Middle Kaskaskia River Watershed Total Maximum Daily Load

DRAFT Stage 1 Report

1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

Report Prepared by:

TETRA TECH

November 2018

Contents

Figures

Tables

Acronyms and Abbreviations

AFOs	animal feeding operations
AQI	Aesthetic Quality Index
AWQMN	Ambient Water Quality Monitoring Network
CAFO	confined animal feeding operation
CWA	Clean Water Act
HSG	hydrologic soil group
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
MGD	millions of gallons per day
MS4	municipal separate storm sewer system
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NVSS	non-volatile suspended solids
RM	river mile
STP	sewage treatment plant
SWCD	soil and water conservation district
TMDL	total maximum daily load
TSI	Trophic State Index
TSS	total suspended solids
USACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQS	water quality standards
WTP	water treatment plant
WWTP	wastewater treatment plant

1. Introduction

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that Total Maximum Daily Loads (TMDLs) be developed for waters that do not support their designated uses. In simple terms, a TMDL is a plan to attain and maintain water quality standards in waters that are not currently meeting them. This TMDL study addresses the approximately 946 square mile Middle Kaskaskia River watershed located in central Illinois (Figure 1). The Upper Kaskaskia River watershed and East Fork Kaskaskia River watershed drain to the Middle Kaskaskia River watershed, but are being addressed in separate TMDL studies. Several waters in the Middle Kaskaskia River watershed have been placed on the State of Illinois 303(d) list, and require the development of a TMDL. This project addresses three impaired segments along the mainstem of the Kaskaskia River and Carlyle Lake.

The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream conditions. This allowable loading represents the maximum quantity of the pollutant that the waterbody can receive without exceeding water quality standards. The TMDL also includes a margin of safety, which reflects uncertainty as well as the effects of seasonal variation. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and nonpoint sources, and restore and maintain the quality of their water resources (U.S. EPA 1991). The Illinois EPA will be working with stakeholders to implement the necessary controls to improve water quality in the impaired waterbodies and meet water quality standards. It should be noted that the controls for nonpoint sources (e.g., agriculture) will be strictly voluntary.

1.1 Water Quality Impairments

Three segments along the mainstem of the Kaskaskia River and Carlyle Lake have been placed on the State of Illinois §303(d) list (Table 1 and Figure 1). There are other impaired waters in the Middle Kaskaskia River watershed that are not being addressed by the TMDL study, including fecal coliform impairments in Kaskaskia River (O-10), Hurricane Creek (OL-02), and Hickory Creek (ON-01) and two aesthetic quality lake impairments in Vandalia Lake and Ramsey Lake. Of the waters being addressed by this TMDL study, one waterbody–pollutant combination was found to be unimpaired (see Table 1 and Appendix A – Unimpaired Stream Data Analysis). In addition, two pollutants (temperature and total suspended solids) are not being addressed as part of this project.

Table 1. Middle Kaskaskia River watershed impairments and pollutants (2016 Illinois 303(d) Draft List)

Name	Segment ID	Segment Length (Miles)	Watershed Area (Sq. Miles) [a]	Designated Uses	Cause of Impairment
Kaskaskia River	IL_O-08	17.74	1,946	Primary Contact Recreation	**Fecal Coliform**
				Public and Food Processing Water Supply	Atrazine [c]
	IL_O-33	15.21	1,774	Aquatic Life	**Dissolved Oxygen**, Temperature [b]
	IL_O-38	21.3	2,383	Primary Contact Recreation	**Fecal Coliform**
Carlyle Lake	IL_ROA	24,580 ac (surface area)	2,945	Aesthetic Quality	**Phosphorus (Total)**, Total Suspended Solids (TSS) [b]

a. Watershed area includes Upper Kaskaskia River watershed (1,568 sq. miles) and East Fork Kaskaskia River watershed (562 sq. miles, IL ROA only).
b. These causes of impairment are not being addressed as part of this project.
c. Impairment was removed from the 2018 draft 303(d) list and is not addressed further in this report. See Appendix A – Unimpaired Stream Data Analysis.
BOLD – TMDLs are addressed in this Stage 1 report

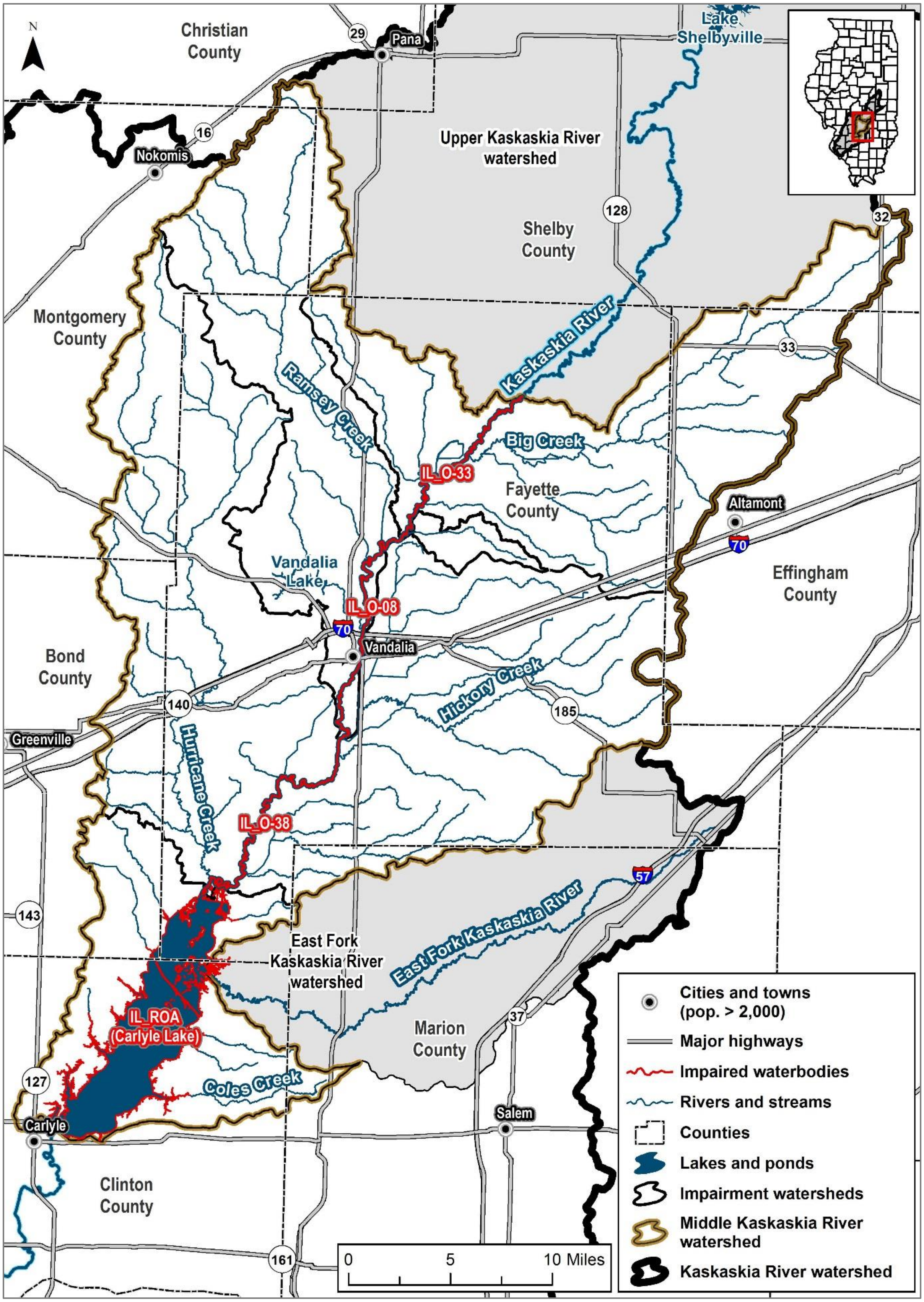


Figure 1. Middle Kaskaskia River watershed, TMDL project area.

1.2 TMDL Endpoints

This section presents information on the water quality standards (WQS) that are used for TMDL endpoints. WQS are designed to protect beneficial uses. The authority to designate beneficial uses and adopt WQS is granted through Title 35 of the Illinois Administrative Code. Designated uses to be protected in surface waters of the state are defined under Section 303, and WQS are designated under Section 302 (Water Quality Standards). Designated uses and WQS are discussed below.

1.2.1 Designated Uses

Illinois EPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB) to assess the designated use support for Illinois waterbodies. The following are the use support designations provided by the IPCB that apply to waterbodies in the Middle Kaskaskia River watershed:

General Use Standards – These standards protect for aquatic life, wildlife, agricultural uses, primary contact (where physical configuration of the waterbody permits it, any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing), secondary contact (any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating, and any limited contact incident to shoreline activity), and most industrial uses. These standards are also designed to ensure the aesthetic quality of the state's aquatic environment.

1.2.2 Water Quality Standards and TMDL Endpoints

Environmental regulations for the State of Illinois are contained in the Illinois Administrative Code, Title 35. Specifically, Title 35, Part 302 contains water quality standards promulgated by the IPCB. This section presents the standards applicable to impairments in the study area. Water quality standards and TMDL endpoints to be used for TMDL development in the Middle Kaskaskia River watershed are listed in Table 2. Impairments of aquatic life, primary contact recreation, and aesthetic quality are present in the watershed.

Table 2. Summary of water quality standards for the Middle Kaskaskia River watershed

Parameter	Units	Water Quality Standard
Dissolved Oxygen [a]	mg/L	March–July > 5.0 min. and > 6.0 7-day mean Aug–Feb > 3.5 min, > 4.0 7-day mean, and > 5.5 30-day mean
Fecal Coliform [b]	#/100 ml	400 in <10% of samples [c]
		Geometric mean < 200 [d]
Phosphorus (Total)	mg/L	0.05

a. Applies to the dissolved oxygen concentration in the main body of all streams, in the water above the thermocline of thermally stratified lakes and reservoirs, and in the entire water column of unstratified lakes and reservoirs.
b. Fecal coliform standards are applicable for the recreation season only (May through October).
c. Standard shall not be exceeded by more than 10% of the samples collected during a 30-day period.
d. Geometric mean based on minimum of 5 samples taken over not more than a 30-day period.

Aquatic life use assessments in streams are typically based on the interpretation of biological information, physicochemical water data, and physical-habitat information from the Intensive Basin Survey, Ambient

Water Quality Monitoring Network, or Facility-Related Stream Survey programs. The primary biological measures used are the fish Index of Biotic Integrity (fIBI; Karr et al. 1986; Smogor 2000, 2005), the macroinvertebrate Index of Biotic Integrity (mIBI; Tetra Tech 2004), and the Macroinvertebrate Biotic Index (MBI; IEPA 1994). Physical habitat information used in assessments includes quantitative or qualitative measures of stream bottom composition and qualitative descriptors of channel and riparian conditions. Physicochemical water data used include measures of conventional parameters (e.g., dissolved oxygen, pH, and temperature), priority pollutants, non-priority pollutants, and other pollutants (U.S. EPA 2002). In a minority of streams for which biological information is unavailable, aquatic life use assessments are based primarily on physicochemical water data.

When a stream segment is determined to be not supporting aquatic life use, generally one exceedance of an applicable Illinois water quality standard (related to the protection of aquatic life) results in identifying the parameter as a potential cause of impairment. Additional guidelines used to determine potential causes of impairment include site-specific standards (35 Ill. Adm. Code 303, Subpart C) or adjusted standards (published in the IPCB's Environmental Register at https://pcb.illinois.gov/Resources/EnvironmentalRegister).

According to Illinois water quality standards, primary contact means ...*any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing* (35 Ill. Adm. Code 301.355). The assessment of primary *contact* use is based on fecal coliform bacteria data. The General Use Water Quality Standard for fecal coliform bacteria specifies that during the months of May through October, based on a minimum of five samples taken over not more than a 30-day period, fecal coliform bacteria counts shall not exceed a geometric mean of 200/100 ml, nor shall more than 10 percent of the samples during any 30-day period exceed 400/100 ml (35 Ill. Adm. Code 302.209). This standard protects primary contact use of Illinois waters by humans.

Due to limited state resources, fecal coliform bacteria is not normally sampled at a frequency necessary to apply the General Use standard, i.e., at least five times per month during May through October, and very little data available from others are collected at the required frequency. Therefore, assessment guidelines are based on application of the standard when sufficient data is available to determine standard exceedances; but, in most cases, attainment of primary contact use is based on a broader methodology intended to assess the likelihood that the General Use standard is being attained.

To assess primary contact use, Illinois EPA uses all fecal coliform bacteria from water samples collected in May through October, over the most recent five-year period (i.e., 2012 through 2016 for this report). Based on these water samples, geometric means and individual measurements of fecal coliform bacteria are compared to the concentration thresholds in Table 3 and Table 4. To apply the guidelines, the geometric mean of fecal coliform bacteria concentration is calculated from the entire set of May through October water samples, across the five years. No more than 10 percent of all the samples may exceed 400/100 ml for a waterbody to be considered Fully Supporting.

