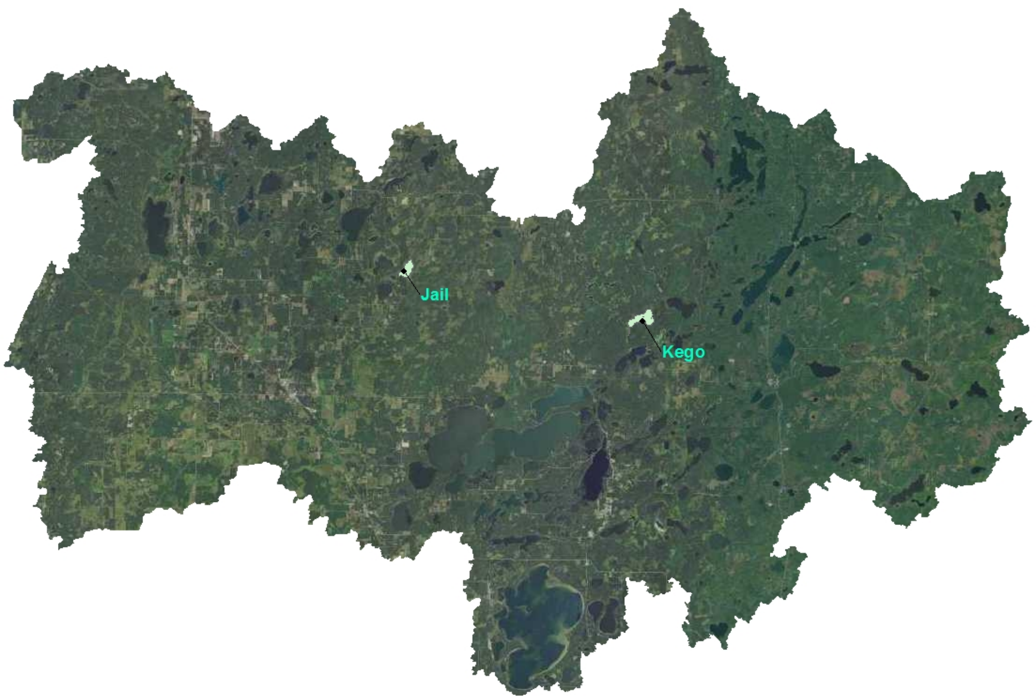
Pine River Watershed Total Maximum Daily Load

An identification of sources of excess phosphorus to two lakes, and the amount of phosphorus that needs to be reduced to improve water clarity



MINNESOTA POLLUTION CONTROL AGENCY

October 2017

wq-iw8-51e

Authors and contributors:

Meghan Jacobson, PhD (Emmons & Olivier Resources, Inc.)

Scott Lucas (Minnesota Pollution Control Agency)

Mitch Brinks (Crow Wing SWCD)

Contents

List of Tables

List of Figures

Acronyms & Units

ac-ft/yr	acre feet per year
AU	Animal Unit
BMP	Best Management Practice
chl-*a*	chlorophyll-*a*
CV	Coefficient of Variation
DNR	Minnesota Department of Natural Resources
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program-Fortran
kg/day	kilograms per day
kg/yr	kilograms per year
km	kilometer
LA	Load Allocation
Lb	pound
lb/ac-yr	pounds per acre per year
lb/yr	pounds per year
m	meter
mg/L	milligrams per liter
mg/m^2-day	milligram per square meter per day
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NLCD	National Land Cover Dataset
NLF	Northern Lakes and Forest
NPDES	National Pollutant Discharge Elimination System
ppb	part per billion
RC	Reserve Capacity
SDS	State Disposal System
SE	Standard Error
sq. km	square kilometer
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
WLA	Wasteload Allocation
WRAPS	Watershed Restoration and Protection Strategies

TMDL Summary Table

<table>
<tr><th>EPA/MPCA Required Elements</th><th colspan="3">Summary</th><th>TMDL Page #</th></tr>
<tr><td>Location</td><td colspan="3">The Pine River Watershed (07010105) is a tributary to the Mississippi River located in north-central Minnesota</td><td>14</td></tr>
<tr><td>303(d) Listing Information</td><td colspan="3">· Impaired waterbodies on the State's 303(d) list:
Jail Lake (aka Big Rice Lake), DNR ID 18041500
Kego Lake, DNR ID 18029300
· Impaired Beneficial Use(s): Aquatic Recreation
· Pollutant of Concern: Nutrients (Phosphorus) /Eutrophication Biological Indicators
· TMDL Target Start/Completion: 2012/2016
· Original listing year: 2010 (Kego), 2012 (Jail)</td><td>11</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td colspan="3">Class 2B Waters Lake Eutrophication Standards, Minn. R. 7050.0222, Subp. 4, Northern Lakes and Forests Ecoregion: TP (µg/L) < 30, Chl-a (µg/L) < 9, Secchi (m) > 2.0.
Based on clear relationships established between TP, Chl-a, and Secchi for MN lakes it is expected that by meeting the TP goal, Chl-a and Secchi will be met (Heiskary and Wilson 2005).</td><td>13</td></tr>
<tr><td rowspan="3">Loading Capacity (expressed as daily load)</td><td colspan="2">Impaired Lake</td><td>Loading Capacity (kg/day)</td><td></td></tr>
<tr><td colspan="2">Jail</td><td>0.453</td><td>31</td></tr>
<tr><td colspan="2">Kego</td><td>0.679</td><td>32</td></tr>
<tr><td rowspan="5">Wasteload Allocation</td><td>Source (Permit #)</td><td>Impaired Lake</td><td>WLA (kg/day)</td><td></td></tr>
<tr><td rowspan="2">Construction Stormwater (MNR100001)</td><td>Jail</td><td>0.0014</td><td>31</td></tr>
<tr><td>Kego</td><td>0.0016</td><td>32</td></tr>
<tr><td rowspan="2">Industrial Stormwater (MNR50000)</td><td>Jail</td><td>0.0014</td><td>31</td></tr>
<tr><td>Kego</td><td>0.0016</td><td>32</td></tr>
<tr><td rowspan="3">Load Allocation</td><td>Impaired Lake</td><td colspan="2">LA (kg/day)</td><td></td></tr>
<tr><td>Jail</td><td colspan="2">0.405</td><td>31</td></tr>
<tr><td>Kego</td><td colspan="2">0.608</td><td>32</td></tr>
<tr><td>Margin of Safety</td><td colspan="3">An explicit 10% margin of safety was accounted for in the TMDL for each lake. This MOS is sufficient to account for uncertainties in predicting loads to the lakes and predicting how lakes respond to changes in phosphorus loading.</td><td>29</td></tr>
<tr><td>Seasonal Variation</td><td colspan="3">Critical conditions in these lakes occur in the summer, when TP concentrations peak and clarity is worst. The water quality standards (Minn. R. 7050.0220) are based on growing season averages. The load reductions are designed so that the lakes will meet water quality standards over the course of the growing season.</td><td>29</td></tr>
<tr><td>Reasonable Assurance</td><td colspan="3">Refer to Section 5 Reasonable Assurances</td><td>33</td></tr>
<tr><td>Monitoring</td><td colspan="3">Refer to Section 6 Monitoring Plan</td><td>35</td></tr>
<tr><td>Implementation</td><td colspan="3">Refer to Section 7 Implementation Strategy</td><td>36</td></tr>
<tr><td>Public Participation</td><td colspan="3">· Public Comment period: April 10 to May 10, 2017
· Refer to Section 8 for a complete list of meetings</td><td>39</td></tr>
</table>

