Chapter 1. Introduction and Background

General information about the Fox River watershed, the Fox River Study Group, Inc. (FRSG), this project, and the report organization are provided in this chapter. A general discussion of surface water quality criteria and standards in Illinois and the role of water quality monitoring and modeling is provided as background for material presented later in this report.

1.1. Overview

The Fox River flows from Wisconsin through northeastern Illinois and joins the Illinois River at Ottawa. The Fox River drains 938 square miles in Wisconsin and 1720 square miles in Illinois. The river and the land in the watershed are used for agriculture, industry, recreation, residences, and urban development. Within the Chicago metropolitan area, there is increasing population growth and pressure from development. The mainstem of the Fox River and the Chain of Lakes region are used for recreation, the Fox River is a source of potable water for public water supply, and the Fox River and its tributaries carry stormwater and receive permitted discharges from wastewater treatment plants, combined sewers, and industry. In Illinois, the population of Fox River watershed by 2020 is expected to increase dramatically (~30 percent) from the 2000 totals, with much of the growth in McHenry and Kane Counties. Consequences of this population growth will be greater demand on the Fox River for public water supply, and stormwater and effluent assimilation. Without proper planning, water quality may decline in the Fox River and its tributaries. Human activities have altered the Fox River watershed both physically and chemically. Water quality of the Fox River and some of its tributaries does not meet all current regulatory goals.

The Illinois Environmental Protection Agency (IEPA) in their *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. In the 2002 IEPA report (IEPA, 2002), the entire length of the Fox River in Illinois is listed as impaired, as well as Nippersink, Poplar, Blackberry, and Somonauk Creeks, and part of Little Indian Creek. The IEPA has included the Fox River and these tributaries on their list of impaired waters commonly called the 303(d) list (IEPA, 2003). The IEPA uses a detailed, stepwise method to develop this list, 303(d) and their rational and methodology are described in *Illinois 2002 Section 303(d) List* (IEPA, 2003).

Concerns about current and future water quality of the Fox River and its tributaries led to the formation of the FRSG, a diverse coalition of stakeholders working together to assess water quality in the Fox River watershed. Participants include Friends of the Fox, Fox River Ecosystem Partnership (FREP), Sierra Club, Fox River Water Reclamation District (Elgin), Fox Metro Water Reclamation District (Aurora), Illinois Environmental Protection Agency (IEPA), Northeastern Illinois Planning Commission (NIPC), as well as representative from Aurora, Batavia, Crystal Lake, Elgin, Geneva, Island Lake, Kane County, Lake in the Hills, St. Charles, and Yorkville. The FRSG began meeting in summer 2001 and incorporated as a nonprofit organization in 2002. The FRSG has developed a sound, professional working relationship voicing and addressing the variety of watershed concerns and issues. The FRSG initiated a program of routine water quality monitoring to augment ambient monitoring in the watershed.

The FRSG is working to foster sustainable growth throughout the watershed. The FRSG outreach statement is contained in Appendix 1.

As part of the FRSG watershed initiative, a plan for scientific study has been developed for the lower portion of the watershed from Stratton Dam, which serves as a control point for the Fox Chain of Lakes, to the river's confluence with the Illinois River at Ottawa. The study has several phases, and information developed in each phase will be used to refine the work plan in subsequent phases. This report presents the findings of phase I of the study, which includes an extensive collection of available data and provides a description of watershed issues, the status of water quality in the watershed, a qualitative understanding of the various mechanisms contributing to the current conditions of the Fox River watershed between Stratton Dam and Ottawa, and recommendations for the next phase of study.

Future phases will include development of watershed scale computer models and in-stream models, monitoring, and evaluation. The purpose of developing a hydrologic and water quality model of the Fox River watershed is to create a tool to assist with watershed decision-making for attaining water quality standards and developing sustainable management measures. The model can provide insight to sources and impacts of nonpoint and point sources of pollution, simulate water quality conditions of alternative scenarios for future land-use practices and effluent loading to the system, and help in designing and assessing alternate management practices to reduce such impacts.