Table 3. Guidelines for Assessing Primary Contact Use in Illinois Streams and Inland Lakes

Degree of Use Support	Guidelines
Fully Supporting (Good)	No exceedances of the fecal coliform bacteria standard in the last five years and the geometric mean of all fecal coliform bacteria observations ≤200/100 ml, and ≤10% of all observations exceed 400/100 ml.
Not Supporting (Fair)	One exceedance of the fecal coliform bacteria standard in the last five years (when sufficient data is available to assess the standard) or The geometric mean of all fecal coliform bacteria observations in the last five years ≤200/100 ml, and >10% of all observations in the last five years exceed 400/100 ml or The geometric mean of all fecal coliform bacteria observations in the last five years >200/100 ml, and ≤25% of all observations in the last five years exceed 400/100 ml.
Not Supporting (Poor)	More than one exceedance of the fecal coliform bacteria standard in the last five years (when sufficient data is available to assess the standard) or The geometric mean of all fecal coliform bacteria observations in the last five years >200/100 ml, and >25% of all observations in the last five years exceed 400/100 ml

Table 4. Guidelines for Identifying Potential Causes of Impairment of Primary Contact Use in Illinois Streams and Freshwater Lakes

Potential Cause	Basis for Identifying Cause - Numeric Standard[1]
Fecal Coliform	Geometric mean of at least five fecal coliform bacteria observations collected over not more than 30 days during May through October >200/100 ml or > 10% of all such fecal coliform bacteria observations exceed 400/100 ml or Geometric mean of all fecal coliform bacteria observations (minimum of five samples) collected during May through October >200/100 ml or > 10% of all fecal coliform bacteria observation exceed 400/100 ml.

1. The applicable fecal coliform standard (35 Ill. Adm. Code, 302, Subpart B, Section 302.209) requires a minimum of five samples in not more than a 30-day period. However, because this number of samples is seldom available in this time frame, the criteria are also based on a minimum of five samples over the most recent five-year period.

The Aesthetic Quality Index (AQI; Table 5) is the primary tool used to assess *aesthetic quality* for freshwater lakes. The AQI represents the extent to which pleasure boating, canoeing, and aesthetic enjoyment are attained at a lake. The Trophic State Index (TSI; Carlson 1977), the percent-surface-area macrophyte coverage during the peak growing season (June through August), and the median concentration of nonvolatile suspended solids are used to calculate the AQI score. Higher AQI scores indicate increased impairment (Table 6).

Assessments of aesthetic quality use are based primarily on physical and chemical water quality data collected by the Illinois EPA through the Ambient Lake Monitoring Program or the Illinois Clean Lakes Program, or by non-Illinois EPA persons under an approved quality assurance project plan. The physical and chemical data used for aesthetic quality use assessments include: Secchi disk transparency, chlorophyll a, total phosphorus (epilimnetic samples only), nonvolatile suspended solids (epilimnetic samples only), and percent surface area macrophyte coverage. Data are collected a minimum of five times per year (April through October) from one or more established lake sites. Data are considered usable for assessments if meeting the following minimum requirements: 1) At least four out of seven months (April through October) of data are available, 2) At least two of these months occurs during the peak growing season of June through August (this requirement does not apply to NVSS) and 3) Usable data are available from at least half of all lakes sites in any given lake each month. A whole-lake TSI value is calculated for the median Secchi disk transparency, median total phosphorus (epilimnetic sample depths only), and median chlorophyll a values. A minimum of two parameter-specific TSI values are required to calculate a parameter-specific use support determination. An assessment is then made based on the parameter specific use support determinations. The 0.05 mg/L Illinois General Use Water Quality Standard for total phosphorus in lakes (35 Ill. Adm. Code 302.205) has been incorporated into the weighting criteria used to assign point values for the AQI.

Table 5. Aesthetic Quality Index

Evaluation Factor	Parameter	Weighting Criteria	Points
1. Median Trophic State Index (TSI)	For data collected May-October: Median lake TSI value calculated from total phosphorus (samples collected at one foot depth), chlorophyll *a*, and Secchi disk transparency	Actual Median TSI Value	Actual Median TSI Value
2. Macrophyte Coverage	Average percentage of lake surface area covered by macrophytes during peak growing season (June through August). Determined by: a. Macrophyte survey conducted during same water year as the chemical data used in the assessment; <u>or</u> b. Average value reported on the VLMP Secchi Monitoring Data form	a. <5 b. ≥5<15 c. ≥15<25 d. ≥25	a. 0 b. 5 c. 10 d. 15
3. Nonvolatile Suspended Solids (NVSS) Concentration	Median lake surface NVSS concentration for samples collected at one foot depth (reported in mg/L)	a. <3 b. ≥3<7 c. ≥7<15 d. ≥15	a. 0 b. 5 c. 10 d. 15

Table 6. Guidelines for Assessing Aesthetic Quality Use in Illinois Freshwater Lakes

Degree of Use Support	Guidelines
Fully Supporting (Good)	Total AQI points are <60
Not Supporting (Fair)	Total AQI points are ≥60<90
Not Supporting (Poor)	Total AQI points are ≥90

2. Watershed Characterization

The Middle Kaskaskia River watershed is located in central Illinois (Figure 1). The headwaters for the watershed begin north of Vandalia City, IL. The Kaskaskia River then flows through Carlyle Lake at the downstream end of the watershed. The watershed covers 946 square miles; major tributaries of the river include Big Creek, Ramsey Creek, Hickory Creek, and Hurricane Creek.

2.1 Jurisdictions and Population

Counties with land located in the watershed area include Bond, Christian, Clinton, Effingham, Fayette, Marion, Montgomery, and Shelby. The city of Vandalia is the only major government unit with jurisdiction in the Middle Kaskaskia River watershed area. The cities of Altamont, Nokomis, Greenville, and Carlyle border the watershed, with the city of Carlyle located along the downstream end of Carlyle Lake. Populations are area weighted to the watershed in Table 7. All county population estimates, with the exception of Fayette County, were adjusted to account for major cities outside the watershed area.

Table 7. Area weighted county populations in watershed

County	2000	2010	Percent Change
Bond	1,649	1,662	1%
Christian	57	55	-4%
Clinton	3,722	4,005	8%
Effingham	3,104	3,109	0%
Fayette	17,959	18,237	2%
Marion	573	549	-4%
Montgomery	2,289	1,970	-14%
Shelby	638	629	-1%
TOTAL	***29,991***	***30,216***	***1%***

Source: U.S. Census Bureau

2.2 Climate

Climate data are available from the National Oceanic and Atmospheric Administration (NOAA) Global Historical Climatology Network Database; Station USC00111290 is located at the southern end of Carlyle Lake near Carlyle, IL along the southern boundary of the watershed. Daily data from 1962-2016 for temperature, precipitation and snowfall are summarized in Table 8. In general, the climate of the region is continental with hot, humid summers and cold winters. The average high winter temperature is 40 °F and the average high summer temperature is 86 °F. The annual average precipitation is approximately 41 inches, including approximately 11 inches of snowfall. In general, larger volumes of precipitation tend to occur between the months of April and September.

Table 8. Climate summary for Carlyle Lake (1962–2016)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High ºF	37	41	53	65	75	84	87	86	79	68	54	42
Average Low ºF	19	23	34	45	55	64	67	65	57	45	35	25
Mean Temperature ºF	25	28	39	51	60	69	72	69	61	50	40	30
Average Precipitation (in)	2.2	2.2	3.6	4.2	4.4	4.5	3.8	3.0	3.4	3.0	3.5	3.1
Average Snowfall (in)	3.5	2.9	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0	0.7	2.2

Source: NOAA Global Historical Climatology Network Database

2.3 Land Use and Land Cover

Land use in the watershed is heavily influenced by agriculture (Figure 2). Urban area is located near the city of Vandalia and several small towns in the watershed. Land use in the watershed includes agriculture – cultivated crops and pasture/hay (approximately 63 percent), forest (approximately 24 percent), and urban (approximately 8 percent). Corn and soybeans are the most common crops, with much smaller areas of spring wheat, alfalfa and other crops. Table 9 presents area and percent by land cover type as provided in the 2011 National Land Cover Database (MRLC 2015).

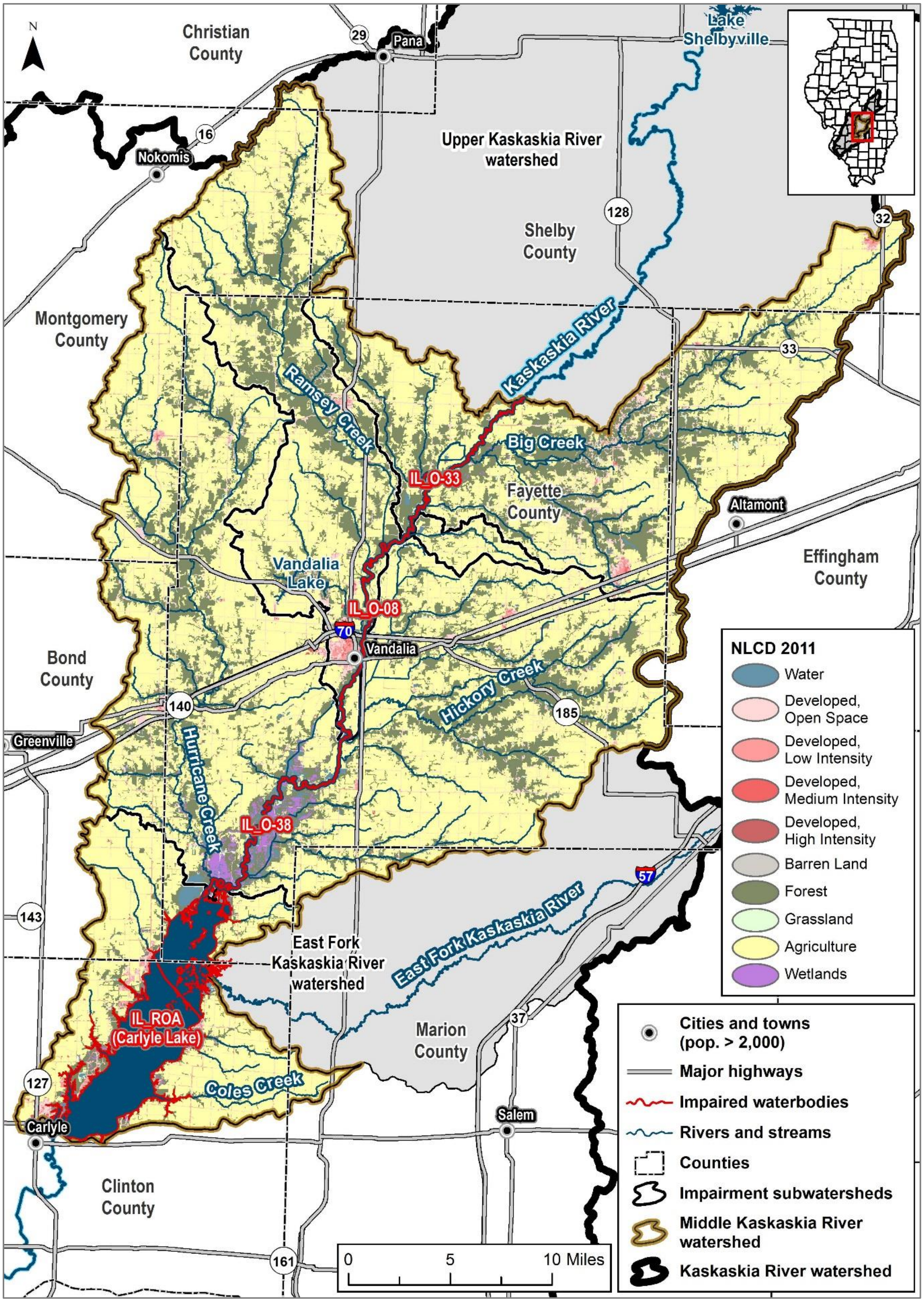


Figure 2. Middle Kaskaskia River watershed land cover (2011 National Land Cover Database).

Table 9. Watershed land use summary

Land Use / Land Cover Category	Acres	Percentage
Cultivated Crops	292,084	48.3%
Deciduous Forest	144,502	23.9%
Hay/Pasture	86,656	14.3%
Developed, Open Space	35,643	5.9%
Open Water	28,869	4.8%
Developed, Low Intensity	8,196	1.4%
Woody Wetlands	3,615	0.6%
Herbaceous	2,472	0.4%
Developed, Medium Intensity	1,528	0.3%
Emergent Herbaceous Wetlands	1,228	0.2%
Developed, High Intensity	357	<0.1%
Evergreen Forest	104	<0.1%
Barren Land	60	<0.1%

Source: 2011 National Land Cover Database

2.4 Topography

Topography is an important factor in watershed management because stream types, precipitation, and soil types can vary dramatically by slope and elevation. The Middle Kaskaskia River watershed varies in elevation from 802 to 438 feet (Figure 3). The Kaskaskia River water elevation varies from 492 feet to 447 feet and is 54 miles long upstream of the inlet to Carlyle Lake, resulting in a river gradient of 0.8 feet per mile. The highest elevations in the watershed are in the headwaters of Ramsey Creek and Hurricane Creek. The watershed topography consists of gently rolling terrain with steeper areas surrounding tributary streams. In the floodplain of Kaskaskia River, the topography is mostly flat (Carlyle Lake Watershed Technical and Planning Committees 2000).

2.5 Soils

The National Cooperative Soil Survey publishes soil surveys for each county in the U.S. These soil surveys contain predictions of soil behavior for selected land uses. The surveys also highlight limitations and hazards inherent in the soil, general improvements needed to overcome the limitations, and the impact of selected land uses on the environment. The soil surveys are designed for many different uses, including land use planning, the identification of special practices needed to ensure proper performance, and mapping of hydrologic soil groups (HSGs).

HSGs refer to the grouping of soils according to their runoff potential. Soil properties that influence the HSGs include depth to seasonal high water table, infiltration rate and permeability after prolonged wetting, and depth to a slower permeable layer (e.g., finer grained). There are four groups of HSGs: Group A, B, C, and Group D. Table 10 describes those HSGs found in the Middle Kaskaskia River watershed. Figure 4 and Table 11 summarizes the composition of HSGs in the watershed. Soils are predominantly C, C/D and D in the watershed. The high proportion of C, C/D and D type soils coupled with agricultural land uses indicate the likelihood of tile drainage.

