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Water-Quality and Biological Assessment of the Iowa River and Tributaries Within and Contiguous to the Meskwaki Settlement of the Sac and Fox Tribe of the Mississippi in Iowa, 2006–07

Scientific Investigations Report 2009–5105

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

Front cover. Background photograph is view along bend in Iowa River below Montour, IA, July 2007 (photograph taken by Jason McVay, USGS). Inset photograph shows USGS and Meskwaki Settlement field personnel collecting water-quality samples on a cross section of the Iowa River near Montour, Iowa, June 2006 (photograph taken by Greg Littin, USGS).

Back cover. Upper left photograph shows USGS hydrologist taking multiprob measurements of the Iowa River from the Avenue E bridge near Montour, IA (photograph taken by Doug Goodrich, USGS). Lower left photograph shows USGS hydrologic technician collecting water-quality sample from the Iowa River near the pow wow grounds, December 2006 (photograph taken by Greg Littin, USGS). Right inset photograph shows USGS and Meskwaki Settlement field personnel collecting and cataloging aquatic macroinvertebrate samples, July 2007 (photograph taken by Jason McVay, USGS).

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By Gregory R. Littin and Jason C. McVay

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Conversion Factors and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square meter (m^2)	4,046.856	acre
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)

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

$$°F=(1.8\times°C)+32.$$

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

$$°C=(°F-32)/1.8.$$

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

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

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

Streambed-sediment concentrations are given in micrograms per gram (µg/g).

Bacteria densities are measured in the number of colony-forming units per 100 milliliters of water (cfu/100 mL).

Acronyms Used in Report

ANSP	Academy of Natural Sciences of Philadelphia
BMIBI	Benthic Macroinvertebrate Index of Biological Integrity
CALFED	California Federal
CIAT	2-Chloro-4-Isopropylamino-6-Amino-s-Triazine
DDT	Dichloro-Diphenyl-Trichloroethane
DELT	Deformities Eroded fins Lesions Tumors
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
EWI	Equal Width Increment
FDA	U.S. Food and Drug Administration
FIBI	Fish Index of Biological Integrity
HQR	High Quality Resource
IBI	Index of Biotic Integrity
IDNR	Iowa Department of Natural Resources
IEPA	Illinois Environmental Protection Agency
IDPH	Iowa Department of Public Health
LRB	Laboratory Reagent Blank
LRL	Laboratory Reporting Level
LRS	Laboratory Reagent Spike
LT-MDL	Long-Term Method Detection Level
MCL	Maximum Contaminant Level
MRL	Minimum Reporting Limit
MTBE	Tert-Butyl Methyl Ether
NAWQA	National Water Quality Assessment
NOAA	National Oceanographic and Atmospheric Administration
NWQL	National Water Quality Laboratory
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	PolyBrominated Dephenyl Ether
PCB	PolyChlorinated Biphenyls
PEL	Probable Effects Level
QA	Quality Assurance
QC	Quality Control
QHEI	Qualitative Habitat Evaluation Index
QMH	Qualitative Multihabitat
RPD	Relative Percentage Difference
RTH	Rich Targeted Habitat
SM	Standard Method
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedure
SV	Screening Value

Acronyms Used in Report—Continued

TEL	Threshold Effects Level
TN	Total Nitrogen
TSS	Total Suspended Solids
UHL	University Hygienic Laboratory
USACOE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WRP	Wetlands Reserve Property

Water-Quality and Biological Assessment of the Iowa River and Tributaries Within and Contiguous to the Meskwaki Settlement of the Sac and Fox Tribe of the Mississippi in Iowa, 2006–07

By Gregory R. Littin and Jason C. McVay

Abstract

In cooperation with the Sac and Fox Tribe of the Mississippi in Iowa (Meskwaki Nation), the U.S. Geological Survey conducted a 2-year baseline assessment of the chemical and biological quality of streams within the Meskwaki Settlement in central Iowa. The Meskwaki Nation is a federally recognized tribe that wishes to establish water-quality standards to safeguard the integrity of surface waters and aquatic biota within the settlement for the health and welfare of the tribal community. The settlement is drained by the Iowa River and four tributaries (Onion, Cattail, Raven, and Bennett Creeks). Water-quality samples were collected at three sites on the Iowa River, two sites on Onion Creek, and one site each on Cattail, Raven, and Bennett Creeks from April 2006 through July 2007. Biological and habitat assessments were conducted at all three sites on the Iowa River and the downstream-most site on Onion Creek from June through August 2007. Analysis of physical properties, major ions, nutrients, trace compounds, bacteria, and total suspended solids in water, and trace metals and organic compounds in streambed sediment provided information about the effects of anthropogenic (human related) activities on the water quality of settlement streams. Analysis of biological samples collected during the summer of 2007, including fish community, benthic macroinvertebrates, and periphyton samples, as well as physical habitat characteristics, provided information on the effects of water quality on the condition of the aquatic environment.

The majority of surface water sampled within the settlement was predominately a calcium bicarbonate type. Nitrates (nitrate plus nitrite as nitrogen) exceeded the U.S. Environmental Protection Agency's (USEPA) primary drinking-water Maximum Contaminant Level of 10 µg/L in 19 of 36 samples from sites on the Iowa River and Raven and Bennett Creeks but not in samples from Onion and Cattail Creeks. None of the samples analyzed for pesticides, trace metals, wastewater, or fuel contaminants were found to exceed drinking-water regulations for the USEPA or State of Iowa targeted constituents. Bacteria densities for *Escherichia coli* (E. coli) ranged from less than 10 to more than 600,000 colony-forming units per 100 milliliters of water and were largest following intense rainfall runoff. The largest densities were recorded in samples collected from the tributaries, most notably from Cattail Creek downstream from the tribal headquarters area and Onion Creek downstream from the sewage lagoons. Arsenic and nickel concentrations in bottom sediment from Onion Creek exceeded the USEPA threshold effects level in a composite sample collected during the habitat assessment in July 2007. Suspended-sediment concentration was estimated in terms of total suspended solids. Overall, Onion and Bennett Creeks were the least turbid, whereas the ephemeral Cattail Creek had the most turbid samples.

Aquatic-community data were collected at four sites on the Meskwaki Settlement during the summer of 2007 to provide a baseline biological assessment of stream conditions. This assessment was based on sampling of the fish, benthic macroinvertebrate, and periphyton communities along with physical habitat characteristics. Individual biological metrics were derived from the data collected during the community surveys. These metrics were used to calculate Indexes of Biological Integrity (IBIs). The calculated values from the IBIs provided a numerical value that was used to provide an assessment of the biological condition at each biological sampling site. The fish community samples indicated that all of the sampling sites would be considered in fair condition, with one exception being a collection site on the Iowa River at Highway 49 near Tama, Iowa, which was classified in poor condition. The benthic macroinvertebrate IBI indicated a classification of good for three of the four biological sampling sites, with the Iowa River near Montour, Iowa, site classified as fair. The periphyton community assessment indicated that the potential for eutrophic conditions exists on the basis of the species that are present in the streams at all of the biological sampling sites. The physical in-stream habitat and proximate-riparian habitat indicate that the Iowa River sites are in fair condition and that the Onion Creek site is in poor condition. A cause for

this difference in classification would be that the Onion Creek site has had greater effects from anthropogenic sources.

Fish-tissue samples, both fillet and liver, were collected to provide an assessment of current fish health and the potential effects on human health related to the contaminants present in fish tissue. Both cadmium and mercury were found in liver samples at concentrations that would warrant fish-consumption advisories. The insecticide dieldrin was also detected at all sites in both the fillet and liver samples at concentrations greater than USEPA risk-based screening values. A few organic wastewater contaminants also were found in fish-tissue samples; a class of chemicals known as polybrominated dephenyl ethers (PBDEs), a flame retardant, was found at all four sites in both fillet and liver samples. Other organic wastewater contaminants found in the whole fish samples from the Onion Creek site were triclosan, an antimicrobial disinfectant, and its degradate methoxytriclosan. The fish-tissue sample results indicated the need for further study of contamination levels and potential health effects so that effective fish-consumption advisory levels can be developed for the Meskwaki Settlement.

Introduction

The Sac and Fox Tribe of the Mississippi in Iowa (Meskwaki Nation) is a federally recognized Native American Tribe. Tribal lands include about 7,300 acres encompassing the Meskwaki Settlement near Tama in central Iowa and another 700-acre tract in Palo Alto County in northwest Iowa. This study was conducted on surface water within and contiguous to the settlement in central Iowa. The Iowa River flows through the southern part of the settlement from west to east and is the major waterway in the area. The tribal members depend on the river for supplemental sustenance from fish and game that normally inhabit the riverine areas.

In 2006, the Meskwaki Nation cooperated with the U.S. Geological Survey (USGS) to conduct a baseline study that included periodic sampling and analysis of water samples from the Iowa River and local tributaries (Onion, Cattail, Raven, and Bennett Creeks) to determine (1) ranges in the quality of water at selected sampling sites, (2) exceedances of State or Federal water-quality standards, and (3) ranges of constituent concentrations in bed sediment in sampled streams. Analyses of physical properties, major ions, nutrients, trace metals, organic compounds, bacteria, and sediment provided information about the effects of anthropogenic (human-related) activities on the water quality of settlement streams. In addition, a biological assessment was conducted during the summer of 2007 to determine the overall condition of aquatic life in streams within the settlement. The biological samples included fish community, benthic macroinvertebrates, and periphyton samples, as well as physical habitat characteristics.

Purpose and Scope

The purpose of this report is to describe a surface-water-quality and biological assessment for use in the determination of baseline conditions and the design and implementation of tribal water-quality-related programs. The data will be used as a basis for developing realistic water-quality standards for surface water on the settlement. The scope includes a presentation and analysis of data including periodic measurements of streamflow and surface-water quality (April 2006 to July 2007), streambed sediment (June and July 2007), and biological and habitat assessments (June 2007 to August 2007). Streamflow data include discharge and stage measurements from three main-stem sites and four tributaries to the Iowa River. Water-quality analyses were conducted on samples collected during base-flow, intermediate, and storm-flow conditions.

Location and Population

The Meskwaki Settlement in central Iowa is located about 40 miles (mi) west of Cedar Rapids near the towns of Toledo and Tama (fig. 1). The settlement was established in 1857 on 80 acres of land purchased by tribal members a year after they were granted residential status from the Iowa General Assembly. Through additional land purchases, the original 80 acres now forms the core of more than 7,300 acres of tribal land.

Approximately 650 of nearly 1,300 tribal members live on the settlement (Bob Hipple, Meskwaki Natural Resources Department, oral commun., 2006). Members generally reside near the boundaries of the settlement, and as with most tribal lands, there is no individual ownership.

Physiographic Setting and Land Use

The settlement is in the landform region known as the Southern Iowa Drift Plain, which is dominated by glacial deposits left by ice sheets that covered this region between 2.5 million and 500,000 years ago (Iowa Department of Natural Resources, 1997). The deposits then were carved by deepening episodes of stream erosion. Native surface and near-surface sediment in the northern area of the settlement consists of gently sloping to very steep, well-drained, silty soils formed in loess on uplands to nearly level, moderately well-drained and poorly drained silty soils formed in alluvium on flood plains and low terraces (Iowa Department of Natural Resources, 2005). Topographic relief varies from a high of 1,000 feet (ft) in the northern and eastern parts of the settlement to a low of 825 ft near the Iowa River valley in the southeastern part of the settlement. The Iowa River enters the settlement at the southwest boundary at sampling site 1 and flows in a southeasterly direction where it forms the southern boundary of much of the settlement (fig. 1).

Figure 1. Location of boundary of Meskwaki Settlement and water-quality and biological sampling sites along the Iowa River and associated tributaries in central Iowa.

Land is used for rural residential, agricultural, recreational, commercial, livestock, and conservational purposes. The latter represents about 40 percent of all land-use cover and includes much of the wetlands along the Iowa River corridor. Vegetation consists of cottonwood, silver maple, and oak along the Iowa River and its tributaries. Cedar, maple, hickory, and oak commonly are found throughout the east residential area surrounding the tribal headquarters. Prairie grasses, such as big and little blue stem, fill much of the open areas. Agriculture is limited and consists of corn and soybeans in the central part of the settlement bounding Onion Creek. Small amounts of alfalfa are grown in the north-central area north of State Highway 30 and on the Wetlands Reserve Property (WRP) near Tama. Livestock consists of bison maintained on noncontiguous property south of the southern boundary of the main settlement area (Kelly Schott, Meskwaki Natural Resources Department, oral commun., 2007).

Historically, the Meskwaki Nation has maintained a society that is based on hunting, gathering, and farming. In recent years, the economic base of the tribe has shifted to retail commerce and gaming. Commercial enterprises include a resort hotel, casino, and trading post located along Highway 30 near the northern boundary of the settlement.

Climate

The climate throughout the settlement is temperate. Average daily high temperatures generally vary from the low 80 degrees Fahrenheit (ºF) during the summer months to the mid-20s ºF during the winter. Precipitation averages about 34 inches per year (in/yr) on the basis of State of Iowa climate records for Toledo (Iowa Department of Agriculture, 2007). However, precipitation measured at the National Weather Service (NWS) Toledo 3N gage (fig. 1) was 22.38 inches (in.) during 2006 and 30.96 in. during 2007. Precipitation measured at the NWS Marshalltown gage, about 15 miles northwest of the settlement, was 34.23 and 35.66 in., respectively, for the same periods of record (Iowa State University Department of Agronomy, 2007).

Design and Methods of Data Collection

Water-Quality Sampling Sites

Sampling locations are listed in table 1 and shown in figure 1. Eight sites were selected for water-quality and sediment sampling using methods described in Averett and Schroder (1994) and Edwards and Glysson (1999). Sites represent combinations of natural and human factors thought to collectively affect the physical, chemical, and biological characteristics of surface-water quality on the settlement with the objective of answering questions regarding source, occurrence, effects, and spatial distribution of potential contaminants. These sites were located upstream from backwater during both low- and high-flow conditions and were accessible for sampling on the basis of site characteristics and landowner permission. Some sampling sites were at or near road overpasses or bridges so that safe access could occur during high-flow sampling.

Biological Assessment Sites

Biological assessments were conducted along three reaches of the Iowa River and one reach of Onion Creek (table 1; fig. 1) on the basis of protocols and guidelines detailed in Barbour and others (2002), Moulton and others (2002), and Fitzpatrick and others (1998). In general, reach lengths ranged from about 500 to 1,000 ft for wadeable streams and from about 1,500 to 3,000 ft for nonwadeable streams. Characterization of physical habitat included documentation of general land use, description of the stream origin and type, summary of the riparian vegetation features, and measurements of in-stream characteristics such as width, depth, flow, water-surface gradient, and substrate. Each proposed site was named and identified by a site number and a location description, as well as by its latitude, longitude, and elevation, as determined by global positioning system (U.S. Environmental Protection Agency, 1992; Federal Geographic Data Committee, 1998).

Sampling Methods

Stream discharges were measured and water-quality samples were collected by USGS and Meskwaki personnel at three locations on the Iowa River and at five locations on four tributaries that drain the settlement (table 1; fig. 1) using methods described in Rantz and others (1982) and Wilde and Radtke (1998). Six synoptic measurements were performed during the first year of this study (April 2006 – July 2007) and included base- and storm-flow conditions (low-flow and high-flow conditions). Additionally, water-quality samples were collected at each of the four habitat sites (sites 1, 3, 5, and 7) during the second year of the investigation (June–August 2007). Water-quality sampling entailed parts-per-billion, equal-width- increment sampling methods (Edwards and Glysson, 1999). Sampling instrumentation included a Yellow Springs Instrument’s multiprobe meter (YSI Corporation, Yellow Springs, OH) for collecting water-quality physical properties, a USGS DH-81 for collecting water-quality samples at wadeable sites, and a USGS D-95 depth-integrated sampler for collecting samples at nonwadeable sites.

Following discharge measurements, instantaneous measurements of water properties (specific conductance, pH, temperature, and dissolved-oxygen concentration) were made. Water samples then were collected for major ions, nutrients, trace metals, pesticides, wastewater compounds, polycyclic aromatic hydrocarbons (PAHs, fuel compounds), and *escherichia coli (E. coli)* and fecal coliform bacteria. As part of onsite training, Meskwaki Nation staff assisted in the collection of samples during both low- and high-flow conditions.

Table 1. Description of sampling site locations within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

[All water-quality and sediment samples were composite samples collected using the equal width increments (EWI) method (Edwards and Glysson, 1999). Shaded rows are comprehensive sampling sites and include periodic water and sediment sampling, and a biological and habitat assessment; mi2, square miles]

Site number (fig. 1)	Site name	Drainage area (mi^2)	Location and selection rationale
1	Iowa River near Montour, IA	1,840	Western boundary of the settlement provides baseline data for water entering the settlement. Water-quality and biological assessment site.
2	Onion Creek below Hwy 30 near Montour, IA	5.0	Tributary to the Iowa River that drains the northern settlement housing area, enters upstream from casino sewage lagoons. Water quality only.
3	Onion Creek near Montour, IA	5.3	Site is downstream from outflow of casino sewage lagoons near mouth of Onion Creek. Water-quality and biological assessment site.
4	Raven Creek near Montour, IA	26.3	Raven Creek at Highway 49 to determine if this creek is a possible source of contamination to the Iowa River. Water quality only.
5	Iowa River at Highway 49 near Tama, IA	1,882	This is a culturally significant site for the Meskwaki Nation and a site of recreation for tribal members. Water-quality and biological assessment site.
6	Bennett Creek near Tama, IA	7.0	Tributary to Iowa River entering on the south side of settlement. Site of restoration project for settlement as well. Water quality only.
7	Iowa River at Wetlands Reserve Property (WRP) near Tama, IA	1,896	Last piece of tribally owned land that the Iowa River passes through before it leaves the settlement. Water-quality and biological assessment site.
8	Cattail Creek near Tama, IA	1.8	Ephemeral discharge from tribal housing area. Storm-flow site, water quality only.

Biological surveys were made during the summer of 2007 on fish, benthic macroinvertebrate, and physical habitat. The sampling methods for the collection of fish, macroinvertebrates, and periphyton used during the survey period followed the protocol discussed in Moulton and others (2002). The surveying methods used for collection of physical habitat data are outlined in Fitzpatrick and others (1998). During fish sampling, the data were collected using direct-current electrofishing equipment mounted on either a backpack or boat depending on the stream depth (Moulton and others, 2002). The fish-sampling methods used by the USGS for both wadeable and large river sites are similar to the methods used by the Iowa Department of Natural Resources (IDNR; Iowa Department of Natural Resources, 2006), and the Ohio Environmental Protection Agency (Ohio EPA; Ohio Environmental Protection Agency, 1987). Fish-tissue samples were collected and processed according to Crawford and Luoma (1992) and shipped to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, for contaminant analysis. Fish collected during the sampling period were identified on site by a U.S. Fish and Wildlife Service (USFWS) biologist to the species level. All fish were returned to the water within the reach sampled other than the fish that were sent into the NWQL for tissue contamination analysis.

