury Land Conditions Trends Analysis Office electroshocked a stream reach near site A10, using a similar but undocumented technique. The data for the reach near site A10 are included in this report but may not be completely comparable to the other nine reaches because of the differences in techniques. The number and weight of fish by species for the 10 stream reaches are listed in appendix 6.

Among the 10 reaches electroshocked in September and October 2000, 45 fish species were collected, representing 10 families (table 18), ranging from 10 to 25 species per reach (table 19). The total number of individuals at the nine USGS electroshocked reaches ranged from 88 to 771, and the total weight of individuals ranged from 371 to 5,322 grams. At site A10, 45 individuals were reported. The fewest species, number of individuals, or lowest total weight were in reaches near sites B3 and A10.

[i]The p-value is the significance level attained by the data (Helsel and Hirsch, 1995, p. 108). The smaller the p-value, the more likely there is a correlation between *E. coli* concentration and the other variable, such as specific conductance or turbidity.

Table 18. Species identified during fish-community inventories at Camp Atterbury near Edinburgh, Indiana, September and October 2000

Scientific name	Common name
Atherinidae	**Silversides**
Labidesthes sicculus	Brook silverside
Catostomidae	**Suckers**
Catostomus commersoni	White sucker
Erimyzon oblongus	Creek chubsucker
Hypentelium nigricans	Northern hog sucker
Minytrema melanops	Spotted sucker
Moxostoma duquesnei	Black redhorse
Moxostoma erythrurum	Golden redhorse
Moxostoma macrolepidotum	Shorthead redhorse
Centrarchidae	**Sunfishes**
Ambloplites rupestris	Rock bass
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Micropterus dolomieu	Smallmouth bass
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis nigromaculatus	Black crappie
Cottidae	**Sculpins**
Cottus bairdi	Mottled sculpin
Cyprinidae	**Carps and minnows**
Campostoma anomalum	Central stoneroller
Cyprinella spiloptera	Spotfin shiner
Cyprinella whipplei	Steelcolor shiner
Luxilus chrysocephalus	Striped shiner
Cyprinidae—Continued	**Carps and minnows—Continued**
Lythrurus umbratilis	Redfin shiner
Notropis atherinoides	Emerald shiner
Notropis boops	Bigeye shiner
Notropis buccatus	Silverjaw minnow
Notropis photogenis	Silver shiner
Notropis stramineus	Sand shiner
Phenacobius mirabilis	Suckermouth minnow
Pimephales notatus	Bluntnose minnow
Pimephales promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Semotilus atromaculatus	Creek chub
Esocidae	**Pikes**
Esox americanus vermiculatus	Grass pickerel
Fundulidae	**Topminnows**
Fundulus catenatus	Northern studfish
Ictaluridae	**Bullhead catfishes**
Ameiurus natalis	Yellow bullhead
Percidae	**Perches**
Etheostoma blennioides	Greenside darter
Etheostoma nigrum	Johnny darter
Etheostoma spectabile	Orangethroat darter
Percina caprodes	Logperch
Percina maculata	Blackside darter
Percina sciera	Dusky darter
Petromyzontidae	**Lampreys**
Lampetra appendix	American brook lamprey

Table 19. Summary of fish-community inventories at Camp Atterbury near Edinburgh, Indiana, September and October 2000

Monitoring site (figure 7) near stream reach	Date of inventory	Method of electroshocking and time (seconds)	Length of stream reach inventoried (feet)	Number of species	Number of individuals	Total weight of individuals (grams)
B1	October 3	Backpack, 2 passes (1st) 1,123; (2nd) 865	450	15	430	3,717
B2	October 3	Backpack, 2 passes (1st) 1,166; (2nd) 719	430	15	320	2,341
B3	October 2	Backpack, 2 passes (1st) 952; (2nd) 758	484	10	88	371
B4	October 23	Barge, 2 passes (1st) 1,496; (2nd) 1,247	900	23	240	1,541
B5	October 10	Backpack, 2 passes (1st) 1,168; (2nd) 1,440	550	13	133	940
B6	October 25	Backpack, 2 passes (1st) 1,431; (2nd) 690	675	22	771	4,635
A4	October 4	Backpack, 2 passes (1st) 1,311; (2nd) 747	481	17	442	2,557
A5	October 16	Barge, 2 passes (1st) 1,886; (2nd) 1,280	635	25	559	5,322
A6	October 2	Backpack, 2 passes (1st) 844; (2nd) 669	408	13	223	626
A10[a]	September 18	Backpack, 1 pass no information	450	10	45	729

[a]Fish-community-inventory data from September 2000 provided by personnel from Camp Atterbury Land Conditions Trends Analysis Office.

The most frequently collected fish were in the family Cyprinidae (carps and minnows), representing 75 percent of all individuals. The top five species based on number of individuals, in order, were bluntnose minnow (*Pimephales notatus*), central stoneroller (*Campostoma anomalum*), spotfin shiner (*Cyprinella spiloptera*), creek chub (*Semotilus atromaculatus*), and steelcolor shiner (*Cyprinella whipplei*). A single specimen of eight species was collected—spotted sucker (*Minytrema melanops*), rock bass (*Ambloplites rupestris*), pumpkinseed (*Lepomis gibbosus*), black crappie (*Pomoxis nigromaculatus*), silver shiner (*Notropis photogenis*), smallmouth bass (*Micropterus dolomieu)*, rainbow darter (*Etheostoma caeruleum*), and fathead minnow (*Pimephales promelas*). One species that was collected, the northern studfish (*Fundulus catenatus*), is listed as a species of concern in Indiana (Dufour, 2000).

The fish-community integrity near the monitoring sites was described by eight measures, including species presence and abundance (appendix 6); species composition, trophic composition, and fish condition (the Index of Biotic Integrity or IBI); and species diversity, biomass, and numbers of individuals (the Modified Index of Well-Being or MIWB). Calculations of the IBI and MIWB are described in the Study Methods section of this report.

The IBI and MIWB scores were ranked in a fish-community-integrity class by use of the scale in table 20. The IBI and QHEI scores also were compared with criteria used by IDEM for evaluating whether the scores fit categories of "full support," "partial support," or "no support" (table 21, p. 51) for the aquatic-life use of the Indiana water-quality standards. Evaluative criteria for the MIWB were not available from IDEM.

Fish-community integrity based on the IBI classification was fair or good near 8 of the 10 monitoring sites; it was exceptional near 9 sites, based on the MIWB. The fish-community integrity near sites A10 and B3 indicated potential concern. Site A10 was not supporting the aquatic-life use because the IBI of 28 was less than the IDEM criteria; the IBI class was poor and the MIWB class was good. (The lowest MIWB for all of the sites was calculated for site A10.) The QHEI for site A10 was 67 (fully supporting the aquatic-life use), indicating that stream habitat probably did not contribute to the low IBI and MIWB. Site B3 with an IBI of 34 was rated as partially supporting the aquatic-life use, according to the IDEM criteria. The IBI class for site B3 was poor, but the MIWB was exceptional. The QHEI score for site B3 was 70, fully supporting the aquatic-life use.

At least four explanations are possible for the poor IBI class near site A10. (1) The different sampling technique used by IDNR personnel for site A10 (for example, one electroshocking pass instead of two) may have contributed to the low IBI because fewer fish were collected. (2) The upstream drainage area near site A10 (2.23 mi^2, table 2) was the smallest of the 10 reaches in the fish-community inventory. (3) The reach near site A10 was on Muddy Branch downstream from the Impact Area; activities in the Impact Area potentially could have affected the fish community. (4) The sampling reach was downstream from Puff Lake, which had a break in the lake spillway during 1999, according to Camp Atterbury personnel. During the excessive flow that partially drained Puff Lake during the spillway break, Camp Atterbury personnel observed predator fish such as largemouth bass from Puff Lake being washed into Muddy Branch (Art Howard, Camp Atterbury Land Conditions Trends Analysis manager, 2000, oral commun.).

At least two explanations are possible for the poor IBI class near site B3 on Saddle Creek. (1) The upstream drainage area (2.95 mi^2, table 2) was the second smallest of the 10 reaches in the fish-community inventory. (2) Reaches of Saddle Creek upstream from site B3 were dry during September and October 2000. No precipitation was recorded at Columbus or Franklin, Ind., (Purdue Applied Meteorology Group, 2001) on the dates in October when fish-community inventories were done. The dry reaches potentially isolated some fish in pools that could have been in the inventory.

The fish-community inventories from 10 reaches at Camp Atterbury in October 2000 were compared with the IDEM fish-community assessment for 32 reaches in the East Fork White River Basin in 1997 (Dufour, 2000). The East Fork White River data were for 19 headwater reaches (59 percent), 9 wadeable reaches (28 percent), and 4 large river reaches; the Camp Atterbury data were for 8 headwater reaches (80 percent) and 2 wadeable reaches (20 percent). Six of the IDEM reaches were in the Driftwood River Basin.

Fish from 9 of the 15 families and 40 of the 84 species listed by IDEM were collected at Camp Atterbury. At Camp Atterbury, the family Cyprinidae (carps and minnows) numerically dominated the fish communities (75 percent of the individuals) as it did in the East Fork White River Basin (60 percent of the individuals).

Of the 45 species identified at Camp Atterbury (table 18), 5 were not listed in the IDEM assessment—brook silverside (*Labidesthes sicculus)*, pumpkinseed (*Lepomis gibbosus*), silver shiner (*Notropis photogenis*), blackside darter (*Percina maculata*), and American brook lamprey (*Lampetra appendix*). A single specimen of the pumpkinseed and silver shiner was collected at Camp Atterbury. Of the five fish species identified by IDEM in the East Fork White River Basin that were considered to be rare, endangered, or of special concern in Indiana, only one of these species was identified at Camp Atterbury—the northern studfish (*Fundulus catenatus*), considered a species of special concern.

Table 20. Fish-community-integrity classes and attributes for Index of Biotic Integrity and Modified Index of Well-Being scores

[IBI, Index of Biotic Integrity (Simon and Dufour, 1998); MIWB, Modified Index of Well-Being (Ohio Environmental Protection Agency, 1987); > , greater than; < , less than]

Index	Range of scores[a]	Community-integrity class	Fish-community attributes
IBI	58 –60	Excellent	No human disturbance; most pollution-intolerant species; full array of age classes; balanced trophic structure
	48 –52	Good	Loss of most pollution-intolerant species; less than optimal species abundance and age classes; trophic structure stressed
	40 –44	Fair	Loss of pollution-intolerant species; fewer species; fewer older top predators; skewed trophic structure
	28 –34	Poor	Dominated by omnivores, tolerant species, and habitat generalist; depressed growth rates; more hybrids and diseased fish
	12 –22	Very Poor	Few fish; mostly introduced and tolerant species; deformities, diseases, parasites, fin damage common
MIWB	>9.4	Excellent	Unusual assemblage of species; sensitive species abundant; exceptional species richness; species with endangered, threatened, or special concern status present
	8.6– 9.4	Good	Usual association of expected species; sensitive species present; high species richness
	6.4– 8.5	Fair	Some expected species absent or in low abundance; sensitive species absent or in low abundance; declining species richness; tolerant species beginning to dominate
	5.0– 6.3	Poor	Many expected species absent or in low abundance; sensitive species absent; low species richness; tolerant species predominate
	<5.0	Very Poor	Most expected species absent; only most-tolerant species remain; very low species richness; community organization lacking

[a]Ranges of scores do not include all values, based on table in Simon and Dufour (1998).

The mean IBI for the 10 reaches at Camp Atterbury (table 21) was 39 (fair), with a range from 28 (poor) to 46 (good). In the East Fork White River Basin (Dufour, 2000), the mean IBI was 37 (fair) and ranged from 12 (very poor) to 54 (excellent). These data indicate that the fish communities at Camp Atterbury generally are typical of the larger East Fork White River Basin. Habitat at Camp Atterbury based on QHEI ranged from 57 to 84 (table 21), with a mean of 72. In the East Fork White River, QHEI ranged from 39 to 83 with a mean of 57. These data indicate that stream habitat at Camp Atterbury generally was better than in the larger basin but the health of the fish communities was not better, based on similar mean IBI scores.

Benthic-Macroinvertebrate-Community Inventories

Benthic macroinvertebrates are animals that live on or in the streambed sediments and on plants, algae, and woody debris of aquatic habitats such as streams and lakes. These animals include aquatic insects, segmented worms, flatworms, snails, clams, and crustaceans. Benthic macroinvertebrates frequently are used in water-quality studies to rank aquatic habitats according to their biological health (Hilsenhoff, 1977 and 1987). Biologists divide animals into taxa, from largest to smallest—phylum, class, order, family, genus, and species.