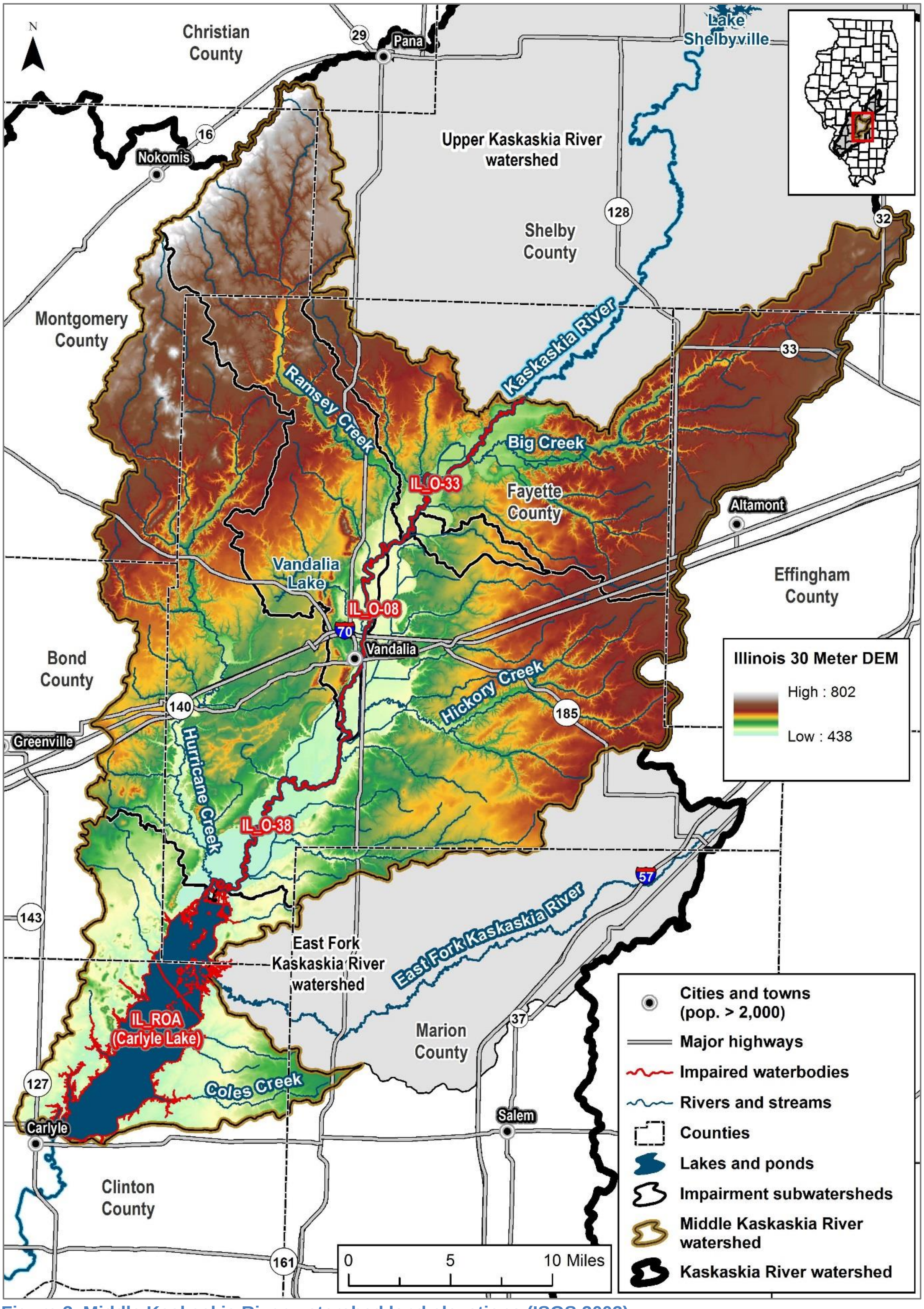


Figure 3. Middle Kaskaskia River watershed land elevations (ISGS 2003).

Table 10. Hydrologic soil group descriptions

HSG	Group Description
A	Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well to excessively drained sands or gravels with a high rate of water transmission.
B	Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
C	Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.
A-C/D	Dual Hydrologic Soil Groups. Certain wet soils are placed in group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition.

Table 11. Percent composition of hydrologic soil groups in watershed

Hydrologic Soil Group (HSG)	Acres	Percentage
B	41,917	6.9%
B/D	26,590	4.4%
C	249,614	41.2%
C/D	128,345	21.2%
D	130,517	21.6%
No Data	28,337	4.7%

Source: NRCS SSURGO Database 2011

A commonly used soil attribute is the K-factor, or the soil erodibility index. The distribution of K-factor values in the Middle Kaskaskia River watershed range from 0.26 to 0.53, with an average value of 0.39 (Figure 5). The higher the K-factor, the more susceptible the soil is to erosion.

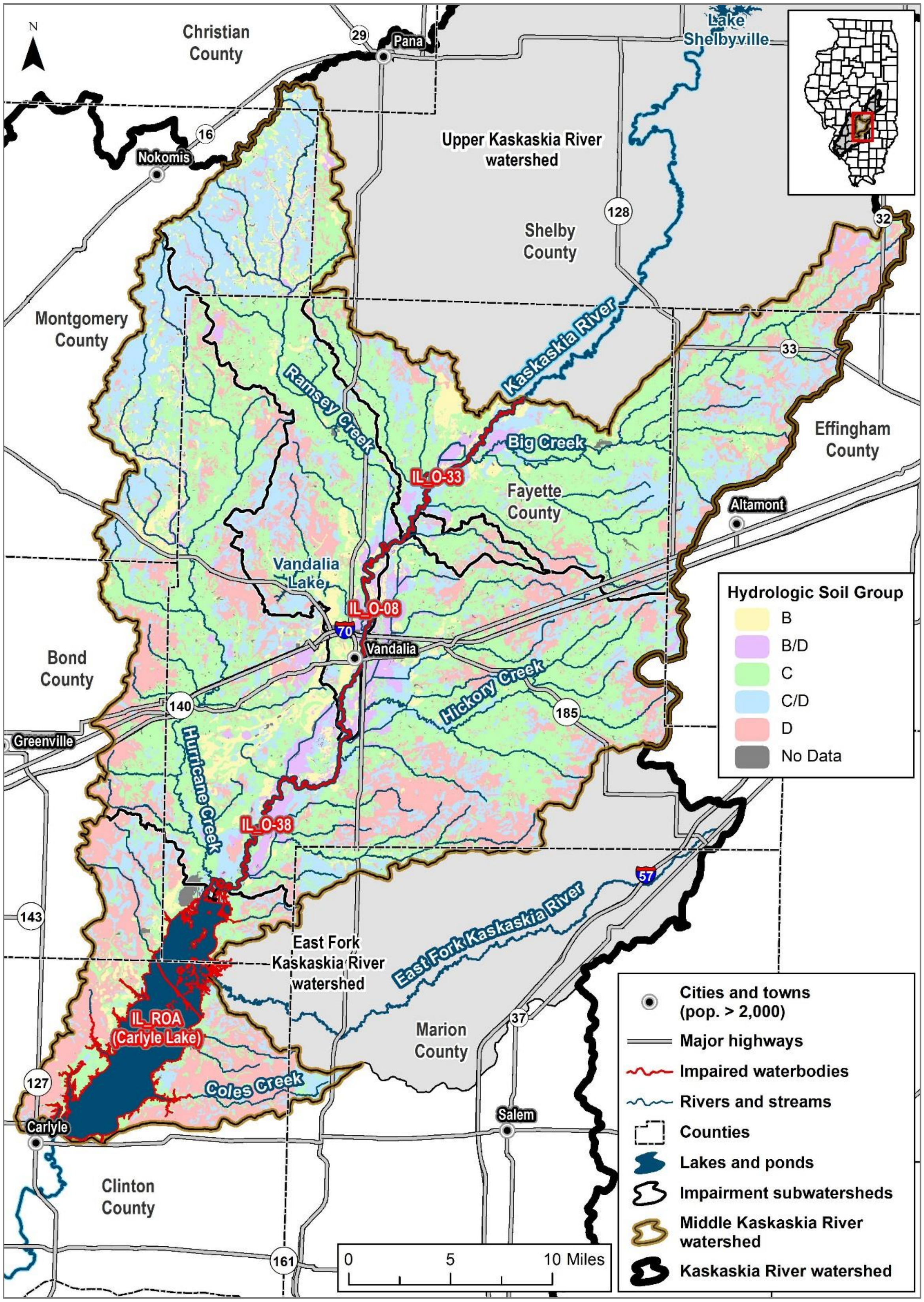


Figure 4. Middle Kaskaskia River watershed hydrologic soil groups (Soil Surveys for Bond, Christian, Clinton, Effingham, Fayette, Marion, Montgomery and Shelby Counties, Illinois; NRCS SSURGO Database 2011).

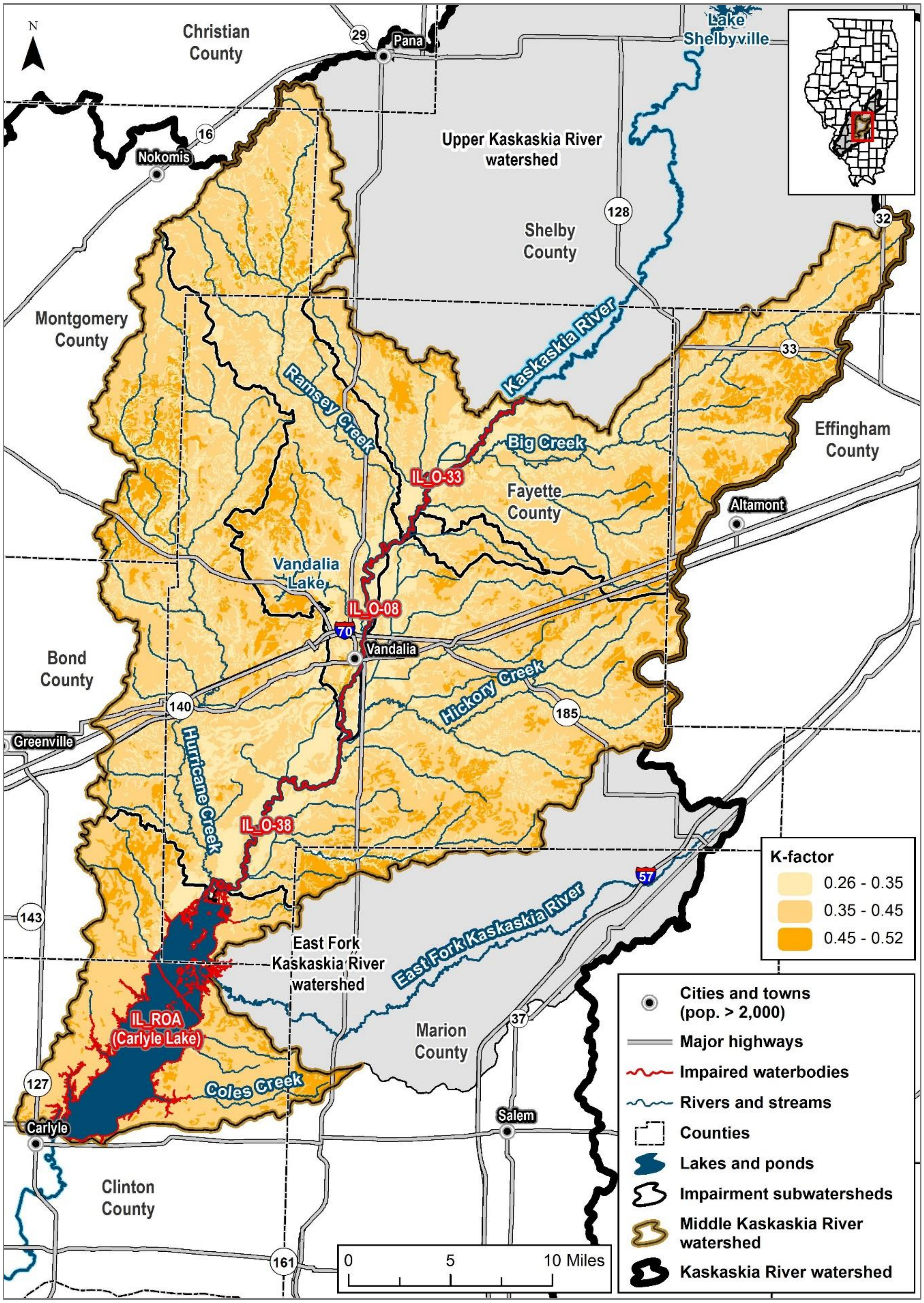


Figure 5. Middle Kaskaskia River watershed soil K-factor values (Soil Surveys for Bond, Christian, Clinton, Effingham, Fayette, Marion, Montgomery and Shelby Counties, Illinois; NRCS SSURGO Database 2011).

2.6 Hydrology

Hydrology plays an important role in evaluating water quality. The hydrology of the Middle Kaskaskia River watershed is driven by local climate conditions and the landscape. The U.S. Geological Survey (USGS) has been collecting flow and water quality data in this watershed since the early 1900s (Table 12 and Figure 9). There are four active USGS gages in the watershed.

The daily average, peak history, and monthly flow data show the inherent variability associated with hydrology. Flow duration curves provide a way to address that variability and flow related water quality patterns. Duration curves describe the percentage of time during which specified flows are equaled or exceeded. Flow duration analysis looks at the cumulative frequency of historic flow data over a specified period, based on measurements taken at uniform intervals (e.g., daily average or 15-minute instantaneous). Duration analysis results in a curve that relates flow values to the percent of time those values have been met or exceeded. Low flows are exceeded a majority of the time, whereas floods are exceeded infrequently. A flow duration curve for active USGS gage 05592500 is presented in Figure 6.

