Contract Report 2005-13

Overview of Recommended Phase III Water Quality Monitoring

Fox River Watershed Investigation

by

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Prepared for the Fox River Study Group

December 2005

Illinois State Water Survey
Center for Watershed Science
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Abstract

This water quality monitoring plan describes the monitoring recommended to provide data needed to improve calibration of the watershed loading (HSPF) and receiving stream (QUAL2) models for the Fox River watershed. Various monitoring schemes were considered in light of available resources. Data gaps identified in the Phase I report as well as preliminary model simulations also were considered in preparing this monitoring plan. Because available resources are a limiting factor, closing data gaps is the primary objective of the proposed monitoring plan. Should additional funds become available, specific additional data collection scenarios would enhance the reliability of the models. These recommendations are written to be incorporated by the Fox River Study Group, Inc. (FRSG) into the request for proposals (RFP) to conduct the monitoring.

The proposed monitoring requires installation and operation of the following: (1) 9 hourly precipitation stations, (2) 11 stream flow gages, (3) 29 ambient water quality monitoring sites, and (4) 16 stations with continuous operation during selected low flow periods. In addition, active combined sewer overflows shall be sampled, five sediment oxygen demand tests shall be performed on the Fox River mainstem, and bed substrate from ten sites shall be analyzed. Preliminary site locations are identified.

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Study Background

The Illinois Environmental Protection Agency (IEPA) *Illinois Water Quality Report 2000* (IEPA, 2000) listed parts of the Fox River in McHenry and Kane Counties and part of Little Indian Creek as impaired. The IEPA 2002 report (IEPA, 2002) listed the entire length of the Fox River in Illinois as well as Nippersink, Poplar, Blackberry, and Somonauk Creeks, and part of Little Indian Creek as impaired. The IEPA included the Fox River and these tributaries on its list of impaired waters, commonly called the 303(d) list (IEPA, 2003). The most prevailing potential causes for listing were flow alterations, habitat, sedimentation/siltation, dissolved oxygen (DO), suspended solids, excess algal growth, fecal coliforms, and polychlorinated biphenyls (PCBs). The most prevailing potential sources for listing were hydromodification and flow regulation, urban runoff, and combined sewer overflows.

The Fox River Study Group, Inc. (FRSG) has embarked on an effort to investigate water quality problems and to develop a watershed plan to preserve and improve water quality of the Fox River and its tributaries. The FRSG is a diverse coalition of stakeholders representing municipalities, county government, sanitary districts, and environmental and watershed groups throughout the Fox River watershed below Stratton Dam. To accomplish its goals, the FRSG has adopted a multi-year, four-phase plan to assess water quality issues, conduct monitoring, and develop a suite of comprehensive computer simulation models of the watershed. When completed, these models will be invaluable tools to help identify pollution sources and quantify the likely impact of measures to remedy existing water quality issues throughout the watershed, as well as to identify and prevent potential new problems. Present efforts focus on the Illinois portion of the Fox River watershed below Stratton Dam.

Two types of water quality models are being developed by the ISWS. A watershed loading model is being prepared for each major tributary to the Fox River to provide insights about the impacts of land use change, fate and transport of pollutants from both point and nonpoint sources, and watershed hydrology. This type of model can be used to forecast outcomes of changes in flow volumes and/or loading to assist with decision-making and establishment of management practices. Watershed models will be an especially useful tool for managing tributary watersheds and evaluating benefits of preventative actions, such as implementing conservation practices that reduce pollutant loading associated with conventional development patterns. A river (receiving stream) water quality model is needed to assess the complex interactions and chemistry of the various constituents in the Fox River mainstem, to simulate pollutant concentrations, and to identify ‘hot spots’.

Monitoring Specifications

Overview

Monitoring outlined herein is designed to complement and enhance existing monitoring data and programs. It will provide important data for continued model development, calibration, and validation, e.g., quantifying loads and characterizing DO regime during low-flow conditions.

Sampling sites are expected to be located on the Fox River mainstem and on major tributaries near their confluence with the Fox River. In addition, a small number of sites in selected tributary watersheds are necessary for calibration of the basic modeling unit (hydrologic response unit or HRU). Preliminary locations categorized by their importance are shown on the attached maps (Figures 1-5). The exact location of each site will be determined depending on accessibility and/or other considerations after the contractor is selected.

Water quality sampling will characterize a wide range of conditions including, but not limited to, fecal coliforms and nutrient loads during storm events as well as continuous monitoring and associated discrete water quality sampling focused on characterizing DO regime during low-flow periods. Monitoring is expected to continue for a minimum of three years, contingent upon funding.

Monitoring Objectives

Monitoring at various sites will be conducted to achieve the following objectives:

(1) *Precipitation Characterization*. Nine hourly precipitation stations should be installed and operated throughout the Fox River watershed to complement the existing network of climate stations (Figure 1). High-priority locations should be given preference when cost prohibits complete installation.

(2) *Load Characterization.* A network of monitoring stations should be installed and operated in the Fox River watershed. Stream flow and ambient water quality concentrations will be measured over a wide range of flow conditions to enable estimation of loads. Sampled flows should span at least the range of discharges defined by the 20-80% annual exceedence flow determined from the Illinois Streamflow Assessment Model or ILSAM (ISWS, 2005a). High-priority locations should be given preference when cost prohibits complete installation.

> (a) <u>Stream Flow Gages</u>. There are nine active United States Geological Survey (USGS) stream flow gages in the study area that coincide with recommended sites: three on the mainstem of the Fox River and six near the outlets of major tributaries. Additional eleven stream flow gages should be installed and operated to complement the existing network of gages (Figure 2): three new gages on the Fox River mainstem, six new gages near the outlets of major tributaries to the Fox River, and two currently inactive USGS gages (South Elgin on the Fox River mainstem and Flint Creek).