Some taxa of benthic macroinvertebrates identified in samples collected from stream reaches

Table 21. Numerical indexes for fish-community inventories and habitat evaluations at Camp Atterbury near Edinburgh, Indiana, September and October 2000

[IBI, Index of Biotic Integrity; MIWB, Modified Index of Well-Being; QHEI, Qualitative Habitat Evaluation Index]

Monitoring site (figure 7)	Index of Biotic Integrity, community-integrity class[a], and Indiana criteria[b]			Modified Index of Well-Being[c] and community-integrity class		Qualitative Habitat Evaluation Index[d] and Indiana criteria[b]	
	IBI	Class	Criteria	MIWB	Class	QHEI	Criteria
B1	38	Fair	Full support	11.6	Exceptional	84	Full support
B2	40	Fair	Full support	11.4	Exceptional	78	Full support
B3	34	Poor	Partial support	9.6	Exceptional	70	Full support
B4	46	Good	Full support	10.6	Exceptional	66	Full support
B5	38	Fair	Full support	10.8	Exceptional	57	Partial support
B6	46	Good	Full support	12.4	Exceptional	75	Full support
A4	38	Fair	Full support	11.8	Exceptional	74	Full support
A5	46	Good	Full support	12.2	Exceptional	80	Full support
A6	36	Fair	Full support	10.8	Exceptional	71	Full support
A10[e]	28	Poor	No support	8.7	Good	67	Full support
Mean	39	Fair	Full support	11.0	Exceptional	72	Full support

[a]Scoring method and community-integrity class from Simon and Dufour (1998); see table 20 in this report.

[b]Criteria for support of aquatic-life use in Indiana water-quality standards from Indiana Department of Environmental Management (2000).

[c]Scoring method based on Gammon (1976) as modified in Ohio Environmental Protection Agency (1987), with community-integrity class from Ohio Environmental Protection Agency (1987, p. 8–13).

[d]Scoring method from Rankin (1989).

[e]Fish-community-inventory data from September 2000 provided by personnel from Camp Atterbury Land Conditions Trends Analysis Office.

at Camp Atterbury in September 2000, with their formal and common names by phylum, class, and order, listed by general class abundance, include

Phylum Arthropoda (arthropods)
- **Class** Insecta (insects)
  - **Order** Coleoptera (beetles)
  - Diptera (flies, midges, mosquitoes)
  - Ephemeroptera (mayflies)
  - Megaloptera (alderflies, dobsonflies, fishflies)
  - Odonata (dragonflies, damselflies)
  - Plecoptera (stoneflies)
  - Tricoptera (caddisflies)
- **Class** Arachnida (ticks, mites)
  - Amphipoda (scuds, sideswimmers)
  - Decapoda (crayfishes)
  - Isopoda (sow bugs)

Phylum Annelida (segmented worms)
- **Class** Oligochaeta (earthworms)
  - Hirudinea (leeches)

Phylum Nematoda (roundworms)

Platyhelminthes (flatworms)

Phylum Mollusca (mollusks)
- **Class** Bivalvia (clams, mussels)
  - Gastropoda (snails)

The total number of organisms and total number of taxa in samples from reaches near monitoring sites are listed in table 22. The largest total numbers of organisms were collected from Nineveh Creek

in wide riffle areas with many large cobbles (sites B2 and site A5). The largest number of taxa (68) was collected near site A4 on the unnamed tributary to Nineveh Creek, whereas the smallest number of taxa (36) was collected near site A5 on Nineveh Creek. These data also are compared graphically in figure 16 (page 54).

In September 2000, a total of 127 unique taxa were found (unpublished data, U.S. Geological Survey, 2001). Of these 127 taxa, 27 were found in 1 reach only, and these single occurrences were in 12 of the 13 reaches. Of the 27 taxa with single occurrences, 19 were insects (10 of which were the pollution-intolerant members of Ephemeroptera, Plecoptera, and Trichoptera). In contrast, 10 of the 127 taxa were found at more than 10 reaches; 8 taxa were insects; 6 of these were Ephemeroptera, Plecoptera, and Trichoptera.

The Hilsenhoff Biotic Index (HBI) for each stream reach near a monitoring site, along with a water-quality-evaluation rating, is listed in table 22. The degrees of organic contamination based on the abundance of pollution-tolerant and pollution-intolerant macroinvertebrate species (HBI scores) are explained in table 23. Pollution-tolerance values obtained from the literature were used for calculating the HBI for arthropods in the samples. Generally, less than eight taxa were counted in a sample for which a tolerance value was not available.

Other numeric indexes, such as diversity or similarity indexes, were available for comparing benthic-macroinvertebrate inventories among samples. A previous evaluation of 12 numeric indexes for data from the White River in Indianapolis by Lydy and others (2000) determined that the

Table 22. Benthic-macroinvertebrate-community inventories at Camp Atterbury near Edinburgh, Indiana, September 2000

[HBI, Hilsenhoff Biotic Index; EPT, insect orders Ephemeroptera, Plecoptera, Trichoptera]

Monitoring site (figure 7) near stream reach	Total number of organisms[a]	Total number of taxa	Hilsenhoff Biotic Index	Water-quality-evaluation rating for HBI	EPT Richness Index
A1	3,164	62	5.75	Fair	10
A2	2,116	57	6.09	Fair	10
A3	3,114	45	5.81	Fair	6
A4	1,841	68	5.19	Good	11
A5	13,573	36	5.83	Fair	7
A6	742	53	5.50	Good[b]	7
A10	1,237	57	4.93	Good	8
B1	1,453	46	5.51	Fair[b]	7
B2	17,149	55	5.69	Fair	7
B3	1,169	53	4.61	Good	8
B4	2,424	55	6.08	Fair	8
B5	2,041	51	5.32	Good	8
B6	1,112	54	5.30	Good	7

[a]Total number of organisms collected in 3 square feet of richest targeted habitat.

[b]Scores were at limit of range for rating (table 23).

Table 23. Hilsenhoff Biotic Index score ranges and water-quality-evaluation ratings

Hilsenhoff Biotic Index score range[a]	Water-quality-evaluation rating[a]	Degree of organic contamination
0.00 – 3.50	Excellent	Not apparent
3.51 – 4.50	Very good	Slight[b]
4.51 – 5.50	Good	Minimal[b]
5.51 – 6.50	Fair	Moderate[b]
6.51 – 7.50	Fairly poor	Appreciable[b]
7.51 – 8.50	Poor	Severe[b]
8.51 – 10.00	Very poor	Very severe[b]

[a]Hilsenhoff (1987) presented the score ranges, ratings, and "degree of organic contamination" descriptions.

[b]The word used to define the degree of organic contamination has been made consistent with descriptions used in the text.

HBI was the most accurate for ranking water quality and the EPT Richness Index was the most descriptive for analyzing differences in water quality. The HBI scores and EPT Richness Index values for the stream reaches near monitoring sites in the study area are compared in figure 16.

For Camp Atterbury in September 2000, the HBI scores ranked water quality as good (minimal organic contamination) in six stream reaches and fair (moderate organic contamination) in seven stream reaches (tables 22 and 23). Inside the Impact Area, sites A1, A2, and A3 were rated fair for water quality based on the HBI (5.75 to 6.09). Site A3 had the lowest EPT Richness Index (6) and had the second fewest taxa (45). Downstream from the Impact Area, sites A5 and B4 were rated fair for water quality based on the HBI (5.83 and 6.08) and had the second and third lowest EPT scores (7 and 8); site A5 had the fewest number of taxa (36).

Qualitative Habitat Evaluations

The QHEI scores for 13 monitoring sites on streams at Camp Atterbury where chemical and biological assessments of water quality were made are presented in table 24 (p. 55). Individual metric scores and maximum scores allowed by the QHEI method are included for comparison.

Generally, the scores for the substrate, instream-cover, and channel-morphology metrics were more variable and had the most effect on the total QHEI score. Site A1 scored lowest on these metrics. Near-maximum scores or maximum scores were given for instream cover, channel morphology, and gradient/drainage area at many sites.

Criteria (Indiana Department of Environmental Management, 2000) for ranges of QHEI scores applied to Indiana water-quality standards are

more than 64—fully supporting aquatic-life use;

51 to 64—partially supporting aquatic-life use;

less than 51—not supporting aquatic-life use.

Among the monitoring sites at Camp Atterbury evaluated in September 2000, site A1 in the Impact Area ranked the lowest with a QHEI of 45, not supporting aquatic-life use; site B5 on Lick Creek ranked second lowest with a score of 57, partially supporting aquatic-life use. Indexes for the other monitoring sites ranged from 64 to 84, fully supporting aquatic-life use.

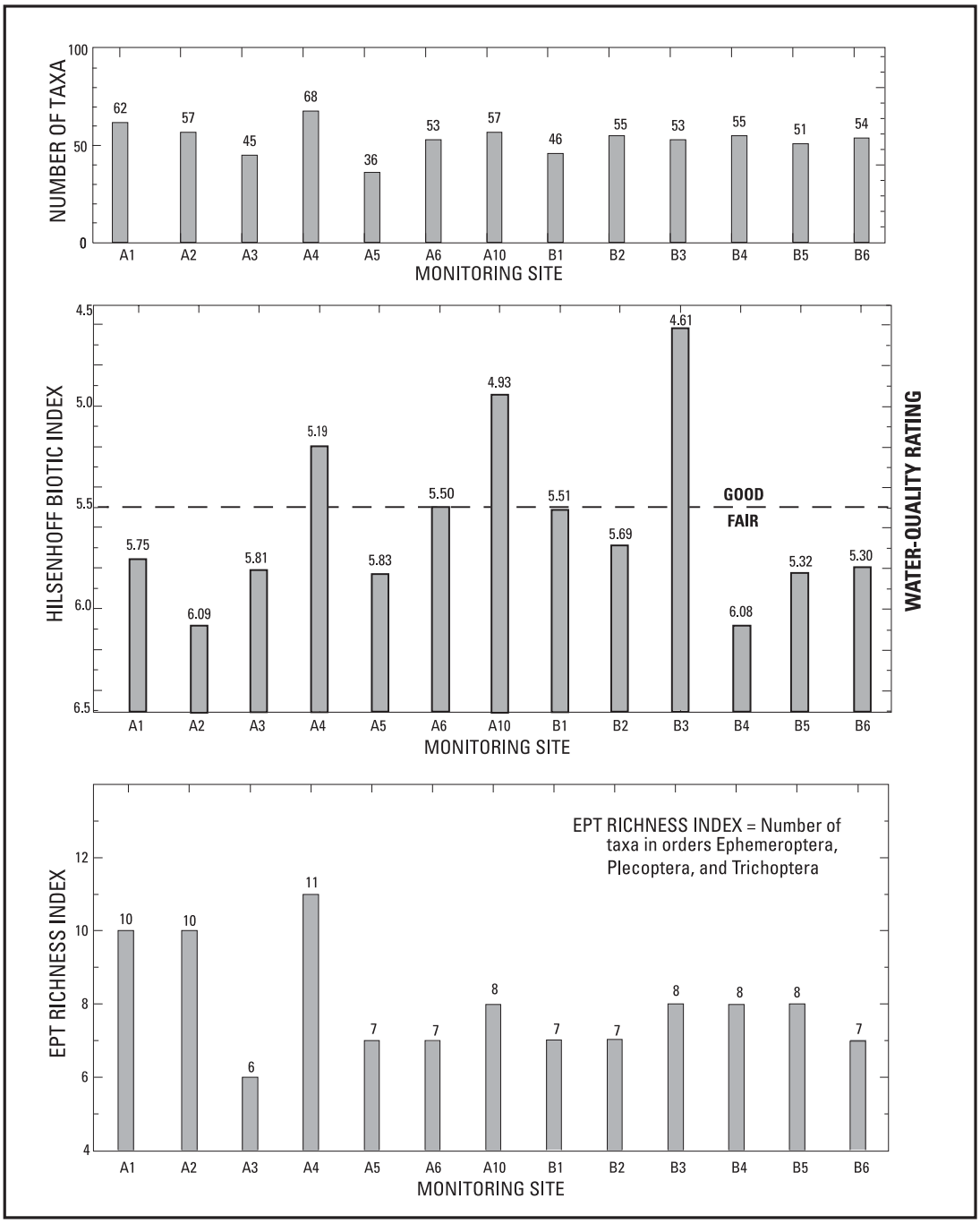


Figure 16. Number of taxa and two numerical indexes for benthic-macroinvertebrate-community inventories at Camp Atterbury near Edinburgh, Indiana, September 2000.