Table 12. USGS gages in impairment watersheds

Gage ID	Watershed Area ($mi.^2$)	Location	Period of Record	Impaired Segment
05592300	47.9	Wolf Creek near Beecher City, IL	1908-1982	-
05592350	87.3	Big Creek at Wrights Corner, IL	1961-1963	**-**
05592355	95.4	Big Creek near Post Oak, IL	1980-1981	-
05592360	35.3	South Fork near Pruett, IL	1980-1981	-
05592370	19.5	Ash Creek near Ramsey, IL	1980-1981	-
05592380	8.93	Bolt Creek near Ramsey, IL	1980-1981	-
05592400	97.3	Ramsey Creek near Ramsey, IL	1980-1981	-
05592500	**1,940**	**Kaskaskia River at Vandalia, IL**	**1908-2016**	**IL_O-08**
05592575	**44.2**	**Hickory Creek near Brownstown, IL**	**1988-2016**	**-**
05592600	77.6	Hickory Creek near Bluff City, IL	1977-1997	-
05592700	0.14	Hurricane Creek tributary near Witt, IL	1956-1980	-
05592800	**152**	**Hurricane Creek near Mulberry Grove, IL**	**1970-2016**	**-**
383706089210701	**2,717**	**Kaskaskia River at Carlyle Lake, IL (in-lake)**	**2017-2018**	**IL_ROA**
383715089204501	- [a]	Carlyle Lake Site 2	1991-1991 [b]	IL_ROA
384408089160001	- [a]	Carlyle Lake	1991-1992 [b]	IL_ROA

BOLD – indicates active USGS gage
a. Lake monitoring station.
b. Water quality data only, no flow data available.

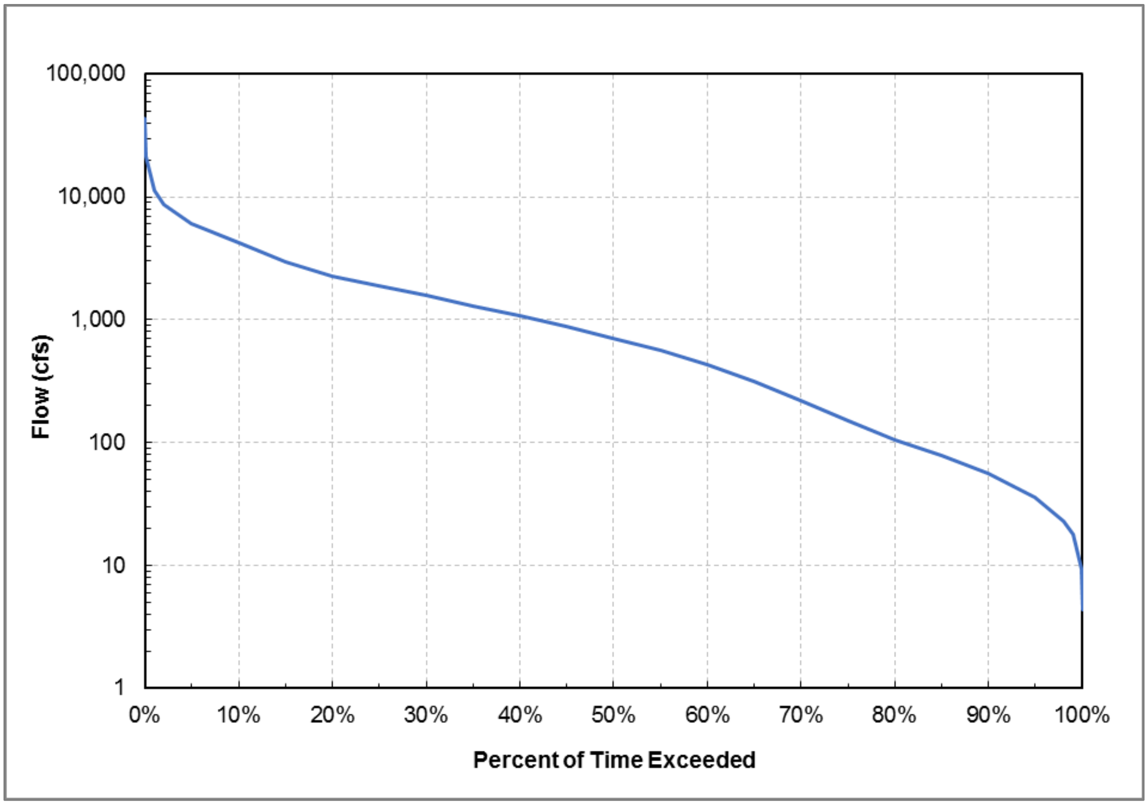


Figure 6. Flow duration curve for USGS gage 05592500, Kaskaskia River at Vandalia, IL (1908-2016).

An evaluation of annual flow at USGS gage 05592500 from 1908–2016 showed that annual flow in 2001 was nearly at the median; thus, it is assumed that 2001 is a typical year. Flow at USGS gage 05592500 is plotted with precipitation from the NOAA Global Historical Climatology Network Database Station USC00111290 (Carlyle Lake) in Figure 7. Flows in the Kaskaskia River decrease significantly during the late summer and early fall with decreasing precipitation.

There are no active flow gages on the Kaskaskia River or other incoming tributaries immediately upstream of Carlyle Lake. Flows through Carlyle Lake are monitored by the U.S. Army Corps of Engineers (USACE) using the water surface elevation. A minimum and maximum water surface elevation is managed by the USACE at the dam to control flooding in and downstream of the lake and to maintain adequate water levels for recreation (USACE 2017).

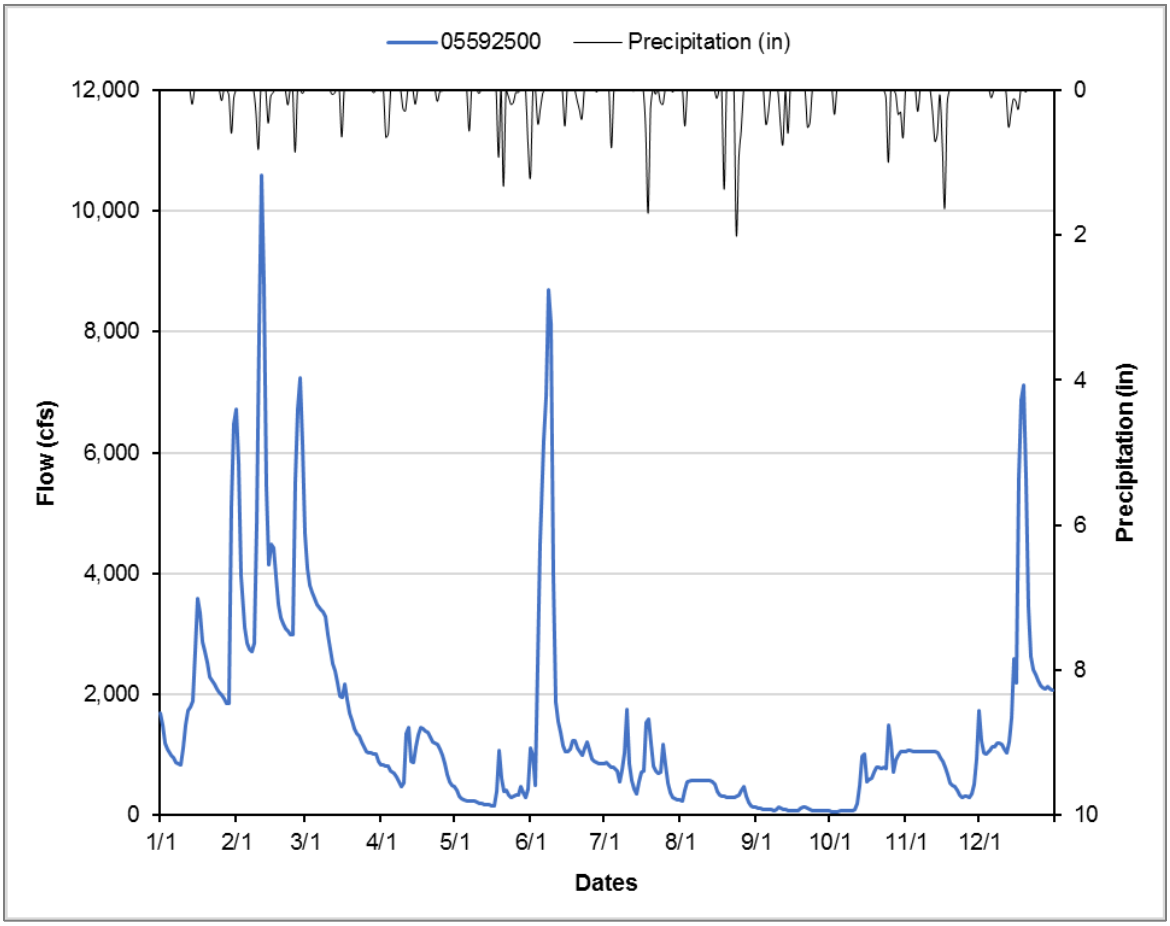


Figure 7. Daily flow in the Kaskaskia River with daily precipitation at Carlyle Lake (USC00111290), 2001.

2.7 Watershed Studies and Other Watershed Information

This section describes several of the studies that have been completed in the watershed.

- **Carlyle Lake Watershed Plan** (Carlyle Lake Watershed Technical and Planning Committees 2000)

  The Carlyle Lake Watershed Plan provides an approach to environmental improvement based on current data and analysis for the Carlyle Lake watershed. The plan was a collaborative effort between the Carlyle Lake Watershed Committee, local SWCDs, and the public. It established goals, concerns, and recommendations for land use and recreation in the watershed. Funding was provided by an Illinois Department of Natural Resources Conservation 2000 Ecosystems Project grant.

- **Carlyle Lake Master Plan** (USACE 2017)

  The Carlyle Lake Master Plan has been developed for use as a guide for resource development impacting Carlyle Lake. The plan was first developed by the United States Army Corps of Engineers in 1962 and has been updated and revised in 1974, 1979, 1986, 1997 and most recently in 2016. A description of Carlyle Lake and the land use, development pressures, and other important features of the Carlyle Lake watershed are included in the plan as well as a specific plan for resource development. Ongoing water quality, high water, fisheries, recreation and other issues are also discussed.

- **Kaskaskia River Watershed, An Ecosystem Approach to Issues and Opportunities** (Southwestern Illinois RC&D, Inc. 2002)

  The plan encompasses the larger Kaskaskia River watershed from Champaign County to Randolph County in southwestern Illinois, covering over 10% of the state of Illinois. The purpose of the plan was to begin a coordinated restoration process in the Kaskaskia River watershed based on sound ecosystem principles. The plan made recommendations on sustainability, diversity, health, variety, connectivity and the ecosystem's ability to thrive and reproduce in order to promote the sustainability of the ecosystem and strengthen the economic base and the quality of life of residents in the region.

- **Vandalia Lake TMDL** (CDM 2004)

  This previous TMDL provides information on nutrient loading from Vandalia Lake.

3. Watershed Source Assessment

Source assessments are an important component of water quality management plans and TMDL development. This section provides a summary of potential sources that contribute listed pollutants (i.e., fecal coliform and phosphorus) in the Middle Kaskaskia River watershed.

3.1 Pollutants of Concern

Pollutants of concern evaluated in this source assessment include fecal coliform and phosphorus. These pollutants can originate from an array of sources including point and nonpoint sources. Point sources typically discharge at a specific location from pipes, outfalls, and conveyance channels. Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters, particularly overland runoff. This section provides a summary of potential point and nonpoint sources that contribute to the impaired waterbodies.

3.2 Point Sources

Point source pollution is defined by the Federal Clean Water Act (CWA) §502(14) as:

> *"any discernible, confined and discrete conveyance, including any ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation [CAFO], or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agriculture storm water discharges and return flow from irrigated agriculture."*

Under the CWA, all point sources are regulated under the NPDES program. A municipality, industry, or operation must apply for an NPDES permit if an activity at that facility discharges wastewater to surface water. Point sources can include facilities such as municipal wastewater treatment plants (WWTPs), industrial facilities, CAFOs, or regulated storm water including municipal separate storm sewer systems (MS4s).

3.2.1 NPDES Facilities (Non-CAFO or stormwater)

NPDES facilities in the study area include municipal and industrial wastewater treatment and public water supply facilities. There are 15 individual NPDES permitted facilities in the project area (Table 14 and Figure 9). Average and maximum design flows and downstream impairments are included in the facility summaries. Three municipal wastewater facilities (IL0023574, IL0025933 and IL0061697) and one public water supply facility (ILG640114) drain directly to impaired waterbodies. The remaining facilities in Table 14 discharge to upstream unimpaired tributaries and are therefore not contributing to project impairments.

Eight wastewater treatment facilities have disinfection exemptions in the watershed which allow a facility to discharge wastewater without disinfection during a specified period. Facilities with disinfection exemptions may be required to provide Illinois EPA with updated information to demonstrate compliance with these requirements. No disinfection exempt facilities directly discharge into fecal-impaired segments.

3.2.2 Municipal Separate Storm Sewer Systems

Regulated storm water runoff can contribute to impairments in the project area. As development increases in the watershed, additional pressure will be placed on receiving waters due to storm water. Impervious areas associated with developed land uses can result in higher peak flow rates, higher runoff volumes and larger pollutant loads. Storm water runoff often contains sediment, nutrients, and bacteria among other pollutants.