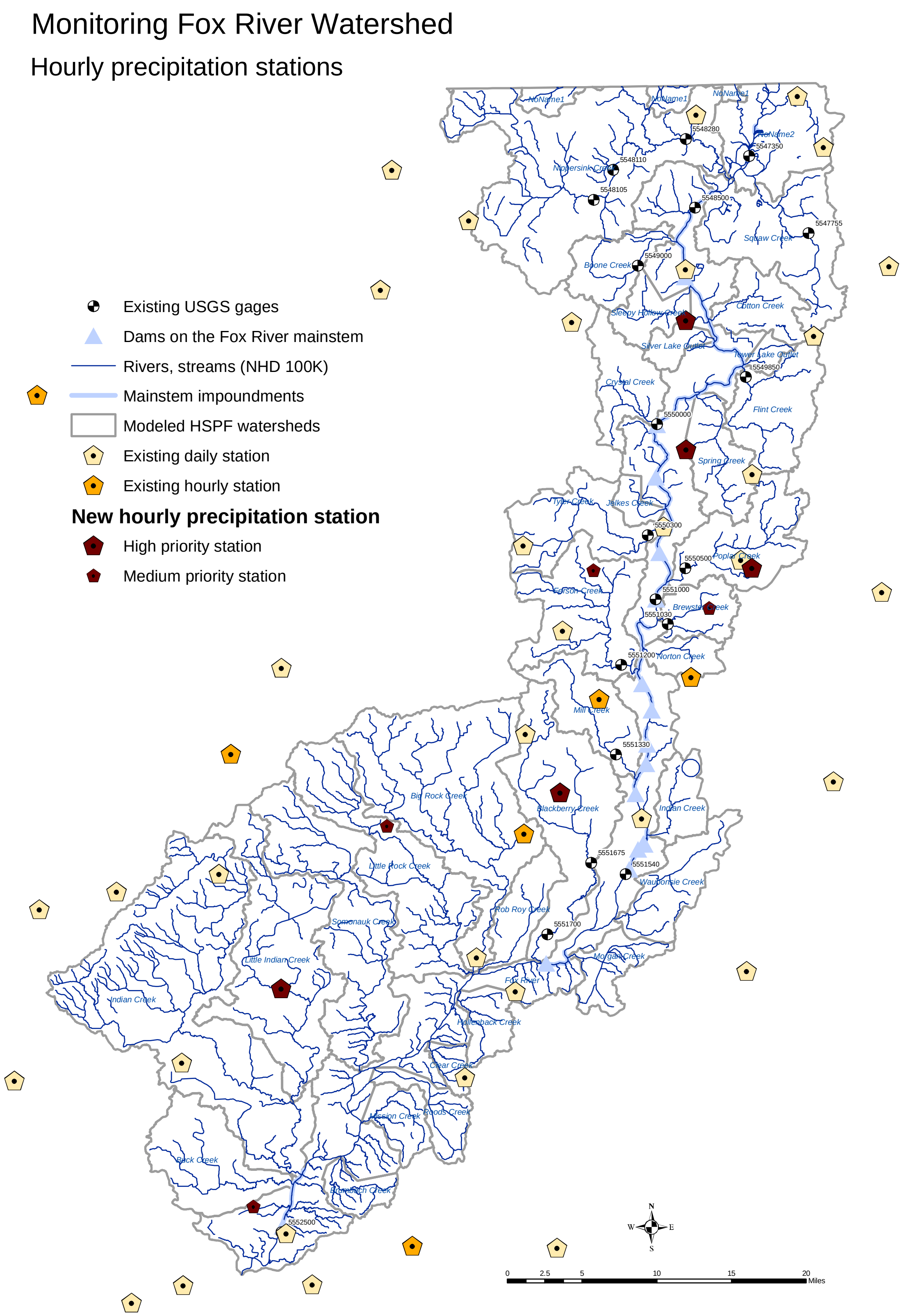

Figure 1. Location of precipitation stations

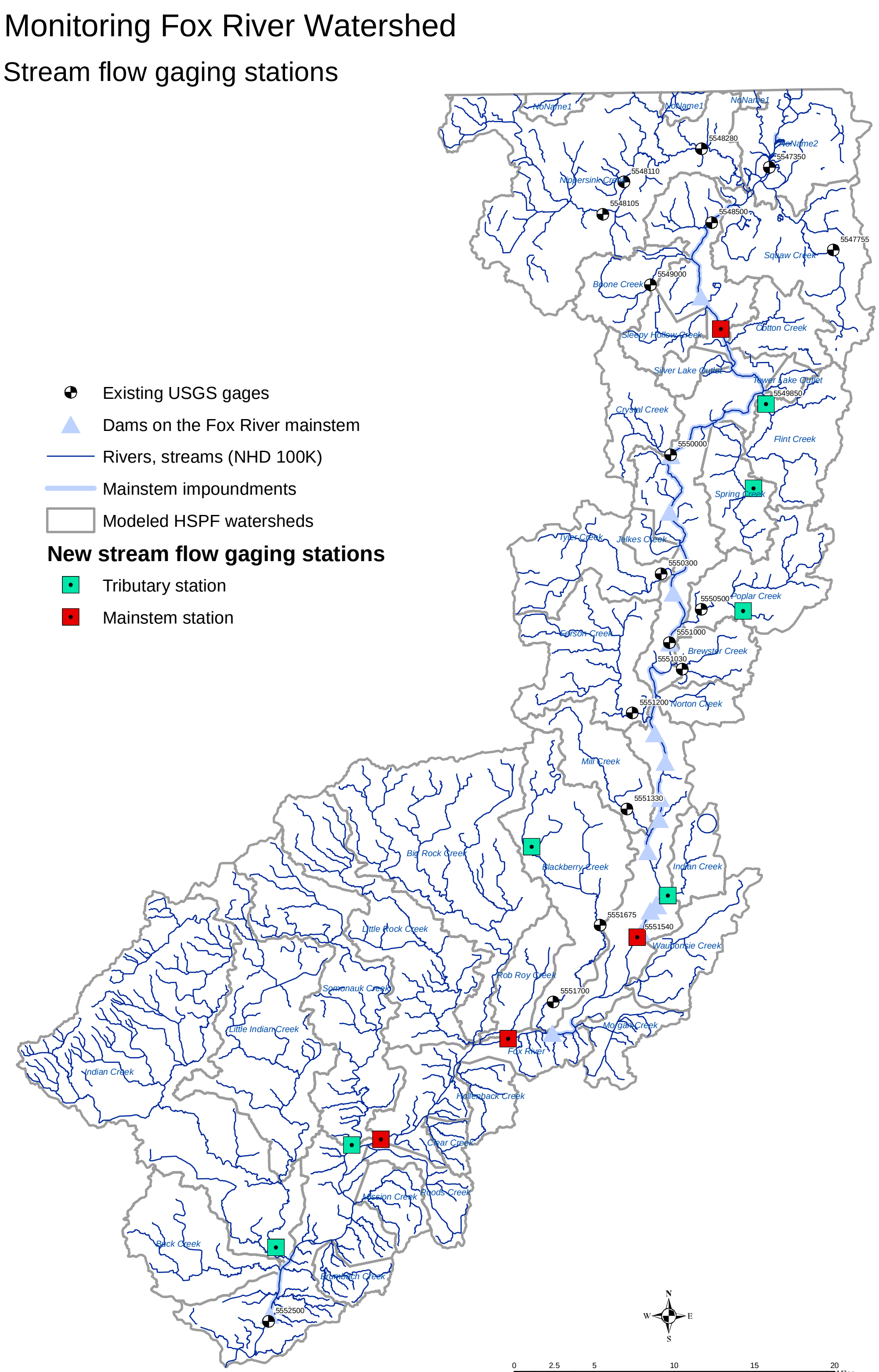

Figure 2. Location of stream flow gaging stations

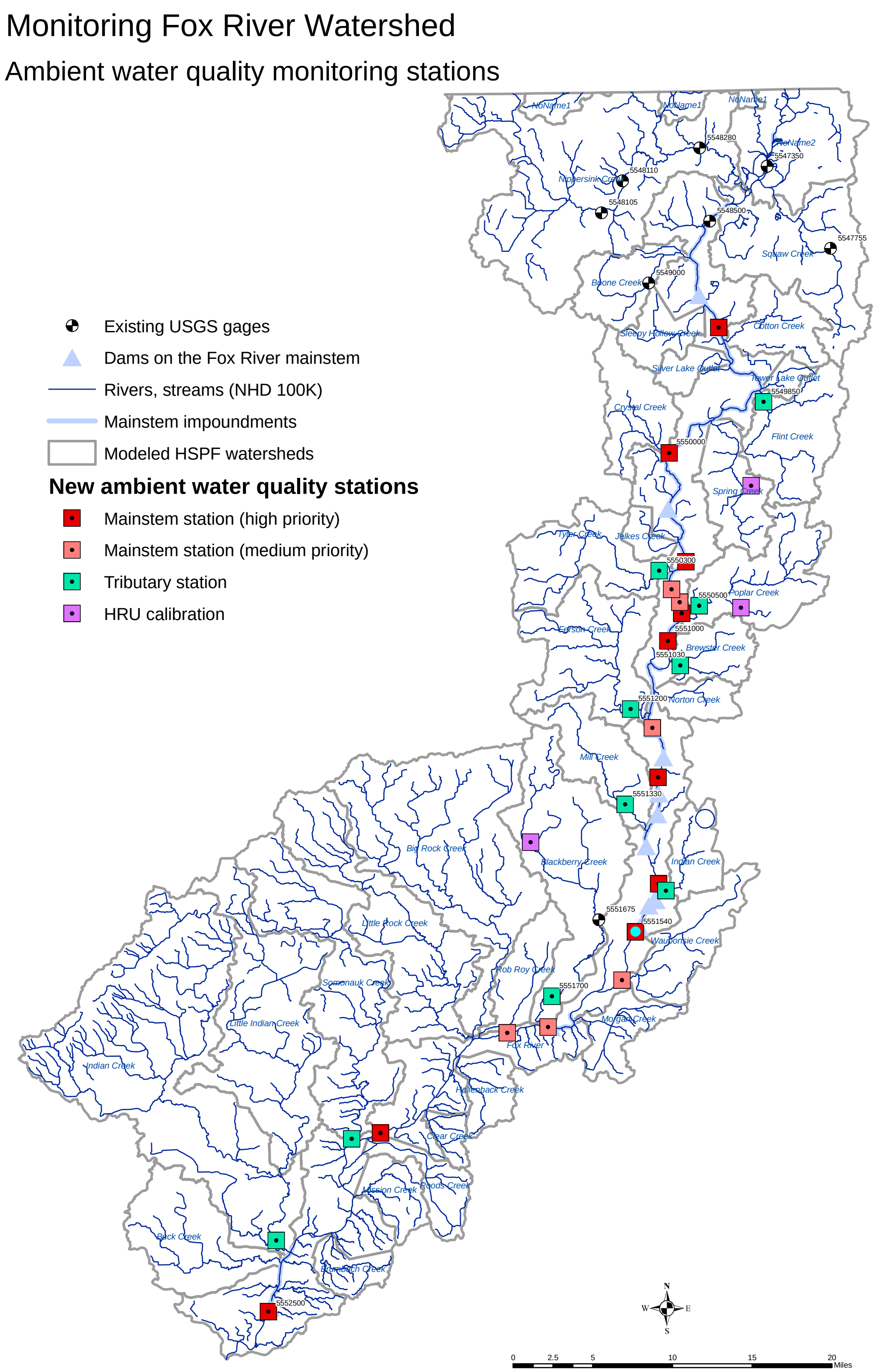

Figure 3. Location of ambient water quality monitoring stations

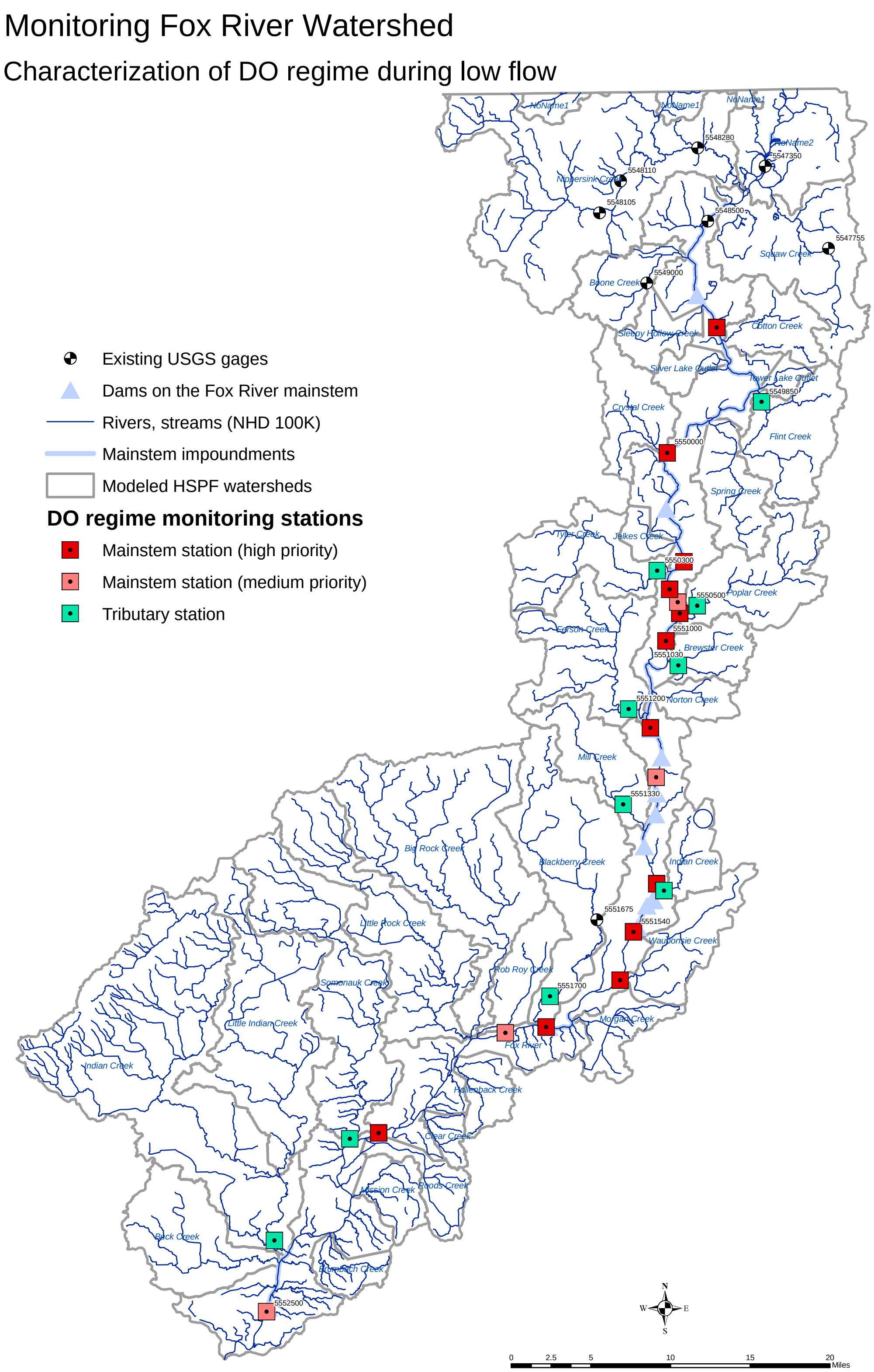

Figure 4. Location of monitoring stations for characterization of DO regime

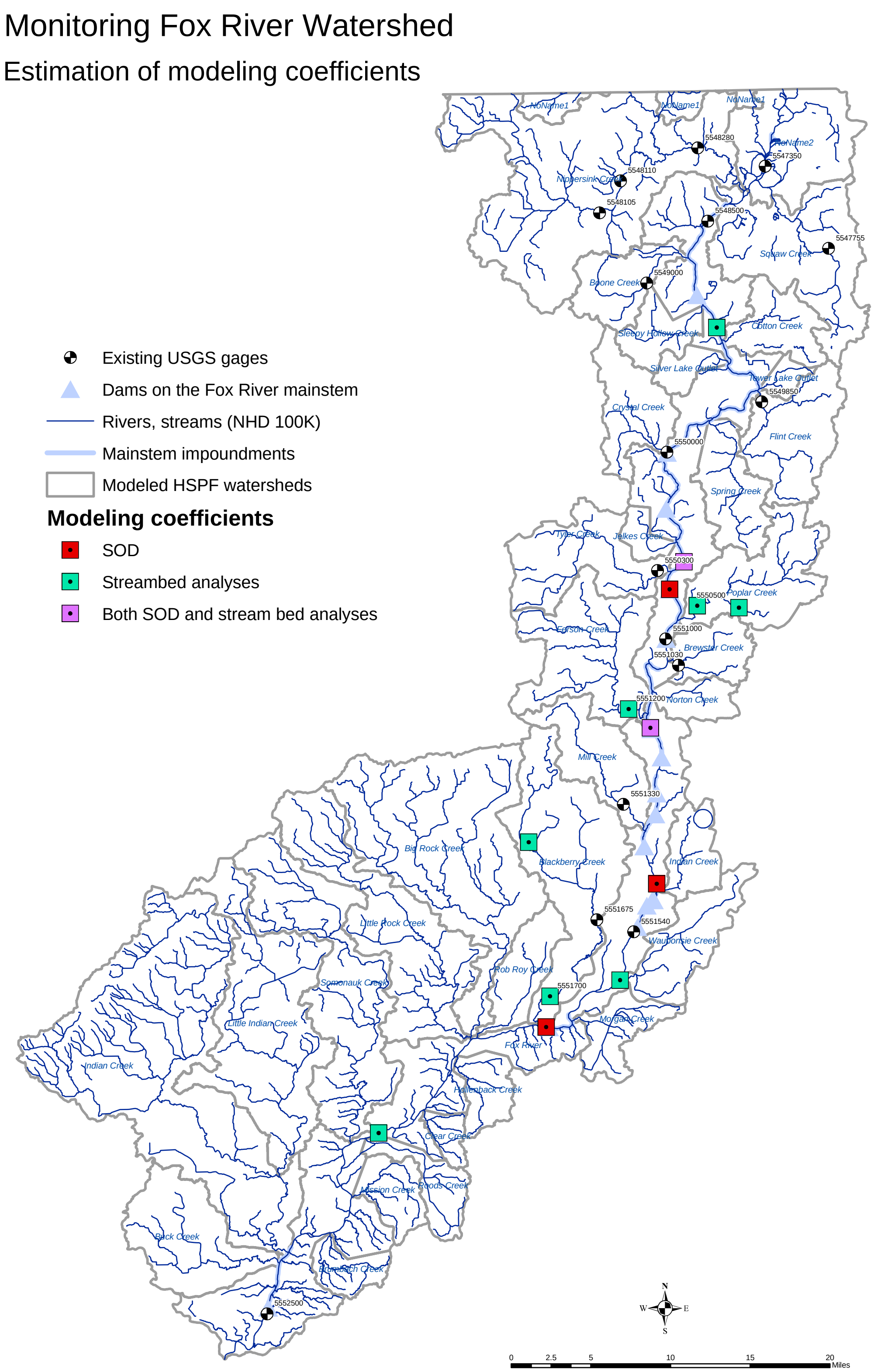

Figure 5. Location of stations for determination of modeling coefficients

(b) Ambient Water Quality Sampling. Twenty-nine ambient water quality monitoring sites should be established and operated throughout the Fox River watershed (Figure 3). The sites include all active and proposed stream flow gaging sites as described above in objective (2)(a) and additional locations. Frequency and number of ambient water quality samples should be sufficient to include a range of flow conditions for determination of loads for sampled constituents. This will require intensive sampling during runoff events and routine (discrete) sampling at regular intervals during periods between storm events. At least one sample should be taken on all tributary sites concurrently with the deployment of datasondes along the Fox River mainstem as described below in objective (3). Sampling for benthic chlorophyll is expected to be less frequent. Discharge should be determined when discrete samples are taken and periodically during runoff events.