Table 24. Qualitative Habitat Evaluation Index (QHEI) metrics and scores at Camp Atterbury near Edinburgh, Indiana, September 2000

Monitoring site (figure 7)	Total QHEI score	QHEI individual metrics						
		Substrate	Instream cover	Channel morphology	Riparian zone	Pool quality	Riffle quality	Gradient/ drainage area
B1	84	13	19	19	9	8	6	10
B2	78	16	13	17	9	7	6	10
B3	70	11	16	10	9	9	7	8
B4	66	10	15	15	9	7	4	6
B5	57	5	11	18	10	5	2	6
B6	75	9	19	18	9	9	5	6
A1	45	3	4	7	8	9	4	10
A2	70	14	11	16	10	4	5	10
A3	64	8	12	18	6	7	3	10
A4	74	9	20	18	9	7	5	6
A5	80	14	18	18	7	7	6	10
A6	71	12	13	14	9	6	7	10
A10	67	7	19	15	9	7	4	6
Maximum possible score	**100**	**20**	**20**	**20**	**10**	**12**	**8**	**10**

Short-Term and Long-Term Conditions

Base-wide water quality of the study area generally is good in the short term (weeks), except for the presence of fecal-indicator bacteria. Sources of the bacteria are upstream from and inside the study area, based on the presence of chemical tracers for human sewage. Long-term (years) water quality in the Impact Area may have been affected by military training that increased trace-element concentrations in sediment and fish and reduced water-quality ratings based on fish and benthic-macroinvertebrate communities.

Base-Wide Water Quality

Water flowing into Camp Atterbury in Nineveh Creek, Prince Creek, Mud Creek, and Saddle Creek was shown to contain small concentrations of the herbicides prometon and metolachlor, concentrations of *E. coli* greater than the Indiana water-quality standards, dissolved inorganic constituents, and suspended sediment. Causes outside the study area may have contributed to fewer pollution-intolerant species of fish and benthic macroinvertebrates at monitoring sites on Prince Creek and Saddle Creek near the upstream boundary of Camp Atterbury. Potential sources of human sewage that caused bacteria contamination of an unnamed tributary to Nineveh Creek were a leaking sewer near the upstream boundary of the study area and a sewer overflow farther downstream.

Water flowing out of Camp Atterbury in Nineveh Creek, Muddy Branch, and Lick Creek was shown to contain *E. coli* concentrations greater than the Indiana water-quality standard. The sources

of bacterial contamination were not identified, but the headwaters for Muddy Branch and Lick Creek are within Camp Atterbury. Effects on the receiving stream, Driftwood River, were not measured in this study. Because of fecal-indicator bacteria concentrations, IDEM (2000) rated the Driftwood River as partially supporting recreational use.

A potential is present for small amounts of lead to be transported in water flowing out of Camp Atterbury, probably during high[j] streamflow. Small concentrations of dissolved lead and total lead were measured in samples from Nineveh Creek, an unnamed tributary to Nineveh Creek, Muddy Branch, and Lick Creek at sites inside of and downstream from the Impact Area. More of the total lead detections were in samples collected during high streamflow. At site B5 on Lick Creek, total lead concentrations increased from 0.56 µg/L during low[j] streamflow to 2.0 µg/L during high streamflow (appendix 4). The 2.0-µg/L total lead concentration in the site B5 sample exceeded the calculated Indiana water-quality standard for lead (1.4 µg/L); total-lead detections at other sites did not exceed the calculated standard.

Many constituents associated with military training, such as explosives, were not detected in water samples from the study area during low- or high-streamflow conditions. Concentrations of inorganic chemical constituents (major ions, nutrients, and trace elements) were less than the Indiana water-quality standards.

Microbiological Contamination

The use of chemical tracers to investigate bacterial contamination for at least three states has been reported by USGS scientists (for example, Frick and Gregory, 2000; Gill and Journey, 2000; and Schumaker and others, 2000) and in a nationwide study (Barnes and others, 2002). Nationwide, at least 1 of 95 organic wastewater contaminants such as pharmaceuticals, hormones, detergent metabolites, and other household chemicals have been found in 80 percent of the streams sampled by the USGS downstream from areas of intense urbanization and animal production (Barnes and others, 2002). Consequently, the presence of these chemicals in water samples contaminated by *E. coli* fecal-indicator bacteria can indicate human or animal waste, or both, as the probable source of the bacteria. The specific chemicals detected can serve as tracers of the wastewater source of the bacteria.

In this study, 66 wastewater tracers were analyzed in 23 of the 80 stream-water samples collected in May and June 2001 throughout the study area. In these 23 samples, seven wastewater tracers were detected two or more times (table 25). The most-frequently detected tracers were the agricultural herbicides prometon and metolachlor. Detections of four tracers (beta-sitosterol, caffeine, cholesterol, or phenol) provided a limited indication that some human sewage might have been present in the samples. Chemicals most indicative of human sewage, however, were not detected in samples from the study area—triclosan (an antimicrobial disinfectant), tri 2-chloroethyl phosphate (a fire retardant), and 4-nonylphenol (a nonanionic detergent metabolite). These three tracers were detected in more than half the streams in the U.S. (Barnes and others, 2002).

Sample sites were grouped by watershed to compare *E. coli* concentrations and detections of wastewater tracers (fig. 17, p. 58). Nine of the 17 water samples with *E. coli* concentrations greater than the single-sample standard of 235 col/100 mL that were tested for wastewater tracers had detections of beta-sitosterol, caffeine, cholesterol, or phenol (indicated by red symbols on fig. 17). These four wastewater tracers were detected in four samples from a tributary of Nineveh Creek (sites E6 and E7; *E. coli* concentrations ranged from 203 to 967 col/100 mL. According to the Camp Atterbury sewer-system maps, a sewer crosses the unnamed tributary upstream from site E6. A sewer overflow was observed upstream from site E7. These indicate potential sources of human sewage may have contributed to *E. coli* concentrations as large as

[j]"High" streamflow during July 2001 was more than 3 $ft^3/s/mi^2$; "low" streamflow during September 2000 was less than 0. $ft^3/s/mi^2$. See the discussion in the Streamflow Conditions section of this report, p. 29.

Table 25. Wastewater tracers detected in water samples collected from 13 monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May 14 through June 14, 2001

[µg/L, microgram per liter; PAH, polynuclear aromatic hydrocarbon]

Wastewater tracer	Number of detections	Description/use	Indicator of human sewage	Range of concentrations (µg/L)
Beta-sitosterol	5	Plant sterol; fecal indicator	Probable	0.58–1.0
Caffeine	1	Stimulant; beverages	Yes	.13
Cholesterol	5	Plant sterol; fecal indicator	Probable	.53–1.1
Diazinon	1	Insecticide; common non-agricultural use	No	.05
Fluoranthene	3	PAH; in coal tar and asphalt	No	.05– .93
Metolachlor	10	Herbicide; mostly agricultural use	No	.01– .27
Phenol	5	Acid; disinfectant, antiseptic	Yes	.22– .59
Prometon	11	Herbicide; common non-agricultural use	No	.01– .08
Pyrene	2	PAH; in coal tar and asphalt	No	.15– .62

2,000 col/100 mL in samples from this tributary, including samples that were not tested for wastewater tracers. The tracers beta-sitosterol, cholesterol, or phenol were detected in samples from sites E2, A6, B3, E5, and B4 (fig. 17) and from sites B5 on Lick Creek and A10 on Muddy Branch. For these seven sites, the number of samples analyzed and the number and type of wastewater tracers detected did not provide consistent indications of the source of the *E. coli* concentrations.

As previously discussed in the section, Microbiological Data, increased turbidity was an indicator for increased *E. coli* concentrations in samples from the study area. Turbidity comes from suspended silt, clay, fine organic and inorganic matter, plankton, and microbiological organisms. Overland runoff from precipitation can transport some of the particles that contribute to turbidity. Although turbidity does not explain the source(s) for increased *E. coli* concentrations in study-area streams in 2001, it may be useful as an indicator of potential concentrations exceeding the single-sample Indiana water-quality standard. Based on previous studies in Indiana, this standard always was exceeded when turbidity was greater than 83 NTU (Silcox and others, 2002, p. 20).

Water Quality at the Impact Area

Short-term (weeks) and long-term (years) water-quality conditions at the Impact Area were evaluated in this study. Regarding short-term conditions, lead was detected in water samples during low and high streamflow at five monitoring sites inside of or downstream from the Impact Area (A3, A4, A5, A8, and A10; appendix 4). Also, concentrations of dissolved iron increased more than tenfold during high streamflow at sites A4 and A10 in the Impact Area (appendix 3). Regarding long-term conditions, the largest concentrations of five trace elements (copper, lead, magnesium, strontium, and zinc) were measured in fish-tissue samples collected near sites A2, A4, or A10 in the Impact Area (table 15). Also, the largest concentrations of

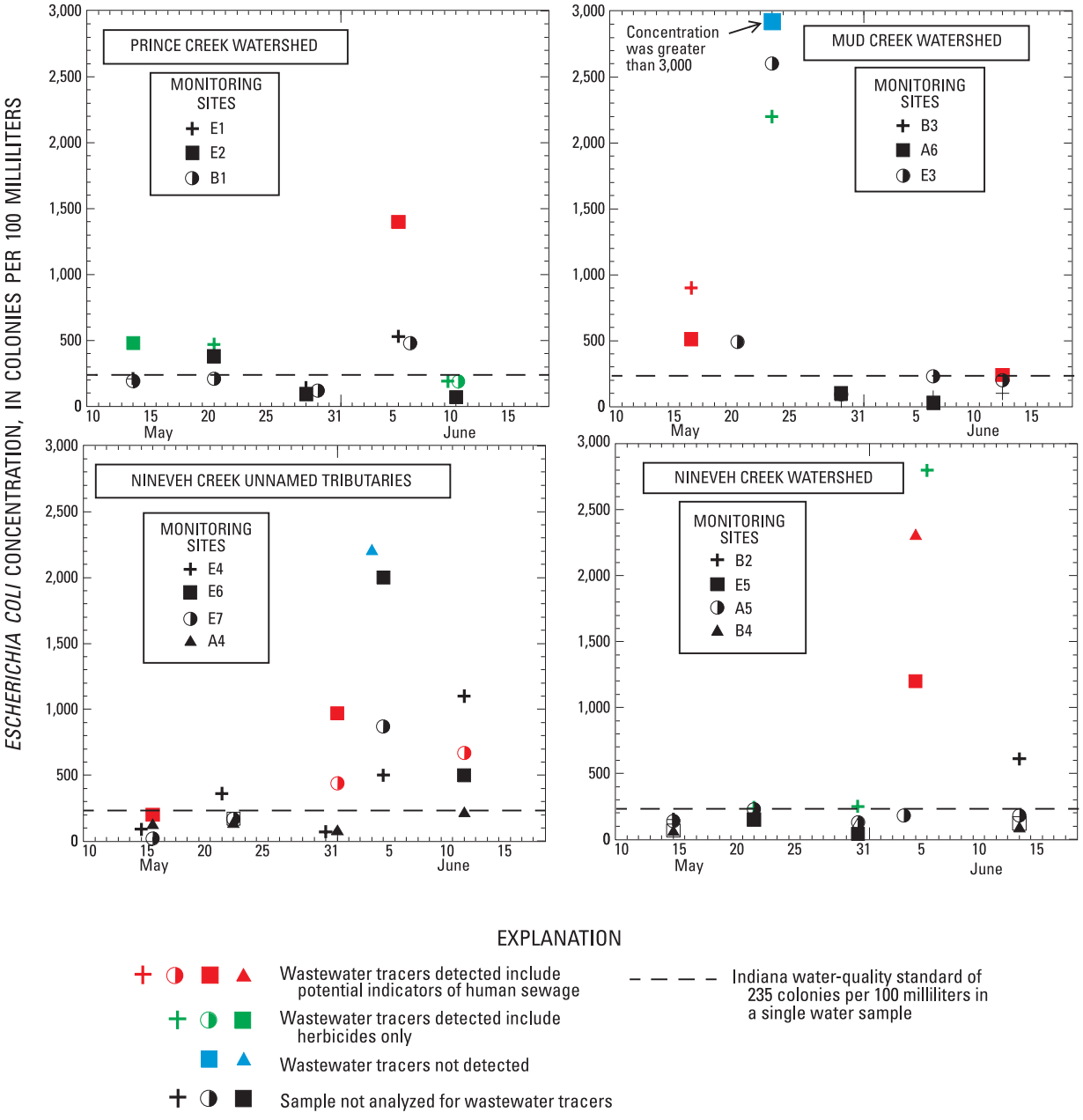


Figure 17. Concentrations of Escherichia coli and detections of wastewater tracers in water samples collected from 14 monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May 14 through June 14, 2001.

these same five trace elements were measured in streambed-sediment samples collected at sites A2 and A4 in the Impact Area (table 12). The lowest IBI score and fish-community-integrity class rating of poor was given to site A10 in the Impact Area (table 21). HBI scores for benthic-macroinvertebrate inventories near sites A1, A2, and A3 in the Impact Area and sites A5 and B4 downstream from the Impact Area indicated moderate organic contamination (tables 22 and 23). Monitoring sites with lead in water samples, large trace-element concentrations in streambed sediment or fish tissue, poor fish-community integrity, or fair water-quality ratings from HBI scores are shown in figure 18.