Under the NPDES program, municipalities serving populations over 100,000 people are considered Phase I MS4 communities. In the impairment watersheds, there are no Phase I communities. Municipalities serving populations under 100,000 people are considered Phase II communities. In Illinois, Phase II communities are allowed to operate under the statewide General Storm Water Permit (ILR40) which requires dischargers to file a Notice of Intent, acknowledging that discharges shall not cause or contribute to a violation of water quality standards.

To assure pollution is controlled to the maximum extent practical, regulated entities operating under the General Storm Water Permit (ILR40) are required to implement six control measures including public education, public involvement, illicit discharge and detection programs, control of construction site runoff, post construction storm water management in new development and redevelopment, and pollution prevention/good housekeeping for municipal operations. Regulated entities operating under the General Storm Water Permit in the impairment watersheds are identified in Table 13 and Figure 8.

Table 13. Permitted MS4s in impairment watersheds

Permit ID	Regulated Entity	Receiving Waters
ILR400052	Foster Township MS4	Kaskaskia River (O-38) and Carlyle Lake (ROA)
ILR400152	Wheatland Township MS4	Kaskaskia River (O-38) and Carlyle Lake (ROA)
ILR400619	Beecher Village MS4	Kaskaskia River (O-33, O-08, O-38) and Carlyle Lake (ROA)

Table 14. Individual NPDES permitted facilities in impairment watersheds

IL Permit ID	Facility Name	Type of Discharge	Receiving Water	Downstream Impairment(s)	Average Design Flow (MGD)	Maximum Design Flow (MGD)	Disinfection Exemption
IL0023574	**Vandalia STP**	**STP**	**Kaskaskia River**	**O-08, O-38, ROA**	**1.3**	**8.25**	**No**
IL0025933	**Corps of Engr-Carlyle Boulder**	**STP**	**Carlyle Lake**	**ROA**	**0.02**	**-**	**No**
IL0032271	*Marathon Petroleum-St. Elmo*	*Water softener backwash, boiler blowdown and stormwater runoff*	*Unnamed ditch to East City reservoir*	*O-33, O-08, O-38, ROA*	*0.35*	*-*	*NA [a]*
IL0037974	*Ramsey Lake State Park*	*STP*	*Unnamed tributary to Ramsey Creek*	*O-08, O-38, ROA*	*0.015*	*0.0375*	*Yes*
IL0050156	*Fillmore STP*	*STP*	*Lanes Branch*	*O-38, ROA*	*0.049*	*0.195*	*Yes*
IL0053996	*IL DNR-Eldon Hazlet State Park*	*STP*	*Unnamed tributary of Carlyle Lake*	*ROA*	*0.045*	*0.11*	*No*
IL0061697	**Hickory Shores Resort**	**STP**	**Carlyle Lake**	**ROA**	**0.01**	**0.02**	**No**
IL0063878	*Beecher City STP*	*STP*	*Wolf Creek*	*O-33, O-08, O-38, ROA*	*0.052*	*0.105*	*Yes*
ILG580027	*Brownstown STP*	*STP*	*Unnamed tributary to Camp Creek North*	*O-38, ROA*	*0.1*	*0.327*	*Yes*
ILG580163	*Stewardson STP*	*STP*	*Wolf Creek*	*O-33, O-08, O-38, ROA*	*0.11*	*2.75*	*Yes*
ILG580191	*Mulberry Grove SD STP*	*STP*	*Owl Creek*	*O-38, ROA*	*0.0864*	*2.37*	*Yes*
ILG580222	*Ramsey STP*	*STP*	*Little Ramsey Creek*	*O-08, O-38, ROA*	*0.171*	*0.632*	*Yes*
ILG582016	*St. Elmo STP*	*STP*	*St. Elmo Ditch*	*O-33, O-08, O-38, ROA*	*0.343*	*1.31*	*Yes*
ILG640114	**Vandalia WTP**	**Public water supply**	**Kaskaskia River**	**O-08, O-38, ROA**	**0.12 [b]**	**-**	**NA [a]**
ILG640141	*Ramsey WTP*	*Public water supply*	*Little Ramsey Creek*	*O-08, O-38, ROA*	*0.014 [b]*	*-*	*NA [a]*

BOLD – NPDES facility drains directly to impaired water
Italics – NPDES facility draining to unimpaired segment.
STP – Sewage treatment plant
WTP– Water treatment plant
MGD – Million gallons per day
a. These facilities are not expected to contribute fecal coliform.
b. Average of DMR flows (2014-2016)

3.2.3 CAFOs

The area that produces manure, litter, or processed wastewater as the result of CAFOs is considered a point source that is regulated through the NPDES Program. In Illinois, the CAFO program is administered by the Illinois EPA through general permit number ILA01. The federal regulations for all CAFOs can be found in 40 CFR Parts 9, 122, and 412.U.S. EPA requires that CAFOs receive a wasteload allocation as part of the TMDL development process. The wasteload allocation is typically set at zero for all pollutants. There is one CAFO in the Middle Kaskaskia watershed: Wilder - South (ILA010051; Figure 8). The facility is located in the Hurricane Creek watershed. Hurricane Creek drains to fecal coliform-impaired segment O-38 of the Kaskaskia River.

3.3 Nonpoint Sources

The term nonpoint source pollution is defined as any source of pollution that does not meet the legal definition of point sources. Nonpoint source pollution typically results from overland stormwater runoff that is diffuse in origin, as well as background conditions. It should be noted that stormwater collected and conveyed through a regulated MS4 is considered a controllable point source. As part of the water resource assessment process, Illinois EPA has identified several sources as contributing to the Middle Kaskaskia River watershed impairments (Table 15).

Table 15. Potential sources in project area based on the Draft 2016 305(b) list

Watershed	Segment	Sources
Kaskaskia River	IL_O-08	Source unknown
	IL_O-33	Source unknown
	IL_O-38	Source unknown
Carlyle Lake	IL_ROA	Source unknown, littoral/shore area modifications (non-riverine), other recreational pollution sources, and crop production (crop land or dry land)

A summary of the potential nonpoint sources of pollutants is provided below, additional information on the primary pollutant sources follow. Potential nonpoint sources of fecal coliform in the Kaskaskia River include animal feeding operations (AFOs), onsite wastewater treatment systems, wildlife and stormwater and agricultural runoff. Nonpoint sources potentially contributing to Carlyle Lake's phosphorus impairment include stormwater and agricultural runoff, stream channel and shoreline erosion (and associated particulate phosphorus), and internal loading.

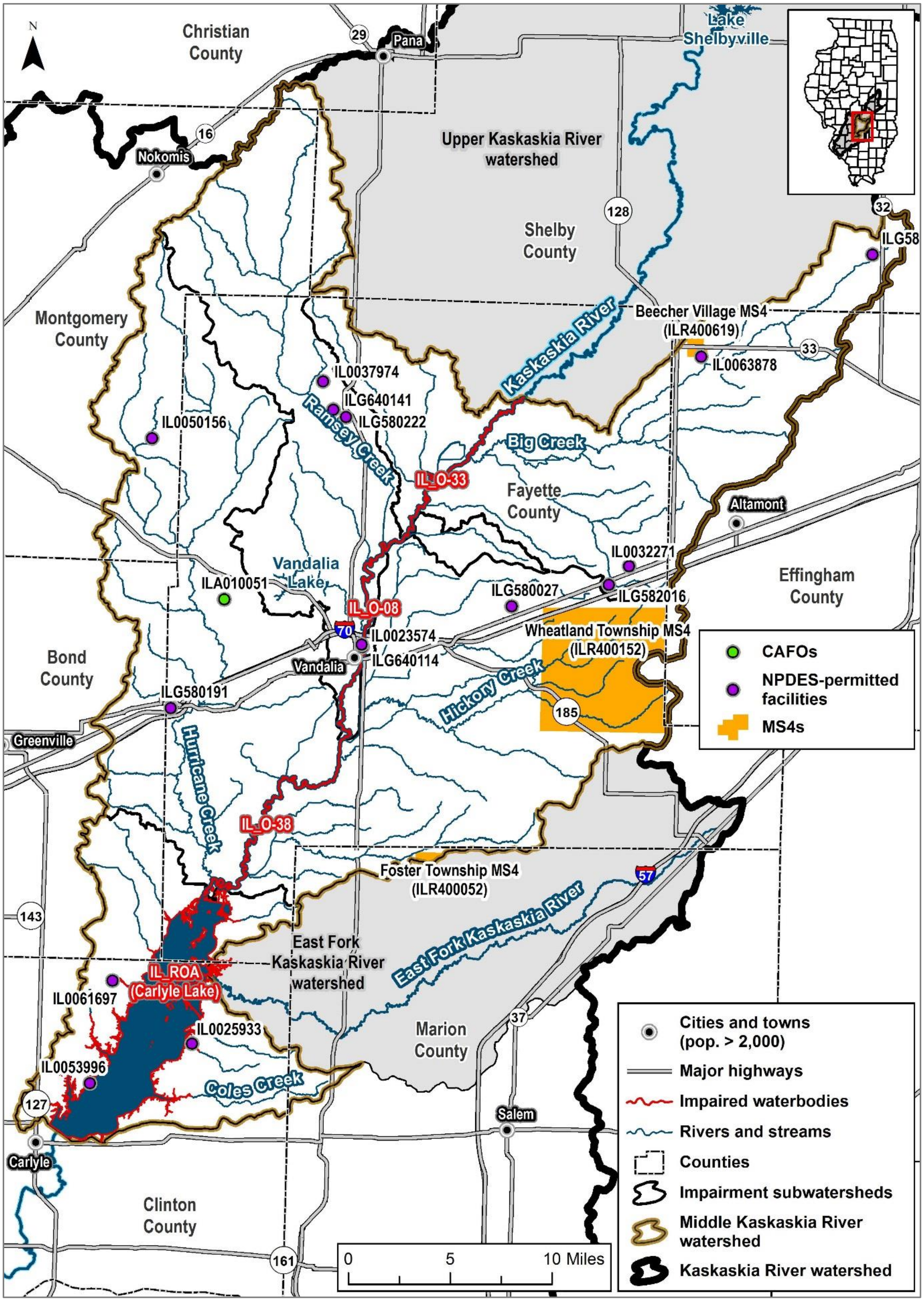


Figure 8. Point sources in impairment watersheds.

3.3.1 Animal Feeding Operations (AFOs)

Animal feeding operations that are not classified as CAFOs are known as animal feeding operations (AFOs) in Illinois. Non-CAFO AFOs are considered nonpoint sources by U.S. EPA. AFOs in Illinois do not have state permits. However, they are subject to state livestock waste regulations and may be inspected by the Illinois EPA, either in response to complaints or as part of the Agency's field inspection responsibilities to determine compliance by facilities subject to water pollution and livestock waste regulations. The animals raised in AFOs produce manure that is stored in pits, lagoons, tanks and other storage devices. The manure is then applied to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. AFOs, however, can pose environmental concerns, including the following:

- Manure can leak or spill from storage pits, lagoons, tanks, etc.
- Improper application of manure can contaminate surface or ground water.
- Manure over application can adversely impact soil productivity.

Livestock are potential sources of bacteria and nutrients to streams, particularly when direct access is not restricted and/or where feeding structures are located adjacent to riparian areas. Watershed specific data are not available for livestock populations. However, county wide data available from the 2012 Census of Agriculture were downloaded and area weighted to estimate the animal population in the project area. An estimated 96,587 animals are in the project area.

3.3.2 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. Common soil-type limitations which contribute to failure include seasonally high water tables, compact glacial till, bedrock, and fragipan. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsley and Witten 1996). Septic systems contain all the water discharged from homes and business and can be significant sources of pollutants. County health departments were contacted for information on septic systems and unsewered communities. Responses were received from Bond, Christian, Effingham, and Fayette Counties. Effingham county reported 4,862 installed septic systems since 1985 and Fayette reported permitting 605 installed septic systems since 2009. Christian and Fayette counties reported three and six unsewered communities, respectively. Bond county requires inspection of newly installed septic systems, but does not have a total count of installed systems or unsewered communities. No information was provided on failure rates or results of compliance testing.

3.3.3 Wildlife

Wildlife such as deer, raccoon, and waterfowl also contribute to fecal coliform loading in the watershed; however, these sources are not typically managed. While no specific information is available on wildlife populations in the watershed or their potential to impact fecal coliform loadings, according to the University of Illinois–Extension, the highest densities of white tail deer in the state are found in wooded areas in watersheds of major rivers. White tail deer are also known to reside in areas with intensively farmed land (University of Illinois–Extension 2017).

3.3.4 Stormwater and Agricultural Runoff

During wet-weather events (snowmelt and rainfall), pollutants are incorporated into runoff and can be delivered to downstream waterbodies. The resultant pollutant loads are linked to the land uses and practices in the watershed. Agricultural and developed areas can have significant effects on water quality if proper best management practices are not in place.

In addition to pollutants, alterations to a watershed's hydrology as a result of land use changes, ditching, and stream channelization can detrimentally affect habitat and biological health. Imperviousness associated with developed land uses and agricultural field tiling can result in increased peak flows and runoff volumes and decreased base flow as a result of reduced ground water discharge. Drain tiles also transport agricultural runoff directly to ditches and streams, whereas runoff flowing over the land surface may infiltrate to the subsurface and may flow through riparian areas.

3.3.5 Stream Channel and Shoreline Erosion

Various forms of erosion are a common source of sediment and associated pollutants such as phosphorus. Erosion may contribute to phosphorus impairment in Carlyle Lake because phosphorus is typically bound to sediment. Bank and channel erosion refers to the wearing away of the banks and channel of a stream or river. High rates of bank and channel erosion can often be associated with water flow and sediment dynamics being out of balance. This can result from land use activities that either alter flow regimes, adversely affect the floodplain and streamside riparian areas, or a combination of both. The USACE (2017) notes significant sediment entering Carlyle Lake from the Kaskaskia River. In a lake environment, shoreline erosion can be caused by changing water levels and wave action.