(c) Combined Sewer Overflow (CSO) Sampling. The cities of Aurora and Elgin use a combined sewer system with several CSOs. Active CSOs should be sampled to help determine loads during and after runoff events. All existing CSOs are shown in Figures 6 and 7.

(3) *Characterization of DO Regime during Low Flow*. Sixteen stations located on the Fox River mainstem should be operated continuously for at least 72 hours during two or three summer low-flow periods (Figure 4). Selected sites characterize impoundments as well as free-flowing areas. Where possible, datasonde deployment should coincide with locations used in the Santucci and Gephard (2003) study. Discrete sampling for nutrients and chlorophyll should occur at both mainstem and tributary stations at regular intervals when datasondes are deployed. At least one sample also should be taken and analyzed for benthic chlorophyll at all stations during this time. Frequency and number of discrete samples should be sufficient to describe diurnal changes in biochemical processes controlling DO cycle. Ambient water quality sites located on tributaries [see objective (2)(b) above] should be sampled at least once during datasondes deployment. Low flows are defined as those less than the 70% exceedence discharge for the given month. Discharges corresponding to specific flow frequencies shall be computed using the ILSAM model (ISWS, 2005a).

(4) *Estimation of Modeling Coefficients.* Five Sediment Oxygen Demand (SOD) tests should be conducted in the Fox River mainstem during low-flow periods concurrently with datasonde deployment. A sample of bed substrate should be collected at ten sites and analyzed for particle distribution and nutrient and organic content. Sites selected for modeling coefficient estimation are shown in Figure 5.

Sampling Locations

Several tributaries will be monitored near their confluence with the Fox River. These include: Blackberry Creek, Brewster Creek, Ferson Creek, Flint Creek, Indian Creek (near Aurora), Indian Creek (near Wedron), Mill Creek, Poplar Creek , Somonauk Creek, and Tyler Creek. Additional stations are located on tributaries to Blackberry Creek, Poplar Creek, and Spring