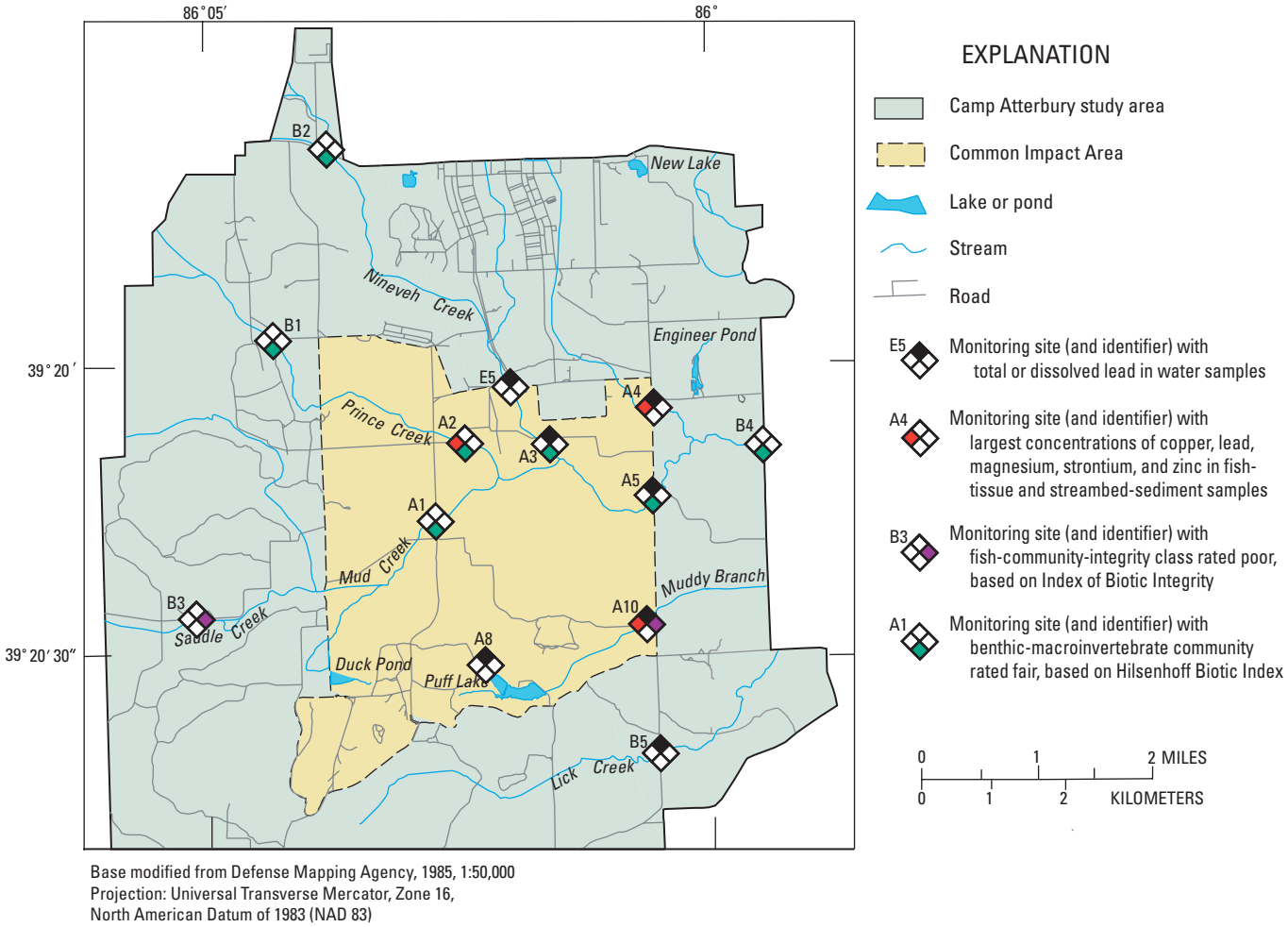
Data from monitoring site B5 indicated short-term effects on water quality potentially caused by military training outside the Impact Area. Lead was detected in water samples from site B5 during low streamflow in September 2000 and high streamflow in July 2001 (appendix 4). A water sample collected during *E. coli* monitoring in May 2001 (table 26, p. 61) contained a total of 2.81 µg/L of 4 wastewater tracers that were reported in samples from other monitoring sites; this sample also contained 3.86 µg/L of 11 wastewater tracers that were not reported from other sites. At least 2 of these 11 wastewater tracers, carbazole and phenanthrene, have potential use in the manufacture of explosives (although the results from this sample are inconclusive). None of these 15 wastewater tracers were reported in a sample collected at site B5 1 week later in May 2001. Eight of these 15 wastewater tracers were analyzed as semivolatile organic compounds in a water sample collected from site B5 in July 2001 (table 26). No semivolatile organic compounds were detected, but the reporting limits for the July 2001 analysis were 10 to 20 times higher than the reporting limits for the May 2001 wastewater tracers (appendix 1).

Uncertainties of Data and Interpretations

The firing ranges in the Impact Area are potential sources of lead detected in water samples during the study. Transport of lead and other trace elements in streams may occur in the particulate phase during high streamflow, as indicated by the greater number of detections of total lead than of dissolved lead (appendix 4). The difference in the reporting limits (appendix 1) for dissolved lead (3 µg/L) and total lead (1 µg/L) may have contributed to this observation. Detections of lead in streambed sediments were unreliable because of analytical problems. Therefore, it is unclear whether lead in streambed sediments was related to total lead in water during high streamflow. Additional data and interpretation regarding lead in water and streambed sediment could help resolve these uncertainties.

For this study, it was assumed that low streamflow primarily would represent ground water discharged through the streambed. The water samples collected at sites B2 and A1 during September 2000 were during average streamflow rather than during low or moderate streamflow when the other sites were sampled (fig. 12). A smaller proportion of ground water may have contributed to streamflow at these two sites than at the other sites. Chemical concentrations might have been different at sites B2 and A1 during lower streamflow, particularly at site A1 in the Impact Area. Streamflow conditions in the study area, however, were estimated with continuous streamflow-gaging data from the Youngs Creek station near Edinburgh, which is in a larger, less-forested watershed than those in the study area. Continuous streamflow data from at least one stream in the study area (such as Nineveh Creek) would reduce the uncertainty regarding streamflow conditions. Also, a more extensive and direct investigation of groundwater quality would help identify locations and streamflow conditions for further monitoring of surface-water quality at Camp Atterbury.

In this study, streambed-sediment samples consisting of particles in the fine sand, silt, and clay-size ranges (less than 200 µm) were analyzed for trace elements. According to Horowitz (1991), many trace elements tend to concentrate on the silt and clay particles (less than 63 µm). A separate analysis of streambed-sediment samples consisting only of particles less than 63 µm would provide a comparison with the results from this study.



Base modified from Defense Mapping Agency, 1985, 1:50,000
Projection: Universal Transverse Mercator, Zone 16,
North American Datum of 1983 (NAD 83)

Figure 18. Selected monitoring sites with chemical and biological assessment of surface-water quality at Camp Atterbury near Edinburgh, Indiana, September and October 2000.

In this study, water samples at site B5 contained lead, semivolatile organic compounds, and polynuclear aromatic hydrocarbons that could be associated with military training. Site B5 was not selected to evaluate quality of water leaving the Impact Area (table 1). Most of the chemical constituents analyzed in water, sediment, and fish-tissue samples from monitoring sites in or near the Impact Area were not analyzed in samples from site B5. Therefore, it is uncertain to what extent military training affected water quality in the Lick Creek Watershed. Future evaluations of water quality in the Impact Area that include Lick Creek would address this uncertainty.

Gross alpha radioactivity (table 8) greater than the 3 pCi/L Indiana water-quality standard was reported in the September 2000 water samples from sites B2 (3.2 pCi/L) and B3 (3.6 pCi/L). The range of possible values for gross alpha radioactivity in these two samples, based on the analytical method, includes values less than the standard. Additional water samples from these two sites were not analyzed for gross alpha radioactivity. Therefore, it is

Table 26. Wastewater tracers detected in a water sample collected from monitoring site B5 on Lick Creek at Camp Atterbury near Edinburgh, Indiana, May 16, 2001

[µg/L, microgram per liter; PAH, polynuclear aromatic hydrocarbon; SVOC, semivolatile organic compound; E, estimated concentration]

Wastewater tracer	Description/use[a]	Concentration (µg/L)	Detections at other sites
Anthracene[b]	PAH; wood preservative; in tar, diesel, or crude oil	0.22E	No
Anthraquinone	SVOC; manufacture of dyes	.51	No
Benzo(a)pyrene[b]	PAH; combustion by-product	.46E	No
Benzophenone	SVOC; fixative for perfumes and soaps	.15E	No
Carbazole	SVOC; manufacture of explosives, dyes, or lubricants	.50	No
Cholesterol	Plant sterol; fecal indicator	1.00E	Yes
Fluoranthene[b]	PAH; in coal tar and asphalt	.93	Yes
Isophrone[b]	SVOC; solvent for lacquer, plastic, silicon, or resin	.18E	No
5-methyl-1H-benzotriazole	SVOC; antioxidant in antifreeze or deicer	.14E	No
N,N-diethyltoluamide	SVOC; mosquito repellent	.06E	No
Monoethyloxyoctylphenol	Non-ionic detergent metabolite	.30E	No
Pentachlorophenol[b]	SVOC; wood preservative	.93E	No
Phenanthrene[b]	PAH; manufacture of explosives; in tar, diesel, or crude	.41E	No
Phenol[b]	Acid; disinfectant, antiseptic	.26E	Yes
Pyrene[b]	PAH; in coal tar and asphalt	.62	Yes

[a]From Agency for Toxic Substances and Disease Registry, 1999; Barnes and others, 2002; and Steven Zaugg, U.S. Geological Survey National Water Quality Laboratory, 2001, written commun.

[b]Analyzed in water sample collected from site B5 in July 2001.

uncertain whether the samples from sites B2 and B3 actually exceeded the standard. Future assessments of surface-water quality that include analysis of specific radioisotopes along with gross alpha radioactivity determinations in samples from sites B2 and B3 could offer an explanation of the results from this study.

Summary

The U.S. Army Atterbury Reserve Forces Training Area (known as Camp Atterbury) in central Indiana near Edinburgh has been used by the Army and the National Guard for more 50 years.

The Indiana Army National Guard required information about the effect of military training on water quality and arranged for the U.S. Geological Survey to make a base-wide assessment of surface-water quality at Camp Atterbury. The assessment examined short-term (weeks) and long-term (years) quality of surface water flowing into, across, and out of a 33,760-acre study area. A more extensive evaluation of the surface-water quality was made at

the 6,300-acre Impact Area that includes firing and bombing ranges for weapons training of ground and air troops.

Short-term water quality was evaluated in September 2000 and July 2001 by analysis of as many as 213 constituents in water samples from 13 monitoring sites on streams and 3 sites on lakes. In this study, concentrations of dissolved and total lead as much as 2 µg/L were detected in water samples during low (less than 0.5 $ft^3/s/mi^2$) and high (more than 3 $ft^3/s/mi^2$) streamflow at seven sites, five inside of and downstream from the Impact Area. The lead concentration in one sample was greater than the calculated Indiana water-quality standard. Many constituents associated with military training, such as explosives, were not detected in water samples from the study area during low or high streamflow conditions. Gross alpha radioactivity in samples from two sites near the upstream boundary of the study area potentially was greater than the Indiana water-quality standard, but the results were inconclusive. Concentrations of other chemical constituents that were detected did not exceed Indiana water-quality standards.

Fecal-indicator bacteria (*E. coli*) concentrations in water were monitored five times at 16 sites on streams and at 4 lakes during May and June 2001. The geometric mean *E. coli* concentrations at all 16 sites on streams were greater than the Indiana water-quality standard. Increases in turbidity are statistically related to increases in *E. coli* concentrations. In samples from two sites on the same stream, *E. coli* concentrations were greater than the single-sample Indiana water-quality standard, and chemical tracers associated with human sewage were detected. These sites were downstream from a potentially leaking sewer and a sewer overflow. The probable sources of the *E. coli* at other sites were not evident.

Long-term water quality was evaluated in September and October 2000 with chemical analysis of streambed sediment and fish tissue and with inventories of fish and benthic-macroinvertebrate communities. Overall, the largest concentrations of copper, lead, manganese, strontium, and zinc were detected in streambed-sediment and fish-tissue samples from three sites in the Impact Area. Detections of lead in streambed sediments were unreliable because of analytical problems. Therefore, it is unclear whether lead in streambed sediments was related to total lead in water during high streamflow. Additional data and interpretation regarding lead in water and streambed sediment could help resolve these uncertainties. The lowest rating of fish-community integrity (poor), based on diversity and pollution tolerance, was computed for one of the three sites in the Impact Area that had large concentrations of trace elements in the streambed sediment. Moderate organic contamination was indicated by numerical indexes of diversity and pollution tolerance in benthic-macroinvertebrate communities near two sites inside of and two sites downstream from the Impact Area. It is uncertain to what extent military training affected water quality in the Lick Creek Watershed near the Impact Area. Future evaluations of water quality in the Impact Area that include Lick Creek would address this uncertainty.