3.3.6 Internal Loading

Internal phosphorus loading from lake bottom sediments can be a substantial component of the phosphorus budget in lakes. Phosphorus in the sediment originates as an external phosphorus load that settles out of the water column to the lake bottom. There are multiple mechanisms by which phosphorus can be released back into the water column as internal loading including:

- Bottom-feeding fish such as carp and black bullhead forage in lake sediments. This physical disturbance can release phosphorus into the water column.
- Wind energy in shallow depths can mix the water column and disturb bottom sediments, which leads to phosphorus release.
- Other sources of physical disturbance, such as boating in shallow areas, can disturb bottom sediments and lead to phosphorus release.

The USACE (2017) reports that Carlyle Lake does not typically stratify during the summer months due to the presence of high winds and the overall shallow depth of the lake. If the lake does stratify, release of phosphorus in the anoxic portion of the lake could occur. The USACE (2017) also notes that low dissolved oxygen concentrations often occur in the lake due to algal blooms during periods of high temperatures and low wind.

4. Water Quality

Routine water quality monitoring is a key part of the Illinois EPA assessment program. The goals of Illinois EPA surface water monitoring programs are to determine whether designated uses are supported, identify causes of pollution (toxics, nutrients, sedimentation) and sources (point or nonpoint) of surface water impairments, determine the overall effectiveness of pollution control programs, and identify long term resource quality trends. Illinois EPA has operated a widespread, active long-term monitoring network in Illinois since 1977, known as the Ambient Water Quality Monitoring Network (AWQMN). The AWQMN is utilized by the Illinois EPA to provide baseline water quality information, to characterize and define trends in the physical, chemical and biological conditions of the state's waters, to identify new or existing water quality problems, and to act as a triggering mechanism for special studies or other appropriate actions.

Additional uses of the data collected by the Illinois EPA through the AWQMN program include the review of existing water quality standards and establishment of water quality based effluent limits for NPDES permits. The AWQMN is integrated with other Illinois EPA chemical and biological stream monitoring programs including Intensive River Basin Surveys, Facility –Related Stream Surveys, Fish Contaminant Monitoring, Toxicity Testing Program and Pesticide Monitoring Subnetwork which are more regionally based (specific watersheds or point source receiving stream) and cover a shorter span of time (e.g. one year) to evaluate compliance with water quality standards and determine designated use support. Information from this program is compiled by Illinois EPA into a biennial report, known as the Illinois Integrated Water Quality Report and Section 303(d) List, required by the Federal CWA.

Along the impaired waterbodies, data were found for numerous stations that are part of AWQMN (Figure 9 and Table 16). Parameters sampled on the waterbodies include field measurements (e.g., water temperature) as well as those that require lab analyses (e.g., fecal coliform, nutrients, and total suspended solids). Data were obtained directly from Illinois EPA.

Table 16. Illinois EPA water quality data for impaired waterbodies

Waterbody	Impaired Segment	AWQMN Sites	Location	Period of Record
Kaskaskia River	O-08	**O-08**	RM 135.7, RT 40-51 Br. (Gallatin St.) SE edge of Vandalia	*1999–2006*, 2007-2016, 2018
		O-39	3 Mi. N Vandalia	-*
		O-51	7 Mi. upstream Vandalia	-*
	O-33	O-64	4 Mi. NE of Vera at Co Rd 2150N	-*
		O-09	6 Mi. S of Herrick	-*
		O-33	RM 157.7, Co Rd 2700N Br. 7 Mi. E Ramsey upstream Big Creek	*2002*, 2007, 2012, 2017
	O-38	O-38	Co Rd 900N Br. 4 Mi. W Shobonieer and 7 Mi. SW Vandalia	-*
Carlyle Lake [a]	ROA	**ROA-1**	No site description	2011 (4 days), 2016 (1 day)
		ROA-2	Site 2 0.5 Mi. offshore from Carlyle	2011 (4 days), 2016 (1 day)
		ROA-3	Site 3 0.5 Mi. off Hazlet State Park South Shelter	2011 (4 days), 2016 (1 day)
		ROA-4	Site 4 2200 ft. NW access area	2011 (4 days), 2016 (1 day)
		ROA-5	Site 5 6000 ft. N into Hazlet State Park	2011 (4 days), 2016 (1 day)
		ROA-6	Site 6 50 ft. S large west arm	2011 (4 days), 2016 (1 day)
		ROA-99	No site description	2011 (2 days)
		Multiple other in-lake sites	-	-*

BOLD – Indicates station with data relevant to impairment
Italics – Data are greater than 10 years old
-* No data available for station in 1999–2016 water quality data received from Illinois EPA
a. Additional data are available from the USACE; see discussion below.
RM – River Mile

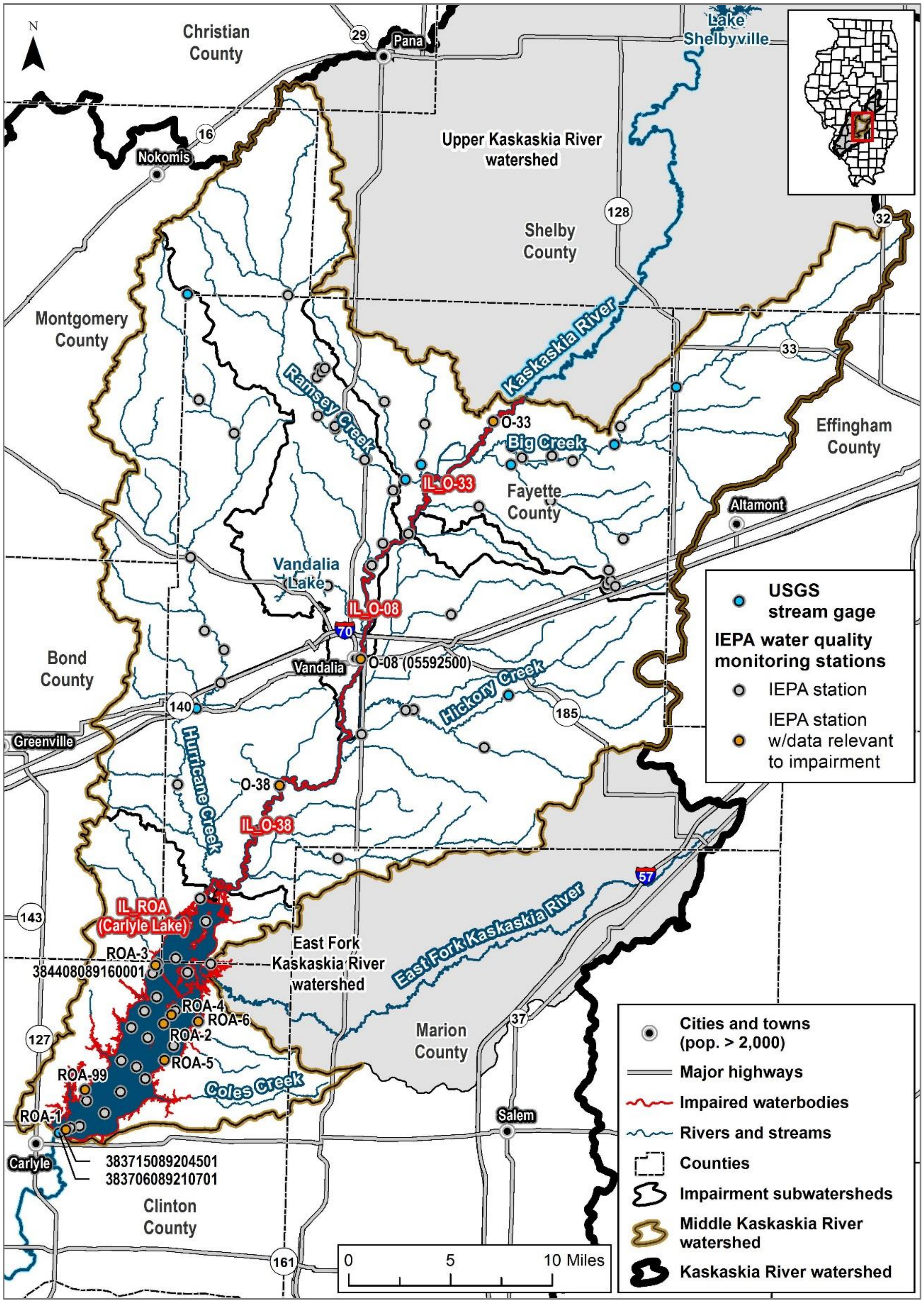


Figure 9. USGS stream gages and Illinois EPA water quality sampling sites in impairment watersheds and along impaired waterbodies.

Monitoring stations on impaired waterbodies with water quality data used in impairment assessment are labeled. Additional monitoring sites on Carlyle Lake are available from the USACE; see discussion below.

4.1 Data Analysis

An important step in the TMDL development process is the review of water quality conditions, particularly data and information used to list segments. Examination of water quality monitoring data is a key part of defining the problem that the TMDL is intended to address. This section provides a brief review of available water quality information provided by the Illinois EPA. The most recent 10 years of data collection, 2007–2016, were used to evaluate impairment for Carlyle Lake (ROA), and the last 5 years of data collection were used to evaluate Kaskaskia River impairments. Annual data requirements for impairment assessment were also included for Carlyle Lake; see Section 1.2.2. Each data point was reviewed to ensure the use of quality data in the analysis below.

4.1.1 Kaskaskia River

The Kaskaskia River is listed as impaired along three segments—O-33 for aquatic life due to low levels of dissolved oxygen, and O-08 and O-38 for primary contact recreation due to fecal coliform. There is one Illinois EPA sampling site with relevant data on O-33 and O-08 and no sampling sites with relevant data on O-38.

Dissolved oxygen measurements were collected on segment O-33 in 2012 and 2017. Dissolved oxygen in July 2012 violated the standard, and the dissolved oxygen impairment on O-33 is confirmed (Figure 10).

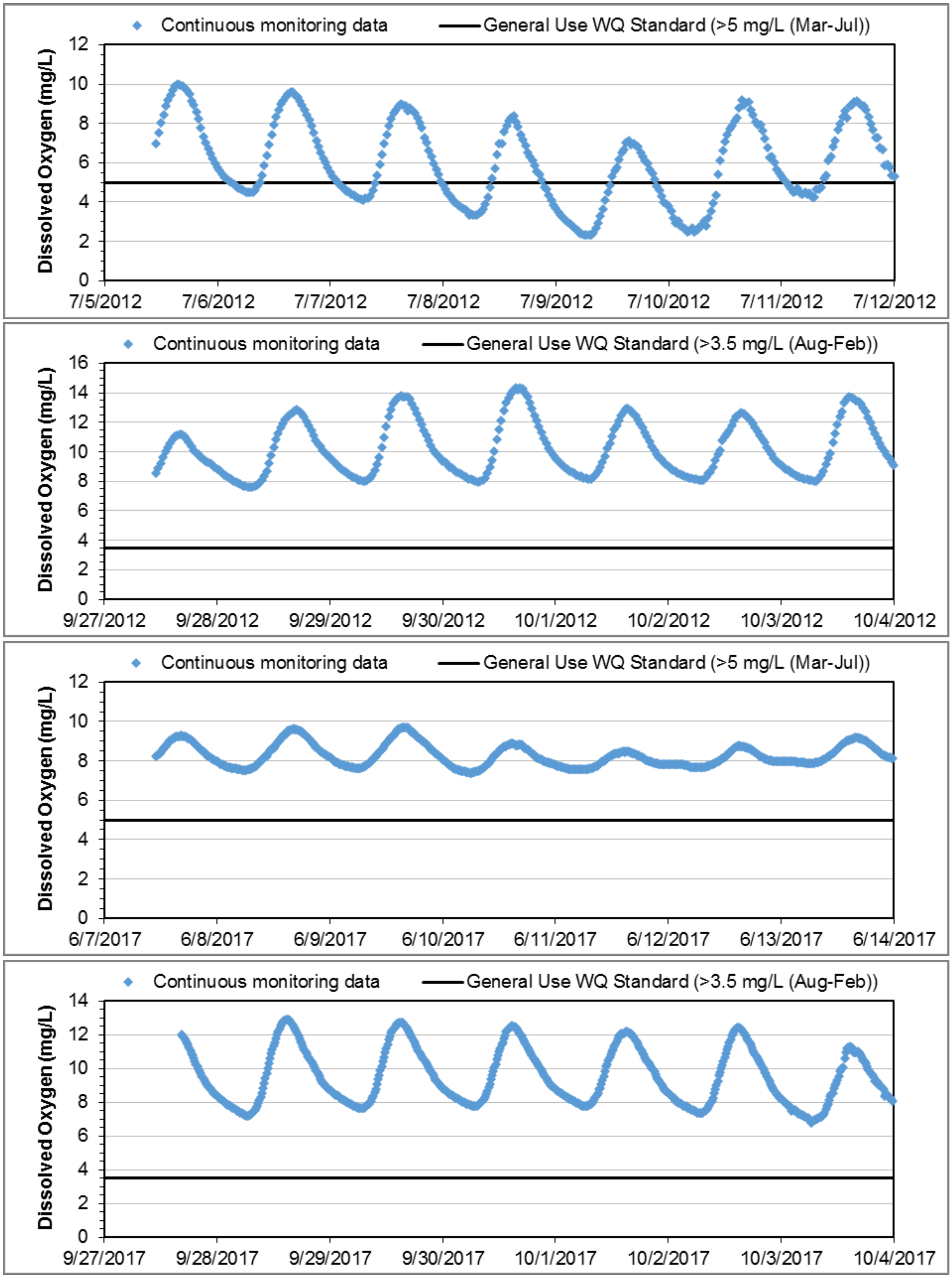


Figure 10. Continuous dissolved oxygen time series, Kaskaskia River O-33 segment (site O-33)

Seventeen fecal coliform samples were collected at O-08 between 2012 and 2016 (Table 17 and Figure 11). Eight exceedances of the single sample maximum standard were observed, with an average reported value above the standard at 1,387 cfu/100 mL. Additional data were collected at O-08 in 2018, and the geometric mean of the five samples taken within a 30-day period is greater than the monthly geometric mean standard (Figure 12). Recreational use impairment is verified for the segment.