Executive Summary

The Clean Water Act (1972) requires that each State develop a plan to identify and restore any waterbody that is deemed impaired by state regulations. A Total Maximum Daily Load Study (TMDL) is required by the Environmental Protection Agency (EPA) as a result of the federal Clean Water Act. A TMDL identifies the pollutant that is causing the impairment and how much of that pollutant can enter the waterbody and still meet water quality standards.

This TMDL study includes two lakes that are on the draft 2014 MPCA 303(d) list of impaired waters located in the Pine River Watershed (HUC 07010105), a tributary to the Mississippi River in central Minnesota.

Information from multiple sources was used to evaluate the ecological health of each lake:

- All available water quality data over the past 10 years (2003 through 2012)
- Fisheries surveys
- Plant surveys
- Stakeholder input

The following pollutant sources were evaluated for each lake: watershed runoff, loading from upstream lakes, atmospheric deposition, lake internal loading, point sources, feedlots, and septic systems. An inventory of pollutant sources was used to develop a lake response model for each impaired lake. These models were then used to determine the pollutant reductions needed for the impaired lakes to meet water quality standards.

The findings from this TMDL study will be used to aid the selection of implementation activities as part of the Pine River Watershed Restoration and Protection Strategy (WRAPS) process. The purpose of the WRAPS report is to support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning. Following completion, the WRAPS report will be publically available on the MPCA Pine River Watershed website:

https://www.pca.state.mn.us/water/watersheds/pine-river

A summary of the lake phosphorus TMDLs and necessary phosphorus reductions is provided in the table below.

Impaired Lake	Loading Capacity (TMDL) (kg/day)	Waste Load Allocation (kg/day)	Load Allocation (kg/day)	Margin of Safety (kg/day)	Total Reduction Needed (%)
Jail Lake	0.453	0.003	0.405	0.045	58%
Kego Lake	0.679	0.003	0.608	0.068	22%

1. Project Overview

1.1 Purpose

This TMDL study addresses aquatic recreation use impairments due to excess nutrients (phosphorus) in two lakes located in the north central portion of the Pine River Watershed (07010105) in north-central Minnesota (Table 1-1). The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) and to quantify the pollutant reductions needed to meet the state water quality standards. These TMDLs for nutrients are being established in accordance with section 303(d) of the Clean Water Act, because the State of Minnesota has determined that these lakes exceed the state established standards for nutrients.

1.2 Identification of Waterbodies

This TMDL study includes two lakes that are on the draft 2014 MPCA 303(d) list of impaired waters due to excess nutrients, namely phosphorus (Table 1-1, Figure 1-1).

Table 1-1. Pine River Watershed Impaired Lakes

Lake Name	Lake ID	Designated Use Class	Affected Use: Pollutant	Year Listed	Target Start/ Completion
Jail Lake (aka Big Rice Lake)	**18041500**	2B/2C	Aquatic Recreation: Phosphorus	2012	2012/2016
Kego Lake	**18029300**	2B/2C		2010	2012/2016

1.3 Priority Ranking

The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

1.4 Description of the Impairments and Stressors

The lake eutrophication impairments in the Pine River Watershed were characterized by phosphorus and chlorophyll-*a* (chl-*a)* concentrations that exceed state water quality standards and Secchi transparency depths below the state water quality standards. Excessive nutrient loads, in particular total phosphorus (TP), lead to an increase in algae blooms and reduced transparency – both of which may significantly impair or prohibit the use of lakes for aquatic recreation. Phosphorus lake response models were developed and TMDLs calculated for all lake eutrophication impairments.