Compared with the larger White River Basin, trace-element concentrations in streambed sediment of the study area were smaller, stream habitat was better, and fish communities were typical. Compared with Indiana Department of Environmental Management criteria, the fish-community integrity for 8 of 10 stream reaches in the study area fully supported aquatic-life use.

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Appendixes

1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001

2. Characteristics and physical properties of water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000

3. Concentrations of dissolved and total recoverable major ions and total nutrients in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

4. Concentrations of dissolved and total trace elements in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

5. Concentrations of *Escherichia coli*, instantaneous streamflow, and water-quality characteristics in water samples collected from monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May and June 2001

6. Fish species, abundance, and total weight in stream reaches near 10 monitoring sites at Camp Atterbury near Edinburgh, Indiana, September and October 2000

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001

[R.L., reporting limit; mg/L, milligram per liter; pCi/L, picocurie per liter; std. unit, standard unit; µS/cm, microsiemen per centimeter; NTU, nephelometric turbidity unit; °C, degree Celsius; col/100 mL, colony per 100 milliliters of water; µg/L, microgram per liter; mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram]

Characteristics, major ions, nutrients			
Constituent	**R.L.**	**Units**	**Media**
Alkalinity	1	mg/L	Water
Dissolved oxygen	.01	mg/L	Water
Dissolved solids	10	mg/L	Water
Gross alpha radioactivity	3.0	pCi/L	Water
Gross beta radioactivity	4.0	pCi/L	Water
pH	.01	std. unit	Water
Specific conductance	1	µS/cm	Water
Suspended sediment	1	mg/L	Water
Total solids	1	mg/L	Water
Turbidity	.01	NTU	Water
Water temperature	.01	°C	Water
E. coli bacteria	1	col/100 mL	Water
Calcium, dissolved	.20	mg/L	Water
Chloride, dissolved	.29	mg/L	Water
Fluoride, dissolved	.1	mg/L	Water
Iron, dissolved	.01	mg/L	Water
Magnesium, dissolved	.014	mg/L	Water
Manganese, dissolved	.0022	mg/L	Water
Potassium, dissolved	.24	mg/L	Water
Silica, dissolved	.09	mg/L	Water
Sodium, dissolved	.09	mg/L	Water
Sulfate, dissolved	.31	mg/L	Water
Nitrogen, total	.1	mg/L	Water
Nitrogen, organic, dissolved	.1	mg/L	Water
Nitrate + nitrite, dissolved	.05	mg/L	Water
Ammonia, dissolved	.02	mg/L	Water
Phosphorus, total	.05	mg/L	Water
Phosphorus, dissolved	.05	mg/L	Water
Orthophosphate, dissolved	.01	mg/L	Water

Trace elements			
Constituent	**R.L.**	**Units**	**Media**
Aluminum, dissolved	100	µg/L	Water
Aluminum, total	12	mg/kg	Solid
Antimony, dissolved	10	µg/L	Water
Antimony, total	1.2	mg/kg	Solid
Arsenic, dissolved	10	µg/L	Water
Arsenic, total	1.2	mg/kg	Solid
Barium, dissolved	10	µg/L	Water
Barium, total	1.2	mg/kg	Solid
Beryllium, dissolved	5.0	µg/L	Water
Beryllium, total	.60	mg/kg	Solid
Boron, dissolved	100	µg/L	Water
Boron, total	12	mg/kg	Solid
Cadmium, dissolved	5.0	µg/L	Water
Cadmium, total	.60	mg/kg	Solid
Calcium, total	24	mg/kg	Solid
Chromium, dissolved	10	µg/L	Water
Chromium, total	1.2	mg/kg	Solid
Cobalt, dissolved	10	µg/L	Water
Cobalt, total	1.2	mg/kg	Solid
Copper, dissolved	10	µg/L	Water
Copper, total	2.4	mg/kg	Solid
Iron, total	12	mg/kg	Solid
Lead, dissolved	3.0	µg/L	Water
Lead, total	1.0	µg/L	Water
Lead, total	1.0	mg/kg	Solid
Magnesium, total	24	µg/L	Water
Magnesium, total	24	mg/kg	Solid
Manganese, total	1.2	mg/kg	Solid

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Trace elements—Continued			
Constituent	**R.L.**	**Units**	**Media**
Molybdenum, dissolved	20	µg/L	Water
Molybdenum, total	2.4	mg/kg	Solid
Nickel, dissolved	40	µg/L	Water
Nickel, total	5.0	mg/kg	Solid
Potassium, total	100	µg/L	Water
Potassium, total	100	mg/kg	Solid
Selenium, dissolved	5.0	µg/L	Water
Selenium, total	1.5	mg/kg	Solid
Silver, dissolved	10	µg/L	Water
Silver, total	1.2	mg/kg	Solid
Sodium, total	180	µg/L	Water
Sodium, total	600	mg/kg	Solid
Strontium, dissolved	10	µg/L	Water
Strontium, total	1.2	mg/kg	Solid
Thallium, dissolved	10	µg/L	Water
Thallium, total	1.4	mg/kg	Solid
Tin, dissolved	100	µg/L	Water
Tin, total	12	mg/kg	Solid
Vanadium, dissolved	10	µg/L	Water
Vanadium, total	1.2	mg/kg	Solid
Zinc, dissolved	20	µg/L	Water
Zinc, total	2.4	mg/kg	Solid

Explosives			
Constituent	**R.L.**	**Units**	**Media**
2-amino-4,6-dinitrotoluene	0.25	µg/L	Water
2-amino-2,6-dinitrotoluene	.25	µg/L	Water
1,3-dinitrobenzene	.25	µg/L	Water
2,4-dinitrotoluene	.25	µg/L	Water
2,6-dinitrotoluene	.25	µg/L	Water
HMX	.25	µg/L	Water
Nitrobenzene	.25	µg/L	Water
2-nitrotoluene	.25	µg/L	Water
3-nitrotoluene	.25	µg/L	Water
4-nitrotoluene	.25	µg/L	Water
RDX	.25	µg/L	Water
Tetryl	.50	µg/L	Water
1,3,5-trinitrobenzene	.25	µg/L	Water
2,4,6-trinitrotoluene	.25	µg/L	Water
2-amino-4,6-dinitrotoluene	.30	µg/g	Solid
2-amino-2,6-dinitrotoluene	.30	µg/g	Solid
1,3-dinitrobenzene	.30	µg/g	Solid
2,4-dinitrotoluene	.30	µg/g	Solid
2,6-dinitrotoluene	.30	µg/g	Solid
HMX	.30	µg/g	Solid
Nitrobenzene	.30	µg/g	Solid
2-nitrotoluene	.30	µg/g	Solid
3-nitrotoluene	.30	µg/g	Solid
4-nitrotoluene	.30	µg/g	Solid
RDX	.30	µg/g	Solid
Tetryl	.60	µg/g	Solid
1,3,5-trinitrobenzene	.30	µg/g	Solid
2,4,6-trinitrotoluene	.30	µg/g	Solid

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Semivolatile organic compounds			
Constituent	**R.L.**	**Units**	**Media**
Acenaphthene	10	µg/L	Water
Acenaphthylene	10	µg/L	Water
Acetophenone	10	µg/L	Water
2-acetylaminofluorene	100	µg/L	Water
4-aminobiphenyl	50	µg/L	Water
3-methylphenol	10	µg/L	Water
Anthracene	10	µg/L	Water
Benzidine	10	µg/L	Water
Benzo(a)anthracene	100	µg/L	Water
Benzo(a)pyrene	10	µg/L	Water
Benzo(b)fluoranthene	10	µg/L	Water
Benzo(g,h,i)perylene	10	µg/L	Water
Benzo(k)fluoranthene	10	µg/L	Water
Benzoic acid	50	µg/L	Water
Benzyl alcohol	10	µg/L	Water
4-bromophenyl phenyl ether	10	µg/L	Water
Butyl benzyl phthalate	10	µg/L	Water
4-chloroaniline	10	µg/L	Water
Bis(2-chloroethoxy)methane	10	µg/L	Water
Bis(chloroethyl)-ether	10	µg/L	Water
Bis(2-chloro-isopropyl)ether	10	µg/L	Water
4-chloro-3-methylphenol	10	µg/L	Water
2-chloro-naphthalene	10	µg/L	Water
2-chlorophenol	10	µg/L	Water
4-chlorophenyl phenyl ether	10	µg/L	Water
Chrysene	10	µg/L	Water
Dibenz(a,h)anthracene	10	µg/L	Water
Dibenzofuran	10	µg/L	Water
Di-n-butyl phthalate	10	µg/L	Water

Semivolatile organic compounds—Continued			
Constituent	**R.L.**	**Units**	**Media**
1,2-dichlorobenzene	10	µg/L	Water
1,3-dichlorobenzene	10	µg/L	Water
1,4-dichlorobenzene	10	µg/L	Water
3,3’-dichlorobenzidine	50	µg/L	Water
2,4-dichlorophenol	10	µg/L	Water
2,6-dichlorophenol	10	µg/L	Water
Diethyl phthalate	10	µg/L	Water
3-3’-dimethylbenzidine	20	µg/L	Water
2,4-dimethylphenol	10	µg/L	Water
Dimethyl phthalate	10	µg/L	Water
4,6-dinitro-2-methylphenol	50	µg/L	Water
2,4-dinitrophenol	50	µg/L	Water
2,4-dinitrotoluene	10	µg/L	Water
2,6-dinitrotoluene	10	µg/L	Water
Di-n-octyl phthalate	10	µg/L	Water
Di(2-ethylhexyl)phthalate	10	µg/L	Water
Fluoranthene	10	µg/L	Water
Fluorene	10	µg/L	Water
Hexachlorobenzene	10	µg/L	Water
Hexachlorobutadiene	10	µg/L	Water
Hexachlorocyclopentadiene	50	µg/L	Water
Hexachloroethane	10	µg/L	Water
Indeno(1,2,3-cd)pyrene	100	µg/L	Water
Isophorone	10	µg/L	Water
2-methyl-naphthalene	10	µg/L	Water
2-methylphenol	10	µg/L	Water
Naphthalene	10	µg/L	Water
2-nitroaniline	50	µg/L	Water
3-nitroaniline	50	µg/L	Water

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Semivolatile organic compounds—Continued			
Constituent	**R.L.**	**Units**	**Media**
4-nitroaniline	50	µg/L	Water
Nitrobenzene	10	µg/L	Water
2-nitrophenol	10	µg/L	Water
4-nitrophenol	50	µg/L	Water
n-nitroso-di-n-butylamine	10	µg/L	Water
n-nitrosodiethylamine	10	µg/L	Water
n-nitrosodimethylamine	10	µg/L	Water
n-nitroso-diphenylamine	10	µg/L	Water
n-nitroso-di-n-propylamine	10	µg/L	Water
n-nitrosomethylethylamine	10	µg/L	Water
Pentachlorobenzene	10	µg/L	Water
Pentachlorophenol	50	µg/L	Water
Phenanthrene	10	µg/L	Water
Phenol	10	µg/L	Water
Pyrene	10	µg/L	Water
1,2,4,5-tetrachlorobenzene	10	µg/L	Water
2,3,4,6-tetrachlorophenol	50	µg/L	Water
1,2,4-trichlorobenzene	10	µg/L	Water
2,4,5-trichlorophenol	10	µg/L	Water
2,4,6-trichlorophenol	10	µg/L	Water

Semivolatile organic compounds—Continued			
Constituent	**R.L.**	**Units**	**Media**
Acenaphthene	400	µg/kg	Solid
Acenaphthylene	400	µg/kg	Solid
Acetophenone	400	µg/kg	Solid
2-acetylaminofluorene	4,000	µg/kg	Solid
4-aminobiphenyl	2,000	µg/kg	Solid
3-methylphenol	400	µg/kg	Solid
Anthracene	400	µg/kg	Solid
Benzidine	4,000	µg/kg	Solid
Benzo(a)anthracene	400	µg/kg	Solid
Benzo(a)pyrene	400	µg/kg	Solid
Benzo(b)fluoranthene	400	µg/kg	Solid
Benzo(g,h,i)perylene	400	µg/kg	Solid
Benzo(k)fluoranthene	400	µg/kg	Solid
Benzoic acid	2,000	µg/kg	Solid
Benzyl alcohol	400	µg/kg	Solid
4-bromophenyl phenylether	400	µg/kg	Solid
Butyl benzyl phthalate	400	µg/kg	Solid
4-chloroaniline	400	µg/kg	Solid
Bis(2-chloroethoxy)methane	400	µg/kg	Solid
Bis(chloroethyl)-ether	400	µg/kg	Solid
Bis(2-chloro-isopropyl)ether	400	µg/kg	Solid
4-chloro-3-methylphenol	400	µg/kg	Solid
2-chloro-naphthalene	400	µg/kg	Solid
2-chlorophenol	400	µg/kg	Solid
4-chlorophenyl phenyl ether	400	µg/kg	Solid
Chrysene	400	µg/kg	Solid
Dibenz(a,h)anthracene	400	µg/kg	Solid
Dibenzofuran	400	µg/kg	Solid
Di-n-butyl phthalate	400	µg/kg	Solid