Fecal coliform data from site O-08 were used to assess impairment on segment O-38. Site O-08 is located approximately five miles north of segment O-38. Recreational use impairment is verified for the segment.

Table 17. Data summary, Kaskaskia River O-08

Sample Site	No. of samples	Minimum (cfu/100 mL)	Average (cfu/100 mL)	Maximum (cfu/100 mL)	Number of exceedances of single sample maximum standard (400 cfu/100 mL)
Fecal Coliform					
O-08	17	78	1,387	10,000	8

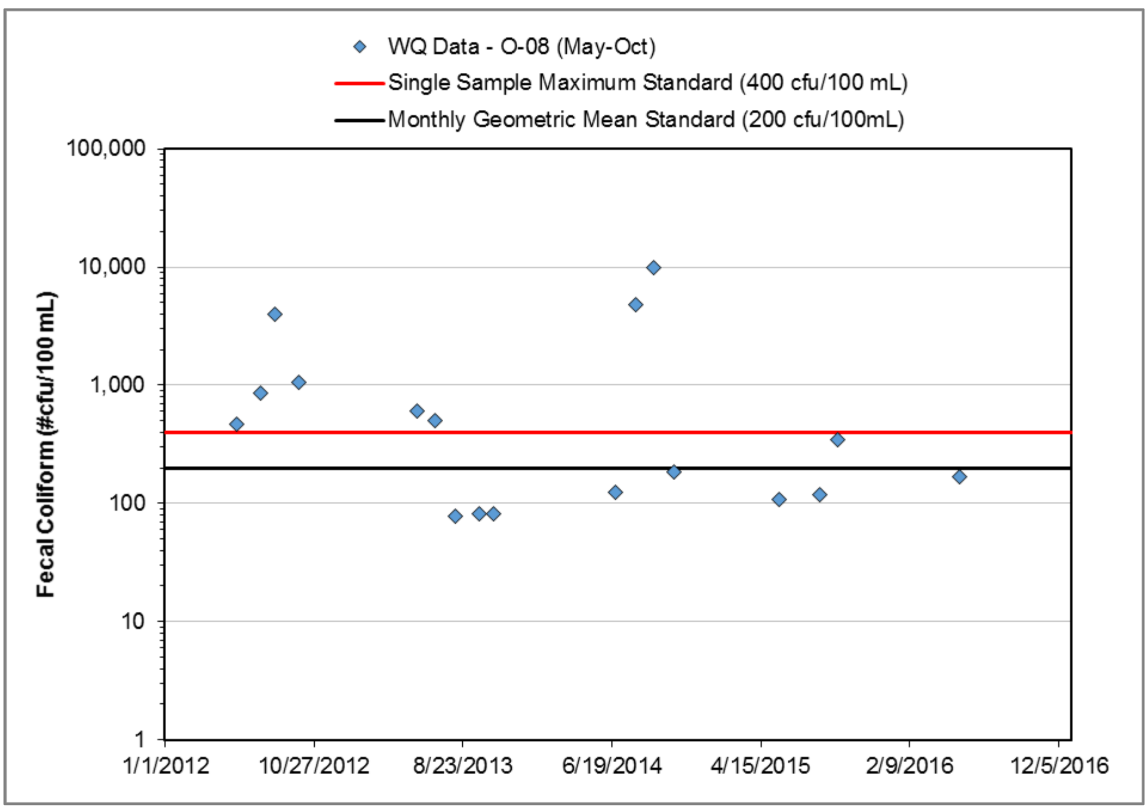


Figure 11. Fecal coliform water quality time series (2012–2015), Kaskaskia River O-08 segment.

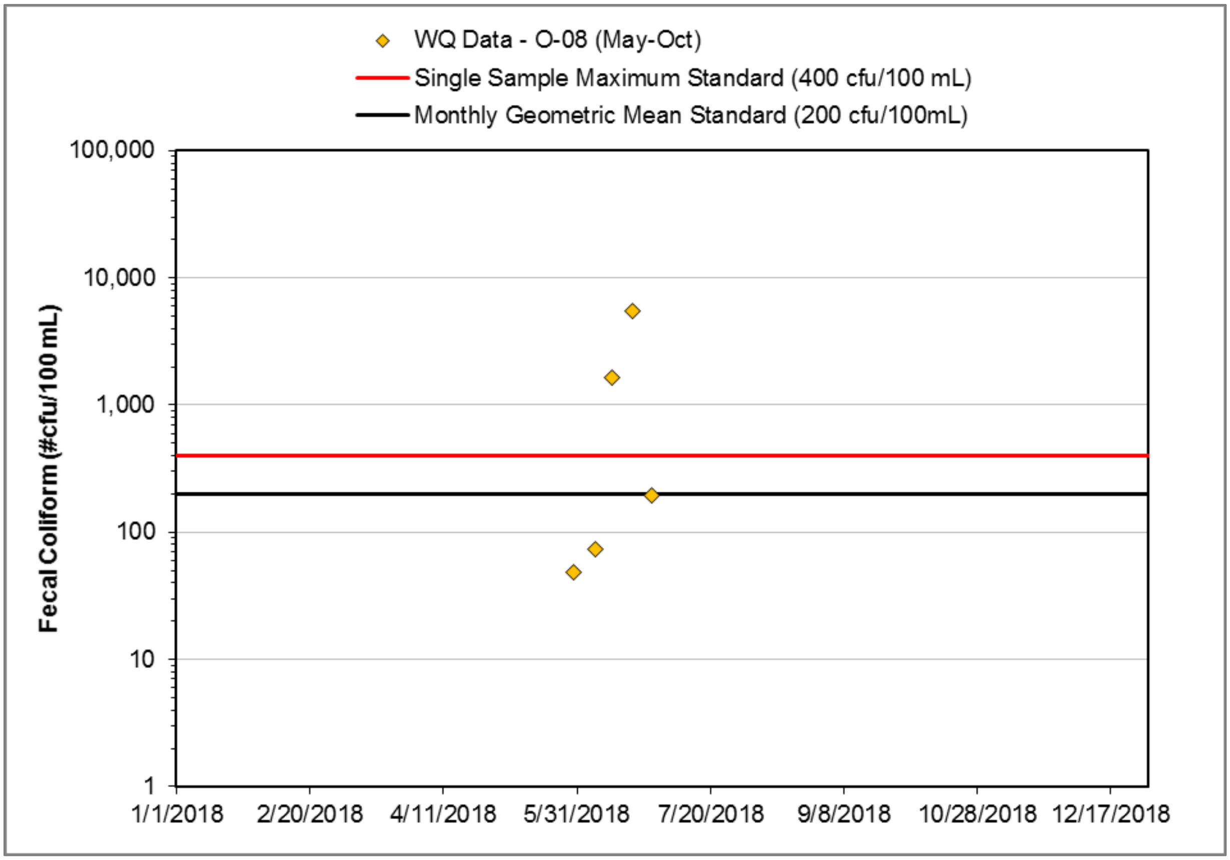


Figure 12. Fecal coliform water quality time series (2018), Kaskaskia River O-08 segment.

4.1.2 Carlyle Lake (ROA)

Carlyle Lake is a 9,947-hectare reservoir located 0.5 miles north of the city of Carlyle, IL and is the largest reservoir in the state of Illinois. It was created in 1967 by impounding the Kaskaskia River and is used for recreation, with approximately 12,000 acres of public land surrounding the shoreline. It has an average depth of 40 feet and is capable of reaching a maximum depth of 58 feet during flood conditions (USACE 2017).

Carlyle Lake (ROA) is listed as impaired for aesthetic quality due to elevated levels of total phosphorus. Seven Illinois EPA sampling sites with relevant data were identified in the lake (Figure 9). Thirty-seven lake samples were collected at the sampling sites between 2011 and 2016 (Table 18). Figure 13 provides the water quality data collected during 2011. All samples exceed the general use water quality standard of 0.05 mg/L, with an average value across all sites of over three times the standard at 0.19 mg/L. Aesthetic quality impairment is confirmed for Carlyle Lake.

Additional phosphorus and chlorophyll-*a* data are available from the USACE from 2005–2017 at eight monitoring sites. Up to five samples were collected per year at each site.

Table 18. Illinois EPA data summary, Carlyle Lake
Additional data are available from the USACE.

Sample Site	Location	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of Exceedances
Phosphorus (Total)						
ROA-1	South end of lake	10 [a]	0.116	0.205	0.332	10
ROA-2	Center of lake	5	0.115	0.176	0.257	5
ROA-3	Western side of lake	5	0.116	0.209	0.262	5
ROA-4	Center of lake	5	0.117	0.194	0.282	5
ROA-5	Eastern side of lake	5	0.122	0.186	0.288	5
ROA-6	Eastern side of lake	5	0.108	0.181	0.288	5
ROA-99	Western side of lake	2	0.124	0.134	0.143	2

a. Two samples were taken on each of 5 days from this sampling station.

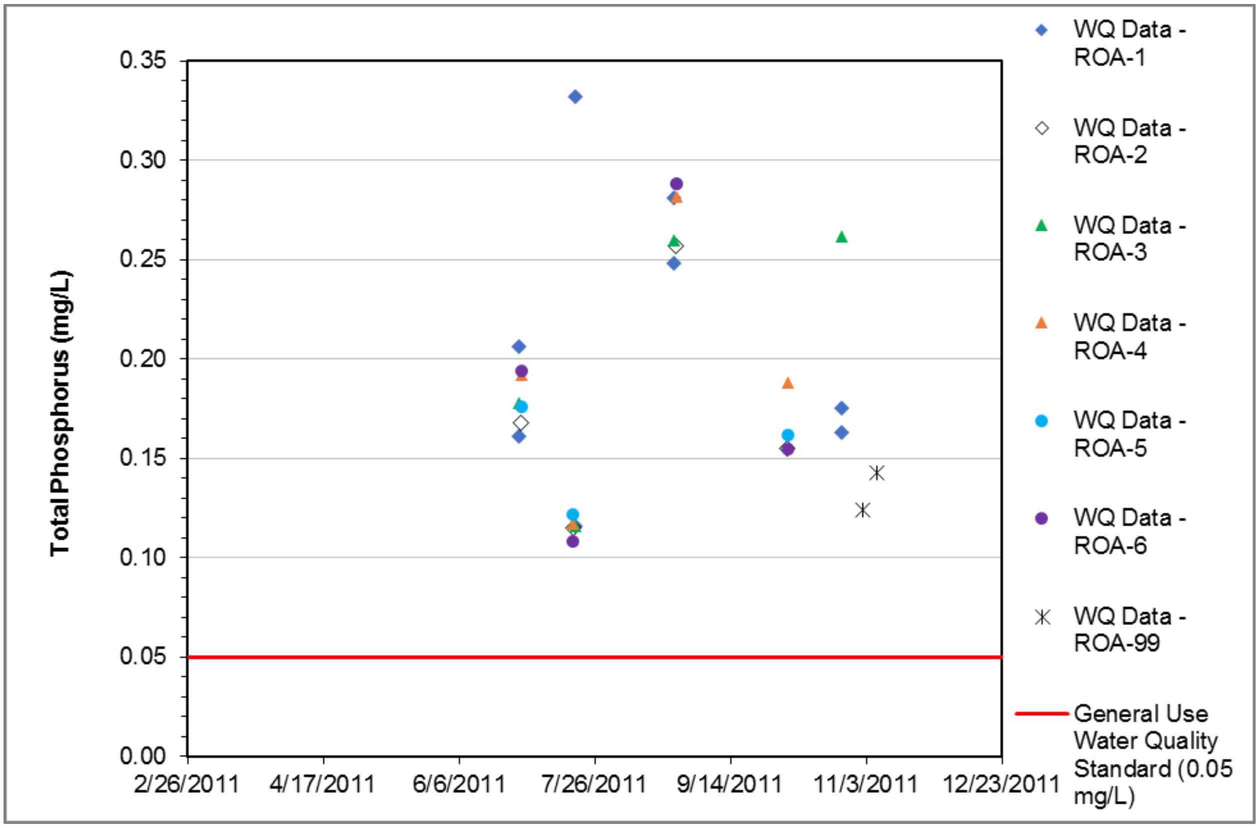


Figure 13. Total phosphorus water quality data, 2011, Carlyle Lake (ROA).

5. TMDL Methods and Data Needs

The first stage of this project has been an assessment of available data, followed by evaluation of their credibility. The types of data available, their quantity and quality, and their spatial and temporal coverage relative to impaired segments or watersheds drive the approaches used for TMDL model selection and analysis. Credible data are those that meet specified levels of data quality, with acceptance criteria defined by measurement quality objectives, specifically their precision, accuracy, bias, representativeness, completeness, and reliability. The following sections describe the methods that are proposed to derive TMDLs and the additional data needed to develop credible TMDLs.

5.1 Stream and Lake Impairments

TMDLs are proposed for all segments with verified impairments (Table 19). A duration curve approach is suggested to evaluate the relationships between hydrology and water quality and calculate the TMDLs for fecal coliform impairments; a Bathtub model is proposed for Carlyle Lake (ROA). For the dissolved oxygen impairment, which is not affected by point sources, it is assumed that the cause of impairment is either eutrophication or non-pollutant based (e.g., the effect of lack of re-aeration in low-gradient streams or the effect of hydromodification).