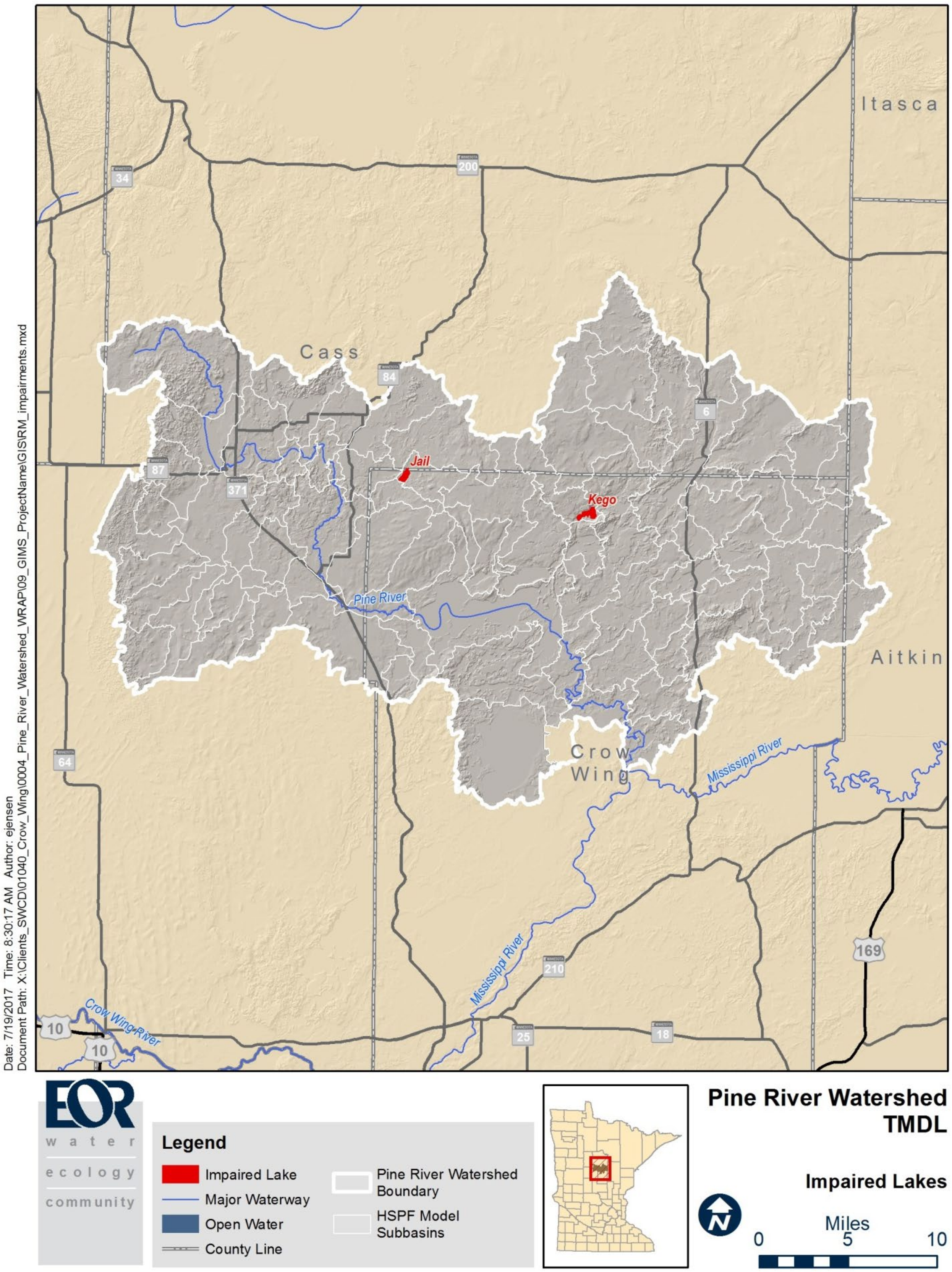


Figure 1-1. Impaired lakes in the Pine River Watershed addressed by this TMDL

2. Applicable Water Quality Standards

2.1 Designated Use

Each lake has a Designated Use Classification defined by the MPCA, which defines the optimal purpose for that waterbody (see Table 1-1). The lakes and streams addressed by this TMDL fall into the 2B, 3C designated use classification: healthy warm water aquatic community; industrial cooling and materials transport without a high level of treatment. Class 2 waters are protected for aquatic life and aquatic recreation and Class 3 waters are protected for industrial consumption as defined by Minn. R. ch. 7050.0140. The most protective of these classes is 2B, for which water quality standards are provided below.

2.2 Lakes

TP is often the limiting factor controlling primary production in freshwater lakes: as in-lake phosphorus concentrations increase, algal growth increases resulting in higher chl-*a* concentrations and lower water transparency. In addition to meeting phosphorus limits, chl-*a* and Secchi transparency standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. R. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (MPCA 2005). Clear relationships were established between the causal factor TP and the response variables chl-*a* and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the chl-*a* and Secchi standards will likewise be met. The applicable water quality standards for the Pine River Watershed impaired lakes in the Northern Lakes and Forests (NLFs) Ecoregion are listed in Table 2-1.

To be listed as impaired (Minn. R. 7050.0150, subp. 5), the summer growing season (June through September) monitoring data must show that the standards for both TP (the causal factor) and either chl-*a* or Secchi transparency (the response variables) were violated. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if it will be listed as impaired. For more details regarding the listing process, see the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 303(b) Report and 303(d) List* (MPCA 2012).

Table 2-1. Lake Eutrophication Standards

Ecoregion	TP (ppb)	Chl-a (ppb)	Secchi (m)
Northern Lakes and Forests	< 30	< 9	> 2.0

3. Watershed and Water body Characterization

The Pine River Watershed is approximately 502,400 acres in size and contains parts of Aitkin, Cass, Crow Wing and Hubbard counties. Pine River and Crosslake are the major cities in the watershed.

3.1 Lakes

The physical characteristics of the impaired lakes are listed in Table 3-1. Lake surface area, volume, mean depth, and littoral area (less than 15 feet) were calculated using Minnesota Department of Natural Resources (DNR) bathymetric data; maximum depth was reported from the DNR Lake Finder website; and watershed areas and watershed to surface area ratios were calculated using Hydrologic Simulation Program-Fortran (HSPF) model subbasin Geographic Information System (GIS) data. Section 10 of this report provides additional information on these lakes.

Table 3-1. Impaired lake physical characteristics

Lake	Surface area (ac)	Littoral area (% total area)	Volume (acre-feet)	Mean depth (feet)	Maximum depth (feet)	HSPF Subbasin ID	Watershed area (incl. lake area) (ac)	Watershed area : Surface area
Jail Lake	183	67%	2,108	11.5	22	98*	3,606	20
Kego Lake	296	63%	3,286	11.1	20	262	5,601	21

* HSPF subbasin 98 was expanded to include the portion of HSPF subbasin 99 that drains to Jail Lake. HSPF subbasin 99 is identified as downstream of Jail Lake in the HSPF model developed for the TMDL.

3.2 Subwatersheds

The watersheds draining to Jail and Kego lakes are illustrated in Figure 3-1 and Figure 3-2. No other upstream lakes or subwatersheds contribute to these lake watersheds.