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Semivolatile organic compounds—Continued			
Constituent	**R.L.**	**Units**	**Media**
1,2-dichlorobenzene	400	µg/kg	Solid
1,3-dichlorobenzene	400	µg/kg	Solid
1,4-dichlorobenzene	400	µg/kg	Solid
3,3'-dichlorobenzidine	2,000	µg/kg	Solid
2,4-dichlorophenol	400	µg/kg	Solid
2,6-dichlorophenol	400	µg/kg	Solid
Diethyl phthalate	800	µg/kg	Solid
3-3'-dimethylbenzidine	800	µg/kg	Solid
2,4-dimethylphenol	400	µg/kg	Solid
Dimethyl phthalate	2,000	µg/kg	Solid
4,6-dinitro-2-methylphenol	2,000	µg/kg	Solid
2,4-dinitrophenol	2,000	µg/kg	Solid
2,4-dinitrotoluene	400	µg/kg	Solid
2,6-dinitrotoluene	400	µg/kg	Solid
Di-n-octyl phthalate	400	µg/kg	Solid
Di-(2-ethylhexyl)phthalate	400	µg/kg	Solid
Fluoranthene	400	µg/kg	Solid
Fluorene	400	µg/kg	Solid
Hexachlorobenzene	400	µg/kg	Solid
Hexachlorobutadiene	400	µg/kg	Solid
Hexachlorocyclopentadiene	2,000	µg/kg	Solid
Hexachloropropene	4,000	µg/kg	Solid
Hexachloroethane	400	µg/kg	Solid
Indeno(1,2,3-cd)pyrene	400	µg/kg	Solid
Isophorone	400	µg/kg	Solid
2-methyl-naphthalene	400	µg/kg	Solid
2-methylphenol	400	µg/kg	Solid
Naphthalene	400	µg/kg	Solid
2-nitroaniline	2,000	µg/kg	Solid
3-nitroaniline	2,000	µg/kg	Solid

Semivolatile organic compounds—Continued			
Constituent	**R.L.**	**Units**	**Media**
4-nitroaniline	2,000	µg/kg	Solid
Nitrobenzene	400	µg/kg	Solid
2-nitrophenol	400	µg/kg	Solid
4-nitrophenol	2,000	µg/kg	Solid
n-nitroso-di-n-butylamine	400	µg/kg	Solid
n-nitrosodiethylamine	400	µg/kg	Solid
n-nitrosodimethylamine	400	µg/kg	Solid
n-nitroso-diphenylamine	400	µg/kg	Solid
n-nitroso-di-n-propylamine	400	µg/kg	Solid
n-nitrosomethylethylamine	400	µg/kg	Solid
Pentachlorobenzene	400	µg/kg	Solid
Pentachlorophenol	2,000	µg/kg	Solid
Phenanthrene	400	µg/kg	Solid
Phenol	400	µg/kg	Solid
Pyrene	400	µg/kg	Solid
1,2,4,5-tetrachlorobenzene	400	µg/kg	Solid
2,3,4,6-tetrachlorophenol	2,000	µg/kg	Solid
1,2,4-trichlorobenzene	400	µg/kg	Solid
2,4,5-trichlorophenol	400	µg/kg	Solid
2,4,6-trichlorophenol	400	µg/kg	Solid

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Volatile organic compounds			
Constituent	**R.L.**	**Units**	**Media**
Acetone	10	µg/L	Water
Acrolein	20	µg/L	Water
Acrylonitrile	20	µg/L	Water
Benzene	1	µg/L	Water
Bromodichloromethane	1	µg/L	Water
Bromoform	1	µg/L	Water
Bromomethane	2	µg/L	Water
2-Butanone (MEK)	5	µg/L	Water
Carbon disulfide	1	µg/L	Water
Carbon tetrachloride	1	µg/L	Water
Chlorobenzene	1	µg/L	Water
Chloroethane	2	µg/L	Water
2-chloroethyl vinyl ether	2	µg/L	Water
Chloroform	1	µg/L	Water
Chloromethane	2	µg/L	Water
Dibromochloromethane	1	µg/L	Water
Dibromomethane	1	µg/L	Water
1,2-dibromomethane (EDB)	1	µg/L	Water
1,2-dichlorobenzene	1	µg/L	Water
1,3-dichlorobenzene	1	µg/L	Water
1,4-dichlorobenzene	1	µg/L	Water
Dichlorodifluoromethane	2	µg/L	Water
1,1-dichloroethane	1	µg/L	Water
1,2-dichloroethane	1	µg/L	Water
1,1-dichloroethene	1	µg/L	Water
Cis-1,2-dichloroethene	1	µg/L	Water
Trans-1,2-dichloroethene	.5	µg/L	Water

Volatile organic compounds—Continued			
Constituent	**R.L.**	**Units**	**Media**
1,2-dichloropropane	1	µg/L	Water
Cis-1,3-dichloropropene	1	µg/L	Water
Trans-1,3-dichloropropene	1	µg/L	Water
Trans-1,4-dichloro-2-butene	1	µg/L	Water
1,4-dioxane	200	µg/L	Water
Ethylbenzene	1	µg/L	Water
Ethyl methacrylate	1	µg/L	Water
Hexane	1	µg/L	Water
2-hexanone	5	µg/L	Water
Iodomethane	1	µg/L	Water
Methylene chloride	1	µg/L	Water
4-methyl-2-pentanone	5	µg/L	Water
Methyl tert-butyl ether	5	µg/L	Water
Styrene	1	µg/L	Water
1,1,2,2,-tetrachloroethane	1	µg/L	Water
Tetrachloroethene	1	µg/L	Water
Toluene	1	µg/L	Water
1,1,1-trichloroethane	1	µg/L	Water
Trichloroethene	1	µg/L	Water
Trichlorofluoromethane	2	µg/L	Water
1,2,3-Trichloropropane	1	µg/L	Water
Trichlorotrifluoroethane	1	µg/L	Water
Vinyl acetate	2	µg/L	Water
Vinyl chloride	1	µg/L	Water
m-Xylene and p-Xylene	2	µg/L	Water
o-Xylene	1	µg/L	Water

Appendix 1. Constituent reporting limits for analysis of water, streambed-sediment, and fish-tissue samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 through July 2001—Continued

Wastewater tracers			
Constituent	**R.L.**	**Units**	**Media**
Acetophenone	0.5	µg/L	Water
Acetyl hexamethyl tetra-hydronaphthalene (AHTN)	.5	µg/L	Water
Anthracene	.5	µg/L	Water
9,10-anthraquinone	.5	µg/L	Water
Benzo(a)pyrene	.5	µg/L	Water
Benzophenone	.5	µg/L	Water
5-methyl-1H-benzotriazole	2	µg/L	Water
3-*beta*-coprostanol	2	µg/L	Water
Beta-sitosterol	2	µg/L	Water
3-*tert*-butyl-4-hydroxyanisole (BHA)	5	µg/L	Water
Bisphenol A	1	µg/L	Water
Bromacil	.5	µg/L	Water
Bromoform	.5	µg/L	Water
Caffeine	.5	µg/L	Water
Camphor	.5	µg/L	Water
Carbaryl	1	µg/L	Water
Carbazole	.5	µg/L	Water
Chlorpyrifos	.5	µg/L	Water
Cholesterol	2	µg/L	Water
Cotinine	1	µg/L	Water
Cumene (isopropylbenzene)	.5	µg/L	Water
Diazinon	.5	µg/L	Water
1,4-dichlorobenzene	.5	µg/L	Water
Dichlorvos	1	µg/L	Water
d-limonene	.5	µg/L	Water
Equilenin	5	µg/L	Water
17-*alpha*-ethynyl estradiol	5	µg/L	Water
17-*beta*-estradiol	5	µg/L	Water
Estrone	5	µg/L	Water
Ethanol,2-butoxy-phosphate	.5	µg/L	Water
Ethyl citrate (triethyl citrate)	.5	µg/L	Water
Fluoranthene	.5	µg/L	Water

Wastewater tracers—Continued			
Constituent	**R.L.**	**Units**	**Media**
Hexahydro hexamethyl cyclopenta benzopyran (HHCB)	0.5	µg/L	Water
Indole	.5	µg/L	Water
Isoborneol	.5	µg/L	Water
Isophorone	.5	µg/L	Water
Isoquinoline	.5	µg/L	Water
Menthol	.5	µg/L	Water
Metalaxyl	.5	µg/L	Water
Methyl salicylate	.5	µg/L	Water
Metolachlor	.5	µg/L	Water
N,N-diethyl-meta-toluamide	.5	µg/L	Water
1-methylnapthalene	.5	µg/L	Water
2-methylnapthalene	.5	µg/L	Water
2,6-dimethylnapthalene	.5	µg/L	Water
Naphthalene	.5	µg/L	Water
Para-cresol	1	µg/L	Water
Diethoxynonyl phenol (total, NPEO2)	5	µg/L	Water
Diethoxyoctyl phenol (OPEO2)	1	µg/L	Water
Monoethoxyoctyl phenol (OPEO1)	1	µg/L	Water
Para-nonyl phenol (total)	5	µg/L	Water
Pentachlorophenol	2	µg/L	Water
4-cumylphenol	1	µg/L	Water
4-*n*-octylphenol	1	µg/L	Water
4-*tert*-octylphenol	1	µg/L	Water
Phenol	.5	µg/L	Water
Phenanthrene	.5	µg/L	Water
Prometon	.5	µg/L	Water
Pyrene	.5	µg/L	Water
Skatol(3-methyl-1H-indole)	1	µg/L	Water
Stigmastanol	2	µg/L	Water
Tetrachloroethylene	.5	µg/L	Water
Tri(2-chloroethyl)phosphate	.5	µg/L	Water
Tri(dichlorisopropyl)phosphate	.5	µg/L	Water
Tributylphosphate	.5	µg/L	Water
Triclosan	1	µg/L	Water

Appendix 2. Characteristics and physical properties of water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000

[pH, log of hydrogen ion concentration; std.unit, standard unit; µS/cm, microsiemen per centimeter; °C, degree, Celsius; mg/L, milligram per liter; NTU, nephelometric turbidity unit; -- , no data]

September 2000

Monitoring site (figure 7)	pH (std. unit)	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Dissolved solids (mg/L)	Turbidity (NTU)	Suspended sediment (mg/L)	Total organic carbon (mg/L)	Dissolved organic carbon (mg/L)
B1	7.85	288	15.9	8.09	174	3	5.30	4.0	3.5
B2	7.85	425	16.0	8.90	265	3	2.70	4.3	3.8
B3	6.90	152	17.6	7.97	96	2	2.90	2.3	1.9
B4	7.94	357	16.9	8.95	225	4	4.70	4.3	3.1
B5	7.29	109	16.2	9.15	100	16	9.00	5.8	4.3
B6	7.17	316	15.1	5.92	195	12	7.70	3.9	3.4
A1	7.15	169	14.4	9.56	104	14	--	--	--
A2	7.99	318	22.9	9.01	193	5	--	--	--
A3	7.79	422	21.3	8.39	279	5	--	--	--
A4	7.81	568	15.2	8.82	346	2	--	--	--
A5	7.93	323	21.4	9.59	203	2	--	--	--
A6	7.26	173	17.2	8.74	112	9	18.1	2.6	2.3
A7	8.72	147	23.5	7.76	88	7	--	--	--
A8	6.13	73.0	20.2	1.85	74	20	--	--	--
A9	6.54	129	22.9	2.07	86	5	--	--	--
A10	7.63	185	17.9	8.76	119	8	--	--	--

July 2001

Monitoring site (figure 7)	pH (std. unit)	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Dissolved solids (mg/L)	Turbidity (NTU)	Suspended sediment (mg/L)
B1	8.4	342	24.0	6.7	196	12	25.2
E5	8.4	480	21.6	7.3	278	23	47.9
A4	8.1	412	20.8	6.4	244	37	64.5
A5	8.4	371	18.7	7.5	211	43	63.9
A10	8.1	201	25.8	6.3	122	38	69.2
B5	7.9	175	20.4	8.3	122	120	73.3

Appendix 3. Concentrations of dissolved and total recoverable major ions and total nutrients in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

[Dissolved concentrations unless otherwise noted; Total, total recoverable; mg/L, milligram per liter; µg/L, microgram per liter; $CaCO_3$, calcium carbonate; E, estimated concentration less than reporting limit; < , not detected at less than reporting-limit concentration; SiO_2, silicon dioxide; N, nitrogen; P, phosphorus]