Table 19. Proposed model summary

Name	Segment ID	Designated Uses	TMDL Parameter(s)	Proposed Model	Proposed Pollutant
Kaskaskia River	IL_O-08	Primary contact recreation	Fecal coliform	Load duration curve	Fecal coliform
	IL_O-33	Aquatic life	Dissolved oxygen	Load duration curve or 4C classification	Phosphorus or non-pollutant
	IL_O-38	Primary contact recreation	Fecal coliform	Load duration curve	Fecal coliform
Carlyle Lake	IL_ROA	Aquatic life	Phosphorus (Total)	Bathtub	Phosphorus (Total)

5.1.1 Load Duration Curve Approach

The primary benefit of duration curves in TMDL development is to provide insight regarding patterns associated with hydrology and water quality concerns. The duration curve approach is particularly applicable because water quality is often a function of stream flow. For instance, sediment concentrations typically increase with rising flows as a result of factors such as channel scour from higher velocities. Other parameters, such as chloride, may be more concentrated at low flows and more diluted by increased water volumes at higher flows. The use of duration curves in water quality assessment creates a framework that enables data to be characterized by flow conditions. The method provides a visual display of the relationship between stream flow and water quality.

Allowable pollutant loads have been determined through the use of load duration curves. Discussions of load duration curves are presented in *An Approach for Using Load Duration Curves in the Development of TMDLs* (USEPA 2007). This approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from extremely high flows to extremely low flows.

2. The flow curve is translated into a load duration (or TMDL) curve by multiplying each flow value (in cubic feet per second) by the water quality standard/target for a contaminant (mg/L), then multiplying by conversion factors to yield results in the proper unit (i.e., pounds per day). The resulting points are plotted to create a load duration curve.

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected. Then, the individual loads are plotted as points on the TMDL graph and can be compared to the water quality standard/target, or load duration curve.

4. Points plotting above the curve represent deviations from the water quality standard/target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load. Further, it can be determined which locations contribute loads above or below the water quality standard/target.

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards/targets.

6. The final step is to determine where reductions need to occur. Those exceedances at the right side of the graph occur during low flow conditions, and may be derived from sources such as illicit sewer connections. Exceedances on the left side of the graph occur during higher flow events, and may be derived from sources such as runoff. Using the load duration curve approach allows Illinois EPA to determine which implementation practices are most effective for reducing loads on the basis of flow regime.

Water quality duration curves are created using the same steps as those used for load duration curves except that concentrations, rather than loads, are plotted on the vertical axis. Flows are categorized into the following five hydrologic zones (U.S. EPA 2007):

- High flow zone: stream flows that plot in the 0 to 10-percentile range, related to flood flows
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions
- Mid-range zone: flows in the 40 to 60-percentile range, median stream flow conditions
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions

The duration curve approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. Table 20 summarizes the general relationship between the five hydrologic zones and potentially contributing source areas (the table is not specific to any individual pollutant). For example, the table indicates that impacts from point sources are usually most pronounced during dry and low flow zones because there is less water in the stream to dilute their loads. In contrast, impacts from stormwater are most pronounced during moist and high flow zones due to increased overland flow from stormwater source areas during rainfall events.

Table 20. Relationship between duration curve zones and contributing sources

Contributing source area	Duration Curve Zone				
	High	Moist	Mid-range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
On-site wastewater systems	M	M-H	H	H	H
Stormwater: Impervious		H	H	H	
Stormwater: Upland	H	H	M		

Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low).

The load reduction approach also considers critical conditions and seasonal variation in the TMDL development as required by the CWA and U.S. EPA's implementing regulations. Because the approach establishes loads on the basis of a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions. An underlying premise of the duration curve approach is correlation of water quality impairments to flow conditions. The duration curve alone does not consider specific fate and transport mechanisms, which may vary depending on watershed or pollutant characteristics.

5.1.2 Bathtub

The Bathtub model is recommended to support TMDL development for Carlyle Lake. Bathtub is a steady state model that predicts eutrophication response in lakes based on empirical formulas developed for nutrient balance calculations and algal response (Walker 1987). The model was developed and is maintained by the USACE. The model requires nutrient loading inputs from the contributing watershed and atmospheric deposition, morphometric data for the lake, and estimates of mixing depth and nonalgal turbidity. A series of linked models will be developed, depending on the availability of bathymetry and other datasets. Data from 2005 through 2017 will be used to calibrate and validate the model.

5.2 Additional Data Needs

Data satisfy two key objectives for Illinois EPA, enabling the agency to make informed decisions about the resource. These objectives include developing information necessary to:

- Determine if the impaired areas are meeting applicable water quality standards for their respective designated use(s)
- Support modeling and assessment activities required to allocate pollutant loadings for all impaired areas where water quality standards are not being met

Additional data may be needed to verify impairment, understand probable sources, calculate reductions, develop calibrated water quality models, and develop effective implementation plans. Table 21 summarizes the additional data needed for each impaired segment.

Table 21. Additional data needs

Name	Segment ID	Designated Uses	TMDL Parameters	Additional Data Needs
Kaskaskia River	IL_O-08	Primary contact recreation	Fecal coliform	None
	IL_O-33	Aquatic life	Dissolved oxygen	To determine relationship with eutrophication
	IL_O-38	Primary contact recreation	Fecal coliform	None
Carlyle Lake	IL_ROA	Aquatic life	Phosphorus (Total)	None
All	All	All	All	Implementation plan development

Specific data needs include:

Determine Relationship with Eutrophication on O-33—A series of DO measurements and chlorophyll-*a* and TP grab samples (two samples per day on three separate sampling days) should be collected from the impaired segment (site O-33) to determine the role of eutrophication, if any, in the impaired segment. Sampling should occur during the warm summer months (July–August) and during low flows to ensure that critical conditions are captured.

Implementation Plan Development—Further in-field assessment may be needed to better determine the source of impairments in order to develop an effective TMDL implementation plan. Additional monitoring could include:

- Windshield surveys
- Streambank surveys and stream assessments for Kaskaskia River: IL_O-08, IL_O-33, IL_O-38
- Lakeshore assessment of Carlyle Lake:
- Farmer/landowner surveys
- Word of mouth and in-person conversations with local stakeholders and landowners

6. Public Participation

<to be updated based on Stage 1 meetings>

7. References

Carlyle Lake Watershed Technical and Planning Committees. 2000. Carlyle Lake Watershed Plan. Developed in cooperation with and funding provided by the Illinois Department of Natural Resource through a Conservation 2000 Ecosystems Project grant.

Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography. 23:361-369.

CDM. 2004. Vandalia Lake TMDL Report.

Horsley and Witten, Inc. 1996. Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine. Casco Bay Estuary Project

IEPA (Illinois Environmental Protection Agency). 1994. Quality assurance project plan. Bureau of Water, Division of Water Pollution Control. Springfield, Illinois.

IEPA (Illinois Environmental Protection Agency). 2016. Draft Illinois Integrated Water Quality Report and Section 303(d) List, 2016. Water Resource Assessment Information and Listing of Impaired Waters. Springfield, IL.

Illinois State Geological Survey (ISGS). 2003. Illinois Statewide 30-Meter Digital Elevation Model. Retrieved from: http://clearinghouse.isgs.illinois.edu/data/elevation/surface-elevation-30-meter-digital-elevation-model-dem.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing Biological Integrity in Running Water: a Method and its Rationale. Illinois Natural History Survey Special Publication 5. Champaign, Illinois.

Multi-Resolution Land Characteristics Consortium (MRLC). 2015. National Land Cover Database (NLCD 2011). Retrieved from: http://www.mrlc.gov.

Smogor, R. 2000 (draft, annotated 2006). Draft manual for Calculating Index of Biotic Integrity Scores for Streams in Illinois. Illinois Environmental Protection Agency, Bureau of Water, Division of Water Pollution Control. Springfield, Illinois.

Smogor, R. 2005 (draft). Interpreting Illinois fish-IBI Scores. Illinois Environmental Protection Agency, Bureau of Water, Division of Water Pollution Control. Springfield, Illinois.

Southwestern Illinois RC&D, Inc. 2002. Kaskaskia River Watershed, An Ecosystem Approach to Issues and Opportunities. Developed in cooperation with and funding provided by the Illinois Department of Natural Resources and U.S. Army Corps of Engineers.

Tetra Tech Inc., 2004. Illinois Benthic Macroinvertebrate Collection Method Comparison and Stream Condition Index Revision, 2004.

University of Illinois Extension. 2017. Living with Wildlife in Illinois. http://web.extension.illinois.edu/wildlife/directory_show.cfm?species=deer. Accessed Nov. 9, 2017.

USACE (U.S. Army Corps of Engineers). 2017. Carlyle Lake Master Plan. St. Louis District.

U.S. EPA (U.S. Environmental Protection Agency). 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. EPA 440/4-91-001. Office of Water, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 2002. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047. Office of Water. Office of Science and Technology. Washington, D.C.

U.S. EPA (U.S. Environmental Protection Agency). 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006. U.S. Environmental Protection Agency, Washington D.C.

Walker, W.W. 1987. Empirical Methods for Predicting Eutrophication in Impoundments. Report 4, Applications Manual, Tech. Rep. E-81-9. Prepared for U.S. Army Corps of Engineers Waterways Exp. Sta. Vicksburg, MS.

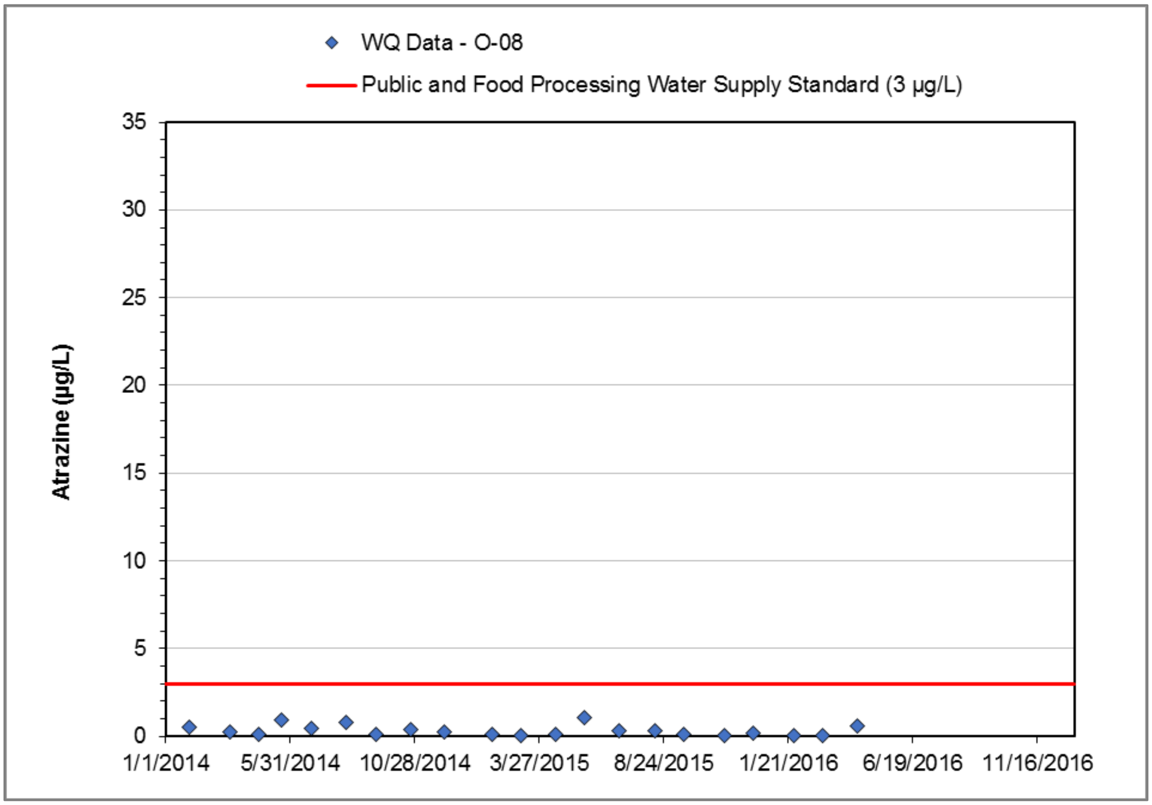
Appendix A – Unimpaired Stream Data Analysis

Kaskaskia River (O-08)

Kaskaskia River segment O-08 is listed for not supporting Public and Food Processing Water Supplies due to elevated levels of atrazine. One Illinois EPA sampling site was identified on the segment, O-08. No samples over the last three years of data collection (2014–2016) were recorded above the 3 µg/L drinking water protection MCL. It is therefore recommended that the segment be delisted for atrazine and no TMDL be developed.

Atrazine data summary, Kaskaskia River O-08

Sample Site	Date	Result (µg/L)	Quarterly Average (µg/L)
Atrazine			
O-08	1/30/2014	0.55	0.4
	3/19/2014	0.26	
	4/23/2014	0.13	0.5
	5/21/2014	0.92	
	6/26/2014	0.44	
	8/7/2014	0.77	0.4
	9/11/2014	0.09	
	10/23/2014	0.39	0.3
	12/3/2014	0.27	
	1/29/2015	0.11	0.1
	3/5/2015	0.08	
	4/16/2015	0.10	0.6
	5/21/2015	1.10	
	7/2/2015	0.29	0.26
	8/13/2015	0.34	
	9/17/2015	0.15	
	11/5/2015	0.06	0.12
	12/10/2015	0.17	
	1/28/2016	0.05	0.05
	3/3/2016	0.05	
	4/14/2016	0.61	0.61



Atrazine water quality time series, Kaskaskia River O-08.