Macroinvertebrate data were collected using two methods, the first being rich-targeted habitat (RTH) and the second being qualitative multihabitat (QMH), which are described further in Moulton and others (2002). The RTH samples were hand samples of woody snags collected at five discrete locations throughout each sampling reach at what is considered the most abundant and best representative habitat available. The QMH samples are collected with a D-frame kick net at all available habitat types within the reach in a designated amount of time. When using the IDNR Index of Biotic Integrity (IBIs), the IDNR standard habitat sample is comparable to the USGS RTH sample and the IDNR multihabitat sample is comparable to the USGS QMH sample. Both the RTH and the QMH samples are used in the IBI calculations. Macroinvertebrate samples were composited and preserved in 10-percent buffered formalin and sent to the NWQL for identification and enumeration of organisms.

Periphyton composite samples were preserved with a final concentration of 5-percent buffered formalin and shipped to the Academy of Natural Sciences of Philadelphia, Pennsylvania (ANSP). Identification and enumeration of periphyton species were performed for each sample by the ANSP.

Physical habitat characteristics were collected according to USGS protocol discussed in Fitzpatrick and others (1998). The IBI that was used to assess the condition of the physical habitat on the Meskwaki Settlement was the Qualitative Habitat Evaluation Index (QHEI), which was developed by the Ohio EPA (Ohio Environmental Protection Agency,1987). The QHEI index metrics are included within the data that are collected when following the USGS protocol.

Suspended- and bed-sediment samples were collected at selected stream locations in conjunction with the physical habitat evaluation (fig. 1; table 1). Analytes included trace metals and pesticides. All aspects of sample collection were conducted in accordance with guidelines and procedures as described in Wilde and Radtke (1998).

Laboratory Methods

Water samples were analyzed at the USGS NWQL for major ions using atomic absorption spectrometry as described in Fishman and Friedman (1989); nutrient concentrations by ion-exchange chromatography and colorimetric methods (Fishman, 1993); and trace metal concentrations in water and bed sediment using methods described in Faires (1993) and Briggs and Meier (1999), respectively. Pesticide compounds in water, bed sediment, and wastewater were analyzed at NWQL using gas chromatographic/mass spectrometric methods described in Foreman and others (1995), Zaugg and others (1995), Furlong and others (1996), and Zaugg and others (2002). Fuel compounds (PAHs) in water were analyzed at the NWQL according to methods described in Connor and others (1998). Water samples were analyzed at the University of Iowa Hygienic Laboratory for *E. coli* and fecal coliform densities using standard methods 9213D and 9222D, respectively (University Hygienic Laboratory, 2004; table 2). Pesticide and trace metal concentrations in fish tissue were determined by the NWQL according to Leiker and others (1995), Hoffman (1996), and U.S. Environmental Protection Agency (USEPA;1996).

Laboratory methods included the analysis of water, bed sediment, and fish tissue for pesticides and metals. Accuracy and precision were determined by analyzing laboratory replicate samples and monitoring recovery of surrogates. Laboratory turnaround times varied by sample medium and procedure but were generally within 30 days of the sample login date. Laboratory standard operating procedures (SOPs) were consistent with USEPA requirements as specified in the method.

The USGS National Water Quality Laboratory collects quality-control data on a continuing basis to evaluate selected analytical methods to determine long-term method detection levels (LT–MDL's) and laboratory reporting levels (LRL's). These values are re-evaluated each year on the basis of the most recent quality-control data and, consequently, may change from year to year.

This reporting procedure limits the occurrence of false positive error. The chance of falsely reporting a concentration greater than the LT–MDL for a sample in which the analyte is not present is 1 percent or less. Application of the LRL limits the occurrence of false negative error. The chance of falsely reporting a non-detection for a sample in which the analyte is present at a concentration equal to or greater than the LRL is 1 percent or less.

Accordingly, concentrations are reported as <LRL for samples in which the analyte was either not detected or did not

Table 2. Laboratory analytical methods used in the analysis of samples from the Meskwaki Settlement, central Iowa, water years 2006–07.

[USGS, U.S. Geological Survey; USEPA, U.S. Environmental Protection Agency; UHL, University Hygienic Laboratory; CALFED, California Federal; SM, standard method]

Group	Medium	Schedule	Method reference
Major ions	Surface water	USGS 2750	Fishman and Friedman (1989); USEPA 200.7/300.0A
Nutrients	Surface water	USGS 2752	Fishman and Friedman (1993); USEPA 200.7/350.1/353.2/365.1/365.4
Trace metals	Surface water	USGS 2703	Faires (1993); USEPA 200.7/200.8/908.0/1631
	Bed sediment	USGS 2420	Briggs and Meier (1999); CALFED-D16
	Fish tissue	USGS 2200	Hoffman (1996); USEPA (1996); CALFED-D16
Organic compounds			
Pesticides	Surface water	USGS 2001	Zaugg and others (1995); USEPA 507/8141
	Bed sediment	USGS 2200	Foreman and others (1995), Furlong and others (1996); USEPA 8081A
	Fish tissue	USGS 2101	Leiker and others (1995); USEPA 8081A/8141
Wastewater contaminants	Surface water	USGS 1433	Zaugg and others (2002); USEPA 508/8081A
Fuel compounds	Surface water	USGS 1378	Connor and others (1998); USEPA 8260
Bacteria	Surface water	UHL	SM9213D, SM9221B/E, SM9222B/D, SM9223B

pass identification. Analytes that are detected at concentrations between the LT–MDL and LRL and that pass identification criteria are estimated. Estimated concentrations will be noted with a remark code of "E." These data should be used with the understanding that their uncertainty is greater than that of data reported without the "E" remark code (Childress and others, 1999).

Quality-Assurance and Quality-Control Methods

Quality assurance (QA) is defined as the procedures used to control the ummeasurable components of the sample collection, processing, and analytical methods (Pirkey and Glodt, 1998). QA elements include SOPs, sample and analysis-sequence protocols, instrument maintenance logs, and personnel training records. Quality-control (QC) data are collected to measure bias and variability of the sample and analytical methods and may include replicate, blank, spike, surrogate samples, and standard reference materials (Mueller and others, 1997). In this study, surface-water samples were collected in accordance with "Methods for Collection and Processing of Surface-Water and Bed-Material Samples for Physical and Chemical Analyses" (Ward and Harr, 1990). Analyses of water-quality analytes were conducted using QA/QC practices of the NWQL, as described in Farrar (1997). Analytical results of quality-control samples are given in table 3 and appendixes 1 through 8 (on CD-ROM in back of this report). All QA/QC procedures were conducted in accordance with the USEPA-approved "Quality Assurance Project Plan" for the study described in this report (on file with the USGS in Iowa City, Iowa).

Sampling Quality Control

Field and Trip Blank Samples

A field blank sample is used to demonstrate that sampling equipment has been cleaned adequately to remove potential contamination introduced by samples collected at previous sites, that sample collection and processing have not resulted in contamination, and that sample handling and transport have not resulted in contamination. Blank samples were prepared by passing laboratory certified deionized water through all sampling equipment to verify cleanliness of the equipment. Nutrient, pesticide, and wastewater contaminant concentrations were analyzed in 11 field blank samples and compared to subsequent environmental samples. A trip blank sample, used to identify contamination that might occur during sample transport and analysis, was collected at sampling site 2 to test for potential volatile organic contamination.

Field Replicate Samples

A field replicate sample is defined as a second sample (or measurement) from the same location, collected in immediate succession, using identical techniques. Field replicate samples commonly are drawn from environmental samples and are used to estimate the precision of sample processing and analysis. Such samples are prepared by partitioning a larger environmental sample from one container into subsamples; samples are split in an enclosed environment using equipment and methods that preclude sample contamination. Replicate samples are sealed, handled, stored, shipped, and analyzed in the same manner as the environmental samples. Precision of replicate results is calculated by the RPD (relative percentage difference) as defined by the difference (range) of each replicate sample set, divided by the average value (mean) of the set times 100. For replicate results, S_1 and S_2, the RPD is calculated from the following equation:

$$RPD = \left\{(S_1 - S_2)/\left\langle(S_1+S_2)/2\right\rangle\right\} * 100,$$

where

S_1 is the concentration from the environmental sample; and

S_2 is the concentration from the replicate sample.

Field replicates were collected at a frequency of 10 percent or greater. Analyte concentrations from a total of 21 nutrient, pesticide, and wastewater replicate samples were compared to concurrent environmental sample concentrations. Table 3 summarizes QA data for selected field blank and replicate sample constituent concentrations. Field blank concentrations were equal to or less than the minimum reporting limit (MRL) for all constituents, indicating little, if any, cross contamination. The maximum RPD for the replicate samples ranged from 1.9 to about 94 percent; the median RPD ranged from 0 to 4.2 percent. When comparing the small concentrations and slight differences between some replicate samples, the RPD can be relatively large, which is generally the case with the majority of replicate samples with a greater than 10 percent RPD (Becher and others, 2001).

Laboratory Quality Control

Spike and Blank Samples and Surrogate Compounds

Laboratory reagent spike (LRS) samples were used to yield information about method performance for organic analysis. An LRS is a sample solution to which known concentrations of the compounds of interest are added. The results are compared to acceptable criteria for each method to assess potential bias of environmental sample results (Pirkey and Glodt, 1998). In addition, laboratory reagent blank (LRB) samples were processed and analyzed in the same fashion as the environmental samples. The LRB matrix has negligible concentrations of compounds of interest and, as such, is used to monitor for laboratory processing contamination. If a compound of interest is detected in the blank sample, then the concentration of that same compound in the environmental sample can be qualified. A surrogate compound is a compound that is expected to perform similarly to the compounds being analyzed in a laboratory method (Pirkey and Glodt, 1998).

Table 3. Summary of analytical results for field blank and replicate samples for selected analytes, Meskwaki Settlement, central Iowa, water years 2006–07.

[MRL, minimum reporting limit; mg/L, milligrams per liter; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; RPD, relative percentage difference; <, less than; CIAT, 2-dichloro-4-isopropyl-amine-6-amino-S-triazine]

Analyte (unit of measurement)	MRL	Number of blank samples	Maximum concentration	Median concentration	Number of blank samples with concentrations greater than MRL	Number of replicate samples	Maximum RPD	Median RPD	Number of replicate samples with greater than 10 percent RPD
Ammonia (mg/L as N)	0.02	5	<0.020	0.006	0	10	93.9	1.1	2
Nitrite (mg/L as N)	.002	4	<.002	<.002	0	9	22.2	0	1
Nitrite plus nitrate (mg/L as N)	.060	5	<.060	<.060	0	10	4.6	.8	0
Orthophosphate (mg/L as P)	.006	4	<.01	<.006	0	9	1.9	.9	0
Acetochlor (µg/L)	. 5	1	<.006	<.006	0	7	11.8	4.2	1
Atrazine (µg/L)	. 5	1	<.007	<.007	0	7	2.2	1.6	0
CIAT (µg/L)	. 5	1	<.014	<.014	0	7	20.9	[1]1.8	2
Metolachlor (µg/L)	. 5	1	<.010	<.010	0	7	4.3	1.7	0

[1]Based on estimated values.

Surrogate compounds were added to all environmental and QC samples to monitor compound recovery and potential environmental effects. In this study, spike and blank samples and surrogate compounds were used in the analysis of all 93 environmental and QC samples.

Water-Quality Assessment

Surface-Water Setting

The Meskwaki Settlement is drained by the Iowa River and its tributaries (fig. 1). The Iowa River enters the settlement along the southwestern boundary of the settlement near the town of Montour and forms much of the southern boundary before leaving along the settlement's southeast boundary near Tama. The main tributaries are Onion and Cattail Creeks from the north and Raven and Bennett Creeks from the south. The headwaters of Onion Creek drain residential lands in the northern part of the settlement before flowing through areas used for limited commercial and agrarian purposes. Cattail Creek, which drains the main tribal residential and headquarters area along the eastern boundary, flows only during periods of intense or prolonged rainfall. Raven and Bennett Creeks drain extensive agricultural lands to the south before passing through sparse residential areas near the banks of the Iowa River. All tributaries enter a broad riparian buffer that borders the Iowa River in the settlement.

Streamflow Data

Miscellaneous streamflow data were collected as conditions allowed at all water-quality sampling locations during times of sample collection (table 4). Measurements were made using a handheld acoustic Doppler velocimeter on tributaries and a trimaran acoustic data-collection platform on the Iowa River. Only one streamflow discharge measurement, at Iowa River near Montour (site 1), was not performed due to unsafe river ice in December 2006. Discharge for Cattail Creek (site 8) was estimated during two runoff periods in 2006. The nearest USGS-maintained gaging station (05451500) is located on the Iowa River in Marshalltown about 15 mi upstream from the settlement. Another Iowa River gage, operated by the U.S. Army Corps of Engineers (USACOE), is located along Highway 63 just south of Tama, about 1 mi east of the settlement (fig. 1). Both of these gaging stations are owned by the USACOE, and daily mean streamflow data are available on the USACOE Web site at *http://www2.mvr.usace.army.mil/nic2/default.cfm*.

Mean discharge for the Iowa River ranged from 905 cubic feet per second (ft^3/s) at site 1 near Montour to 1,034 ft^3/s at site 7 adjacent to the WRP (table 4). The minimum discharge recorded for the Iowa River was 354 ft^3/s at site 1 and the maximum discharge was 1,890 ft^3/s at site 7. No discharge measurements were performed during storm flow but on the basis of data recorded at the Marshalltown (05451500) and Marengo (05453100) gaging stations (U.S. Geological Survey, 2007, 2008), discharge along the Iowa River in the settlement exceeded 6,000 ft^3/s on five occasions during 2006–07 (fig. 2) and a maximum discharge of about 14,000 ft^3/s probably was reached in late April 2007.

Measurements on Onion Creek ranged from less than 0.01 ft^3/s during July 2006 at site 2 to a maximum of 1.80 ft^3/s during April 2006 at site 3. Mean discharge ranged from about 0.5 ft^3/s at site 2 to about 0.7 ft^3/s at site 3. Discharge from sites 4 and 6 ranged from less than 1 ft^3/s during August and September 2006 for Bennett Creek to 26.8 ft^3/s during December 2006 for Raven Creek. Mean flow in Bennett Creek was about 3.5 ft^3/s, whereas mean flow in Raven Creek was about 15.4 ft^3/s.

Table 4. Statistical summary of surface-water discharge at Iowa River and tributary sampling sites within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

[mi^2, square miles; ft^3/s, cubic feet per second; --, not available]

Site number (fig. 1)	Site name	Drainage area (mi^2)	Minimum discharge (ft^3/s)	Maximum discharge (ft^3/s)	Mean (ft^3/s)	Number of measurements or estimates	Type of measurements
1	Iowa River near Montour, Iowa	1,840	354	1,554	905	6	Periodic
2	Onion Creek below Highway 30 near Montour, Iowa	5.0	.004	1.72	.49	6	Periodic
3	Onion Creek near Montour, Iowa	5.3	.08	1.80	.66	7	Periodic
4	Raven Creek near Montour, Iowa	26.3	6.09	26.8	15.37	6	Periodic
5	Iowa River at Highway 49 near Tama, Iowa	1,882	371	1,830	1,031.9	7	Periodic
6	Bennett Creek near Tama, Iowa	7.0	.75	7.86	3.49	6	Periodic
7	Iowa River at WRP near Tama, Iowa	1,896	381	1,890	1,034.3	7	Periodic
8	Cattail Creek near Tama, Iowa	1.8	--	[1]3	--	2	Stormflow only

[1] Estimated

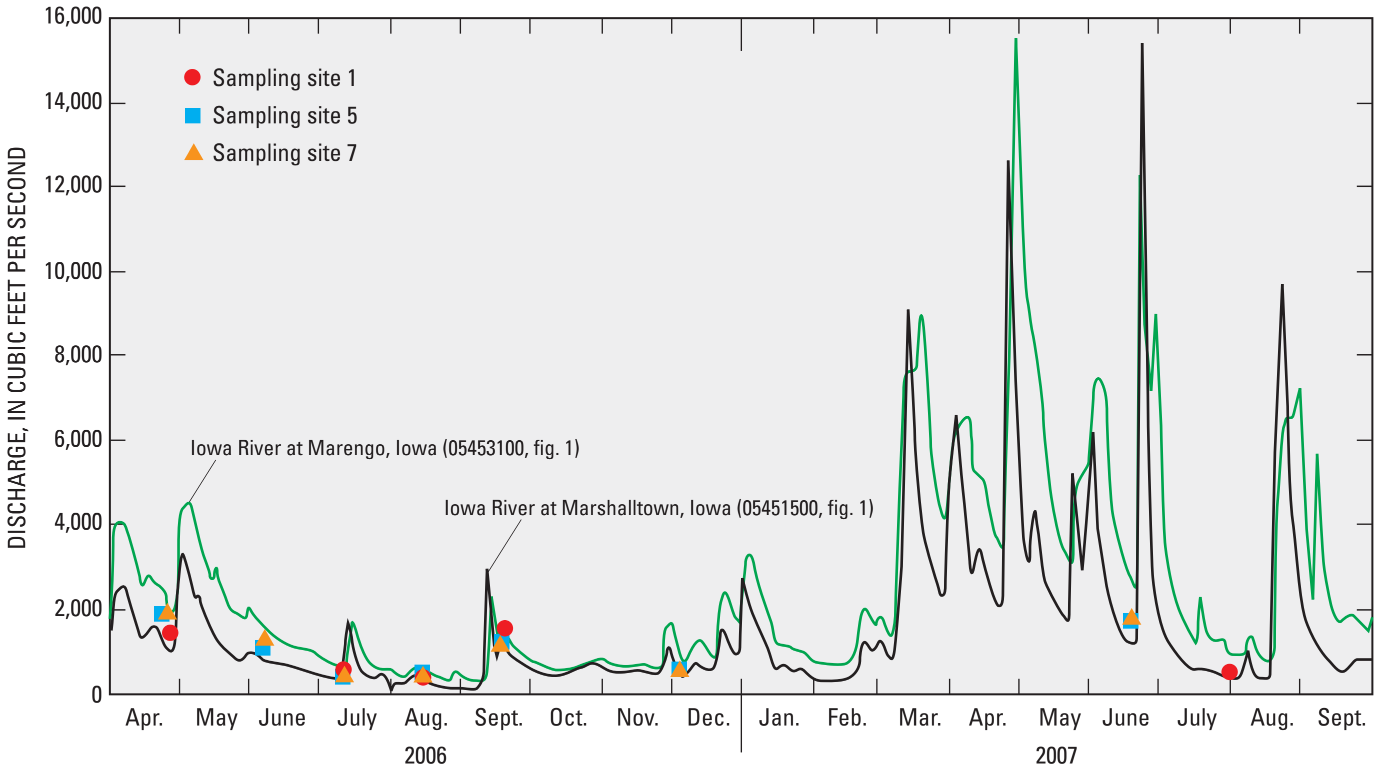

Figure 2. Comparison of discharge measurements at streamflow gages upstream and downstream from sampling sites 1, 5, and 7 on the Iowa River at the Meskwaki Settlement, April 2006–September 2007.