September 2000

Monitoring site (figure 7)	Calcium (mg/L)	Magnesium (mg/L)		Potassium (mg/L)		Sodium (mg/L)		Iron (µg/L)	Manganese (µg/L)	Hardness (mg/L as $CaCO_3$)
		Dissolved	Total	Dissolved	Total	Dissolved	Total			
B1	36	11	12	2.1	2.0	7.0	6.7	<10	15.2	127
B2	58	20	20	3.0	3.2	5.7	5.2	5.6	18.1	221
B3	14	7.1	6.9	1.7	1.8	5.7	5.3	16	28.2	48.0
B4	50	16	16	2.0	1.9	5.3	4.9	13	29.3	205
B5	15	6.3	6.4	1.6	1.6	4.5	4.4	26	89.9	50.0
B6	38	14	14	2.5	2.3	9.2	8.7	10	582	120
A1	18	7.5	8.0	1.4	1.3	4.7	5.0	35	79.2	70.0
A2	41	13	13	2.0	2.0	6.8	6.5	6.8	19.0	141
A3	63	22	22	2.7	2.6	5.2	4.9	5.9	636	230
A4	85	27	27	1.2	1.2	3.7	3.6	6.8	30.4	295
A5	43	14	14	2.4	2.3	5.7	5.2	17	23.1	156
A6	18	7.9	7.6	1.5	1.5	5.4	5.0	21	36.0	62.0
A7	14	7.7	7.9	.97	.98	3.3	3.2	17.4	6.9	54.0
A8	11	3.3	3.2	.91	1.1	2.1	2.0	294	397	33.0
A9	19	5.7	6.1	.93	1.0	2.0	2.1	25.9	57.5	70.0
A10	27	7.5	7.5	.95	.91	3.0	3.0	7.2	55.6	98.0

July 2001

Monitoring site (figure 7)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (µγ/L)	Manganese (µg/L)	Hardness (mg/L as $CaCO_3$)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L as SiO_2)
B1	38	13	1.9	7.3	<10	18	130	12	0.1 E	5.0
E5	59	21	2.0	4.1	11	39	222	7.4	.1 E	8.0
A4	54	15	2.3	2.2	71	34	177	3.2	.1 E	9.5
A5	45	15	1.8	4.8	45	39	157	6.6	.1 E	7.8
A10	24	7.5	1.4	3.2	120	100	87.0	1.2	.1 E	4.0
B5	18	7.0	.90	4.6	57	89	52.0	1.2	<.2	11

Appendix 3. Concentrations of dissolved and total recoverable major ions and total nutrients in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001—Continued

September 2000

Monitoring site (figure 7)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Sulfate (mg/L)	Charge balance	Organic nitrogen (mg/L as N)	Ammonia (mg/L as N)	Nitrate and nitrite (mg/L as N)	Nitrite (mg/L as N)	Phosphorus (mg/L)	Orthophosphate (mg/L as P)
B1	10	0.1	5.1	14	-0.95	0.2	<0.02	<0.05	<0.01	<0.05	<0.01
B2	9.5	.1	6.4	15	-1.39	.3	<.02	.23	<.01	<.05	.01
B3	5.1	<.1	6.3	19	+2.78	.1	<.02	<.05	<.01	<.05	<.01
B4	6.1	.1	8.3	15	-5.47	.2	<.02	.07	<.01	<.05	<.01
B5	1.4	<.1	8.9	22	+ .51	.2	<.02	<.05	<.01	<.05	<.01
B6	4.9	.1	6.2	42	+ .88	.2	.05	.17	<.01	<.05	<.01
A1	2.8	<.1	9.6	20	-3.85	.2	<.02	<.05	<.01	<.05	<.01
A2	9.9	.1	5.1	13	+1.98	.2	<.02	<.05	<.01	<.05	<.01
A3	9.5	.2	6.1	15	+1.00	.2	<.02	<.05	<.01	<.05	<.01
A4	4.5	.2	13	27	+ .51	.1	<.02	.06	<.01	<.05	.02
A5	7.7	<.1	6.3	14	- .18	.3	<.02	<.05	<.01	<.05	<.01
A6	3.8	<.1	11	19	+1.87	.1	<.02	.07	<.01	<.05	<.01
A7	.9	.1	1.3	20	-1.50	.4	<.02	<.05	<.01	<.05	<.01
A8	.9	<.1	10	5.9	+9.16	.3	<.02	<.05	<.01	<.05	<.01
A9	.7	.1	3.7	4.0	+1.11	.3	<.02	<.05	<.01	<.05	<.01
A10	.8	.1	8.8	4.9	+ .84	.3	<.02	<.05	<.01	<.05	<.01

July 2001

Monitoring site (figure 7)	Sulfate (mg/L)	Charge balance
B1	17	+0.68
E5	17	- .89
A4	16	+2.08
A5	17	+ .95
A10	12	- .87
B5	24	+4.22

Appendix 4. Concentrations of dissolved and total trace elements in water samples collected at Camp Atterbury near Edinburgh, Indiana, September 2000 and July 2001

[All concentrations for dissolved trace elements, unless otherwise noted; concentrations in microgram per liter; iron, manganese, and silica reported with major ions; < , not detected at less than reporting limit concentration; E, estimated concentration less than reporting limit]

September 2000

Monitoring site (figure 7)	Barium	Boron	Cobalt	Copper	Lead	Total lead	Molybdenum	Selenium	Strontium	Tin
B1	22.9	30.6E	<10	2.9E	<3.0	<1.0	<20	<5	65.5	<100
B2	42.8	32.5E	<10	<10	<3.0	<1.0	2.9E	<5	176.0	<100
B3	19.6	34.1E	<10	<10	<3.0	<1.0	<20	<5	54.0	<100
B4	36.7	28.2E	<10	3.2E	<3.0	<1.0	<20	<5	110.0	<100
B5	25.1	32.7E	<10	3.3E	<3.0	.56E	<20	<5	53.1	<100
B6	48.8	31.0E	<10	2.4E	<3.0	.54	<20	<5	116.0	<100
A1	25.6	32.9E	<10	<10	<3.0	<1.0	<20	<5	58.5	<100
A2	28.4	30.0E	<10	<10	<3.0	<1.0	<20	<5	79.0	<100
A3	52.1	26.6E	<10	<10	1.5E	<1.0	<20	<5	192.0	<100
A4	58.3	17.4E	<10	2.3E	<3.0	<1.0	2.3 E	<5	138.0	<100
A5	33.0	33.4E	<10	<10	<3.0	<1.0	<20	<5	104.0	<100
A6	26.7	29.9E	<10	<10	<3.0	<1.0	<20	<5	59.9	<100
A7	6.6E	36.0E	<10	<10	<3.0	<1.0	<20	<5	44.9	4.8E
A8	25.8	18.7E	1.0E	<10	<3.0	.55E	<20	4.4E	32.7	5.4E
A9	14.6	23.4E	<10	<10	<3.0	<1.0	<20	<5	50.5	<100
A10	18.2	17.2E	<10	2.3E	<3.0	<1.0	<20	<5	51.7	<100

July 2001

Monitoring site (figure 7)	Barium	Boron	Cadmium	Copper	Lead	Total lead	Molybdenum	Selenium	Strontium	Tin
B1	22.7	33.8 E	0.51 E	9.1 E	<3.0	<1.0	2.0 E	<5	75.9	<100
E5	49.8	24.0 E	.49 E	3.4 E	<3.0	.70E	2.2 E	<5	151	<100
A4	49.6	32.1 E	.47 E	3.5 E	<3.0	1.0	2.1 E	<5	95.2	<100
A5	38.0	31.2 E	.45 E	4.1 E	<3.0	.50E	2.0 E	<5	104	<100
A10	22.1	18.2 E	<5.0	<10	<3.0	1.0 E	<20	<5	58.3	<100
B5	28.9	26.0 E	.41 E	3.0 E	<3.0	2.0	<20	<5	57.1	<100

Appendix 5. Concentrations of *Escherichia coli*, instantaneous streamflow, and water-quality characteristics in water samples collected from monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May and June 2001

[*E. coli*, *Escherichia coli*; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic foot per second; µS/cm, microsiemen per centimeter; mg/L, milligram per liter; °C, degree Celsius; NTU, nephelometric turbidity unit]

Monitoring site (figure 7)	Date	*E. coli* concentration (col/100 mL)	Instantaneous streamflow (ft^3/s)	pH (standard units)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NTU)
Week 1								
E1	5-14	210	0.03	7.7	339	8.2	16.1	82
E2	5-14	480	.31	7.6	312	6.8	16.7	3.7
E3	5-21	490	11	7.2	173	8.5	18.7	20
E4	5-15	90	.03	8.0	515	8.0	15.6	4.5
E5	5-15	67	1.4	7.9	545	7.5	16.2	2.7
E6	5-16	200	.03	7.5	499	6.0	19.4	8.7
E7	5-16	21	.24	7.6	594	6.2	16.8	2.9
B1	5-14	190	.60	8.0	402	9.6	15.6	2.3
B2	5-15	150	.69	7.9	574	7.5	15.2	1.9
B3	5-17	900	.19	6.8	152	7.3	16.2	8.2
B4	5-15	54	4.4	8.0	430	8.5	18.7	3.0
B5	5-16	100	.06	7.5	223	7.7	22.0	19
A4	5-16	120	.58	7.9	572	10	18.6	2.9
A5	5-15	140	3.9	7.9	411	8.3	17.5	3.5
A6	5-17	510	.09	7.3	218	7.0	19.2	16
A10	5-16	130	.01	7.8	263	8.0	19.1	7.0
Week 2								
E1	5-21	470	.05	7.7	366	7.9	19.6	64
E2	5-21	380	1.5	7.8	297	6.8	21.5	5.5
E3	5-24	2,600	34	7.2	150	8.4	13.8	170
E4	5-22	360	.29	7.8	602	8.7	14.8	3.4
E5	5-22	150	3.2	7.8	566	8.1	16.6	5.5
E6	5-23	170	.06	7.5	583	5.3	15.0	5.1
E7	5-23	170	.42	7.7	608	6.9	12.4	4.1
B1	5-21	210	2.0	7.9	375	8.1	19.2	3.9
B2	5-22	240	1.2	7.9	546	8.2	16.0	2.0
B3	5-24	2,200	11	7.1	140	8.2	14.4	26
B4	5-22	170	23	8.0	346	8.6	18.3	11
B5	5-23	860	.25	7.8	243	8.8	14.8	34
A4	5-23	130	1.2	7.9	594	8.4	13.4	3.7
A5	5-22	230	19	7.9	321	8.8	18.2	12
A6	5-24	5,500	15	7.2	153	8.4	13.5	120
A10	5-23	150	.33	7.8	240	8.5	14.8	7.2

Appendix 5. Concentrations of *Escherichia coli*, instantaneous streamflow, and water-quality characteristics in water samples collected from monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May and June 2001—Continued

Monitoring site (figure 7)	Date	*E. coli* concentration (col/100 mL)	Instantaneous streamflow (ft^3/s)	pH (standard units)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NTU)
Week 3								
E1	5-29	140	0.07	7.7	344	8.4	18.3	62
E2	5-29	93	3.3	7.9	286	8.3	19.8	5.8
E3	5-30	93	6.9	7.4	178	9.5	16.3	10
E4	5-31	72	.35	7.8	591	9.1	13.6	3.1
E5	5-31	41	7.0	7.8	536	9.1	14.7	3.9
E6	6-1	970	.51	7.5	601	6.2	14.8	3.4
E7	6-1	440	.95	7.7	598	7.6	13.8	4.6
B1	5-30	120	4.1	7.9	369	9.1	17.1	3.5
B2	5-31	250	3.6	8.1	501	10	14.2	2.3
B3	5-30	43	3.3	7.2	160	8.5	17.1	3.8
B4	5-31	110	22	7.9	398	9.0	15.1	6.8
B5	6-1	400	.63	7.6	224	8.8	15.0	17
A4	6-1	73	2.0	7.9	591	9.4	14.1	3.4
A5	5-31	130	23	7.9	380	9.4	15.0	7.2
A6	5-30	100	2.8	7.4	187	9.4	15.5	12
A10	6-1	110	.60	7.7	231	8.6	15.3	6.5
Week 4								
E1	6-6	530	2.2	8.0	306	8.8	19.3	280
E2	6-6	1,400	12	7.8	252	8.6	17.5	37
E3	6-7	230	16	7.3	155	9.1	17.0	15
E4	6-5	500	.76	7.8	503	8.9	14.6	4.3
E5	6-5	1,200	12	7.9	487	9.1	14.5	21
E6	6-5	2,000	.78	7.7	534	8.9	15.0	4.8
E7	6-5	870	1.1	7.6	534	7.7	14.0	6.5
B1	6-7	480	19	7.8	303	8.3	18.6	17
B2	6-6	2,800	110	7.7	293	8.6	16.9	540
B3	6-7	70	5.0	7.1	145	8.6	17.8	3.8
B4	6-5	2,300	47	8.0	328	9.5	15.6	19
B5	6-4	110	.31	7.6	221	8.7	14.0	21
A4	6-4	2,200	2.8	7.8	513	8.9	13.7	8.6
A5	6-4	180	14	8.0	404	9.0	14.6	4.6
A6	6-7	28[a]	8.3	7.3	160	9.2	16.8	12
A10	6-4	1,800	.87	7.6	205	9.0	13.8	150