Activities in the watershed upstream of Stratton Dam have and will continue to have impacts downstream. A comprehensive study of the Fox River watershed ultimately must consider the watershed as a whole and involve interest groups from the Chain of Lakes region and Wisconsin. The proposed plan of study of the watershed below Stratton Dam is a starting point for looking at the issues specific to this part of the watershed for later incorporation into a full watershed plan. In a larger context, the Fox River watershed is part of the Illinois River basin. The Illinois Rivers Decision Support System (ILRDSS), under development at the Illinois State Water Survey (ISWS), is a technology and communication framework to provide scientific support and access to high-quality information for restoration of the Illinois River and its watershed. Data and information compiled for the Fox River watershed are available on the ILRDSS Web site (http://ilrdsssws.uiuc.edu).

1.2. Objectives and Products

The purpose of the multi-phase project proposed by the ISWS is to assist the FRSG to meet their goal of sustainable growth throughout the watershed by assembling and disseminating data and providing technical tools and support. Education and information dissemination are an important aspect of developing stakeholder support for the decisions and planning made using the data and technical tools. The focus of phase I of the project, reported herein, is to compile all available data; objectively analyze the data; develop recommendations and a plan for development of tools, such as models; and to provide wide access to the information via the Internet. The study focuses on examining the water chemistry, algae, and fecal coliform bacteria constituents and development of models to simulate the watershed processes of transport and in-stream dynamics of those constituents. This report is only one of the products of the study. The

Fox River Watershed Investigation Web site, (http://ilrdss.sws.uiuc.edu/fox), accessed through the ILRDSS Web site, is a portal to other products:

- a database of publications reporting water-quality data for the Fox River watershed
- a project bibliography
- geographically referenced datasets and metadata with online mapping tools
- a water quality database, FoxDB, with an interface for viewing and loading data
- an electronic version of this report

1.3. Report Organization

This report contains an executive summary, nine chapters, references, and seven appendices. Each chapter was written to stand alone; however, discussions in prior chapters provide background information for understanding and interpreting information. Chapter 1 provides an overview of the project and background information on measures of water quality. Chapter 2 describes physical features of the watershed and introduces many of the Geographic Information System (GIS) datasets that can be viewed and accessed via the Fox River Watershed Investigation Web site. Chapter 3 reviews various water quality publications covering the Fox River watershed and includes a discussion of various water quality constituents commonly used to evaluate the health of a water body. Chapter 4 describes the project database containing water quality sample data and the data quality system developed. Chapter 5 presents the analysis of the water quality data, trends, and data gaps. Chapter 6 covers sediment chemistry issues. Chapter 7 reviews water quality models and recommendations for model applications in the Fox River watershed. Chapter 8 presents information about the Web site created for the project and describes various electronic datasets that may be accessed from the site. Chapter 9 presents a summary of the report. The appendices include a statement by the FRSG, a data dictionary for the water quality database, a description of how data from other sources was translated to the database, an overview of the interface used to view and enter database data, an interim report prepared in May 2003 regarding the FRSG monitoring, and descriptions of various water quality models.

1.4. Acknowledgments

The interest, dedication, leadership, hard work, collaboration, and helpful input from the members of the Fox River Study Group, Inc. (FRSG), provided the core inspiration for the project. Fundamental to formulation of the project was the participation and encouragement of the Illinois Environmental Protection Agency (IEPA), which funded this first phase. Tim Kluge, IEPA, serves as liaison. Members of the FRSG provided oversight throughout the project. Vern Knapp, senior hydrologist, Illinois State Water Survey (ISWS), provided technical guidance and support throughout the project and also report review. Jaswinder Singh, an experienced ISWS modeler, provided valuable guidance and assistance in developing model recommendations. Kathy Brown, ISWS GIS specialist, prepared datasets and many of the maps. Bill Saylor, ISWS information specialist, assisted in acquiring data. Sangjun Kang, a graduate student at the University of Illinois at Urbana-Champaign (UIUC) assisted with research and database development. Ashfaque R. Riad, UIUC student, entered data. Becky Howard and Patti Hill prepared the camera-ready copy of the report. Eva Kingston edited the report. Linda Hascall provided graphic and illustration guidance. Mike Demissie, head of the ISWS Watershed Science Section (WSS), provided technical comments, guidance, and general support that were very helpful in defining the project and forming the ISWS/WSS Fox project team.