Water-Quality Data

Water-quality samples were collected at eight locations throughout the settlement (fig. 1). Samples were collected at approximately 5-week intervals between April and September 2006, followed by winter samples collected during late November and early December. Storm-flow samples were collected from all four tributaries by tribal technicians during August 2006 and again during November 2006 at Cattail Creek. In 2007, samples were collected in conjunction with habitat assessments conducted during June and July. Water-quality data for all sites are given in appendixes 1 through 8.

Water-quality data are divided into seven categories of analytes and include physical properties, major ions, nutrients, trace metals, organic compounds, bacteria, and total suspended solids. Major constituents within each category are discussed as they relate to the quality of water defining baseline conditions. Where applicable, constituents are compared to the State of Iowa water-quality criteria for primary and secondary contact (Iowa Administrative Code, 2002). Changes in water chemistry and sediment concentration are explored as a function of water movement within the stream network of the settlement.

The surface water in the Iowa River within and contiguous to the Meskwaki Settlement is classified according to the State of Iowa (Iowa Administrative Code, 2002) as Class A for primary contact recreation; Class B (WW) potential for wildlife, fish, aquatic and semi-aquatic life; and as HQR, or "high quality resource," having substantial recreational or ecological significance. A set of criteria were established by the State of Iowa to protect these uses by assuring that water-quality levels are maintained or improved to meet the designated-use criterion. The criteria include levels of protection necessary to prevent chronic and acute toxicity to aquatic life and harmful effects to human health through consumption of fish (Iowa Administrative Code, 2002). Accordingly, chronic levels can be exceeded only in "mixing zones" (mathematically defined areas where wastewater or agricultural discharge mixes with stream water) or outside mixing zones for a brief time. Acute levels can be exceeded only at the "point of initial dilution" where the point source enters the stream (Iowa Administrative Code, 2002). A mathematical model for delineating dimensions of a mixing zone and zone of initial dilution can be found in "Supporting Document for Iowa Water Quality Management Plans" (Iowa Department of Natural Resources, 2000). A complete list of criteria for chemical constituents by use designations can be accessed on the Web at *http://www.iowadnr.com/water/standards/files/chapter61.pdf*.

The physical, chemical, and biological compositions of surface water in the Iowa River and its tributaries are in a constant flux, both spatially and temporally, due to the dynamic relation between climate, streamflow, stream morphology, and land-use practices. Water quality, therefore, typically falls within a range of values for a specific body of water under a specific set of conditions. It is this range that defines the baseline conditions as discussed in the following sections.

Physical Properties

Specific conductance, pH, water temperature, and dissolved oxygen concentrations did not indicate adverse water-quality conditions. Specific conductance is a measure of the ability of water to conduct an electrical current and varies as a function of the concentration of dissolved solids in the sample—the larger the concentration of dissolved solids, the larger the specific conductance. Smaller specific conductance values generally followed rainfall. Specific conductance for the Iowa River ranged from 391 to 782 microsiemens per centimeter (µS/cm) at 25 degrees Celsius (ºC) with a median value of 654 µS/cm, and from 289 to 703 µS/cm for the tributaries, with a median value of 548 µS/cm. In general, values were similar for all sites along the Iowa River on a specific day. Both the minimum and maximum values for the tributaries were recorded at Site 3 below the sewage lagoons. Water temperatures for all sites were typical for the times of the year that the sites were sampled. Temperatures ranged from a low of 0 ºC in December to a high of 28 ºC in July. The pH ranged from 7.7 to 8.9 standard units in the Iowa River and 7.2 to 8.4 in the tributaries. The USEPA secondary drinking-water regulation (acceptable range) for pH is 6.5 to 8.5 (U.S. Environmental Protection Agency, 2007b). Biological and chemical processes are directly affected by the availability of dissolved oxygen in the water. Dissolved oxygen concentrations ranged from 6.8 to 22.7 milligrams per liter (mg/L) for the Iowa River, and 2.9 to 14.2 mg/L in the tributaries. The lowest value, 2.9 mg/L, was measured in Onion Creek due presumably to the effect of ground-water flow to the tributary or effluent from lagoons. The unusually high value of 22.7 mg/L, recorded on the Iowa River near Montour in July, 2007 was attributed to an observed algae bloom.

Major Ions

Water commonly is described by its major dissolved components, those chemical constituents that make up the bulk of inorganic dissolved solids in a sample of water. According to Hem (1985), they are defined as constituents generally present in concentrations exceeding 1.0 mg/L, whereby the predominant cation and anion concentrations, in milliequivalents per liter, define the water type. The dissolved cations that comprise a major part of the samples include calcium, magnesium, sodium, and potassium. Dissolved anions include sulfate, chloride, nitrate, and carbonate. Nitrate concentrations are discussed in more detail in the section on ”Nutrients.”

Water Type

A trilinear diagram (Piper, 1944) illustrates the relative percentages of major cations and anions for all the samples collected during the study (fig. 3). The major-ion composition for each site was selected on the basis of the respective median concentration of dissolved solids. The diagram indicates that the majority of surface water sampled within the settlement was predominately a calcium bicarbonate type, which is the most common type of natural water found in Iowa. Major-ion data for the Iowa River, including Raven and Bennett Creeks from the south, plotted in a tight group. General clustering of data indicates sources of water that have potentially common processes affecting the water quality. Common processes would include surface-water runoff from similar land-surface areas with similar land-use practices and ground-water inflow containing natural or human inputs that might significantly alter the major-ion composition. Sites 2 and 3 on Onion Creek and site 8 on Cattail Creek, which plotted outside the group, represent urban effects in contrast with the Iowa River and Raven and Bennett Creeks, which largely represent agricultural effects.

Dissolved Solids

Dissolved solids, also referred to as total dissolved solids (TDS) or total solids (Hem, 1985), is the residue on evaporation at a given temperature, in this case 105 ºC, whereby the liquid is evaporated off and the remaining residue is weighed. Dissolved solids in surface water from the Meskwaki Settlement ranged from 182 to 492 mg/L (indicated as residue on evaporation at 180 degrees Celsius in the appendixes). As with specific conductance, smaller values in surface water generally followed rainfall.

The State of Iowa is currently (2009) revising its interim 2004 dissolved solids site-specific criteria in favor of a numerical chloride and sulfate criteria similar to that proposed by the Illinois Environmental Protection Agency (IEPA) for protection of aquatic life (Iowa Department of Natural Resources, 2007). Accordingly, research by the IEPA has shown that although other more toxic cations could occur in industrial waste, the relative concentrations of individual constituents, chloride and sulfate in this case, are more effective in determining toxicity than dissolved solids (Iowa Department of Natural Resources, 2007). The current interim dissolved solids toxicity level is 1,000 mg/L, above which acute toxicity tests would be required to show that facility discharge will not result in toxicity to aquatic life.

Nutrients and Dissolved Organic Carbon

Nutrients, primarily nitrogen and phosphorus (as orthophosphate), are monitored in surface water because substantial amounts can result in excessive plant growth, such as algae, and reduction in dissolved oxygen. Nitrogen concentrations, in the bio-available form of nitrate, in excess of 3 mg/L generally are attributed to human activities (Madison and Brunett, 1984), and large concentrations, primarily of phosphorus, have been linked to hypoxia in the Gulf of Mexico (Alexander and others, 2007).

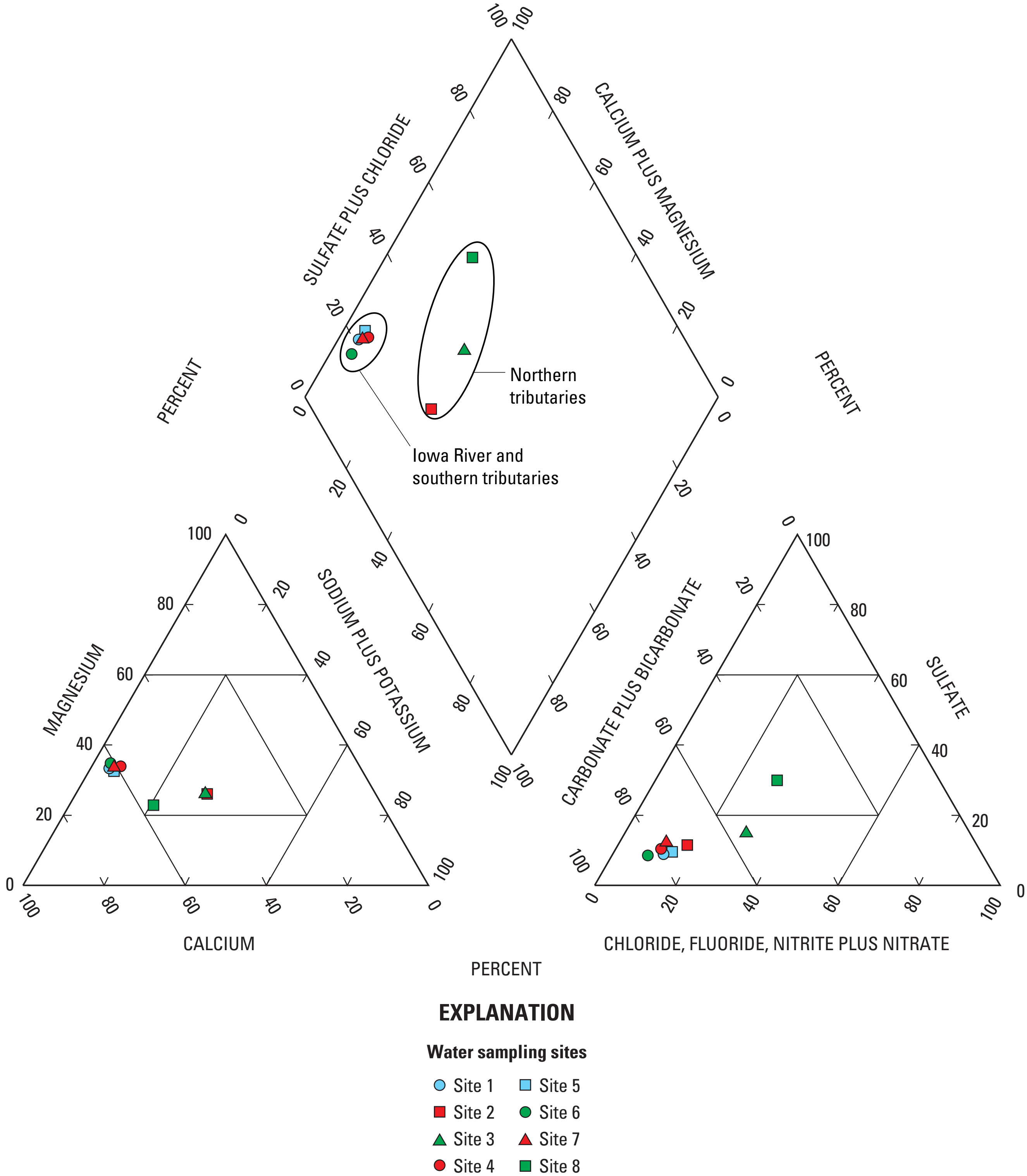

Figure 3. Relative median compositions of surface water within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

Nitrate (nitrate plus nitrite as nitrogen) concentrations, which constituted about 95 percent of the median total dissolved nitrogen, ranged from 1.85 to 14.2 mg/L in the Iowa River (sites 1, 5, and 7) with a median concentration of 11.0 mg/L; 0.19 to 6.72 mg/L in Onion and Cattail Creeks (sites 2, 3, and 8) with a median concentration of 1.10 mg/L; and 2.56 to 13.4 mg/L in Raven and Bennett Creeks (sites 4 and 6) with a median concentration of 7.50 mg/L (table 5; fig. 4). About 62 percent of the nitrate samples collected from the Iowa River exceeded the USEPA MCL of 10 mg/L for drinking water as compared to 0 percent from Onion and Cattail Creeks and 43 percent from Raven and Bennett Creeks. Phosphorus in the form of orthophosphate ranged from 0.02 to 5.74 mg/L, with a median concentration of 0.13 mg/L at all sites. The largest concentrations were in samples collected from Onion Creek downstream from the sewage lagoons (site 3) which had a median orthophosphate concentration of 3.09 mg/L.

Nutrient concentrations from the Iowa River (sites 1, 5, and 7) were compared with concentrations from the Wapsipinicon River near Tripoli, Iowa (table 6). The Wapsipinicon River near Tripoli (index map, fig. 1), a reference site for the USGS National Water-Quality Assessment (NAWQA) Program's Eastern Iowa Watershed Assessment, was selected because of its similar land use and large percentage of stream-corridor wetlands as compared to other central Iowa drainage basins (Becher and others, 2001). Although maximum nitrate concentrations in the Iowa River were less than that for the Wapsipinicon River, the median concentrations indicate that, for the Iowa River, concentrations in excess of the MCL were more prolonged. The difference in ranges in total nitrate concentrations between the two rivers likely is attributed to the temporal extent of the respective datasets. Phosphorus (orthophosphate) concentrations were consistently larger in the Iowa River at all sites but for the single outlier of 0.29 mg/L in the Wapsipinicon River.

Dissolved organic carbon (DOC) concentrations in natural water ranges from about 2 to 15 mg/L, with a median of about 5 mg/L (Degens, 1982). DOC in stream samples collected from the Meskwaki Settlement ranged from about 2.5 to 56 mg/L (appendixes 1–8), with a median concentration of about 8.0 mg/L, which is consistent with concentrations of 5 to 60 mg/L in water draining swamps and wetlands (Thurman, 1985; Becher and others, 2001). The largest concentrations

Table 5. Statistical summary of nutrient concentrations in water samples from the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07, and comparison to water-quality guidelines.

[Location of sampling sites shown in figure 1; mg/L, milligrams per liter; MCL, Maximum Contaminant Level (U.S. Environmental Protection Agency's primary drinking water regulations, 2007b); Min, minimum; Max, maximum; N, nitrogen; P, phosphorus; --, not applicable]

Nutrient	Minimum reporting level (mg/L)	Concentration			MCL (mg/L)	Number of samples exceeding MCL/number of samples
		Min	Max	Median		
Iowa River (sites 1, 5, and 7)						
Ammonia, as N	0.05	0.002	0.067	0.008	--	--
Nitrate plus nitrite, as N	.1	1.85	14.2	11.0	10	13/21
Nitrite, as N	.02	.016	1.017	.021	1	1/20
Nitrogen, as N, total	.06	2.32	15.3	12.5	--	--
Orthophosphate, as P	.05	.059	.285	.13	--	--
Northern tributaries (sites 2, 3, and 8)						
Ammonia, as N	.05	.009	14.28	.036	--	--
Nitrate plus nitrite, as N	.1	.19	6.72	1.10	10	0/16
Nitrite, as N	.02	.003	.145	.022	1	0/15
Nitrogen, as N, total	.06	.52	16.2	2.0	--	--
Orthophosphate, as P	.05	.022	5.74	.401	--	--
Southern tributaries (sites 4 and 6)						
Ammonia, as N	.05	.003	.088	.026	--	--
Nitrate plus nitrite, as N	.1	2.56	13.4	7.50	10	6/14
Nitrite, as N	.02	.008	.07	.041	1	0/14
Nitrogen, as N, total	.06	4.3	12.6	7.50	--	--
Orthophosphate, as P	.05	.021	.18	.065	--	--

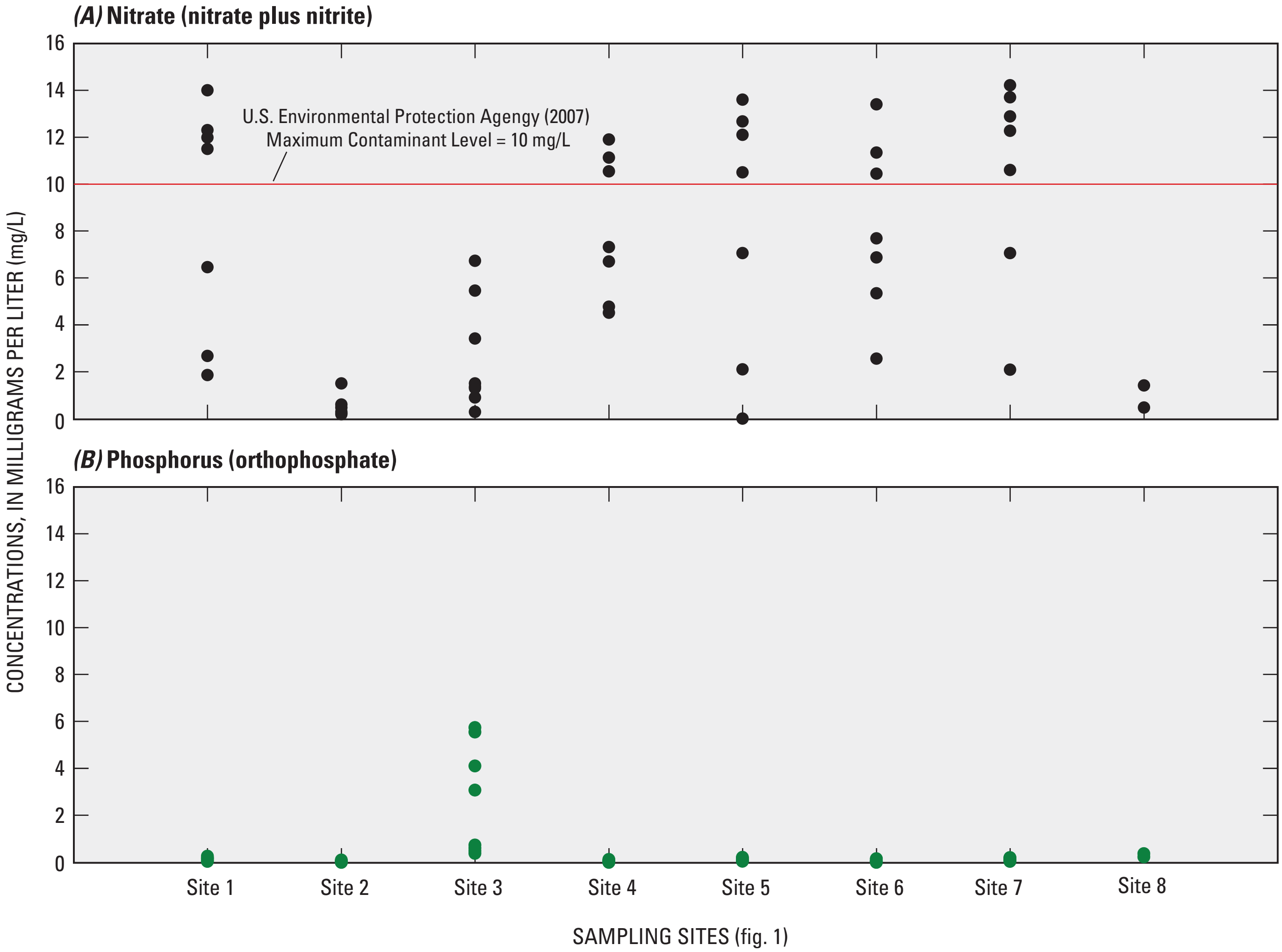

Figure 4. Concentrations of nitrate and phosphorus in surface water within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

occurred in Raven Creek near Montour (site 4), which had a median concentration of 17.6 mg/L.