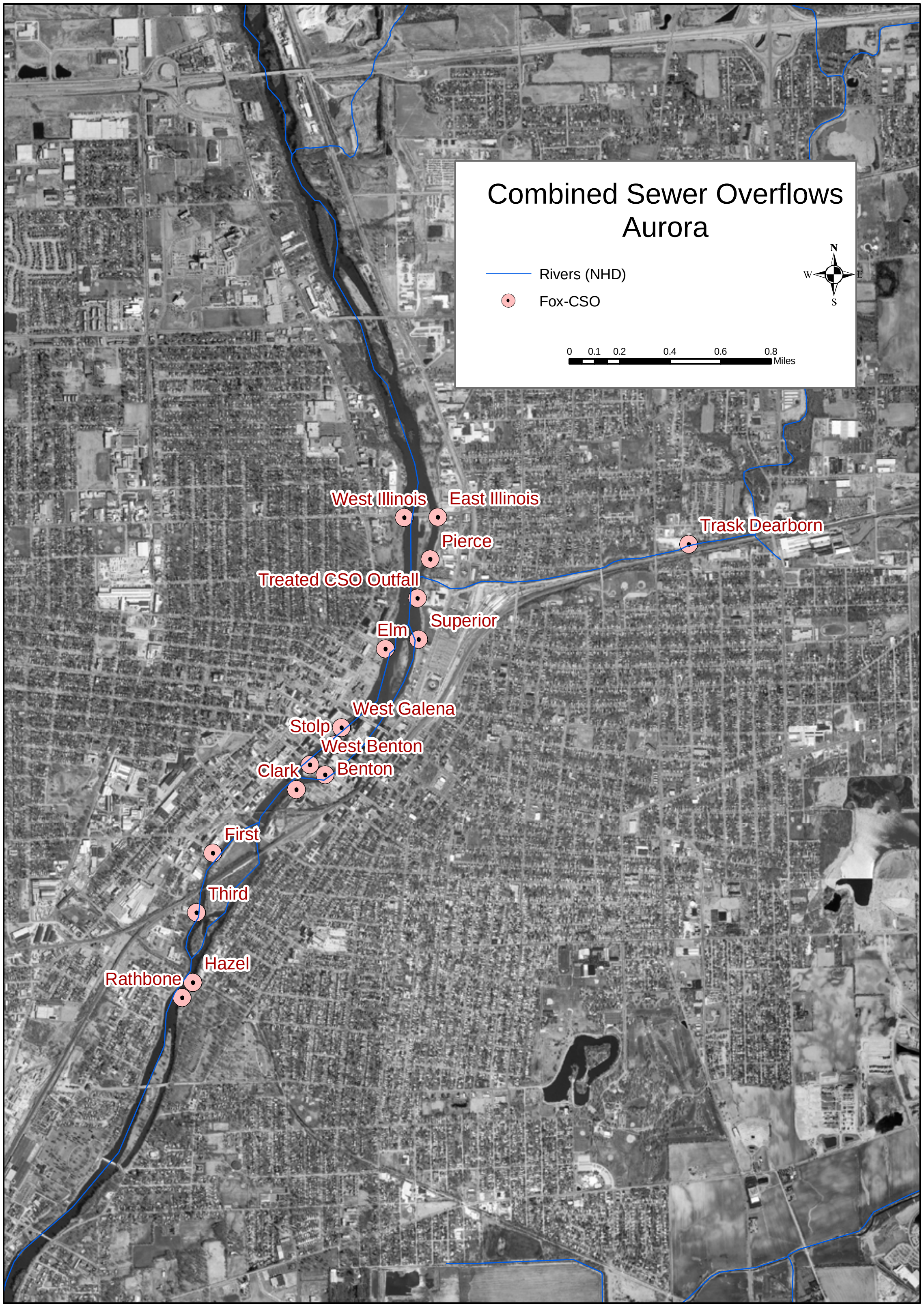

Figure 6. Location of CSOs in Aurora

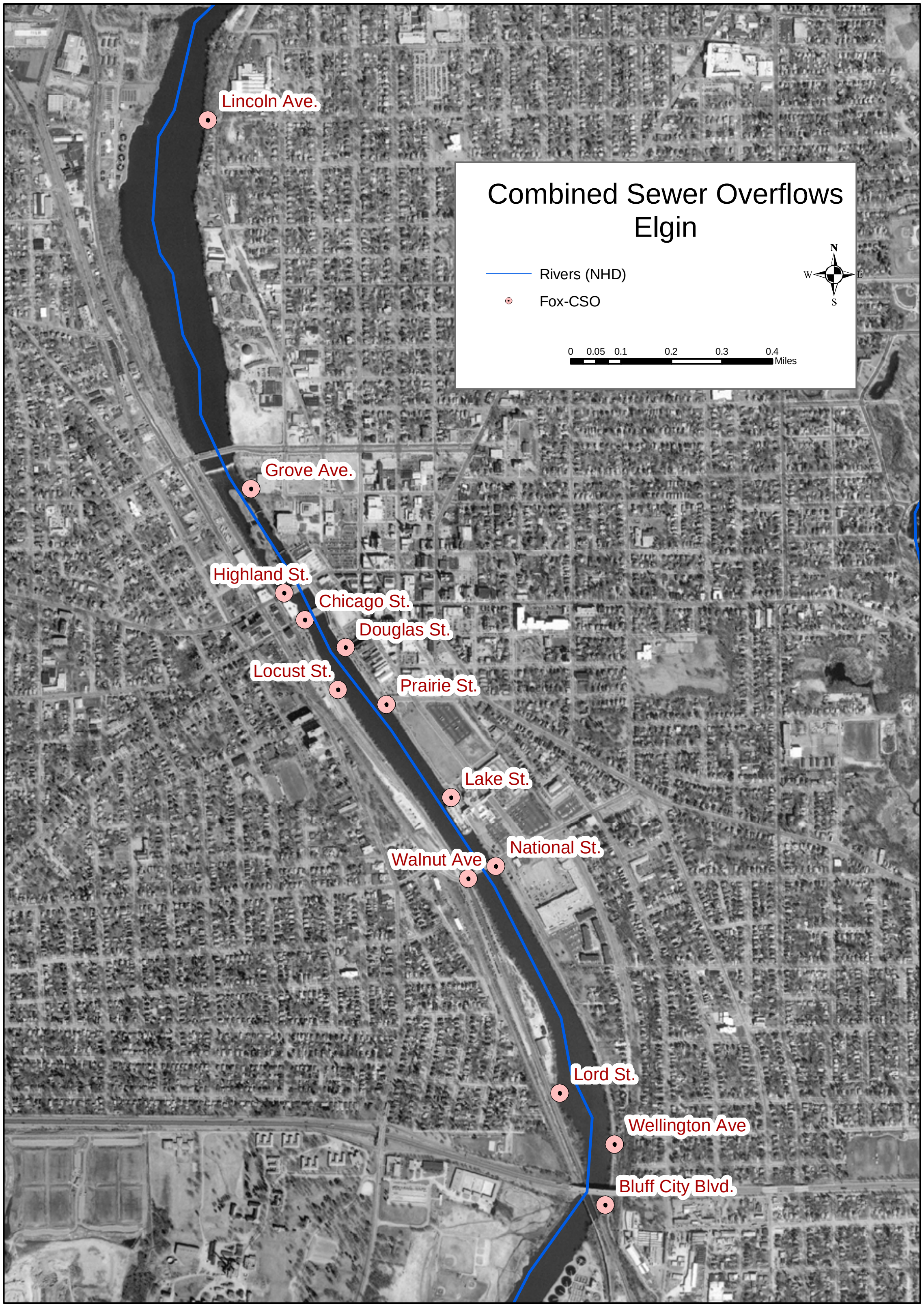

Figure 7. Location of CSOs in Elgin

Creek. Stations are shown (Figures 1-5). Table 1 categorizes all stations based on priority and provides monitoring details for each station.

Sampling Methods and Equipment

Precipitation Gages

Precipitation gages used for this project should be capable of operation throughout the year. Achieved accuracies should be within 0.5% (full scale) or 1% (1 inch/hour intensity), depending on the type of sensing mechanism selected. Calibration and maintenance procedures should follow those supplied by the equipment manufacturer.

Unit and final data for precipitation shall be delivered to the FRSG within 3 months of the conclusion of each 12-month data collection period.

Stream Gaging

Collection of stage data and development of rating curves will follow accepted USGS methodologies as outlined by Rantz et al. (1982), Buchanan and Somers (1982), Carter and Davidian (1968), Kennedy (1983), and others. This will include the requirement that stage measurements achieve primary record accuracies of 0.01 foot or less.

Sufficient discharge measurements will be made to provide adequate information for development of an accurate rating in the shortest time frame feasible for each station. This may necessitate collection of discharge information during nontraditional work hours. For those sites at which a traditional stage discharge rating is not applicable, methodologies used to determine discharge still will follow accepted USGS standard procedures for the selected type of gaging installation.

Unit and final data for stage and discharge or other unit values shall be delivered to the FRSG within 3 months of the conclusion of each 12-month data collection period. Calibration and maintenance procedures should follow those supplied by the equipment manufacturer. Unit value data will be archived and made available to all interested parties after review and acceptance by the FRSG for the duration of the project. A complete record of all unit value and final data, in an agreed upon database format, shall be submitted to the FRSG upon project completion.