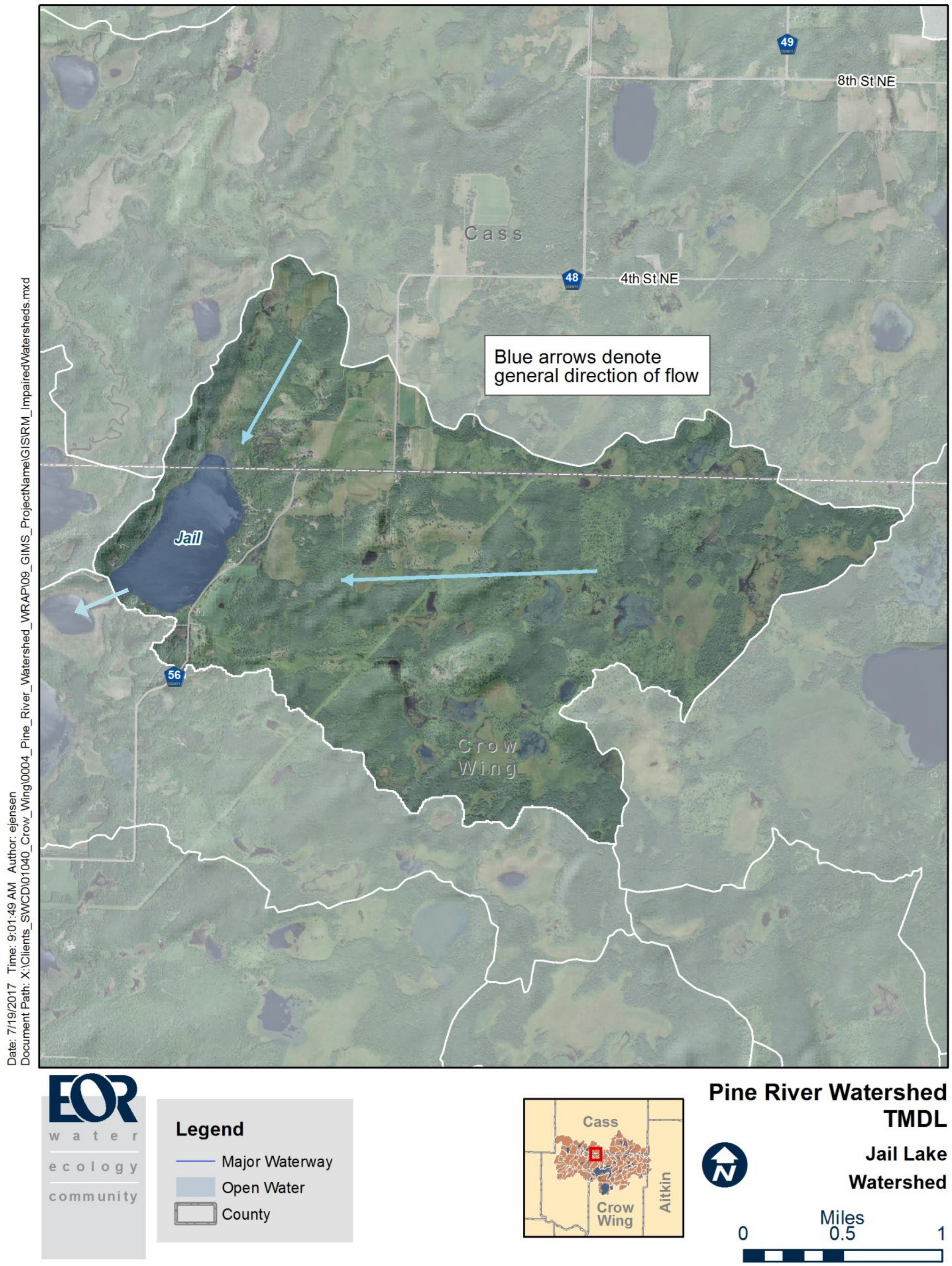


Figure 3-1. Jail Lake Watershed

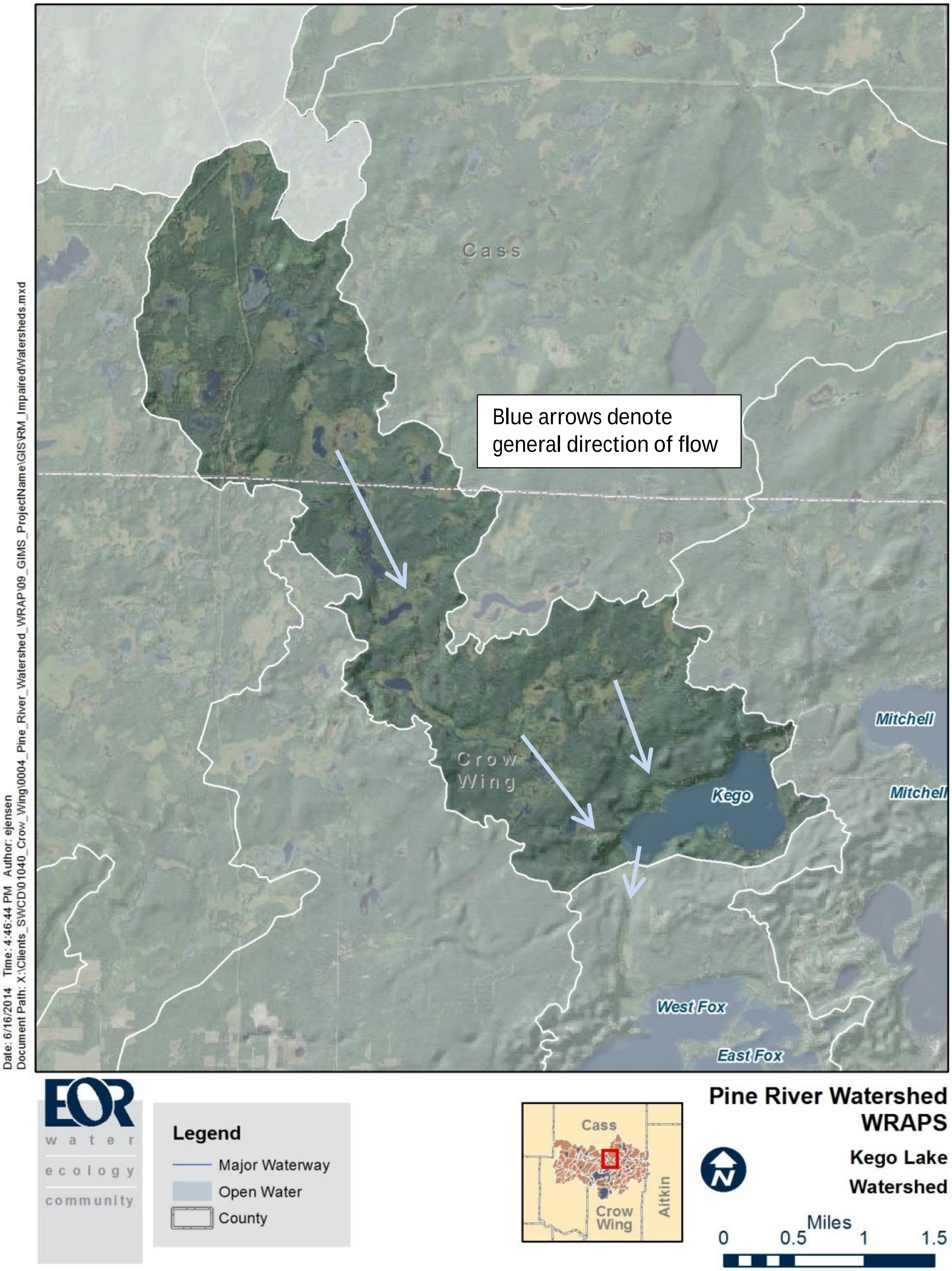


Figure 3-2. Kego Lake Watershed

3.3 Land Use

Land cover in the Pine River Watershed was assessed using the Multi-Resolution Land Characteristics Consortium 2011 National Land Cover Dataset (http://www.mrlc.gov/nlcd2011.php). This information is necessary to draw conclusions about pollutant sources and best management practices (BMPs) that may be applicable within each subwatershed. The land cover distribution within impaired lake watersheds is summarized in Table 3-2. Grassland includes: native grass stands, alfalfa, clover, long