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the sponsor or the Illinois State Water Survey.

1.5. Measures of Water Quality

Natural systems are highly variable, and no single, simple set of standards can be used to evaluate environmental quality. The health or quality of a river system may be evaluated on the basis of whether or not it is usable for designated purposes. In the Clean Water Act the resource quality of water is defined in terms of the degree to which predefined beneficial uses (i.e., designated uses) of those waters are attained (i.e., supported). This is referred to as “use attainment.” Use categories adopted by the IEPA are: Overall, Aquatic Life, Fish Consumption, Primary Contact (Swimming), Secondary Contact (Recreation), Indigenous Aquatic Life, and Public Water Supply. Five categories are used to rank the degree to which a water body supports its designated use(s): full, threatened, partial support, nonsupport, and not assessed. The IEPA prepares a biennial report subtitled the Clean Water Act, Section 305(b) Report, which lists Illinois water bodies and their use support. In addition to this report, the IEPA prepares a list, pursuant to Section 303(d) of the Clean Water Act of “waters for which any designated use is identified as partial or nonsupport based on chemical, biological and/or physical data supporting the Section 305(b) Report” (IEPA, 2003, p.4). The IEPA uses a combination of biological and chemical criteria to assess the use attainment of Illinois’ waters. The criteria are briefly described in the following paragraphs.

Biological measures, such as the Index of Biotic Integrity (IBI), have been formulated, and can be used as indicators of the health of the aquatic ecosystem. The purpose of such indices is to define an objective method of compiling information on the abundance and diversity of aquatic organisms from which a numerical score can be computed and used for stream-to-stream comparisons, or temporal or spatial comparisons within a stream network. Observations of the biological and aesthetic aspects of rivers and streams demonstrate the viability or “health” of a water body. Systematic monitoring of these aspects of the water resource will provide historical datasets for comparison and point to changes in the system.

There are several indices that may be used to calculate a numerical value that represents the biological viability of a water body. Fish and macroinvertebrates are the most commonly used groups in rivers and streams, while benthic algae and macroinvertebrates are commonly used in assessments of lakes. The IEPA interprets fish data using the Index of Biotic Integrity or IBI (Karr et al., 1986; Bertrand et al., 1996). The IBI is a family of indices first developed by Dr. James Karr for use in small streams in Illinois and Indiana (Karr et al., 1986). The Macroinvertebrate Biotic Index or MBI (IEPA, 1994) is used to assess insects, crustaceans, and benthic populations. The MBI rates stream health using a taxa tolerance to pollution and sample density. The choice of scoring criteria is best developed on a regional basis for water bodies of similar ecological characteristics. The IEPA uses the following criteria to classify aquatic life use support for streams (IEPA, 2002a, p.28):

IBI $\geq$ 41 and MBI $\leq$ 5.9	Full Support
IBI $\geq$ 20 but < 41 and 5.9 < MBI $\leq$ 8.9	Partial Support
IBI $\leq$ 20 or MBI > 8.9	Nonsupport

A lack of species abundance, diversity, or both suggests a poor aquatic environment.

When data are not available to compute an IBI or MBI for a water body, chemical data and criteria are used to evaluate use attainment. Physical water quality parameters such as dissolved oxygen (DO) concentration, temperature, and acidity (pH) have been linked to the viability of the aquatic habitat and serve as specific, readily measurable indicators of water quality. Chemical analyses of water and stream sediments provide information on nutrients, metals, pathogens, and other constituents that interact within the aquatic system and may point to sources of pollutants that degrade the viability of the riverine environment.