Sediment Sampling

Suspended sediment samples should be collected at all 29 ambient water quality stations. Techniques and equipment used to collect these samples were standardized by the Federal Interagency Sedimentation Project (FISP) and are described in Guy and Norman (1970), Edwards and Glysson (1988, 1999), Shelton (1994), and specific equipment manuals and documentation provided by the FISP (1952, 1953, 1963). The purpose for collection of

Table 1. List of Monitoring Stations (H: high-priority station, M: medium-priority station)

Category	*Water body*	*Stream gage*	*Ambient water quality monitoring (including suspended sediment)*		*DO characterization during low flow*		*Modeling coefficients measured*
			Routine (discrete) sampling	*Storm events*	*Continuous*	*Tributary sample*	
HRU	Tributary to Blackberry Creek	H	H	H			Substrate
	Tributary to Poplar Creek	H	H	H			Substrate
	Tributary to Spring Creek	H	H	H			
Mainstem	Fox River	(USGS gage)	H	H	M		
	Fox River	H	H	H	H		Substrate
	Fox River	M	M	M	M		
	Fox River		M	M	H		SOD
	Fox River		M	M	H		Substrate
	Fox River	H (reinstate USGS gage)	H	H	H		
	Fox River		H	H	H		SOD
	Fox River		H	H	M		
	Fox River		M	M	H		SOD, substrate
	Fox River	(USGS gage)	H	H	H		
	Fox River		H	H	H		
	Fox River		M	M	M		
	Fox River		M	M	H		SOD
	Fox River		H	H	H		SOD, substrate
	Fox River	(USGS gage)	H	H	H		
	Fox River	H	H	H	H		Substrate
Tributary near the confluence with the Fox River	Blackberry Creek	(USGS gage)	H	H		H	Substrate
	Brewster Creek	(USGS gage)	H	H		H	
	Ferson Creek	(USGS gage)	H	H		H	Substrate
	Flint Creek	H (reinstate USGS gage)	H	H		H	
	Indian Creek (Aurora)	H	H	H		H	
	Indian Creek (Wedron)	H	H	H		H	
	Mill Creek	(USGS gage)	H	H		H	
	Poplar Creek	(USGS gage)	H	H		H	Substrate
	Somonauk Creek	H	H	H		H	
	Tyler Creek	(USGS gage)	H	H		H	

suspended sediment samples is to determine the physical and geotechnical properties of transported sediments and to collect sufficient concentration data to determine the sediment discharge for selected sites. Procedures to determine sediment discharge should follow accepted USGS practices as described in *Determination of Fluvial Sediment Discharge* (FISP, 1963), Porterfield (1972), and others.

It is envisioned that automated pump samplers will be used for this work effort. Because pumped samples are neither depth-integrated nor isokinetic samples, it is especially important to conduct adequate single vertical sampling, and cross-sectional and point sampling to ascertain the representativeness of pumped samples collected. Such quality assurance and quality control (QA/QC) samples should be collected across the expected range of flows. In addition, pump samplers chosen for deployment should be capable of maintaining USEPA-recommended line speeds of at least 2 feet/second at maximum head for the sites at which samplers are deployed.

Data on the size of material comprising the streambed, across the entire channel and including floodplains, are essential for study of the long-range changes in channel conditions and for computation of unmeasured or total load (Edwards and Glysson, 1988). Proper selection of bed material samplers will be determined by water depths and velocities present at the intended sampling site. After selection of proper equipment, sufficient samples should be collected across a stream transect to ensure a representative sample: normally 10-20 samples from the entire cross section.

Unit and final data for suspended sediment concentration and loads shall be delivered to the FRSG within 3 months of the conclusion of each 12-month data collection.

Discrete Water Quality Sampling

Routine and storm sampling should be conducted at all 29 ambient water quality stations. Methods used to collect discrete water quality samples should follow accepted methods described in Ward and Harr (1990), Shelton (1994), Friedman and Erdmann (1982), and Clesceri et al. (1989). Constituents analyzed in a sample are discussed in the next section (Constituents and Analytical Methods).

Equipment and methods used should be designed to collect samples representative of ambient stream conditions at the time of collection, and sampling frequency should be sufficient to capture temporal changes in water quality as well as changes in response to storm events at a given site. Thus, care should be taken to avoid sample contamination through sampler design, deployment, or operator error. Strict adherence to published holding times for sample analytes must be observed and any noncompliance identified in the final data. Sufficient QA/QC samples, including cross sections, duplicates, standard, and trip blanks, for all types of sampling equipment used should be collected.

Calibration and maintenance procedures should follow those supplied by the equipment manufacturer. Unit and final data for constituent concentration and loads shall be delivered to the FRSG within 3 months of the conclusion of each 12-month data collection.

Continuous Water Quality Sampling

This project requires collection of continuous water quality information at 16 stations on the Fox River mainstem. Measured parameters will include DO, temperature, pH, conductivity and chlorophyll *a*. Use, including site selection, operation, calibration, data reduction and analysis, of continuous water quality monitors should follow accepted methods described in Wagner et al. (2000). Additional information can be obtained from internal documents of such agencies as the Illinois State Water Survey and the Metropolitan Water Reclamation District of Greater Chicago, which have made substantial efforts to standardize the collection of continuous water quality data.

Maintenance procedures should follow those supplied by the equipment manufacturer. Unit and final data for constituent concentration and loads shall be delivered to the FRSG within 3 months of the conclusion of each 12-month data collection period.

Constituents and Analytical Methods

Water samples are to be collected and analyzed using US EPA-approved protocols and procedures if available. For those procedures where US EPA-approved methods do not exist (e.g., SOD), proposed protocols should be based on those available in the peer-reviewed literature and approved in advance by the FRSG. Any laboratories analyzing the samples must be accredited and certified for constituents analyzed.

Samples will be analyzed for the following constituents:

- Fecal Coliform
- Nitrate
- Nitrite
- Ammonia
- Total Kjeldahl Nitrogen (TKN)
- Dissolved Reactive Phosphorus (DRP)
- Total Phosphorus (TP)
- Biochemical Oxygen Demand (BOD_5)
- Suspended Sediment
- DO
- pH
- Temperature
- Conductivity

In addition, samples collected on mainstem and tributary outlet sites will be analyzed for:

- Suspended Chlorophyll a
- Benthic Chlorophyll a (limited sampling on mainstem only)

Benthic chlorophyll *a* shall be analyzed in a limited number of samples, including, but not limited to, samples taken during continuous monitoring.

All sampling and analysis protocols and procedures will be incorporated into a quality assurance project plan (QAPP) for the project approved by the FRSG before monitoring efforts begin.

Additional Specifications

Quality Assurance Project Plan (QAPP). A QAPP should be prepared and submitted to the FRSG for review and acceptance before equipment is deployed and data collection begins. The QAPP should clearly define the project, project organization and responsibility, QA objectives and criteria, data collection and sampling methods and procedures, as well as schedules for equipment calibration where applicable. In addition, complete methodologies for data reduction, validation, and reporting should be defined, as well as plans for internal QC checks, performance and system audits, and assessment of data variability, accuracy, representativeness, and completeness. The QAPP must adhere to US EPA guidelines (USEPA, 2001)

Data Format. It is essential to store all collected data in clearly documented electronic format. Both raw and processed data and calculated values shall be stored in a relational database. The database format for processed data should include the essential structure and information specified in the existing project database (FoxDB) so that relevant data can be directly uploaded to the FoxDB. All nomenclature, keys, and lookup values should match those used in the FoxDB. The FoxDB database and database structure can be obtained at the Fox River Watershed Investigation Web site (ISWS, 2005b).