Trace Metals

Improvements in analytical equipment and methodologies are continually changing the ability to detect the minutest presence of trace metals in natural water. The term "trace" is used most often to refer to substances that commonly occur at concentrations less than 1 mg/L or 1,000 micrograms per liter (µg/L) (Hem, 1985). Technological advances in mass spectrometry have enhanced detection levels of 17 dissolved trace metals in the range from 1 to 0.001 µg/L (Faires, 1993; Fishman and Friedman, 1989). In addition, cold-vapor atomic fluorescence spectrometry was used to test for the presence of dissolved mercury (Garbarino and Damrau, 2001).

Nine of the 18 trace metals analyzed in stream-water samples from the Meskwaki Settlement are on the USEPA's list of metals assigned maximum contaminant levels (MCLs) for primary drinking water (U.S. Environmental Protection Agency, 2007b; table 7). They are antimony, arsenic, barium, beryllium, cadmium, chromium, mercury, selenium, and uranium. However, none of the samples analyzed had concentrations exceeding the respective MCLs or the State of Iowa criteria for chronic or acute toxicity (Iowa Administrative Code, 2002). Of the five analytes for which secondary MCLs (SMCL) exist (aluminum, copper, manganese, silver, and zinc), only manganese was found to exceed its respective SMCL of 50 mg/L (U.S. Environmental Protection Agency, 2007b). Manganese concentrations in the Iowa River ranged from 0.7 To 27 mg/L, with a median concentration of 1.8 mg/L, whereas concentrations in water from the tributaries ranged from 3.9 to 1,060 mg/L, with a median value of 56.3 mg/L. Seventeen of the 30 samples collected from the tributaries exceeded the SMCL, with about 65 percent of the exceedances coming from the Onion Creek sites. Large concentrations of soluble manganese may indicate anthropogenic input to the surface-water system (Hem, 1985), but it is unknown what the actual source(s) may be.

Table 6. Statistical summary of nutrient concentrations in water samples from the Iowa River at the Meskwaki Settlement, central Iowa, water years 2006–07, and the Wapsipinicon River near Tripoli, Iowa, water years 1996–2004.

[Location of sampling sites shown in figure 1; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; WRP, Wetlands Reserve Property; <, less than; --, not applicable]

Constituent	Number of samples	Concentration, in milligrams per liter				
		Minimum	25th percentile	Median	75th percentile	Maximum
Iowa River near Montour, Iowa (site 1)						
Ammonia (as N), dissolved	7	<0.010	<0.040	0.011	0.04	0.066
Nitrate plus nitrite (as N), dissolved	7	1.85	2.67	11.5	12.3	14
Nitrite (as N), dissolved	6	.016	.017	.024	.034	.035
Nitrogen (as N), total	6	2.36	5.74	12.3	13.38	15.1
Orthophosphate (as P), dissolved	6	.062	.082	.153	.198	.232
Iowa River at Highway 49 near Tama, Iowa (site 5)						
Ammonia (as N), dissolved	7	<.010	<.020	.007	.017	.068
Nitrate plus nitrite (as N), dissolved	7	2.11	7.05	12.1	13.6	13.7
Nitrite (as N), dissolved	7	.016	.018	.018	.031	.04
Nitrogen (as N), total	7	2.6	7.49	12.6	14.5	15.3
Orthophosphate (as P), dissolved	7	.071	.097	.126	.214	.241
Iowa River at WRP near Tama, Iowa (site 7)						
Ammonia (as N), dissolved	7	<.010	<.020	.007	.011	.065
Nitrate plus nitrite (as N), dissolved	7	2.09	7.05	12.3	13.7	14.2
Nitrite (as N), dissolved	7	.017	.018	.021	.03	.037
Nitrogen (as N), total	7	2.32	7.48	12.6	14.5	15.1
Orthophosphate (as P), dissolved	7	.059	.081	.14	.216	.23
Wapsipinicon River near Tripoli, Iowa (05420680)						
Ammonia (as N), dissolved	76	--	[1].007	[1].22	[1].08	.88
Nitrate plus nitrite (as N), dissolved	76	.11	2.62	4.94	7.98	15
Nitrite (as N), dissolved	76	.006	.018	.035	.057	.146
Nitrogen (as N), total	9	.88	1.96	4	9.61	[2]13.5
Orthophosphate (as P), dissolved	75	--	.01	.022	.05	.29

[1] Value is estimated by using a log-probability regression to estimate the values of data below the detection limit.

[2] Anomalous value is attributed to the small sample set for total nitrogen as compared to the other nitrogen species.

Organic Compounds

In Iowa, as elsewhere in the Midwest, organic compounds such as pesticides are largely associated with use in the control of weeds and insects for agriculture. Compounds associated with non-agricultural uses commonly are found in pharmaceuticals, cosmetics, road and building materials, and automotive products, to name but a few. Whether entering the environment through direct application to crops, from landfills, sewage waste, fuel spills, or negligence, many of these compounds eventually end up contaminating rivers and streams generally as a result of surface runoff following intense or prolonged rainfall. To understand the extent to which these contaminants are present in waterways within the Meskwaki Settlement, surface-water samples were analyzed for the presence of pesticides, wastewater compounds, and fuel compounds.

Pesticides

Laboratory analyses were conducted to determine the presence of pesticide contaminants in water samples collected from all eight sampling sites in the settlement (fig. 1). Samples were analyzed for 54 pesticide compounds that included herbicides and insecticides. Twelve of the 54 compounds had detectable concentrations among the 50 samples analyzed (table 8). Of those, 163 quantifiable detections were recorded in addition to 76 unquantifiable (estimated) detections. Atrazine had quantifiable detections in all 50 samples, metolachlor

Table 7. Statistical summary of trace metal concentrations in water samples from the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07, and comparison to water-quality guidelines.

[Location of sampling sites shown in figure 1; µg/L, micrograms per liter; MCL, Maximum Contaminant Level (U.S. Environmental Protection Agency's primary drinking-water regulations, 2007b); SMCL, secondary Maximum Contaminant Level (U.S. Environmental Protection Agency's secondary drinking-water regulations, 2007b); E, estimated value; <, less than; --, no data]

Trace metal	Minimum reporting level (mg/L)	Concentration (µg/L)			MCL (µg/L)	SMCL (µg/L)	State of Iowa criteria[1] (µg/L)			Number of samples
		Minimum	Maximum	Median			Chronic aquatic toxicity	Acute aquatic toxicity	Harmful to humans	
Iowa River (sites 1, 5, and 7)										
Aluminum	1.6	E1.4	17.2	3.0	--	50	388	4,539	--	21
Antimony	.2	E.2	.3	.2	6	--		--		21
Arsenic	.12	1.4	2.6	2.1	10	--	200	360	50	21
Barium	.2	62.8	132	115	2,000	--		--		21
Beryllium	.06	<.06	<.06	<.06	4	--		--		21
Cadmium	.04	E.02	.05	<.04	5	--	15	75	168	21
Chromium	.04	.06	.4	.1	100	--	40	60	3,365	21
Cobalt	.04	.07	.39	.19	--	--		--		21
Copper	.04	.61	12.8	1.5	--	1,000	35	60	1,000	21
Lead	.08	E.04	1.24	.1	--	--	30	200	--	21
Manganese	.2	.7	27	1.8	--	50		--		21
Mercury	.01	<.01	<.01	<.01	2	--	2.1	4	.15	3
Molybdenum	.4	1.4	2.9	2	--	--		--		21
Nickel	.06	.73	5.21	1.58	--	--	650	5,800	4,584	21
Selenium	.08	1	2.3	1.8	50	--	125	175	--	21
Silver	.2	<.2	<.2	<.2	--	100	--	100	--	21
Uranium	.04	1.72	4.81	3.75	30	--		--		21
Zinc	.06	E.4	52.1	1.8	--	5,000	450	500	5,000	21
Northern tributaries (sites 2, 3 and 8)										
Aluminum	1.6	2	23.8	5.4	--	50	388	4,539	--	16
Antimony	.2	E.1	.9	.2	6	--		--		16
Arsenic	.12	1	4	1.8	10	--	200	360	50	16
Barium	.2	65.4	229	126	2,000	--		--		16
Beryllium	.06	<.06	<.06	<.06	4	--		--		16
Cadmium	.04	E.02	.14	<.04	5	--	15	75	168	16
Chromium	.04	E.07	3.2	.1	100	--	40	60	3,365	16
Cobalt	.04	.22	.87	.45	--	--		--		16
Copper	.04	.64	6.34	1.84	--	1,000	35	60	1,000	16
Lead	.08	E.04	.27	.1	--	--	30	200	--	16
Manganese	.2	3.9	1,060	105	--	50		--		16
Mercury	.01	--	--	--	2	--	2.1	4	.15	0
Molybdenum	.4	1.2	56.3	2.8	--	--		--		16
Nickel	.06	1.55	5.75	2.76	--	--	650	5,800	4,584	16
Selenium	.08	.2	3.4	.4	50	--	125	175	--	16
Silver	.2	<.2	<.2	<.2	--	100	--	100	--	16
Uranium	.04	.33	2.21	1.74	30	--		--		16
Zinc	.06	E.5	38.5	4.3	--	5,000	450	500	5,000	16
Southern tributaries (sites 4 and 6)										
Aluminum	1.6	1.7	16	3.6	--	50	388	4,539	--	14
Antimony	.2	E.1	.5	.2	6	--		--		14
Arsenic	.12	.6	2.5	1.1	10	--	200	360	50	14
Barium	.2	109	156	144	2,000	--	--			14
Beryllium	.06	<.06	<.06	<.06	4	--	--			14
Cadmium	.04	E.02	.1	E.02	5	--	15	75	168	14
Chromium	.04	.09	1	.2	100	--	40	60	3,365	14
Cobalt	.04	.1	.4	.25	--	--		--		14
Copper	.04	E.34	7.79	1.84	--	1,000	35	60	1,000	14
Lead	.08	E.05	.75	<.08	--	--	30	200	--	14
Manganese	.2	17.5	65.5	32.2	--	50		--		14
Mercury	.01	--	--	--	2	--	2.1	4	.15	0
Molybdenum	.4	.6	3.1	1	--	--	--			14
Nickel	.06	.83	5.58	2.08	--	--	650	5,800	4,584	14
Selenium	.08	1	2.7	1.8	50	--	125	175	--	14
Silver	.2	<.2	<.2	<.2	--	100	100	--	--	14
Uranium	.04	.76	1.72	1.33	30	--		--		14
Zinc	.06	E.3	14.1	.9	--	5,000	450	500	5,000	14

[1] State of Iowa water-quality criteria (Iowa Administrative Code, 2002).

Table 8. Analytical results for selected pesticides in water samples from the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07, and comparison to water-quality guidelines.

[µg/L, micrograms per liter; MCL, Maximum Contaminant Level (U.S. Environmental Protection Agency's primary drinking-water regulations, 2007b; HAL, health advisory level, (U.S. Environmental protection Agency, 1996); E, estimated; <, less than; --, not applicable]

Pesticide	Minimum reporting level (µg/L)	Range in concentration (µg/L)	Median (µg/L)	MCL (µg/L)	HAL (µg/L)	State of Iowa criteria (µg/L)			Number of detections/ number of samples
						Chronic aquatic toxicity	Acute aquatic toxicity	Harm-ful to humans	
Acetochlor	0.006	E0.003 to 0.091	0.040	--	--	--	--	--	35/50
Alachlor	.005	<.005 to .01	<.005	2	--	--	--	--	4/50
Atrazine	.005	.028 to 1.10	.107	3	--	--	--	--	50/50
Carbaryl	.041	E.003 to E.035	E.017	--	--	--	--	--	5/50
Chlorpyrifos	.005	E.004 to .010	<.005	--	--	0.041	0.083	--	5/50
CIAT (2-chloro-4-isopropyly-amino-6-amino-s-triazine)	.050	E.013 to E.127	E.049	--	--	--	--	--	50/50
Cyanazine	.005	<.018 to .067	<.018	--	1	--	--	--	1/50
Dacthal	.003	E.001 to .005	<.003	--	--	--	--	--	8/50
Malathion	.027	<.016 to .318	<.027	--	--	--	--	--	2/50
Metolachlor	.005	E.008 to 1.45	.045	--	70	--	--	--	48/50
Prometon	.010	E.004 to .064	<.010	--	100	--	--	--	14/50
Simazine	.018	E.003 to .609	<.005	4	--	--	--	--	17/50

in 48 of 50, acetochlor in 30 of 50, simazine in 14 of 50, and alachlor in 4 of 50 samples. Atrazine, simazine, and alachlor are on the USEPA's list of contaminants for primary drinking water (U.S. Environmental Protection Agency, 2007b), but none were present in concentrations that exceeded their respective MCL (table 8; fig. 5). Chloripyrifos ranged in concentration from less than 0.005 to 0.010 mg/L and is the only pesticide analyzed that is regulated by the State. All samples from all sites contained one or more quantifiable detections of pesticides (table 9). Of the unquantifiable (estimated) detections, the triazine degradate ciat (2-chloro-4-isopropylamino-6-amino-s-triazine) was found in all samples and accounted for about 66 percent of the detections (appendixes 1–8).

Wastewater Compounds

Laboratory analyses were conducted to determine the presence and concentration of wastewater contaminants in water samples collected from sites 2 and 3 on Onion Creek, upstream and downstream from the Meskwaki sewage-lagoon outflow, respectively; Cattail Creek downstream from the tribal headquarters and central housing complex; and the three sites along the Iowa River (fig. 1). Analyses included 67 compounds consisting of pesticides, fragrance (HHCB), insect repellant (DEET), and petroleum derivatives (polycyclic aromatic hydrocarbons; PAHs). Pesticide compounds and PAHs usually are not found in sewage effluent and most likely represent transport due to surface runoff. Thirty-six of the 67 wastewater compounds were detected among 36 samples analyzed. Of that, nine quantifiable detections were recorded (table 10) in addition to 217 unquantifiable detections (appendixes 1–8). Six of the nine quantifiable detections were from Onion Creek site 3 and included four occurrences of HHCB and one each of caffeine and DEET. In comparison, site 2 had no quantifiable detections of any compound and about 9 percent of the total number of detections, or about 75 percent fewer total detections than site 3 (table 11). DEET also was detected in a sample from the Iowa River near Montour (site 1). A single detection of the pesticide metolachlor was found in a sample from the Iowa River at the Wetlands Reserve Property (WRP). Of the unquantifiable detections, caffeine, the fragrance derivatives (HHCB and AHTN), and insect repellent (DEET) accounted for approximately 50 percent of the 36 compounds. PAHs accounted for approximately 22 percent of the 36 compounds, and metolachlor accounted for about 11 percent. Most of the PAH detections occurred following runoff. All but 4 of the 24 unquantifiable detections of metolachlor were from the Iowa River. Only phenol, of which there were three unquantifiable detections, is regulated by the State[1]; estimated concentrations ranged 0.008 to 0.172 µg/L.

[1] State regulations for class B(WW) water are 50, 2,500 and 300 µg/L for chronic and acute toxicity for aquatic life and human health levels, respectively.