In Illinois, the Illinois Pollution Control Board (IPCB) has established four primary sets of water quality standards for each of four identified beneficial uses. Within the Fox River watershed, only General Use Standards and Public and Food Processing Water Supply Standards apply. Numerical standards have been established for DO and pH and for a number of elements from arsenic to zinc. The standard for ammonia nitrogen is a function of temperature and pH. Acute and chronic standards have been set for un-ionized ammonia, arsenic, and several other toxic substances. Notable is that a standard has not been established for phosphorus in streams and rivers.

Generally, a standard (or a criterion) for a harmful substance should have three components: 1) magnitude: how much of a pollutant (or pollutant parameter, such as toxicity), expressed as concentration is allowable; 2) duration: the period of time (averaging period) over which the in-stream concentration is averaged for a comparison with criteria concentrations (this specification limits the duration of a concentration above the criteria.); and 3) frequency: how often the criteria can be exceeded. Many states, including Illinois, simplified the frequency/duration component by substituting the rule that a numeric standard for certain parameters must be maintained (not to be exceeded) at all times. Such a limitation is a statistical impossibility because there is always a chance, albeit a very remote one, that a constituent may reach a high but statistically possible value that exceeds an established standard.

Tables 1.1 and 1.2 are reproductions of Tables 3.1 and 3.2, respectively, from the IEPA Illinois Water Quality Report, 2002 (IEPA, 2002a). A more specific discussion and presentation of Illinois water quality standards approved by the IPCB are published in Title 35 of the *Illinois Administrative Code* Part 302 (IAC, 2002).

Nutrient guidelines for rivers and streams have been proposed (USEPA, 2000a). These guidelines were developed on the basis of assessments of background concentrations (reference conditions) of various parameters by ecoregions. The Fox River watershed lies within Ecoregion VI, subecoregion 54, called the Central Corn Belt Plain. Ecoregional nutrient criteria are intended to address "cultural eutrophication," the effects of excess nutrient inputs (USEPA,

Table1.1. Illinois Water Quality Standards[1] (IEPA, 2002a)

Parameter	*Units*	*General use*	*Public and food processing water supply*	*Secondary contact and indigenous aquatic life*
pH	SU	6.5 minimum 9.0 maximum	6.5 minimum 9.0 maximum	6.0 minimum 9.0 maximum
Dissolved Oxygen	mg/L	5.0 minimum	5.0 minimum	4.0 minimum [2]
Arsenic	µg/L	[3]	50	1000
Barium	µg/L	5000	1000	5000
Boron	µg/L	1000	1000	---[4]
Cadmium	µg/L	[3]	10	150
Chloride	mg/L	500	250	---
Chromium (Total)	µg/L	---	50	---
Chromium (Trivalent)	µg/L	[3]	[3]	1000
Chromium (Hexavalent)	µg/L	[3]	[3]	300
Copper	µg/L	[3]	[3]	1000
Cyanide	mg/L	[3]	[3]	0.1
Fluoride	mg/L	1.4	1.4	15
Iron (Total)	µg/L	---	---	2000
Iron (Dissolved)	µg/L	1000	300	500
Lead	µg/L	[3]	50	100
Manganese	µg/L	1000	150	1000
Mercury	µg/L	[3]	[3]	0.5
Nickel	µg/L	1000	1000	1000
Phenols	µg/L	100	1.0	300
Selenium	µg/L	1000	10	1000
Silver	µg/L	5.0	5.0	100
Sulfate	mg/L	500	250	---
Total Dissolved Solids	mg/L	1000	500	1500
Total Residual Chlorine	µg/L	[3]	[3]	---
Zinc	µg/L	1000	1000	1000
Fecal Coliform Bacteria				
May-Oct.	#/100ml	200 [5]	2000	---
Nov.-April	#/100ml	---	2000	---
Ammonia Nitrogen (total)(total)	mg/L	15 [6]	15 [6]	---
Un-ionized Ammonia	mg/L	[3]	[3]	0.1
Nitrate Nitrogen	mg/L	---	10.0	---
Oil and Grease	mg/L	---	0.1	15.0
Total Phosphorus	mg/L	0.05 [7]	0.05 [7]	---