Summary

The monitoring plan proposed in this report was designed to provide additional information for model development. Products resulting from this effort include:

- Hourly precipitation time series for nine stations.
- Hourly and daily stream flow time series for 11 stations.
- Measured concentrations of specified constituents accompanied by instantaneous stream flow for 29 stations and for active CSOs.
- Calculated loads of specified constituents (summarized in intervals no longer than daily) for 29 stations and for active CSOs.
- 15-minute time series of concentrations during low flow for 16 stations (datasondes).
- Time series of concentrations during low flow for 26 stations (discrete samples).
- The SOD results for 5 stations.
- Bed substrate analysis results for 10 stations.
- All unit and final data archived in an agreed upon electronic format.
- A QAPP, annual summary reports, final report, and any other documentation (i.e., specified by the QAPP).

References

Buchanan, T.J., and W.P. Somers. 1968. Stage Measurement at Gaging Stations, Book 3, Chapter A7. *Techniques of Water-Resources Investigations of the United States Geological Survey*. U.S. Government Printing Office, Washington, DC. Currently in its 4^{th} printing (1982).

Carter, R.W., and J. Davidian. 1968. General Procedure for Gaging Streams, Book 3, Chapter A6. *Techniques of Water-Resources Investigations of the United States Geological Survey*.U.S. Government Printing Office, Washington, DC. Currently in its 4^{th} printing (1989).

Clesceri, L.S., A.E. Greenberg, and R.R. Trussell (eds.). 1989. *Standard Methods for the Examination and Treatment of Water and Wastewater* (17th edition.), Washington, DC, pp. 2-1s, 5-82.

Edwards, T.K., and G.D. Glysson. 1988. *Field Methods for Measurement of Fluvial Sediment*: USGS, U.S. Geological Survey Open-File Report 86-531, Reston, VA.

Edwards, T.K., and G.D. Glysson. 1999. Field Methods for Measurement of Fluvial Sediment, Book 3, Chapter C2. *Techniques of Water-Resources Investigations of the United States Geological Survey*, U.S. Government Printing Office, Washington, DC.

Federal Interagency Sedimentation Project. 1952. *The Design of Improved Types of Suspended Sediment Samplers.* FISP, Interagency Report 6, St. Anthony Falls Hydraulics Laboratory, Minneapolis, MN.

Federal Interagency Sedimentation Project. 1953. *Field Tests on Suspended Sediment Samplers, Colorado River at Brigh Angel Creek near Grand Canyon, AZ.* FISP, Interagency Report F, Iowa University Hydraulics Laboratory, Iowa City, IA.

Federal Interagency Sedimentation Project. 1963. *Determination of Fluvial Sediment Discharge.* FISP, Interagency Report 14, St. Anthony Falls Hydraulics Laboratory, Minneapolis, MN.

Friedman, L.C., and D.E. Erdmann. 1982. Quality Assurance Practices for the Chemical and Biological Analyses of Water and Fluvial Sediments, Book 5, Chapter A6. *Techniques of Water-Resources Investigations of the United States Geological Survey*. U.S. Government Printing Office, Washington, DC.

Guy, H.P., and V.W. Norman. 1970. Field Methods for Measurement of Fluvial Sediment, Book 3, Chapter C2. *Techniques of Water-Resources Investigations of the United States Geological Survey.* U.S. Government Printing Office, Washington, DC.

Illinois Environmental Protection Agency. 2000. *Illinois Water Quality Report 2000.* IEPA, IEPA/BOW/00-005. Bureau of Water, Division of Water Pollution Control, Springfield, IL.

Illinois Environmental Protection Agency. 2002. *Illinois Water Quality Report 2002*. IEPA, IEPA/BOW/02-006, Springfield, IL (http://www.epa.state.il.us/water/water-quality/report-2002/305b-2002.pdf, accessed August 22, 2003).

Illinois Environmental Protection Agency. 2003. *Illinois 2002 Section 303(d) List*. IEPA, IEPA/BOW/03-016, Springfield, IL (http://www.epa.state.il.us/water/watershed/reports/303d-report/2002-report/303d-report-2002.pdf, accessed November 6, 2003).

Illinois State Water Survey. 2005a. Illinois Streamflow Assessment Model, ILSAM. (http://gismaps.sws.uiuc.edu/ilsam/, accessed September 1, 2005).

Illinois State Water Survey. 2005b. Fox River Watershed Investigation. Illinois Rivers Decision Support System (http://ilrdss.sws.uiuc.edu/fox/, accessed September 1, 2005).

Kennedy, E.J. 1983. Computation of Continuous Records of Streamflow, Book 3, Chapter A13. *Techniques of Water-Resources Investigations of the United States Geological Survey.* U.S. Government Printing Office, Washington, DC.

Porterfield, G. 1972. Computation of Fluvial-Sediment Discharge, Book 3, Chapter C3. *Techniques of Water-Resources Investigations of the United States Geological Survey*. U.S. Government Printing Office, Washington, DC.

Rantz, S.E., and others. 1982. *Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge.* U.S. Geological Survey Water-Supply Paper 2175, Washington, DC.

Santucci, Jr., V.J., and S.R. Gephard. 2003. *Fox River Fish Passage Feasibility Study*. Max McGraw Wildlife Foundation, Dundee, IL.

Shelton, L.R. 1994. *Field Guide for Collecting and Processing Stream-Water Samples for the National Water-Quality Assessment Program.*USGS, U.S. Geological Survey Open-File Report 94-455, Sacramento, CA.

U.S. Environmental Protection Agency. 2001. *EPA Requirements for Quality Assurance Project Plans.* USEPA, Office of Environmental Information, EPA QA/R-5, EPA/240/B-01/00, Washington, DC.

Wagner, R.J., Harold C. Mattraw, G.F. Ritz, and B.A. Smith. 2000. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting*. USGS, U.S. Geological Survey Water-Resources Investigations Report 00-4252, Reston, VA.

Ward, J.R., and Harr, Albert, 1990, *Methods for Collection and Processing of Surface-Water and Bed-Material Samples for Physical and Chemical Analyses*. USGS, U.S. Geological Survey Open-File Report 90- 140, Reston, VA.

Illinois State WATER Survey (1895)