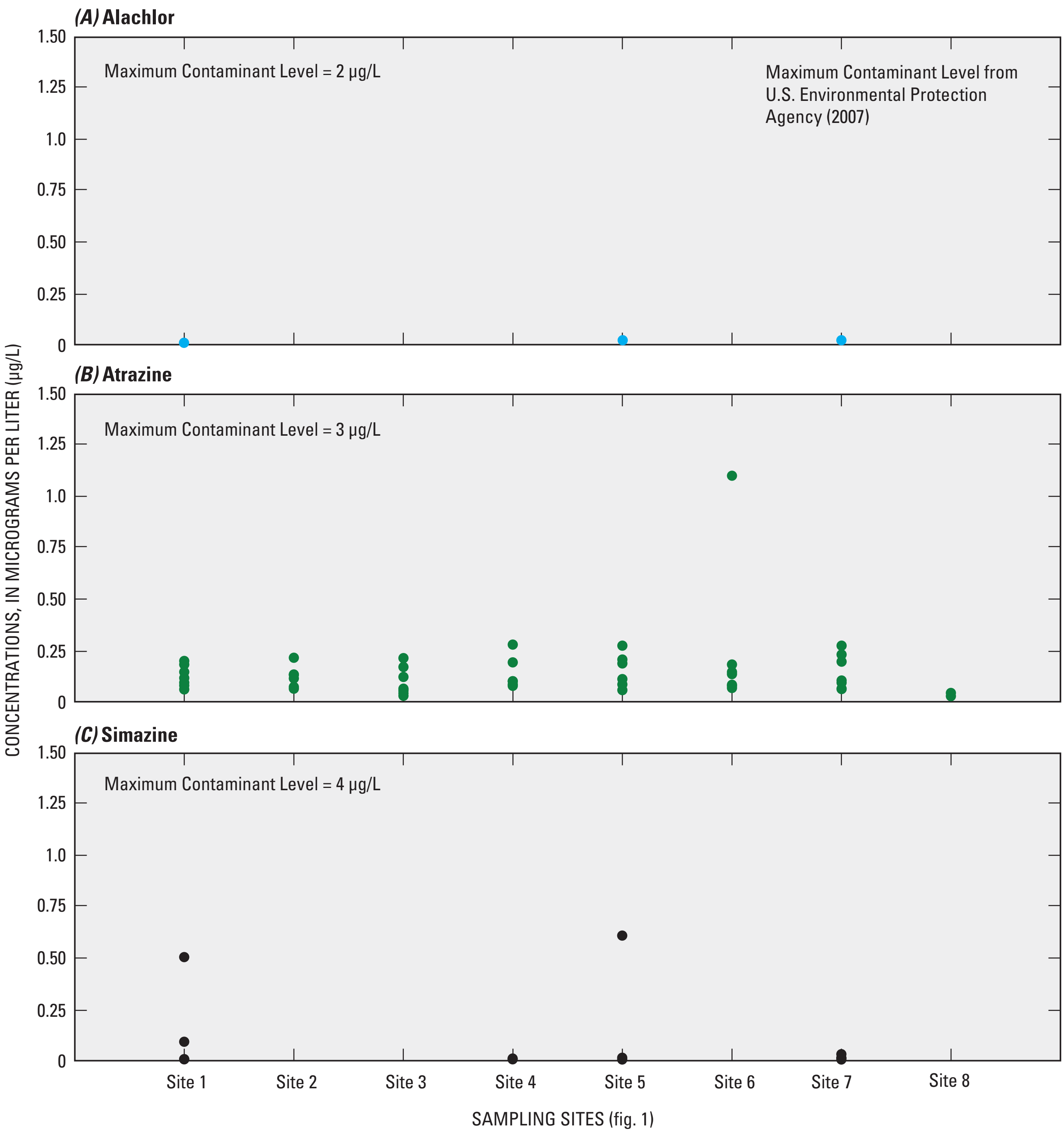

Figure 5. Concentrations of selected pesticides in surface water within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

Table 9. Frequency of quantifiable pesticide detections in water samples from the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

[Pesticide compounds listed in order of decreasing detection frequency. µg/L, micrograms per liter; --, not applicable]

Pesticide compound	Percentage of samples with detections	Number of samples	Maximum concentration (µg/L)	Minimum reporting limit (µg/L)	Action/use[1]
Any compound	100	50	1.45	--	--
Atrazine	100	50	1.10	0.005	Selective herbicide/corn, sorghum
Metolachlor	92.0	50	1.45	.005	Selective herbicide/corn, sorghum, pasture
Acetochlor	60.0	50	.091	.006	Selective herbicide/corn, soybeans
Simazine	28.0	50	.609	.018	Selective herbicide/corn
Prometon	16.0	50	.064	.010	Nonselective herbicide
Dacthal	10.0	50	.005	.003	Herbicide metabolite
Chlorpyrifos	6.0	50	.010	.005	Insecticide/corn, soybeans
Alachlor	8.0	50	.010	.005	Preemergent herbicide/corn, soybeans
Malathion	3.9	50	.318	.027	Nonselective insecticide
Cyanazine	2.0	50	.067	.005	Selective herbicide/corn

[1]Modified from Kolpin and others (1993).

Table 10. Frequency of quantifiable wastewater compound detections in water samples from the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

[Wastewater compounds listed in order of decreasing detection frequency. µg/L, micrograms per liter; --, not applicable]

Wastewater compound	Percentage of samples with detections	Number of samples	Maximum concentration (mg/L)	Reporting limit (mg/L)	Action/use[1]
Any compound	25.0	36	1.33	--	--
HHCB	8.3	36	.598	0.5	Fragrance/personal care products
N,N-diethyltoluamide (DEET)	5.6	36	1.33	.5	Insect repellant
Caffeine	2.8	36	1.11	.5	Stimulant/coffee, soft drinks, medicine
Carbaryl	2.8	36	.25	.041	Contact insecticide
Metolachlor	2.8	36	.169	.16	Selective herbicide/corn, sorghum, pasture
Indole	2.8	36	1.09	.5	Chemical reagent/perfumery, medicine; flavoring agent

[1]Modified from Kolpin and others (1993).

Table 11. Relations between quantifiable and unquantifiable wastewater compound detections in water samples from the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

Site number	Site name	Quantifiable detections	Unquantifiable detections	Total detections	Relative percentage of detections
1	Iowa River near Montour, IA	1	28	29	12.8
2	Onion Creek below Highway 30 near Montour, IA	0	20	20	8.9
3	Onion Creek near Montour, IA	6	82	88	38.9
5	Iowa River at Highway 49 near Tama, IA	1	35	36	15.9
7	Iowa River near Tama, IA	1	34	35	15.5
8	Cattail Creek near Tama, IA	0	18	18	8.0

Fuel Compounds

Tests were conducted to determine the presence of fuel compounds in water samples collected from sites 1–3, 5, 7, and 8 (fig. 1) and included benzene, ethylbenzene, tert-butyl methyl ether (MTBE), toluene, and xylene. Of the 34 samples collected, the only detections that occurred were for toluene in the Iowa River near Montour (site 1) and at Highway 49 near Tama (site 5). Both sample concentrations were at the reporting limit of 0.1 µg/L and may have resulted from motorcraft discharge at the time of sampling. Due to their volatility in contact with the atmosphere, fuel compounds are not commonly detected in Iowa streams under normal circumstances (S.J. Kalkhoff, U.S. Geological Survey, oral commun, 2007).

Bacteria

Bacteria samples were collected at all sites during this study and included *E. coli* and fecal coliform. *E. coli* is a type of fecal bacteria that comes from human and animal wastes that may be washed into waterways during periods of rainfall or snowmelt runoff. Fecal coliform is used to indicate the potential presence of harmful bacteria in water supplies. For surface water designated as Class “A,” primary contact recreation, the State of Iowa’s sample maximum *E. coli* content has been set at 235 colony forming units per 100 milliliters (cfu/100 mL) from March 15 through November 15, except when affected by surface runoff (Iowa Administrative Code, 2006).

Between April and October 2006 and 2007, *E. coli* densities in samples from the Iowa River within and contiguous to the settlement ranged from less than 10 to 1,600 cfu/100 mL with a median value of about 160 cfu/100 mL (table 12; fig. 6). In general, densities over 200 cfu/100 mL were storm-flow related. *E. coli* densities in tributaries north of the Iowa River ranged from 73 to 880 cfu/100 mL in Onion Creek at the upstream site 2, and from 130 to 440,000 cfu/100 mL downstream from the sewage lagoons (site 3). A density of 440,000 cfu/100 mL, in a storm-flow sample collected in August 2006, was likely the result of overflow from the sewage lagoons just upstream from sampling site 3. Densities in two storm-flow samples from Cattail Creek were 1,700 and 610,000 cfu/100 mL. The unusually large bacterial density was reportedly due to raw sewage from a local residential septic system (K. Schott, Meskwaki Natural Resources Department, oral commun., 2006). *E. coli* densities measured south of the Iowa River in samples from Raven and Bennett Creeks ranged from 1,100 to 23,000 cfu/100 mL and 270 to 33,000 cfu/100 mL, respectively.

E. coli densities in samples from the Iowa River and its tributaries within and contiguous to the Meskwaki Settlement were either equal to or less than the respective densities for fecal coliform in the same samples (fig. 6).

Total Suspended Solids

Median total suspended solids (TSS) concentrations ranged from less than or equal to about 20 mg/L at sampling sites 2, 3, and 6 on Onion and Bennett Creeks to more than 150 mg/L at site 8 on Cattail Creek (fig. 7). Water with TSS concentrations less than about 20 mg/L generally is considered to be relatively clear, whereas water with TSS concentrations more than about 150 mg/L is considered dirty (Michigan Department of Environmental Quality, 2008). Median TSS concentrations for water from sites 1, 5, and 7 on the Iowa River and site 4 at Raven Creek fall within the cloudy or murky range. In this regard, TSS provides an indication of median water-quality conditions in relation to turbidity for the Meskwaki Settlement.

TSS originally was developed for the analysis of wastewater samples but has become a common measure in the analysis of natural water as a surrogate for suspended-sediment concentration. However, a recent study has shown that TSS values provide, at best, an estimation of suspended sediment only when the sand fraction of a suspended-sediment sample is less than about 25 percent of the dry sediment mass (Gray and others, 2000). In general, although TSS is a fair approximation of suspended-sediment concentration at base flow, it should not be used for computing sediment load other than during base-flow conditions.

Sediment-Quality Data

Streambed sediment samples were collected in conjunction with the biological assessments from the three sampling sites along the Iowa River (sites 1, 5, and 7) and from Onion

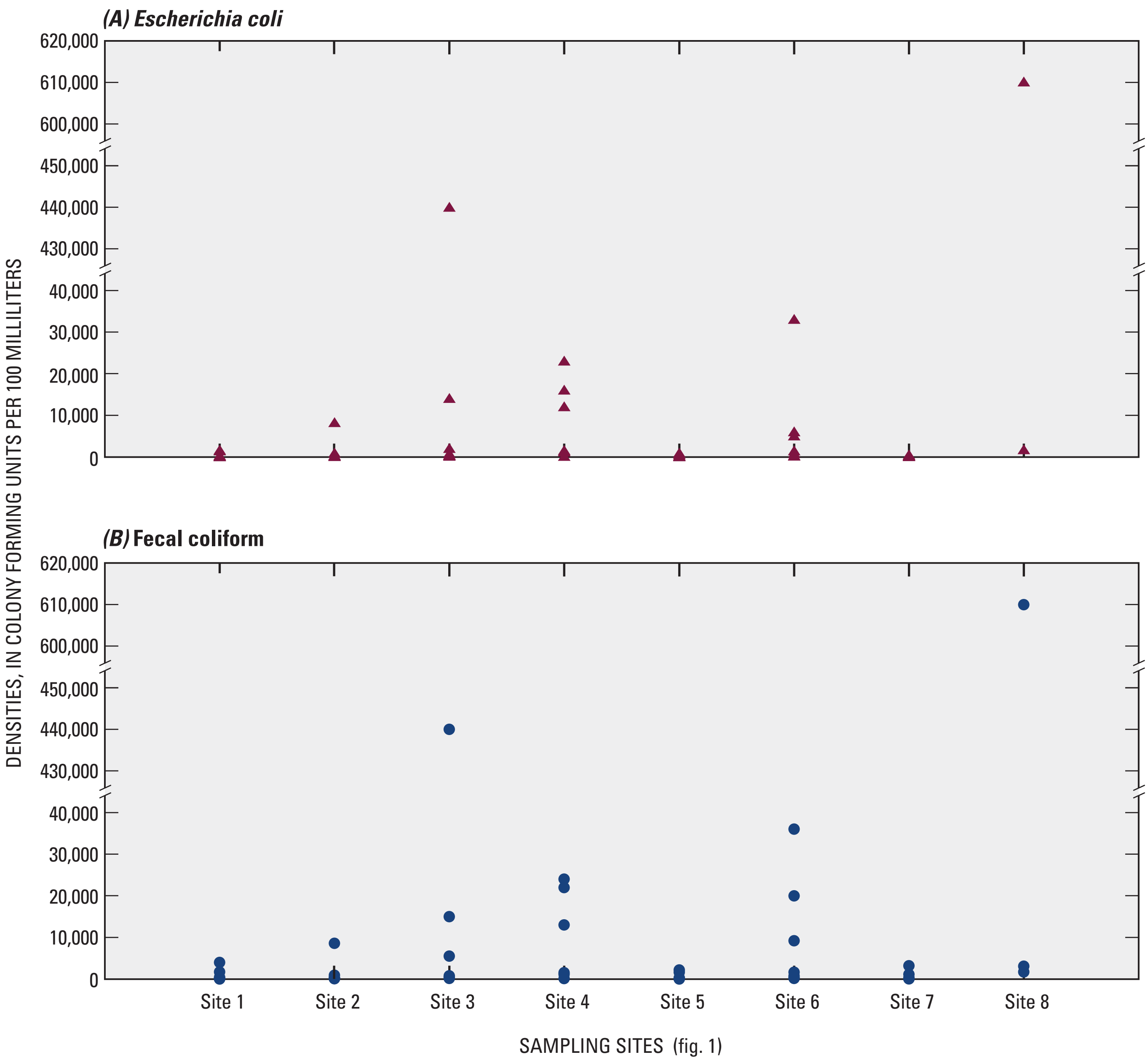

Figure 6. Bacteria densities in surface water within and contiguous to the Meskwaki Settlement, central Iowa, between April and October, water years 2006–07.

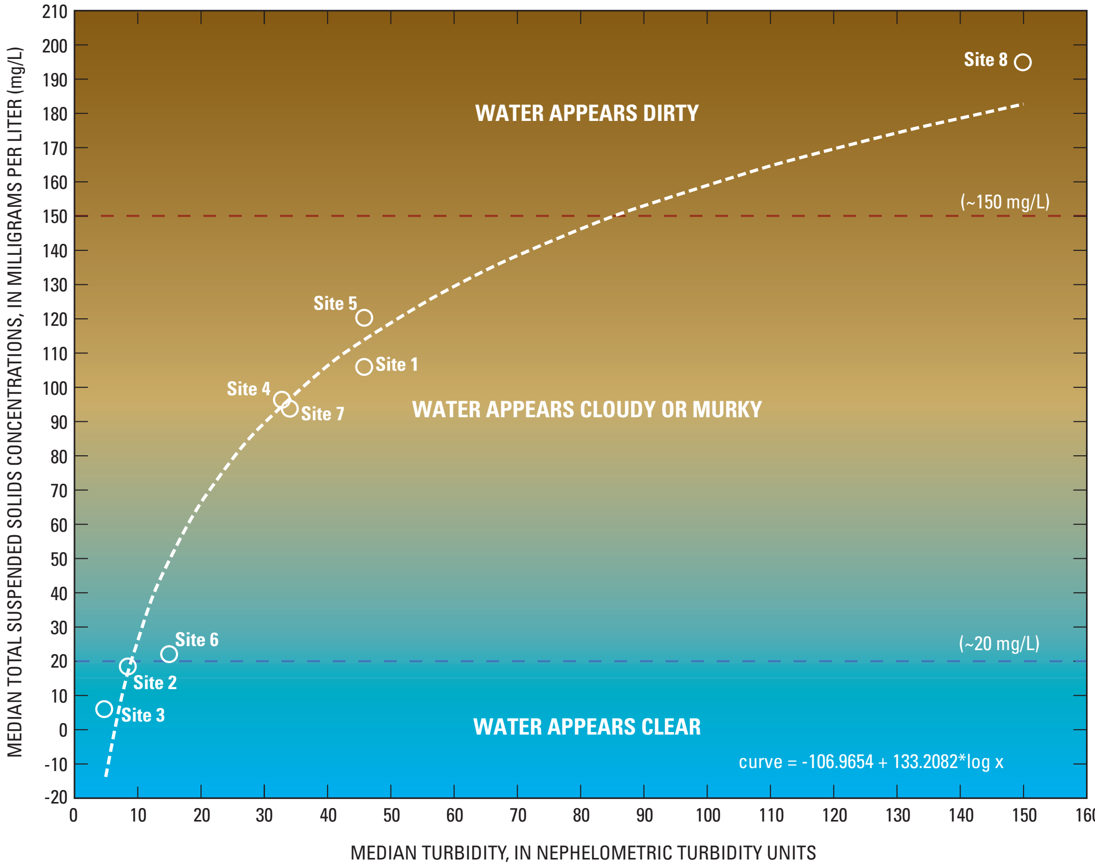

Figure 7. Concentrations of median total suspended solids compared to median turbidity in surface water within and contiguous to the Meskwaki Settlement, central Iowa, water years 2006–07.

Creek downstream from the sewage lagoons (site 3). Because aquatic species often feed off nutrients attached to streambed sediment, *in-situ* or in suspension, they are susceptible to ingesting chemicals and metals adsorbed to the granular surfaces. Toxic concentrations for some species may be attained over time through bioaccumulation. The Florida Department of Environmental Protection developed a set of effects-based guidelines for its coastal waters through a statistical comparison of chemical concentrations associated with biological effects to concentrations associated with no observed effects (U.S. Environmental Protection Agency, 2004a). Adopted by the USEPA, the "threshold effects level" (TEL) represents the concentrations below which toxic biological effects rarely occur, the "probable effects level" (PEL) represents the concentrations above which toxic effects usually occur, and values ranging between the TEL and PEL represent those concentrations where toxic effects occasionally occur. The TEL and PEL guidelines can be used as a screening tool because the effects-correlation procedure does not demonstrate that a particular contaminant is solely responsible for an adverse organism response (Schnoebelen and others, 2003; U.S. Environmental Protection Agency, 2004a).

Trace Metals and Organic Compounds

No trace metal concentrations were found in sediment from the Iowa River that exceeded either the TEL or PEL guidelines (table 13). However, arsenic and nickel concentrations of 13.4 and 19 micrograms per gram (µg/g) were found in a composite sample from Onion Creek (site 3) that exceeded the TEL of 7.24 and 15.9 µg/g, respectively. The source of the metals is unknown. Also, it is unknown if any silver concentrations exceeded the TEL of 0.733 µg/g because the minimum reporting level for silver is 1.0 µg/g. Tests for organic compounds sorbed to sediment included 108 compounds. None of the samples were found to contain organic compounds exceeding the respective minimum reporting limits.

Biological Assessment

During the summer of 2007, biological data were collected at the Meskwaki Settlement. Three sites on the Iowa River—Iowa River near Montour (site 1), Iowa River at County Road E49 near Tama (site 5), and Iowa River at Wetlands Reserve Property near Tama (site 7), and one site on Onion Creek—Onion Creek near Montour (site 3)—were sampled. These sites were sampled to provide a baseline assessment of aquatic biological conditions. The biological samples collected included fish community, benthic macroinvertebrates, and periphyton samples, as well as physical-habitat measurements. In addition, fish-tissue samples were collected at these four sites. Where available, Indexes of Biological Integrity (IBI) were used to assess the overall condition of the specific biotic communities. A benefit of using an IBI is to provide a translation of an ecologist's assessment of the biological community into a value that will make sense to persons unfamiliar with ecological communities (Hughes and others, 1998). An IBI consists of a series of biotic community attributes, termed metrics, which reflect basic structural characteristics of biotic assemblages (Lyons, 1992). Each individual metric is rated and that rating is based on quantitative expectations of what is considered excellent biotic integrity.