term hay, and pasture. Cropland includes: all annually planted row crops (corn, soybeans, wheat, oats, barley, etc.), and fallow crop fields. Wetland includes: wetlands, and marshes. Open water includes: all lakes and rivers.

Table 3-2. Land Cover Type distribution by impaired lake watershed (2011 NLCD)

	Jail	Kego
Land Cover Type	**Area (% total)**	
Cultivated Crops	2.4%	0%
Developed	2.1%	1.8%
Forest	61.3%	69.9%
Grassland / Herbaceous	1.2%	0.4%
Hay / Pasture	3.1%	0.3%
Open Water	10.5%	6.2%
Shrub / Scrub	4.3%	6.1%
Wetlands	15.1%	15.2%

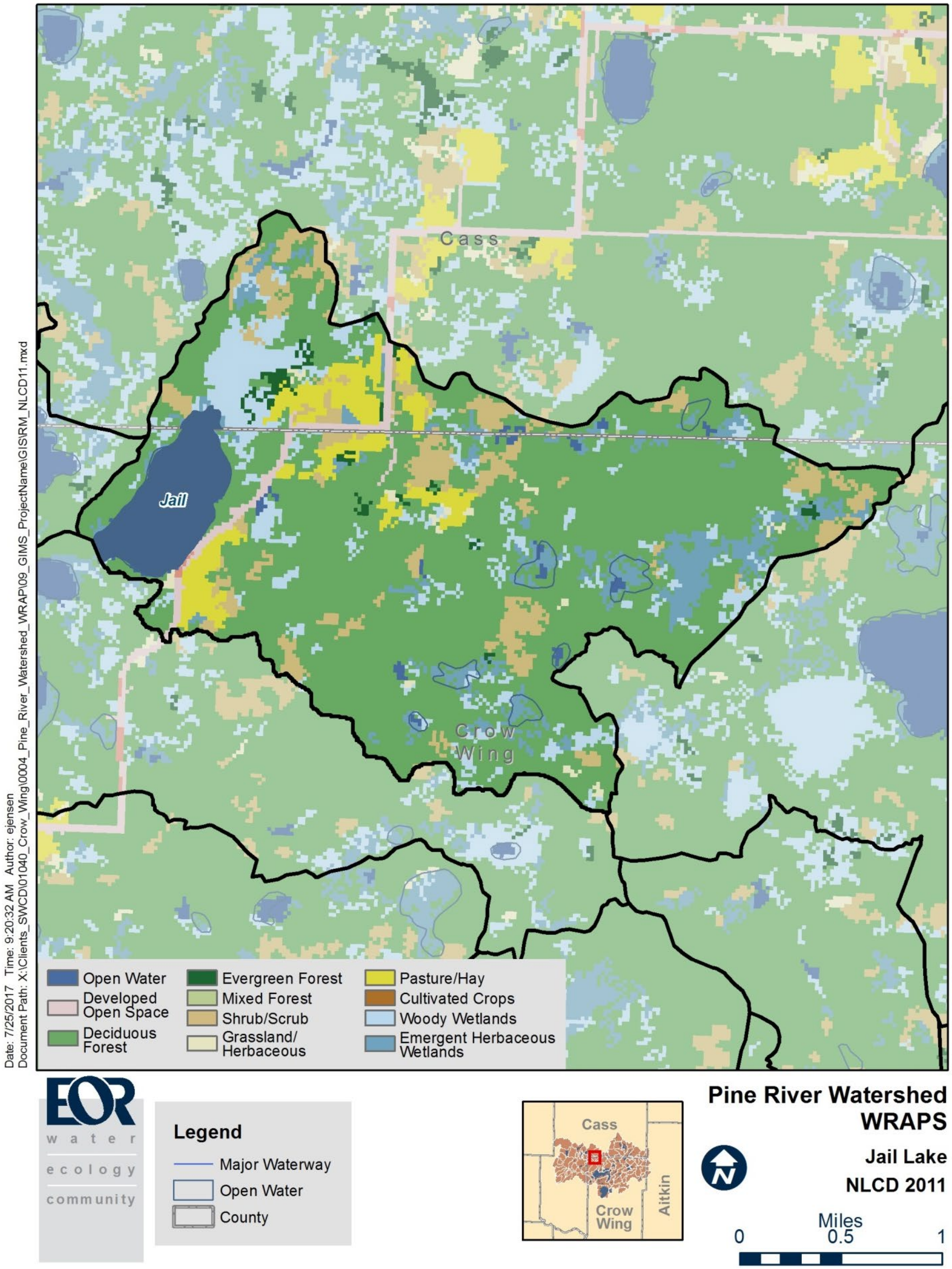


Figure 3-3. Land cover distribution in the Jail Lake Watershed (NLCD 2011)