Appendix 5. Concentrations of *Escherichia coli*, instantaneous streamflow, and water-quality characteristics in water samples collected from monitoring sites on streams at Camp Atterbury near Edinburgh, Indiana, May and June 2001—Continued

Monitoring site (figure 7)	Date	*E. coli* concentration (col/100 mL)	Instantaneous streamflow (ft^3/s)	pH (standard units)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NTU)
Week 5								
E1	6-11	190	0.08	7.8	307	7.6	21.6	45
E2	6-11	68	3.4	8.0	261	7.7	22.3	4.9
E3	6-13	200	1.7	7.9	190	7.5	20.8	13
E4	6-12	1,100	.24	7.9	520	7.9	20.8	2.8
E5	6-14	120	4.2	7.9	494	9.4	25.8	3.2
E6	6-12	500	.49	7.6	539	5.9	18.4	3.4
E7	6-12	670	.83	7.7	540	6.9	17.1	4.3
B1	6-11	200	4.9	7.9	324	8.2	21.4	4.3
B2	6-14	610	2.1	7.9	489	8.1	20.1	2.8
B3	6-13	100	.75	7.0	155	7.4	19.2	3.9
B4	6-14	82	11	8.0	408	8.3	25.0	4.0
B5	6-12	110	.22	7.4	186	7.6	21.3	24
A4	6-12	210	2.0	7.8	533	8.6	18.9	4.7
A5	6-14	180	11	7.9	393	7.7	22.6	5.1
A6	6-13	240	.63	7.4	194	7.7	20.5	12
A10	6-13	120	.16	7.8	238	7.2	23.6	7.6

[a]Concentration is estimated because relative percent difference of duplicate samples was greater than 20 percent.

Appendix 6. Fish species, abundance, and total weight in stream reaches near 10 monitoring sites at Camp Atterbury near Edinburgh, Indiana, September and October 2000

Monitoring site (figure 7)	Species name	Common name	Number of individuals	Weight of individuals (grams)
B1	*Campostoma anomalum*	Central stoneroller	151	1,246
	Luxilus chrysocephalus	Striped shiner	25	438
	Notropis buccatus	Silverjaw minnow	2	4
	Pimephales notatus	Bluntnose minnow	111	373
	Rhinichthys atratulus	Blacknose dace	4	9
	Semotilus atromaculatus	Creek chub	37	335
	Catostomus commersoni	White sucker	7	706
	Hypentelium nigricans	Northern hog sucker	2	203
	Labidesthes sicculus	Brook silverside	27	44
	Lepomis macrochirus	Bluegill	2	7
	Lepomis megalotis	Longear sunfish	16	256
	Micropterus punctulatus	Spotted bass	2	13
	Etheostoma nigrum	Johnny darter	23	43
	Etheostoma spectabile	Orangethroat darter	18	30
	Fundulus catenatus	Northern studfish	3	10
B2	*Campostoma anomalum*	Central stoneroller	145	1,168
	Luxilus chrysocephalus	Striped shiner	17	416
	Notropis buccatus	Silverjaw minnow	25	55
	Notropis stramineus	Sand shiner	8	22
	Pimephales notatus	Bluntnose minnow	47	146
	Rhinichthys atratulus	Blacknose dace	1	5
	Semotilus atromaculatus	Creek chub	9	246
	Hypentelium nigricans	Northern hog sucker	2	21
	Ameiurus natalis	Yellow bullhead	1	3
	Cottus bairdi	Mottled sculpin	13	88
	Lepomis cyanellus	Green sunfish	1	15
	Lepomis macrochirus	Bluegill	2	2.5
	Etheostoma nigrum	Johnny darter	6	9
	Etheostoma spectabile	Orangethroat darter	10	13
	Fundulus catenatus	Northern studfish	33	132

Appendix 6. Fish species, abundance, and total weight in stream reaches near 10 monitoring sites at Camp Atterbury near Edinburgh, Indiana, September and October 2000—Continued

Monitoring site (figure 7)	Species name	Common name	Number of individuals	Weight of individuals (grams)
B3	*Campostoma anomalum*	Central stoneroller	7	57
	Cyprinella spiloptera	Spotfin shiner	1	4
	Luxilus chrysocephalus	Striped shiner	1	7
	Pimephales notatus	Bluntnose minnow	6	13
	Semotilus atromaculatus	Creek chub	38	113.5
	Catostomus commersoni	White sucker	2	47
	Erimyzon oblongus	Creek chubsucker	5	43.5
	Lepomis macrochirus	Bluegill	7	50
	Lepomis megalotis	Longear sunfish	1	10
	Etheostoma spectabile	Orangethroat darter	20	26
B4	*Campostoma anomalum*	Central stoneroller	4	32
	Cyprinella spiloptera	Spotfin shiner	6	10
	Cyprinella whipplei	Steelcolor shiner	30	61.5
	Notropis photogenis	Silver shiner	1	2
	Notropis stramineus	Sand shiner	64	120
	Pimephales notatus	Bluntnose minnow	51	143
	Pimephales promelas	Fathead minnow	1	3
	Hypentelium nigricans	Northern hog sucker	11	150
	Moxostoma erythrurum	Golden redhorse	11	654
	Moxostoma macrolepidotum	Shorthead redhorse	3	145
	Cottus bairdi	Mottled sculpin	5	30
	Lepomis megalotis	Longear sunfish	4	10
	Lepomis megalotis	Longear sunfish	7	45
	Lepomis microlophus	Redear sunfish	2	14
	Micropterus punctulatus	Spotted bass	2	8
	Pomoxis nigromaculatus	Black crappie	1	4
	Etheostoma spectabile	Orangethroat darter	6	7
	Etheostoma nigrum	Johnny darter	15	14.5
	Percina maculata	Blackside darter	3	12
	Percina caprodes	Logperch	1	14
	Percina sciera	Dusky darter	9	39
	Fundulus catenatus	Northern studfish	1	4
	Lampetra appendix	American brook lamprey	2	19

Appendix 6. Fish species, abundance, and total weight in stream reaches near 10 monitoring sites at Camp Atterbury near Edinburgh, Indiana, September and October 2000—Continued

Monitoring site (figure 7)	Species name	Common name	Number of individuals	Weight of individuals (grams)
B5	*Cyprinella spiloptera*	Spotfin shiner	12	44
	Cyprinella whipplei	Steelcolor shiner	8	56
	Luxilus chrysocephalus	Striped shiner	5	107
	Notropis buccatus	Silverjaw minnow	3	3
	Pimephales notatus	Bluntnose minnow	17	58
	Semotilus atromaculatus	Creek chub	38	289
	Catostomus commersoni	White sucker	11	68
	Erimyzon oblongus	Creek chubsucker	17	59
	Lepomis macrochirus	Bluegill	13	95
	Micropterus dolomieu	Smallmouth bass	1	6
	Etheostoma caeruleum	Rainbow darter	1	1
	Percina maculata	Blackside darter	3	5
	Esox americanus vermiculatus	Grass pickerel	4	149
B6	*Cyprinella spiloptera*	Spotfin shiner	286	676
	Cyprinella whipplei	Steelcolor shiner	223	980
	Luxilus chrysocephalus	Striped shiner	20	179
	Lythrurus umbratilis	Redfin shiner	4	5
	Notropis atherinoides	Emerald shiner	6	17
	Notropis buccatus	Silverjaw minnow	36	69
	Pimephales notatus	Bluntnose minnow	108	211
	Semotilus atromaculatus	Creek chub	2	45
	Catostomus commersoni	White sucker	11	641
	Erimyzon oblongus	Creek chubsucker	6	160
	Hypentelium nigricans	Northern hog sucker	1	48
	Minytrema melanops	Spotted sucker	1	15
	Moxostoma duquesnei	Black redhorse	3	91
	Lepomis cyanellus	Green sunfish	11	358
	Lepomis macrochirus	Bluegill	10	98
	Lepomis megalotis	Longear sunfish	27	353
	Lepomis gibbosus	Pumpkinseed	1	16
	Micropterus punctulatus	Spotted bass	3	84
	Micropterus salmoides	Largemouth bass	1	14
	Etheostoma nigrum	Johnny darter	1	1
	Percina maculata	Blackside darter	2	5
	Esox americanus vermiculatus	Grass pickerel	8	569

Appendix 6. Fish species, abundance, and total weight in stream reaches near 10 monitoring sites at Camp Atterbury near Edinburgh, Indiana, September and October 2000—Continued

Monitoring site (figure 7)	Species name	Common name	Number of individuals	Weight of individuals (grams)
A4	*Campostoma anomalum*	Central stoneroller	116	472
	Cyprinella spiloptera	Spotfin shiner	31	70
	Cyprinella whipplei	Steelcolor shiner	1	3
	Luxilus chrysocephalus	Striped shiner	24	250.5
	Lythrurus umbratilis	Redfin shiner	2	4
	Pimephales notatus	Bluntnose minnow	102	255
	Semotilus atromaculatus	Creek chub	91	793
	Catostomus commersoni	White sucker	11	146
	Erimyzon oblongus	Creek chubsucker	4	26
	Hypentelium nigricans	Northern hog sucker	2	108
	Cottus bairdi	Mottled sculpin	14	64
	Lepomis cyanellus	Green sunfish	2	62
	Lepomis megalotis	Longear sunfish	3	53
	Micropterus punctulatus	Spotted bass	1	4
	Etheostoma nigrum	Johnny darter	4	4.5
	Etheostoma spectabile	Orangethroat darter	29	34.5
	Esox americanus vermiculatus	Grass pickerel	5	208
A5	*Campostoma anomalum*	Central stoneroller	69	600
	Cyprinella spiloptera	Spotfin shiner	1	1
	Cyprinella whipplei	Steelcolor shiner	14	54
	Luxilus chrysocephalus	Striped shiner	12	145
	Notropis boops	Bigeye shiner	100	274
	Notropis buccatus	Silverjaw minnow	5	10
	Notropis stramineus	Sand shiner	19	27
	Phenacobius mirabilis	Suckermouth minnow	2	12
	Pimephales notatus	Bluntnose minnow	140	558
	Semotilus atromaculatus	Creek chub	4	18
	Catostomus commersoni	White sucker	5	250
	Hypentelium nigricans	Northern hog sucker	41	1,176
	Moxostoma erythrurum	Golden redhorse	14	671
	Ameiurus natalis	Yellow bullhead	3	217
	Ambloplites rupestris	Rock bass	1	9
	Lepomis cyanellus	Green sunfish	1	23
	Lepomis macrochirus	Bluegill	11	146

Appendix 6. Fish species, abundance, and total weight in stream reaches near 10 monitoring sites at Camp Atterbury near Edinburgh, Indiana, September and October 2000—Continued

Monitoring site (figure 7)	Species name	Common name	Number of individuals	Weight of individuals (grams)
A5–Continued				
	Lepomis megalotis	Longear sunfish	56	666
	Micropterus punctulatus	Spotted bass	8	275
	Etheostoma blennioides	Greenside darter	16	63
	Etheostoma spectabile	Orangethroat darter	10	16
	Etheostoma nigrum	Johnny darter	14	15
	Percina maculata	Blackside darter	8	45
	Percina caprodes	Logperch	1	18
	Lampetra appendix	American brook lamprey	4	33
A6	*Campostoma anomalum*	Central stoneroller	24	76
	Cyprinella spiloptera	Spotfin shiner	17	48
	Luxilus chrysocephalus	Striped shiner	2	26
	Notropis buccatus	Silverjaw minnow	3	8
	Pimephales notatus	Bluntnose minnow	31	88
	Semotilus atromaculatus	Creek chub	60	141
	Catostomus commersoni	White sucker	45	90
	Lepomis cyanellus	Green sunfish	2	5
	Lepomis megalotis	Longear sunfish	14	91
	Micropterus punctulatus	Spotted bass	3	11
	Etheostoma nigrum	Johnny darter	4	6
	Etheostoma spectabile	Orangethroat darter	16	25
	Percina maculata	Blackside darter	2	11
A10	*Semotilus atromaculatus*	Creek chub	11	301
	Erimyzon oblongus	Creek chubsucker	3	105
	Ameiurus natalis	Yellow bullhead	2	93
	Lepomis cyanellus	Green sunfish	4	67
	Lepomis macrochirus	Bluegill	17	126
	Lepomis microlophus	Redear sunfish	1	13
	Micropterus salmoides	Largemouth bass	1	3
	Etheostoma nigrum	Johnny darter	1	1
	Etheostoma spectabile	Orangethroat darter	1	1
	Percina maculata	Blackside darter	4	19