The sites within the Meskwaki Settlement were separated into large river and wadeable sites. The three sites on the Iowa River are considered large river sites, and Onion Creek is considered a wadeable site. This separation is important to know because the choice of indexes used has been based upon drainage area of the sampling site. Wadeable streams are considered to have drainage areas of less than 1,000 square miles (mi^2), and large river sites are considered to fall in the range from 1,000 mi^2 and 2,300 mi^2 (Simon, 2007).

There are few large river indexes in use today. Reasons for this may include that within large rivers systems there is increased difficulty in accurately sampling the different biotic assemblages, and few quality reference sites are available to develop expectations of metric values (Davis and Simon, 1995).

Fish Community

The Iowa Department of Natural Resources (IDNR) has developed a Fish Index of Biological Integrity (FIBI) for wadeable streams (Wilton, 2004). The Iowa FIBI classifies the biological condition of the fish population in a six-tiered approach (fig. 8). This approach is endorsed by the USEPA as a tool to evaluate the biological condition of a water body (U.S. Environmental Protection Agency, 2005). A tiered approach provides resource managers with a tool that will help develop and refine water-quality management practices. On a basis of this approach, tiers 3 and 4 reflect the biological condition in most Iowa rivers and streams (Wilton, 2004: fig. 8). For the purpose of comparison, the Iowa FIBI was used for all of the sites sampled in this study, although the drainage areas for the three Iowa River sampling sites within the Meskwaki Settlement are 1,840 mi^2 (site 1), 1,882 mi^2 (site 5), and 1,896 mi^2 (site 7; appendix 9).

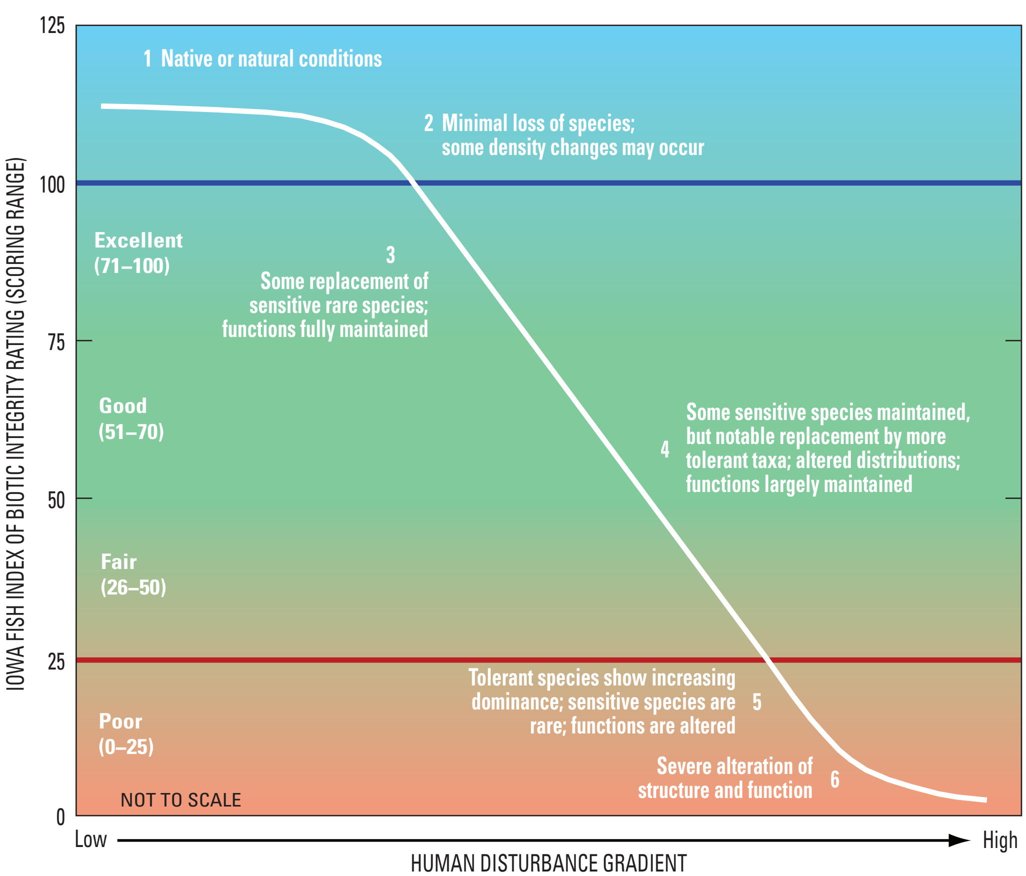

Figure 8. Fish Index of Biological Integrity (FIBI) qualitative scoring ranges in relation to a conceptual tiered (1–6) human disturbance gradient.

Table 12. Statistical summary of *escherichia coli* (*E. coli*) densities at selected sampling sites along the Iowa River and tributaries within and contiguous to the Meskwaki Settlement, central Iowa, between April and October, water years 2006–07.

[cfu/100 mL, colony forming units per 100 milliliters; Min, minimum; Max, maximum; <, less than; WRP, Wetlands Reserve Property; --, not applicable]

Site number	Site name	*E. coli* (cfu/100mL)				
		Min	Max	Median	Number of samples	Number of samples exceeding 235 cfu/100 mL
1	Iowa River near Montour, IA	10	1,600	160	6	3
2	Onion Creek below Highway 30 near Montour, IA	73	880	150	6	2
3	Onion Creek near Montour, IA	130	440,000	330	8	7
4	Raven Creek near Montour, IA	1,100	23,000	6,750	6	6
5	Iowa River at Highway 49 near Tama, IA	<10	900	175	6	2
6	Bennett Creek near Tama, IA	270	33,000	3,200	6	6
7	Iowa River at WRP near Tama, IA	30	450	155	6	2
8	Cattail Creek near Tama, IA	1,700	610,000	--	2	2

Drainage area is important to note because it is a factor in the calculation of several of the metrics within the FIBI. Due to the concern that the Iowa index was developed for wadeable sites, an index developed for large rivers by the Ohio Environmental Protection Agency (Ohio EPA), (Ohio Environmental Protection Agency, 1987) was used in an attempt to validate the Iowa wadeable site index results. The individual metrics used for each particular index can be found in Wilton (2004). The results calculated by the two indexes are described in table 14.

On the basis of the Iowa FIBI, all of the sampling sites have calculated indexes indicating a fair classification except for the Iowa River at Highway 49 near Tama (site 5). This site was classified just below fair by a value of 1.1, which is about 5.4 percent of the range of results for all of the sites combined. Possible reasons for this FIBI score could be attributed to the fact that the sampling at this site was difficult, and a small number of fish were obtained. Difficult conditions at site 5 were due to the large abundance of woody snags and trees. These snags and trees made for hazardous conditions during boat operation as well as obstacles for netters which lead to missed fish. Due to the small number of fish obtained, an adjustment, as discussed in Wilton (2004), was needed to account for the small number, which led to a lower index score.

The FIBI score for the Iowa River sites was calculated using the IDNR FIBI. The ungaged IDNR reference site North Skunk River near Rosehill, in southeastern Iowa (fig. 1) was used as a comparison. This site was selected because it had the closest drainage area (529 mi^2) to the Iowa River sites as well as being located in the same level IV ecoregion (47f) as described by Chapman and others (2002). The North Skunk River had an FIBI score of 36, which would be classified as fair (Wilton, 2004). This fair classification is consistent with the fair classification values outlined in table 14 as determined for the Iowa River sites within the Meskwaki Settlement.

Also, the FIBI score for the wadeable site Onion Creek near Montour, Iowa (site 3), was calculated using the IDNR FIBI. The IDNR reference site at Richland Creek near Haven (05451900) in central Iowa (fig. 1) was used for comparison. The reasons for selecting this site were based on similar drainage areas (56 mi^2 for Richland Creek) as well as being located within the same level IV ecoregion (47f). Richland Creek near Haven (05451900) had an index score of 42 (Wilton, 2004), which also would be classified as fair. This classification is consistent with the fair classification of 45 that was calculated for Onion Creek (table 14). The consistency of IBI scores between the Richland Creek reference site (05451900) and Onion Creek (site 3) could be attributed to the conditions during the sampling period at Onion Creek. Increased flow during the time of fish sampling at Onion Creek would have provided additional habitat for fish species that typically would not inhabit the reach during base-flow conditions. This increased habitat availability due to the higher flows in Onion Creek may have triggered fish from the Iowa River into moving upstream into Onion Creek, which resulted in a higher FIBI score. The use of the Ohio EPA index was not applicable because this site is considered wadeable, and the Iowa FIBI is considered valid for this stream.

In an attempt to validate the findings of the IDNR FIBI, an alternative FIBI was determined to be useful. The Ohio EPA method was used by the USGS NAWQA program (Sullivan, 2000) to assess six sites sampled by the USGS in 1996. Of these six sites, two of them were on the Iowa River, and one was the Iowa River at Marengo (05453100, fig. 1), which is just 48 river miles downstream from the most downstream site sampled within the Meskwaki Settlement during 2007. When calculating an index value using the Ohio EPA method for the Iowa River sites within the Meskwaki Settlement,

Table 13. Statistical summary of selected trace metals in streambed-sediment samples from the Iowa River in comparison to samples from Onion Creek, Meskwaki Settlement, central Iowa, August 2007.

[µg/g, Min, minimum; Max, maximum; micrograms per gram; TEL, threshold effects level; PEL, probable effects level; --, not applicable; bold value, exceeds U.S. Environmental Protection Agency's (2004a) sediment-quality guideline; <, less than]

Trace metal	Concentrations in streambed-sediment samples (µg/g) Iowa River (sites 1, 5, and 7)				Onion Creek (site 3)	Sediment-quality guidelines[1] (µg/g)	
	Min	Max	Median	Mean		TEL	PEL
Aluminum	36,800	39,200	36,900	37,630	30,600	--	--
Antimony	.1	.1	.1	.1	.41	--	--
Arsenic	2.3	2.9	2.8	2.7	13.4	7.24	41.6
Barium	487	525	497	503	731	--	--
Beryllium	.75	.82	.76	.78	.87	--	--
Bismuth	<.06	<.06	<.06	<.06	.06	--	--
Cadmium	.06	.09	.07	.07	.32	.676	4.21
Cerium	18.3	23.1	20.7	20.7	46.4	--	--
Cesium	.50	.55	.52	.52	.98	--	--
Chromium	10.5	14.1	14.1	12.9	17.8	52.3	160
Cobalt	4.8	5.4	5.2	5.1	17.1	--	--
Copper	<2	<2	<2	<2	<2	18.7	108
Gallium	7.6	7.9	7.7	7.7	6.7	--	--
Iron	7,580	8,870	7,830	8,093	17,600	--	--
Lanthanum	9.0	11.3	10.0	10.1	16.1	--	--
Lead	8.54	8.83	8.55	8.6	16.8	30.2	112
Lithium	1.6	2.7	2.4	2.2	4.2	--	--
Manganese	597	609	601	602	2,980	--	--
Mercury	<.01	<.01	<.01	<.01	<.01	.13	.696
Molybdenum	.1	.1	.1	.1	1	--	--
Nickel	8.3	8.9	8.4	8.5	19	15.9	42.8
Niobium	1.8	3.2	1.9	2.3	3.8	--	--
Phosphorus	216	347	237	267	759	--	--
Rubidium	37.6	41.4	39.5	40.0	39.0	--	--
Scandium	1.6	2.3	2.0	2.0	2.7	--	--
Selenium	.1	.1	.1	.1	.2	--	--
Silver	<1	<1	<1	<1	<1	.733	1.77
Strontium	202	218	209	210	138	--	--
Thallium	.24	.26	.24	.25	.29	--	--
Thorium	1.90	2.36	2.04	2.10	3.11	--	--
Titanium	477	845	530	617	923	--	--
Uranium	.49	.57	.57	.54	.92	--	--
Vanadium	13.8	18.8	14.5	15.7	37.7	--	--
Yttrium	5.4	6.7	5.7	5.9	11.1	--	--
Zinc	14.3	17	14.5	15	33	124	271

a classification of fair was determined for all three sites (table 14). This determination of fair is consistent with the IDNR FIBI scores. The fair classification of the Meskwaki Iowa River sites illustrates an increased level of quality compared to the sites previously mentioned in the Sullivan report. The Iowa River at Marengo had a score of 22 which is considered poor using the Ohio EPA large river index. The time frame for the collection of the Iowa River at Marengo data could likely be the reason for the classification of poor.

Benthic Macroinvertebrate Community

The IDNR also has developed a Benthic Macroinvertebrate Index of Biological Integrity (BMIBI) for wadeable streams (Wilton, 2004). The BMIBI classifies the biological condition of the invertebrate population in a tiered approach similar to the FIBI (fig. 9). This approach is endorsed by the USEPA as a tool to evaluate the biological condition of a water body. A tiered approach provides resource managers with a tool that will help develop and refine water-quality management practices.

On the basis of this approach, tiers 3 and 4 reflect the biological condition in most of Iowa's rivers and streams (Wilton, 2004). Within tiers 3 and 4, the expected classifications using the BMIBI include excellent, good, and fair (fig. 9). The index includes 12 individual metrics. For the purpose of comparison, this index was used for all of the sites sampled in this study, although the drainage areas for the Iowa River sites within the Meskwaki Settlement varied from 1,840 to 1,896 mi^2. The results calculated by this index are described in table 15. All of the Iowa River sites within the Meskwaki Settlement have calculated index scores indicating a good classification except for the Iowa River near Montour (site 1) which was classified as fair.

The Iowa River sites were compared to the North Skunk River near Rosehill, Iowa, using the BMIBI scores. The North Skunk River near Rosehill is considered a reference site for the IDNR within ecoregion 47f. This site was selected for the same reasons as it was for the FIBI because it had a drainage area similar in size to the Iowa River sites as well as being located in the same level IV ecoregion (47f), as described by Chapman and others (2002). The North Skunk River site had a BMIBI score of 53 (Wilton, 2004), which would be classified as fair. The fair classification from the North Skunk River is

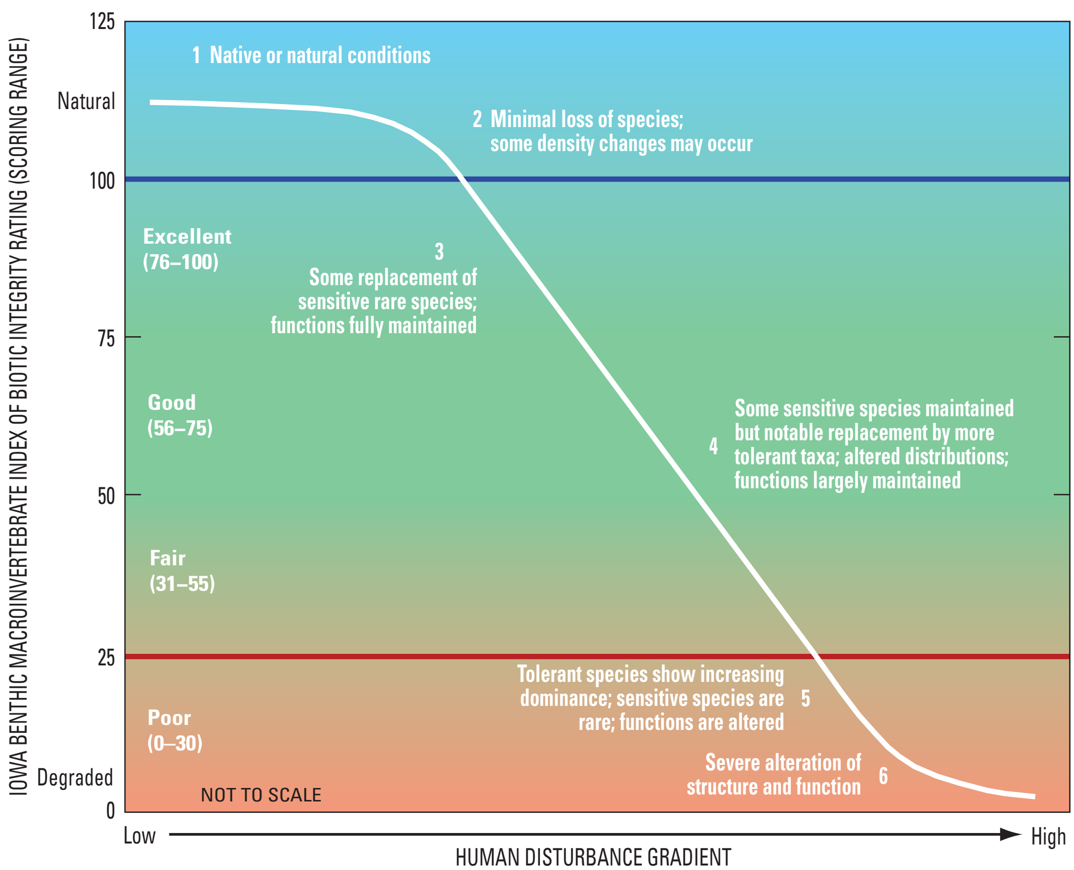

Figure 9. Benthic Marcoinvertebrate Index of Biological Integrity (BMIBI) qualitative scoring ranges in relation to a conceptual tiered (1–6) human disturbance gradient.

Table 14. Fish Indexes of Biological Integrity (FIBI) for fish community data collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions: DNR, Department of Natural Resources; EPA, Environmental Protection Agency; FIBI, Fish Indexes of Biotic Integrity; WRP, Wetlands Reserve Property; --, not applicable]

Site number (fig. 1)	Site name	Iowa DNR FIBI[1]	Ohio EPA FIBI[2]	Classification
1	Iowa River near Montour, Iowa	42.1	28	Fair (Iowa FIBI) Fair (Ohio EPA FIBI)
3	Onion Creek near Montour, Iowa	45.0	--	Fair (Iowa FIBI)
5	Iowa River at Highway 49 near Tama, Iowa	24.9	30	Poor (Iowa FIBI) Fair (Ohio EPA FIBI)
7	Iowa River at WRP near Tama, Iowa	26.3	36	Fair (Iowa FIBI) Fair (Ohio EPA FIBI)

[1] Iowa FIBI maximum score is 100. Scores are classified as 100–71 (excellent), 70–51 (good), 50–26 (fair), 25–0 (poor) (Wilton, 2004).

[2] Ohio EPA maximum score is 60. Scores are classified as 60–50 (excellent), 48–40 (good), 38–26 (fair), 24–16 (poor), less than 16 (very poor). (Ohio Environmental Protection Agency, 1987).