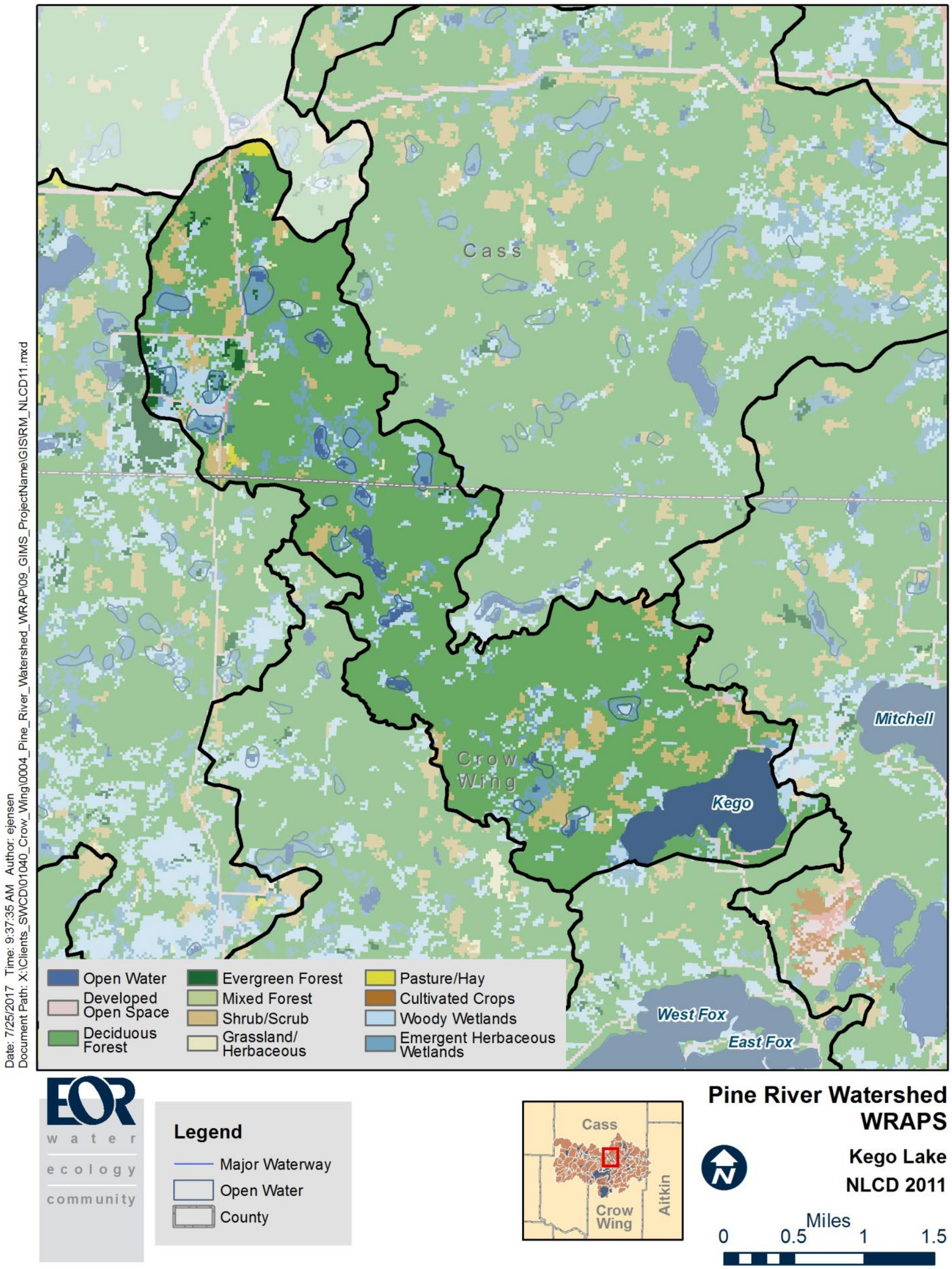


Figure 3-4. Land cover distribution in the Jail Lake Watershed (NLCD 2011)

3.4 Current/Historic Water Quality

The existing in-lake and in-stream water quality conditions were quantified using data downloaded from the MPCA Environmental Quality Information System (EQuIS) database and available for the 10 year time period (2003 through 2012). This corresponds to a 10-year time period ending with the 2011 and 2012 Intensive Watershed Monitoring for the Pine River Watershed that the MPCA used to assess the entire watershed for impairments in the 2012 assessment cycle (MPCA 2012). Growing season means of TP, chl-*a*, and Secchi depth were calculated using monitoring data from June through September. Information on the species and abundance of macrophyte and fish present within the lakes was compiled from DNR fisheries surveys.

3.4.1 Lakes

3.4.1.1 Water Quality

The 10-year (2003 through 2012) growing season mean TP, Chl-*a*, and Secchi for each impaired lake is listed in Table 3-3.

Table 3-3. 10-year growing season mean TP, Chl-*a*, and Secchi, 2003-2012

Lake Name	10-year Growing Season Mean (June – September)					
	TP		Chl-*a*		Secchi	
	(µg/L)	CV	(µg/L)	CV	(m)	CV
Northern Lakes and Forest Ecoregion	**< 30**	**--**	**< 9**	**--**	**> 2.0**	**--**
Jail	**53**	14%	**29**	22%	**1.3**	4%
Kego	**33**	7%	**10**	19%	**2.0**	7%

3.5 Pollutant Source Summary

3.5.1 Phosphorus

A key component to developing a nutrient TMDL is understanding the sources contributing to the impairment. This section provides a brief description of the potential sources in the watershed contributing to excess nutrients in the impaired lakes addressed in this TMDL. The following sections discuss the major pollutant sources that have been quantified using collected monitoring data and water quality modeling to both assess the existing contributions of pollutant sources and target pollutant load reductions.