Table 1.1. Concluded

Parameter	*Units*	*General use*	*Public and food processing water supply*	*Secondary contact and indigenous aquatic life*
Aldrin	µg/L	---	1.0	---
Dieldrin	µg/L	---	1.0	---
Endrin	µg/L	---	0.2	---
Total DDT	µg/L	---	50.0	---
Total Chlordane	µg/L	---	3.0	---
Methoxychlor	µg/L	---	100.0	---
Toxaphene	µg/L	---	5.0	---
Heptachlor	µg/L	---	0.1	---
Heptachlor epoxide	µg/L	---	0.1	---
Lindane	µg/L	---	4.0	---
Parathion	µg/L	---	100.0	---
2,4-D	µg/L	---	100.0	---
Silvex	µg/L	---	10.0	---

Notes:
mg/L = milligrams per liter
µg/L = micrograms per liter
(1) 35 IL. Adm. Code Part 302 (1999).
(2) Excluding the Calumet-Sag Channel, which shall not be less than 3.0 mg/L at any time.
(3) Acute and Chronic Standards (see Table 1.2).
(4) (---) means no numeric standard specified; narrative standard applies.
(5) Water body reaches physically unsuited for primary contact uses and not found in urban areas or parks may be designated as unprotected
(6) The allowable concentration varies in accordance with water temperature and pH values. 15 mg/L is the maximum total ammonia nitrogen value allowed. In general, as both temperature and pH decrease, the allowable value of total ammonia nitrogen increases as calculated from the un-ionized ammonia nitrogen standards.
(7) Standard applies to certain lakes and reservoirs and at the point of entry of any stream to these lakes and reservoirs.

Table 1.2. Acute and Chronic Illinois General Use Water Quality Standards [1]

Parameter	*Units*	*Acute standard [2]*	*Chronic standard [3]*
Un-ionized ammonia			
April-October	mg/L	0.33	0.057 [6]
November-March	mg/L	0.14	0.025 [6]
Arsenic (total)	µg/L	360	190
Cadmium (total)	µg/L	exp[A+B ln(H)] A = -2.918, B = 1.128 but not to exceed 50 µg/L	exp[A+B ln(H)] A = -3.490 B = 0.7852
Chlorine (total residual)	µg/L	19	11
Chromium (total Hexavalent)	µg/L	16	11
Chromium (total trivalent)	µg/L	exp[A+B ln(H)] A = 3.688 B = 0.819	exp[A+B ln(H)] A = 1.561 B = 0.819
Copper (total)	µg/L	exp[A+B ln(H)] A = -1.464 B = 0.9422	exp[A+B ln(H)] A = -1.465 B = 0.8545
Cyanide (weak acid dissociable) [4]	µg/L	22	5.2
Lead (total)	µg/L	exp[A+B ln(H)] A = -1.301 B = 1.273	exp[A+B ln(H)] A = -2.863 B = 1.273
Mercury (total) [5]	µg/L	2.6	1.3

Notes:
Where: Exp(x) = base of natural logarithms raised to x power
ln(H) = natural logarithm of hardness of the receiving water in mg/L
[1] 35 IL. Adm. Code Part 302 (1999).
[2] Not to be exceeded except where a zone of initial dilution is granted.
[3] Not to be exceeded by the average of at least four consecutive samples collected over any period of at least four days.
[4] American Public Health Association. 1998. Standard Methods for the Examination of Water and Wastewater. 20th edition. American Public Health Association, American Water Works Association, Water Environment Federation. 4500-CN 1. STORET No. 718.
[5] Human health standard is 0.012 mg/L.
[6] Unless an effluent modified water is recognized in an NPDES permit.