Table 15. Benthic Macroinvertebrate Index of Biological Integrity (BMIBI) for data collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions: DNR Department of Natural Resources; BMIBI, Benthic Macroinvertebrate Index of Biological Integrity; WRP, Wetlands Reserve Property]

Site number (fig. 1)	Site name	Iowa DNR BMIBI[1]	Iowa BMIBI classification
1	Iowa River near Montour, Iowa	53.8	Fair
3	Onion Creek near Montour, Iowa	60.6	Good
5	Iowa River at Highway 49 near Tama, Iowa	67.2	Good
7	Iowa River at WRP near Tama, Iowa	68.2	Good

[1] Iowa BMIBI maximum score is 100. Scores are classified as 100–76 (excellent), 75–56 (good), 55–31 (fair), 30–0 (poor) (Wilton, 2004).

less favorable than the good classification that was determined for two of the Iowa River sites within Meskwaki Settlement.

Also, the BMIBI score for the wadeable site Onion Creek near Montour (site 3) was calculated using the IDNR reference site at Richland Creek near Haven, Iowa, as a comparison. The reasons for selecting this site were based on similar drainage areas as well as being located within the same level IV ecoregion (47f). Richland Creek near Haven had a BMIBI index score of 64 (Wilton, 2004) which would indicate a good classification. This classification is consistent with the good classification (BMIBI index score of 60.6) that was calculated for Onion Creek (site 3). The consistent score between Onion Creek and the reference stream is indicative of the quality invertebrate habitat available in Onion Creek at the time sampling took place.

Periphyton (Algae)

The USEPA assessment data for 2004 for the State of Iowa indicates that of the 7,830 mi of rivers and streams sampled in Iowa, 76.2 percent were either impaired or threatened. Nutrient contamination was among the top 10 causes of impairment in Iowa rivers and streams (U.S. Environmental Protection Agency, 2004b). Nutrient enrichment can be detected through water sampling with chemical analysis for nitrogen, phosphorus, and their transformation products as well as periphyton (benthic algae) and phytoplankton (algae in suspension) sampling and analysis. For the ecological part of the study that took place at the sites within the Meskwaki Settlement, periphyton samples were collected to assess the condition of the water.

The two metrics that were used for the periphyton assessment are the indicators of nutrient enrichment and trophic condition (Porter, 2008). The first metric, nutrient enrichment, is based on a weighted average (WA) of taxa that are indicative of either low or high nutrient conditions (Potapova and Charles, 2007). The WA metric was derived from the NAWQA database (*http://infotrek.er.usgs.gov/nawqa_queries/biomaster/index.jsp*) by scientists from ANSP. The NAWQA data were divided into a national data set and five ecoregion data sets. Because there is evidence that diatom metrics or indices developed in one geographic area are less successful when applied in other areas (Potapova and Charles, 2007), the study described in this report chose to use the diatom metrics for the Central and Western Plains level IV ecoregion delineated by Potapova and Charles (2007). The second metric, trophic condition of the water body (Van Dam and others, 1994), is described by a percentage of the total richness composed of taxa that are considered tolerant of eutrophic conditions.

The WA metric results indicate that a large percentage of the diatom species that were collected from all of the ecological sampling sites within the Meskwaki Settlement indicate nutrient enriched conditions (table 16). On a scale from 0 to 10, the lowest WA score was 8.78 and the highest was 10.0. As the WA metric results moved toward a WA score of 10 a greater expectation of nutrient enrichment occurs. The diatoms metric scores for low and high phosphorus as well as low and high nitrogen were assigned by Potapova and Charles (2007) on the basis of the following water-sample nutrient concentrations. Diatoms that were attributed to low WA scores corresponded to water samples with total phosphorus (TP) concentrations of less than or equal to 0.01 mg/L, whereas high WA scores corresponded to concentrations greater than or equal to 0.1 mg/L. Diatoms that were attributed to a low WA score corresponded to water samples with total nitrogen (TN) concentrations less than or equal to 0.2 mg/L, and those diatoms that were attributed to a high WA score corresponded to concentrations greater than or equal to 3 mg/L. The implication of the WA metric results is that the species that were present at the Meskwaki Settlement sampling sites indicate nutrient enriched conditions. The nutrient data for the water samples that were collected during the same sampling period (table 16) also indicate nutrient enriched (eutrophic) conditions.

The trophic condition metric used in this periphyton assessment is from Van Dam and others (1994) and includes a new metric label that combines three of the trophic (TR) levels [mesotrophic-eutrophic (TR_ME), eutrophic (TR_ET), and polytrophic (TR_PT)] into one metric, eutrophic (TR_E). The percentage of taxa of species falling within metric codes 4, 5, and 6 (table 17) relative to the total taxa richness of all species samples was calculated and is shown in table 18. The range of trophic condition results for the four sites sampled for periphyton has TR_E values between 47.9 and 61.7 percent. These results show that at a minimum 47.9 percent of the species that are present show tolerance for or require large nutrient concentrations. The trophic conditions at the sampling sites show an imbalance in the trophic preferences by the species that are present. The results once again indicate that surface water within the Meskwaki Settlement could be considered nutrient enriched, which leads to greater potential for primary production and possibly eutrophic conditions.

Documentation has shown that intense row crop production and confined animal feeding operations in Iowa, Illinois, and southern Minnesota have resulted in accelerated nutrient and organic enrichment in tributary streams as well as in the Mississippi River (Goolsby and others, 1991; Coupe and others, 1995). This documented enrichment of the upper Midwest is consistent with the ecological results found during the 2007 sampling cycle of the surface water within the Meskwaki Settlement.

Fish Tissue

During the summer of 2007, fish-tissue data were collected on the Meskwaki tribal lands for analysis of selected organochlorine, trace metals, and organic wastewater contaminants. Detection of organochlorine pesticides, and trace metals within fish tissue has led to the posting of fish-consumption advisories all across the United States. In 2005, 26 percent of the nation's river miles were under fish-consumption advisories (U.S. Environmental Protection Agency, 2007a).

Common carp were chosen for tissue analysis because of the relative availability of these fish in Iowa rivers and streams. Common carp feed on invertebrates and detritus near the stream bottom and, because organochlorines sorb to sediment that tends to settle on the stream bottom, common carp have a propensity for greater exposure to organochlorines.

Table 16. Weighted average (WA) results for periphyton community data collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions: RNr ratio of high nitrogen and low nitrogen indicators, RPr ratio of high phosphorus and low phosphorus indicator species; WRP, Wetlands Reserve Property; mg/L, milligrams per liter]

Site number (fig. 1)	Site name	Weighted averages[1]		Median total concentrations during sampling period 2007[2]		Indication of weighted average
		RNr	RPr	Nitrogen (mg/L)	Phosphorus (mg/L)	
1	Iowa River near Montour, Iowa	9.87	10	2.67	0.285	High nutrient
3	Onion Creek near Montour, Iowa	10	9.96	1.30	.407	High nutrient
5	Iowa River at Highway 49 near Tama, Iowa	9.25	9.94	13.6	.126	High nutrient
7	Iowa River at WRP near Tama, Iowa	9.63	8.78	13.7	.125	High nutrient

[1] Weight average scale 0 to 10: 0 being low indicator of nutrient enrichment, 10 being high indicator of nutrient enrichment (Potapova, and Charles, 2007).

[2] High nitrogen greater than or equal 3 mg/L; Low nitrogen less than or equal to 0.2 mg/L: High phosphorous greater than or equal to 0.1 mg/L: Low phosphorous less than or equal to 0.01 mg/L.

Table 17. Trophic conditions defined for periphyton community data collected from the Meskwaki Settlement, central Iowa, 2007.

Metric label[1]	Metric code	Metric name	Metric description
TR_OL	1	Oligotraphentic diatoms	Oligotrophic
TR_OM	2	Oligotraphentic – mesotraphentic diatoms	Oligotrophic-mesotrophic
TR_MT	3	Mesotraphentic diatoms	Mesotrophic
TR_ME	4	Mesotrapentic – eutraphentic diatoms	Mesotrophic-eutrophic
TR_ET	5	Eutrophentic	Eutrophic
TR_PT	6	Hypereutraphentic	Polytrophic
TR_EY	7	Eurytraphentic diatoms	Indifferent—wide range of tolerance nutrients
TR_E	4+5+6	Eutrophic diatoms	Tolerance or requirements of large nutrient concentrations

[1] See metric description from Van Dam and others (1994).

Table 18. Trophic condition results for periphyton community data collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions: TR_E, eutrophic diatom metric, indicates percentage of taxa in metric codes 4, 5, 6 (table 15); %, percent; WRP, Wetlands Reserve Property; mg/L, milligrams per liter]

Site number (fig. 1)	Site name	TR_E	Median total concentrations during sampling period 2007		Indication of trophic condition
			Nitrogen (mg/L)	Phosphorus (mg/L)	
1	Iowa River near Montour, Iowa	60.5 %	2.67	0.285	High nutrient
3	Onion Creek near Montour, Iowa	61.7%	1.30	.407	High nutrient
5	Iowa River at Highway 49 near Tama, Iowa	54.3 %	13.6	.126	High nutrient
7	Iowa River at WRP near Tama, Iowa	47.9 %	13.7	.125	High nutrient

[1] Large nitrogen concentration greater than or equal 3 mg/L; small nitrogen concentrations less than or equal to 0.2 mg/L Large phosphorus concentrations greater than or equal to 0.1 mg/L: small phosphorous concentrations less than or equal to .01 mg/L (from Van Dam and others, 1994).

Two separate tissues, fillets and liver, were dissected and removed from the sampled fish. The carp were filleted, and the fillets were sent to the NWQL for organochlorine and organic wastewater contaminant analysis. The livers were preserved and sent to the NWQL for organochlorine, trace metal, and organic wastewater contaminant analysis.

Due to the size of Onion Creek, there were not any large bottom-dwelling fish species that could be dissected for analysis. To provide an assessment of organochlorine and organic wastewater contaminant concentrations in the fish tissue from Onion Creek, creek chubs (*Semotilus atromaculatus*) were collected and processed. Creek chubs were chosen at this site on the basis of availability. The creek chub fish-tissue analysis included eight composited whole fish, the livers of which were a composite of all eight fish livers for the analysis of organochlorine and organic wastewater contaminants. An assessment of the trace metal concentration in the fish tissue at the Onion Creek site was not done because the mass of tissue needed for processing could not be collected due to the small size of the fish that are present in the creek. The methods used for the dissection and processing of the fish are documented in Crawford and Luoma (1993).

The purpose of the fish tissue assessment was to document the level of contamination within the fish-tissue samples and whether or not they were at a level that would affect human health. To objectively provide a risk to human health from the consumption of fish on the settlement, a few important concerns were addressed. First, fish-tissue contamination levels for human consumption are based on the fish fillet samples; livers typically are not used for human-health concerns because the general population commonly does not consume fish liver tissue. Liver tissue is used most widely for determining occurrence and distribution of contaminants in the fish population. Therefore, any contaminant detected in the fish liver tissue is discussed in the following paragraphs as occurring in the fish tissue and not in terms of human-health concerns.

For the State of Iowa, there are three different contamination levels that are provided by three separate government agencies. The first being the U.S. Food and Drug Administration (FDA) action levels (U.S. Food and Drug Administration, 2000), which are guidelines used for fish that are bought and sold in the marketplace. The FDA action levels represent a limit at or above which the FDA may take legal action to remove products from the marketplace (U.S. Environmental Protection Agency, 2000). The FDA methodology to determine these action levels was never intended to be protective of recreational, tribal, ethnic, and sustenance fishers who typically consume larger quantities than the general population (U.S. Environmental Protection Agency, 2000). The USEPA uses a risk-based approach at setting levels called screening values (SVs). Both the USEPA and the FDA agree that the USEPA's risk-based approach is favorable to determine local fish consumption advisories (U.S. Environmental Protection Agency, 2000). Exceedance of a USEPA SV should be taken as an indicator that more site-specific monitoring and/or evaluation of human risk is needed (U.S. Environmental Protection Agency, 2000). The Iowa Department of Public Health (IDPH) has used a combination of the FDA action levels and the USEPA's risk-based levels to develop advisory levels for water within Iowa's borders (Iowa Department of Natural Resources, 2006). The SVs from the USEPA and the action levels from the FDA are only guidelines and not regulatory values. The three different advisory levels are described in table 19.

Of the selected organochorines analyzed in the fish fillet tissue, samples from three Iowa River sites exceeded the USEPA SV (table 20) for dieldrin of 0.0025 parts per million (ppm; U.S. Environmental Protection Agency, 2000). Dieldrin also was found in large concentrations in liver samples from all of the sites (table 21). Lipophilic contaminants, such as organochlorines, tend to accumulate in fatty tissues of fish, and the liver is a storage area for fats, which could explain the larger concentrations of dieldrin in this organ. Generally, the liver is not consumed, so the human health risk may be considered low. Dieldrin is an organochlorine insecticide that was banned completely from production in 1974 by the USEPA and for which all uses were voluntarily banned by industry in 1987 (U.S. Environmental Protection Agency, 2000). The USEPA SV is used as a management tool for this contaminant when detected in fillet tissue because the IDPH has not developed advisory levels for dieldrin.

Trace metal concentrations in fish tissue were analyzed using dissected carp liver. Once again fish liver tissue is used most commonly as a tool to determine the occurrence of a contaminant in the environment and typically is not used to assess fish or human-health concerns. Both cadmium and mercury were found at concentrations that would warrant fish-consumption advisories if these levels were detected in the fish fillet tissue (table 22).

The fish-tissue samples also were analyzed for organic wastewater contaminants. Current (2008) research is documenting that there are many chemical and microbial constituents in the environment that have not been considered previously as contaminants. A USGS study (Koplin and

Table 19. Comparison of consumption advisory protocols for whole or fillet-fish tissue samples.

[FDA, U.S Food and Drug Administration; IDPH, Iowa Department of Public Health; USEPA, U.S.Environmental Protection Agency; ppm, parts per million; PCBs, polychlorinated biphenyls; DDT, dichloro-diphenyl-trichloroethane]

Contaminants	FDA action level[1] (ppm)	USEPA screening value[2] (ppm)	IDPH advisory level[3] (ppm)	Consumption allowance for IDPH
		Organochlorines		
Chlordane (sum of all degradates)	0.3	0.114	0 to 0.6 0.6 to 5.0 5.0 and over	Unrestricted consumption One meal per week Do not eat
DDT (sum of all degradates)	5.0	.117	none	Use USEPA value for recreation fishers
Dieldrin	.3	.0025	none	Use USEPA value for recreation fishers
PCBs (sum of all degradates)	2.0	.02	0 to 0.2 0.2 to 1.0 1.0 and over	Unrestricted consumption One meal per week Do not eat
		Trace metals		
Arsenic	none	1.2	none	Use USEPA value for recreation fishers
Cadmium	none	4.0	none	Use USEPA value for recreation fishers
Mercury	1.0	.40	0 to 0.2 0.2 to 1.0 1.0 and over	Unrestricted consumption One meal per week Do not eat
Selenium	none	20.0	none	Use USEPA value for recreation fishers

[1] U.S. Food and Drug Administration (2000), Modified from Iowa Department of Natural Resources (2006).

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

[3] Iowa Department of Natural resources (2006).

Table 20. Results of analysis of selected organochlorine pesticides in whole or fillet fish-tissue samples collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions: ppm, parts per million is equal to milligrams per kilogram and micrograms per gram; USEPA, U.S. Environmental Protection Agency (2000); WRP, Wetlands Reserve Property; DDT, dichloro-diphenyl-trichloroethane; PCBs, polychlorinated biphenyls]

Site number (fig. 1)	Site name (whole fish or fillet samples)	Chlordane (ppm)	DDT (ppm)	Dieldrin (ppm)	PCBs (ppm)	Contamination level
1	Iowa River near Montour, IA[2]	0.0042	0.0332	0.0077	0.0063	Above USEPA Screening value for dieldrin
3	Onion Creek near Montour, IA[1]	.0001	.0030	.0004	0	None
5	Iowa River at Highway 49 near Tama, IA[2]	.0014	.0498	.0070	.0025	Above USEPA Screening value for dieldrin
7	Iowa River at WRP near Tama, IA[2]	.0041	.0722	.0146	.0164	Above USEPA Screening value for dieldrin

[1] Composite of fish tissues

[2] Fillets only

Table 21. Results of analysis of selected organochlorine pesticides in fish liver or liver dilution samples collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions; ppm, parts per million; WRP, wetlands reserve property; DDT, dichloro-diphenyl-trichloroethane; PCBs, polychlorinated biphenyls]

Site number (fig. 1)	Site name	Chlordane (ppm)	DDT (ppm)	Dieldrin (ppm)	PCBs (ppm)
1	Iowa River near Montour, IA[1]	0.0033	0.0875	0.0160	0.0053
3	Onion Creek near Montour, IA[2]	.0022	.0675	.0188	.0045
5	Iowa River at Highway 49 near Tama, IA[1]	.0003	0	.0184	.0018
7	Iowa River at WRP near Tama, IA[1]	.0002	.0552	.0113	.0059

[1] Whole liver

[2] Composite of fish liver

others, 2002) documented that detectable quantities of organic wastewater contaminants occur in U.S. streams at a national scale. Little is understood about these contaminants, and ongoing research is developing analytical tools to better understand the transport and fate of the chemicals as well as the potential effect that these contaminants may have on organisms. The three most notable organic contaminants that were found in the fish tissue sampled in this study were a group of flame-retardant chemicals known as polybrominated dephenyl ethers (PBDEs) as well as triclosan and its degradate methoxytriclosan (table 23).

A class of flame retardants known as PBDEs is a group chemicals that are added to products to make them more difficult to burn. Some of the more common products are found in electronic enclosures (televisions), plastics used for business equipment, and foam in the cushioning of furniture. They are released into the environment during manufacture of the products and through consumer use of the products. PBDEs do not dissolve easily in water, and therefore, large concentrations of PBDEs are not found in water (Centers for Disease Control, Agency for Toxic Substances and Disease Registry, 2004). The main source of human exposure to PBDEs may be through foods, particularly those with high fat content, such as fatty fish (Centers for Disease Control, Agency for Toxic Substances and Disease Registry, 2004). The fish-tissue samples collected on the Meskwaki Settlement had concentrations of PBDEs at all four of the sampling sites in both fillet and liver tissue. Although the flame retardant results in table 23 seem small, as of 2008 there are no regulations or advisory levels established for the consumption of fish with PBDEs present to make a determination if these values adversely affect human health.