Phosphorus in lakes often originates on land. Phosphorus from sources such as phosphorus-containing fertilizer, manure, and the decay of organic matter can adsorb to soil particles. Wind and water action erode the soil, detaching particles and conveying them in stormwater runoff to nearby waterbodies where the phosphorus becomes available for algal growth. Organic material such as leaves and grass clippings can leach dissolved phosphorus into standing water and runoff or be conveyed directly to waterbodies where biological action breaks down the organic matter and releases phosphorus.

3.5.1.1 Permitted

No MS4s, Wastewater Treatment Plants (WWTPs), Concentrated Animal Feeding Operations (CAFOs), industrial stormwater or wastewater facilities requiring a National Pollutant Discharge Elimination System (NPDES) Permit are located in the impaired lake watersheds. Phosphorus loads for construction and industrial stormwater NPDES permitted sources were determined using the methods described in Section 4.1.3 below.

3.5.1.2 Non-permitted

The following sources of phosphorus not requiring NPDES Permit coverage were evaluated:

- Watershed runoff
- Loading from upstream waters
- Runoff from feedlots not requiring NPDES Permit coverage
- Atmospheric deposition
- Septic systems
- Lake internal loading

Watershed runoff

A HSPF model (RESPEC 2014) was used to estimate watershed runoff volumes from the direct drainage area of impaired lakes. The HSPF model generates overland runoff flow and phosphorus load on a daily time step for subwatersheds in the Pine River Watershed based on land cover and soil type and calibrated using meteorological data through 2009. The 1996 through 2009 average annual flow was calculated for inputs to the lake BATHTUB models to represent baseline conditions. The 1996 through 2009 average annual phosphorus load and average annual volume for the impaired lake drainage areas are listed in Table 3-4.

Phosphorus loads from specific sources within the watershed (upstream waters, feedlots not requiring NPDES Permit coverage, and subsurface sewage treatment systems (SSTS)) were also independently estimated to determine their relative contributions, as described in the following sections.

Table 3-4. 1996-2009 HSPF modeled average annual runoff depth and areal phosphorus load for the impaired lake watersheds

Impaired Lake	1996-2009 Average Annual		
	Runoff (ac-ft/yr)	Phosphorus Load (lb/ yr)	Phosphorus Load (kg/ yr)
Jail	2,178	334.6	0.104
Kego	3,153	449.8	0.090

Feedlots not requiring NPDES permit coverage

Runoff during precipitation and snow melt can carry phosphorus from uncovered feedlots to nearby surface waters. For the purpose of this study, non-permitted feedlots are defined as being all registered feedlots without an NPDES/State Disposal System (SDS) Permit that house under 1,000 animal units (AUs). While these feedlots do not fall under NPDES regulation, other state regulations still apply through the MPCA Feedlot Program. Phosphorus loads from non-permitted registered feedlots were estimated based on assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA 2004) and MPCA registered feedlot data listed in Table 3-5. Note that not all of the phosphorus generated in raw manure reaches downstream water bodies. Statewide, a small fraction of feedlots discharge surface runoff (35% according to MPCA 2004) and of these, only a small fraction of the TP discharged eventually reaches downstream water bodies (0.44% according to MPCA 2004).

One hundred-fifty head of cattle were observed by the local MPCA feedlot officer in 2017. These cattle graze near a stream that discharges directly to Jail Lake. Due to the close proximity of the feedlot to Jail Lake, the fraction of feedlots contributing to waters was assumed to be 1 instead of 0.35.

Table 3-5. Feedlots not requiring NPDES permits phosphorus load assumptions

Parameter	Unit	Jail	Kego
Beef cattle	AU	150	0
	lb/AU-yr	33.5	33.5
Dairy cows	AU	0	0
	lb/AU-yr	47.8	47.8
Swine	AU	0	0
	lb/AU-yr	26.6	26.6
Total P generated	lb/yr	5,025	0
Fraction of feedlots contributing to waters		1	0.35
P fraction lost to surface waters (average flow)		0.0044	0.0044
Total Annual Load from Feedlots not Requiring NPDES Permits	lb/yr	22	0
	kg/yr	**10**	**0**

Subsurface sewage treatment systems (SSTS)

Phosphorus loads from SSTS were estimated based on loading assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA 2004) listed in Table 3-6. Crow Wing County has inspected 3,498 individual septic systems per Minn. R. ch. 7080 since 2008, representing approximately 14% of all systems in the County. Of the systems inspected, 140 tanks, or 4%, were found to be non-compliant. All of these systems were either abandoned or upgraded within 10 months to meet Minn. Stat. 115.55, subd. 11. Crow Wing County also conducted 922 septic tank assessments on shoreline properties from 2009 to 2010. The results showed that over 90% of tanks had been recently pumped according to Minn. R. 7080.2450 (requiring a maintenance assessment at least once every three years and pumped out when sludge (settled mass) and scum (floating mass) accumulate to the point of endangering the soil treatment system). In addition, of the approximately 100 systems that were also inspected as part of the project, only three were non-compliant. Jail and Kego Lakes are located in Crow Wing County and were assigned a failure rate of 3% (MPCA 2012 SSTS Annual Report).