2000b). They are derived from a prescribed statistical analysis (USEPA, 2000a) of water quality data for the region. They are a starting point for the development more refined criteria. There are two recommended ways of establishing a reference (background) condition. The preferred method is to choose the 75th percentile (upper 25th percentile) of a reference population of streams. For example, for a given constituent where low concentrations are desirable, 75 percent of the streams have a value above the "reference" concentration and 25 percent have concentrations below that value. The upper 25th percentile was chosen by USEPA because it is likely associated with minimally impacted conditions, will be protective of designated uses, and provides management flexibility. When reference streams are not identified, the second method is to determine the lower 25th percentile of the population of all streams within a region. The 25th percentile of the entire population was chosen by USEPA to represent a surrogate for an actual reference population. Data analyses to date indicate that the lower 25th percentile from an entire population roughly approximates the 75th percentile for a reference population (USEPA, 2000b). The reference conditions for subecoregion 54, based on the 25th percentile are given in Table 1.3.

Standards have not been established for many parameters, including some pathogens, and parent and degraded synthetic organic compounds. The lack of a standard does not imply that a substance cannot reach a critical or harmful concentration, only that a consensus to establish a limit has not been reached, and meeting all required standards does not guarantee a healthy riverine environment.

The interactions of the various physical, chemical, and biological components are complex, and many combinations may provide a successful environment. Like a flexible rubber membrane, the environment can stretch to take many forms, but there are limits to the squeezing and stretching that can be endured before negative impacts are registered. Computer models have been developed to simulate the various processes and complex interactions within a watershed and its water bodies. These models serve as tools to assess combinations of constraints on and inputs to the watershed system that can sustain a healthy riverine environment.

Table 1.3. Reference Conditions for Level III Ecoregion 54 (after USEPA, 2000b)

Parameter	*25th percentiles based on all seasons' data for the decade*
Nitrogen, Total Kjeldahl (TKN) (mg/L)	0.663
Nitrite and Nitrate, (NO_2+NO_3) (mg/L)	1.798
Nitrogen Total (TN) (mg/L) - calculated	2.461
Nitrogen, Total (TN) (mg/L) - reported	2.95
Phosphorus, Total (TP) (µg/L)	72.5
Turbidity (NTU)	14
Turbidity (FTU)	6.04
Turbidity (JCU)	31.6
Chlorophyll *a*, Fluorometric, Corrected (µg/L)	2
Chlorophyll *a*, Phytoplankton, Spectrophotometric Acid (µg/L)	7.01
Chlorophyll *a*, Trichromatic, Uncorrected (µg/L)	3.18

1.6. Monitoring and Modeling

Long-term datasets derived from water quality monitoring provide a basis for identifying trends in water quality, indicating declining or improving conditions. Monitoring is essential for providing oversight and stewardship of the resource. Routine monitoring is conducted by the IEPA, the U.S. Geological Survey (USGS) and since 2001 the FRSG in the Fox River watershed. Analysis of monitoring data and comparison of results to standards or guidelines provide an objective measure of the health of the riverine environment. Natural systems are inherently highly variable, no two watersheds develop exactly the same. This variability impedes establishing universal, comprehensive in-stream water quality standards. Standards have not been set for many constituents that nevertheless contribute to the environmental health. Because watershed characteristics are in many aspects unique to an individual watershed, monitoring data are necessary to evaluate attainable guidelines for a particular watershed.

Monitoring alone does not provide a link between sources and observed effects. Complex processes within the watershed link pollutant source to the riverine environment. Precipitation and subsequent runoff from the land surface carry materials to rivers and streams. Mechanical, chemical, and biological processes transform constituents as they are transported within the stream network. Water quality models are mathematical models of the physical and chemical or biochemical processes embodied in computer code. They represent the current level of understanding of the physical and chemical processes with different levels of detail. Using well calibrated models, links between sources of pollution and impacts can be identified and watershed management options evaluated before implementation.