Triclosan is a chemical found in many personal care products (antibacterial soaps, dish-washing detergents, toothpaste) and has been detected in water samples collected downstream from wastewater treatment facilities (Kolpin and others, 2002). Due to this relation to wastewater treatment facilities, it has been proposed that triclosan has the potential to be used as an indicator of human fecal contamination (Glassmeyer and others, 2005). Whole fish tissues sampled at Onion Creek site 3, which is downstream from the wastewater plant for the Meskwaki Settlement had concentrations

Table 22. Results of analysis of selected trace metals in fish-liver samples collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions; ppm, parts per million; WRP, Wetlands Reserve Property]

Site number (fig. 1)	Site name	Arsenic (ppm)	Cadmium (ppm)	Mercury (ppm)	Selenium (ppm)
1	Iowa River near Montour, IA	0.537	7.2	0.205	8.9
3	Iowa River at Highway 49 near Tama, IA	.401	3.3	.061	3.6
5	Iowa River at WRP near Tama, IA	.886	18.5	.285	12.2

Table 23. Results of analysis of selected organic wastewater contaminants in fish-tissue samples collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions; ND, not detected; ppm, parts per million; WRP, Wetlands Reserve Property]

Site number (fig.1)	Site name	Flame retardants (ppm)	Methoxytriclosan (ppm)	Triclosan (ppm)
		Whole fish or fillet samples		
1	Iowa River near Montour, IA[2]	0.0007	ND	ND
3	Onion Creek near Montour, IA[1]	.0352	0.0285	0.0532
5	Iowa River at Highway 49 near Tama, IA[2]	.0051	ND	ND
7	Iowa River at WRP near Tama, IA[2]	.0139	ND	ND
		Liver or liver dilutions		
1	Iowa River near Montour, IA[4]	.0088	ND	ND
3	Onion Creek near Montour, IA[3]	.0164	ND	ND
5	Iowa River at Highway 49 near Tama, IA[4]	.0112	ND	ND
7	Iowa River at WRP near Tama, IA[4]	.0126	ND	ND

[1] Composite of fish tissues

[2] Fillets only

[3] Composite of fish livers

[4] Whole liver

of 0.0532 ppm of triclosan and 0.0285 ppm of the degradation product methoxytriclosan. Accumulation of triclosan in fish tissue has been linked to possible endocrine disruption resulting in sexual dimorphic traits within fish anatomy. Foran and others (2000) documented that changes in fin length and nonsignificant trends in sex ratio suggest triclosan is potentially weakly androgenic. The effects from consumption of fish with concentrations of triclosan on human health are not understood at this time although ongoing research is taking place to determine the effects of triclosan exposure on the human population.

The fish-tissue sample results indicated the need for further study of contamination levels and potential health effects so that effective fish-consumption advisory levels can be developed for the Meskwaki Settlement.

Physical Habitat

Physical habitat assessments are important to the analysis of the overall condition of a river or stream. Ecological studies have implicated or directly shown that habitat is an important determination of the distribution and abundance of fishes and aquatic invertebrates in streams (Stalnaker and others, 1995). There is a significant relation between in-stream physical habitat and the survival of aquatic communities. This relation is such that high-quality instream habitat tends to increase aquatic species diversity. An example of this in regards to fish is that young, juvenile, and adult fish have different habitat type preferences. It has been documented that shallow shoreline and backwater areas are important to the rearing and refuge of small fish species as well as juvenile large species of fish (Greenberg and others, 1996). To assess the quality of the in-stream physical habitat for this study, the Qualitative Habitat Evaluation Index (QHEI) was determined to be most useful. The QHEI was first developed by the Ohio EPA in 1989 (Rankin, 2006). The QHEI index was selected for this study because it is used extensively in the Midwestern United States (Frimpong and others, 2005). The individual metrics used in the QHEI index are described in table 24. The values of the individual QHEI metrics are summed, and the results are assigned a narrative range or classification. Rankin (2006) cautions that habitat effects on aquatic life, however, occur at multiple spatial scales and that narrative ranges are general and not always predictable of aquatic assemblages at any given site. The results of the QHEI for the sampling sites on the Meskwaki Settlement are found in table 25.

The results of the QHEI for the Iowa River sites seem to be consistent with the results of the FIBI at the same Iowa River sites, which resulted in similar classifications of fair. One exception was the Iowa River at Highway 49 near Tama (site 5), which had an Iowa FIBI classification of poor (table 14); this again could be related to the difficult sampling conditions during the fish survey. However, the Ohio EPA FIBI indicated a fair classification for the same site. The Ohio FIBI is not as affected by the sample size as the Iowa FIBI. The Iowa River sites showed little sign of disturbance; the multiple series of meanders and bends along with the large riparian buffer zone are what increased the QHEI scores for the Iowa River sampling sites.

Onion Creek near Montour (site 3) had a QHEI classification of poor (table 25). This is not consistent with the FIBI classification, which had a result of fair (table 14). The metrics that comprise the QHEI reflect poorly on the Onion Creek site. Onion Creek is a stream that has been straightened to meet anthropogenic needs, which has resulted in a stream with characteristics that lack sinuosity and a lack of available habitat. A high degree of sinuosity typically provides channel characteristics that allow increased diversity of habitat and fauna (Barbour and others, 1999). Sinuosity allows for the absorption of the energy during high flows, protects the stream from excessive erosion and flooding, and provides refuge for benthic invertebrates and fish during storms (Barbour and others, 1999). The straightening of the channel on Onion Creek has adversely affected the quality of the in-stream habitat.

The FIBI for Onion Creek likely resulted in a classification of fair because recent rainfall resulted in a water-surface elevation above previously observed stages. The fish survey took place during a time when Onion Creek was able to provide stream margin habitat, which would lead to the potential for a more diverse fish community. Natural, variable

Table 24. Individual metrics for the Ohio Environmental Protection Agency Qualitative Habitat Evaluation Index (QHEI) used in physical habitat assessment.

Metric number	Metric name	Metric definition[1]
1	Substrate	Two parts—substrate type (does one type dominate?) and substrate quality (embeddedness). Maximum possible score is 20.
2	In-stream cover	Includes presence of in-stream cover type and amounts of cover. Maximum possible score is 20.
3	Channel morphology	Include four parts—sinuosity, development, channelization, and stability. Maximum possible score is 20
4	Bank erosion and riparian zone	Three parts—erosion, riparian width, flood-plain quality. Maximum possible score is 10.
5a	Pool and current	Includes maximum pool depth, channel width, and current velocity. Maximum possible score is 12.
5b	Riffle and run	Includes riffle depth, run depth, riffle/run substrate type, and embeddedness. Maximum possible score is 8.
6	Gradient	Metric score based on severity of gradient. Maximum possible score is 8.

[1] Adapted from Rankin (2006).

Table 25. Results of Qualitative Habitat Evaluation Index (QHEI) assessment of physical habitat data collected from the Meskwaki Settlement, central Iowa, 2007.

[See table 1 for site descriptions: Ohio EPA, Ohio Environmental Protection Agency; WRP, wetlands reserve property]

Site number (fig. 1)	Site number	Ohio EPA QHEI[1]	Classification
1	Iowa River near Montour, IA	54.5	Fair
3	Onion Creek near Montour, IA	32.5	Poor
5	Iowa River at Highway 49 near Tama, IA	54.5	Fair
7	Iowa River at WRP near Tama, IA	54.5	Fair

[1] Ohio EPA QHEI narrative ranges: greater than 75 excellent, 60–74 good, 45–59 fair, 30–44 poor, less than 30 very poor (Rankin, 2006).

flows create and maintain the dynamics of in-channel and flood-plain conditions and habitats that are essential to aquatic and riparian species (Poff and others, 1997). This increase in flow would have allowed fish species that had taken refuge in downstream habitats, such as the Iowa River, to travel upstream to utilize the new habitat that the rainfall had created.

The data used to calculate the QHEI for Onion Creek were collected under conditions with less streamflow than the fish survey. The results of the QHEI were representative of the conditions at the time of measurement.

Summary and Conclusions

In cooperation with the Sac and Fox Tribe of the Mississippi in Iowa (Meskwaki Nation), the U.S. Geological Survey conducted a 2-year baseline assessment of the chemical and biological quality of streams within the Meskwaki Settlement in central Iowa. The Meskwaki Nation is a federally recognized tribe that wishes to establish water-quality standards to safeguard the integrity of surface waters and aquatic biota within the settlement for the health and welfare of the tribal community. The settlement is drained by the Iowa River and four tributaries (Onion, Cattail, Raven, and Bennett Creeks). Water-quality samples were collected at three sites on the Iowa River, two sites on Onion Creek, and one site each on Cattail, Raven, and Bennett Creeks from April 2006 through July 2007. Biological and habitat assessments were conducted at all three sites on the Iowa River and the downstream-most site on Onion Creek from June through August 2007.

The physical, chemical, and biological compositions of surface water in the Iowa River and its tributaries are in a constant flux, both spatially and temporally, owing to the dynamic relation between climate, streamflow, stream morphology, and land-use practices. Water quality, therefore, typically falls within a range of values for a specific body of water under a specific set of conditions. It is this range that defines the baseline conditions for streams throughout the Meskwaki Settlement.

Water temperature, specific conductance, pH, and dissolved-oxygen concentrations did not indicate any adverse water-quality conditions during this study. The majority of surface water sampled within the Settlement was predominately a calcium-bicarbonate type. Grouping of major ion data on a trilinear plot indicate that Sites 2 and 3 on Onion Creek and Site 8 on Cattail Creek represent more urban influences in contrast with the Iowa River and Raven and Bennett Creeks, which largely represent agricultural influences. None of the samples analyzed for trace metals had concentrations exceeding the respective MCLs or the State of Iowa criteria for chronic or acute toxicity. Of the five analytes for which secondary MCL's exist, only manganese was found to exceed its respective SMCL of 50 micrograms per liter (μg/L).

High concentrations of soluble manganese may indicate anthropogenic input to the surface-water system, but it is unknown what the actual source(s) may be. About 62 percent of the nitrate samples collected from the Iowa River exceeded the USEPA MCL of 10 mg/L for drinking water as compared to 0 percent of the samples from Onion and Cattail Creeks and 43 percent from Raven and Bennett Creeks. Atrazine, simazine, and alachlor are on the State and USEPA's list of contaminants for primary drinking water but none were present in concentrations that exceeded their respective MCL. Chloripyrifos is regulated by the State and ranged in concentrations from 0.005 to 0.01 μg/L.

Tests were conducted to determine the presence of wastewater contaminants in water samples collected from Onion Creek upstream and downstream from the Meskwaki sewage lagoons outflow; Cattail Creek downstream from the tribal headquarters and central housing complex; and the three sites along the Iowa River. Of the 67 compounds tested for, only nine quantifiable detections were recorded, in addition to 217 unquantifiable (estimated) detections. Six of the nine compounds detected were from the Onion Creek Site 3 and included four perfume derivatives and an insect repellant. Phenol, of which there were three unquantifiable detections, is regulated by the State and ranged from estimates of 0.008 to 0.172 μg/L. Tests also were conducted to determine the presence of fuel compounds in water samples collected from the same sites as the wastewater samples and included toluene, benzene, ethylbenzene, xylene, and tert-butyl methyl ether (MTBE). Of the 34 samples collected, only toluene was detected at a reporting limit of 0.1 μg/L.

Bacteria samples were collected at all sites during this study and included *Escherichia coli* (*E. coli*) and fecal coliform. For waters designated as Class "A", primary contact recreation, the State of Iowa's maximum allowable *E. coli* content has been set at 235 colony forming units per 100 milliliters (cfu/100 mL) from March 15 through November 15, except when affected by surface runoff. Between April and October 2006 and 2007, *E. coli* densities in samples from the Iowa River within and contiguous to the settlement ranged from less than 10 to 1,600 cfu/100 mL with a median value of about 160 cfu/100 mL. *E. coli* densities in tributaries north of the Iowa River ranged from 73 to 880 cfu/100 mL in Onion Creek at the upstream site 2, and from 130 to 440,000 cfu/100 mL downstream from the sewage lagoons (site 3). *E. coli* densities measured south of the Iowa River in samples from Raven and Bennett Creeks ranged from 1,100 to 23,000 cfu/100 mL and 270 to 33,000 cfu/100 mL, respectively.

Streambed sediment samples were collected in conjunction with the biological assessment from the three sampling sites along the Iowa River (Sites 1, 5, and 7) and from Onion Creek downstream from the sewage lagoons.

The USGS and the Meskwaki Nation, with assistance from the USFWS, collected and identified fish, benthicmacroinvertebrate, periphyton, and physical habitat data at four sites within the Meskwaki Settlement to provide baseline information. Selected Indexes of Biologic Integrity (IBI) were used that provide quantifiable values to assess the current condition of the fish and macroinvertebrate communities. The index scores were classified on the basis of a tiered system that places the scores into a classification of excellent, good, fair, or poor. The classifications then were compared to Iowa DNR reference sites to evaluate how the Meskwaki sites compare in the State of Iowa. The algae community was assessed using two separate metrics—one based on a weighted average of taxa by using a ratio of high to low nutrient enrichment indicator species and the other based on the percentage of total taxa richness composed of eutrophic indicator species present. These metric scores provide a quantifiable value to assess the level of nutrient enrichment and trophic condition that exists. An assessment of the physical habitat was determined using a qualitative technique. Additionally, fish-tissue samples were collected and analyzed for selected organochlorine, trace metal, and organic wastewater contaminant bioaccumulation.

The fish IBI indicated that the health of the fish population was similar to what was expected within the level IV ecoregion (47f) in Iowa. On the basis of index scores, the Iowa River sites and the Onion Creek site all indicated a fair classification with one exception, the Iowa River at Highway 49 near Tama (site 5), which had a poor classification. This poor classification could be related to the difficult sampling conditions.

The benthic macroinvertebrate IBI indicated that the health of the macroinvertebrate population was good at all of the sites other than the Iowa River near Montour (site 1), which was rated fair. A classification of good could be considered better than what would be expected at comparable streams within ecoregion 47f.

The periphyton metrics for the species that were present indicated that the potential for eutrophic conditions existed. The water within the Meskwaki Settlement was considered nutrient enriched, leading to greater potential for primary production and possibly a eutrophic condition.

The insecticide dieldrin was detected in the fish liver tissue at all four of the sites sampled. Dieldrin also was found in fillet tissue samples at the three Iowa River sites at concentrations above the USEPA screening value. Detections at the Onion Creek near Montour (site 3) were confined to the liver tissue. The USEPA screening values are guidelines and not regulatory; they are provided as a management tool for natural-resource managers. Both cadmium and mercury were found in liver tissue samples at concentrations that would warrant fish consumption advisories if these levels were detected in the fillet fish tissue. Of the organic wastewater contaminants that were found in the fish tissue sampled in this study, there were three that were most notable—a group of flame-retardant chemicals known as polybrominated dephenyl ethers (PBDEs) as well as the antibacterial agent triclosan and its degradate methoxytriclosan. These contaminants currently (2008) do not have any fish consumption advisory recommendations by any of the regulatory agencies in Iowa.

The qualitative habitat evaluation index (QHEI) was used to assess the condition of the physical habitat. The Iowa River sites resulted in a QHEI score and a classification of fair. In contrast, the Onion Creek site located downstream from settlement sewage lagoons resulted in an evaluation of poor. These results were indicative of the conditions observed during data collection. Onion Creek has been straightened throughout the majority of its drainage. This has lead to a loss of sinuosity, which can lead to the inability of the stream to develop and provide in-stream habitat for fish and invertebrates during all flow conditions. Sinuosity and in-stream habitat are important factors in the QHEI used to provide this analysis. In contrast, the Iowa River sites scored well in the habitat assessment due to several factors including the greater number of meanders and bends that are indicative of a sinuous stream. The Iowa River sites also had large riparian zones.

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Glossary

Analyte A substance or chemical constituent that is undergoing analysis.

Androgenic Pertaining to the stimulation or control of the development and maintenance of masculine characteristics.

Anthropogenic Caused or produced by humans, commonly used in reference to environmental effects.

Backwater Water backed up or retarded in its course as compared with its normal or natural condition of flow.

Base flow Sustained or fair-weather runoff composed largely of groundwater discharge, in most streams.

Baseline data A reference set of initial conditions used for comparison with data collected at a later time for the purpose of interpreting changes over time.

Benthic Pertaining to the biogeographic region that includes the bottom of a lake, river, sea, or ocean.

Ephemeral A stream or portion of a stream which flows only in direct response to precipitation, and whose channel is at all times above the water table.

Eutrophic Characterized by an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes shallow water of oxygen in summer.

Health Advisory Level (HAL) Also known as the Maximum Contaminant Level Goal (MCLG), the level below which no adverse noncarcinogenic health effects should result from a lifetime of exposure, assuming a consumption of 2 liters per day of drinking water. Exceeding this value does not mean that a specific set of adverse health effects will occur in humans ingesting the water. The risk of adverse health effects, however, increases.

Lipophilic Having an affinity for, tending to combine with, or capable of dissolving in lipids or fatty tissue.

Macroinvertebrate Traditionally used to refer to aquatic invertebrates including *insects*, *crustaceans*, *molluscs* and *worms*, which inhabit a river channel, pond, lake, wetland, or ocean and that are visible to the naked eye.

Maximum Contaminant Level (MCL) Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable regulations established by the U.S. Environmental Protection Agency.

Microsiemens Metric unit of the measure of electric conductance.

Organochlorine An *organic compound* containing at least one *covalently bonded chlorine* atom. Organochlorines are persistent in the environment because they are resistant to rapid decomposition; they are, however, readily sorbed to sediment. Many pesticides used in society today are classified as organochlorines.

PAHs Polycyclic aromatic hydrocarbons are produced as byproducts of fuel burning or incomplete combustion of organic materials.

Periphyton A complex matrix of algae attached to submerged substrata in almost all aquatic ecosystems.

Riparian Pertaining to the banks of a river or stream.

Secondary Maximum Contaminant Level (SMCL) Non-enforceable guidelines regulating contaminants that may cause cosmetic or aesthetic effects in drinking water.

Sinuosity The ratio of channel length between two points on a channel to straight line distance between the same two points; a method of measuring the meandering of a river.

Storm flow Increase in stream discharge resulting from direct precipitation and surface runoff entering stream channels promptly after rainfall.

Synoptic measurements Measurements taken concurrently at multiple locations for the purpose of documenting conditions at a given time.

Water year In U.S. Geological Survey reports dealing with surface-water supply, the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending September 30, 2007, is called the “2007 water year.”

Wetlands Reserve Property Property voluntarily set aside by the tribe to protect, restore, and enhance wetlands on the settlement through technical and financial support by the U.S. Department of Agriculture’s Natural Resource Conservation Service.

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