Table 3-6. SSTS phosphorus loads to impaired lakes and assumptions (MPCA 2004)

Parameter	Unit	Jail	Kego
Shoreline SSTS[a]	#	33	30
Seasonal Residence (4 mo/yr)[b]	%	75%	73%
Permanent Residence	%	25%	27%
Conforming Systems	%	97%	97%
Failing Systems[c]	%	3%	3%
Capita per Residence[d]	#	2.22	2.24
P Production per Capita	lb/yr	1.95	1.95
Conforming SSTS %P “passing”[±]	%	20%	20%
Failing SSTS %P “passing” [±]	%	43%	43%
Conforming Systems	#	32	29
Failing Systems	#	1	1
P Load Conforming SSTS	lb/yr	14	13
P Load Failing SSTS	lb/yr	1	1
Total Shoreline SSTS P Load	lb/yr	15	14
	kg/yr	7	6
Total Shoreline SSTS P Load due to Failing	**kg/yr**	**0.2**	**0.2**

[±] %P “passing” refers to the fraction of phosphorus in the septic system discharged (passing) to surface waters
[a] Jail: Bing Aerial Photo; Kego: F. Strohmeier pers. comm.
[b] Jail: Approximated; Kego: F. Strohmeier pers. comm.
[c] MPCA 2012 SSTS Annual Report
[d] 2007-2011, U.S. census bureau, http://quickfacts.census.gov/qfd/maps/minnesota_map.html

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters. Average phosphorus atmospheric deposition loading rates were ~0.24 lb/ac of TP per year for an average rainfall year for the Upper Mississippi River Basin (Barr 2007 addendum to MPCA 2004). This rate was applied to the lake and stream surface area to determine the total atmospheric deposition load per year to the impaired lakes.

Table 3-7. Atmospheric deposition phosphorus loads to impaired lakes [MPCA 2004]

Parameter	Unit	Jail	Kego
Atmospheric deposition	lb/yr	128	121
	kg/yr	**58**	**55**

Internal Loading

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments or macrophytes and is released back into the water column. Internal loading can occur via:

1. *Chemical release from the sediments:* Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (>9). If a lake’s hypolimnion (bottom area) remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column

when the lake loses its stratification at the time of fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.

2. *Physical disturbance of the sediments*: Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind mixing. This is more common in shallow lakes than in deeper lakes.
3. *Decaying plant matter*: Specifically curly-leaf pondweed (Potamogeton crispus) which is an invasive plant that dies back mid-summer, which is during the season to which the TMDL will apply and when water temperatures can accelerate algal growth. Curly-leaf pondweed is not present in the impaired lakes.

No sediment samples were available to estimate internal loading rates of phosphorus due to anoxic release from the sediments using the statistical regression equations developed from measured release rates and sediment P concentrations for a large set of North American lakes (Nürnberg 1988; Nürnberg 1996). Internal loading due to physical disturbance is difficult to estimate reliably and was therefore not included in the lake phosphorus analyses. In lakes where internal loading due to these sources is believed to be substantial, the internal load estimates derived from lake sediment data presented here are likely an underestimate of the actual internal load.

Some amount of internal loading is implicit in the BATHTUB lake water quality model, therefore internal loading rates added to the BATHTUB model during calibration represents the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset (see Section 4.1.1: Model Calibration). The implicit amount of internal loading in BATHTUB is typically smaller than the calibrated BATHTUB rates for shallow lakes because the BATHTUB model development lake dataset is less representative of this lake type and therefore accounts for less implicit internal loading in shallow lakes. This was the case for both impaired lakes, where the calibrated BATHTUB release rates ranged from 0.1 to 0.6 mg TP/m^2 per calendar day (Table 3-8). The calibrated BATHTUB phosphorus release rates were greater for Jail Lake than Kego Lake, likely because Jail Lake is shallower than Kego Lake and Jail Lake has curly-leaf pondweed present.

Table 3-8. Internal phosphorus load assumptions and summary

Lake	% Littoral (< 15 feet deep)	BATHTUB Calibrated Excess Phosphorus Release Rate	BATHTUB Calibrated Excess Phosphorus Internal Load	
		(mg/m^2-calendar day)	(kg/yr)	(lb/yr)
Jail	67%	0.623	**169.0**	**372.6**
Kego	63%	0.096	**41.9**	**92.4**

4. TMDL Development

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified and estimated in the pollutant source assessment. The loading capacity (TMDL) of each lake or stream was then estimated using an in-lake water quality response model or stream load duration curve and was divided among WLAs and LAs. A TMDL for a waterbody that is impaired as the result of excessive loading of a particular pollutant can be described by the following equation:

$$\boxed{\textbf{TMDL = LC = } \sum \textbf{WLA + } \sum \textbf{LA + MOS + RC}}$$

Where:

Loading capacity (LC): the greatest pollutant load a waterbody can receive without violating water quality standards;

Wasteload allocation (WLA): the pollutant load that is allocated to point sources, including WWTFs, regulated construction stormwater, and regulated industrial stormwater, all covered under NPDES Permits for a current or future permitted pollutant source;

Load allocation (LA): the pollutant load that is allocated to sources not requiring NPDES Permit coverage, including non-regulated stormwater runoff, atmospheric deposition, and internal loading;

Margin of Safety (MOS): an accounting of uncertainty about the relationship between pollutant loads and receiving water quality;

Reserve Capacity (RC): the portion of the loading capacity attributed to the growth of existing and future load sources.

4.1 Phosphorus

4.1.1 Loading Capacity

For the lake TMDL derivations, runoff flow and phosphorus load modeled by HSPF (RESPEC 2014) were used to estimate existing watershed phosphorus loading to the impaired lakes. The watershed phosphorus loads served as input to BATHTUB models, which were used to estimate in-lake water quality. The BATHTUB models were calibrated to existing in-lake water quality data (10-year growing season means) and were then used to identify the phosphorus load reductions needed to meet State in-lake water quality standards.

The modeling software BATHTUB (Version 6.1) was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). It has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater; and outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

Long-term averages were used as input data to the models, due to the lack of detailed annual loading and water balance data for each of the lakes. The outputs from the phosphorus source assessment (*Section 3.5)* were used as inputs to the BATHTUB lake models. The models were calibrated to existing phosphorus concentrations (as the 2003 through 2012, June through September average), and then were used to determine the phosphorus reductions needed to meet each lake's phosphorus standard. The phosphorus reduction needed to meet the phosphorus standard, calculated from the BATHTUB model, was subtracted from the total existing phosphorus load to determine each lake's loading capacity. The loading capacity of each lake is the TMDL; the TMDL is then split into WLAs, LAs, and a MOS. Regression equations developed by the MPCA (Heiskary and Wilson 2005) suggest that the two response variables, Secchi depth and chl-*a*, should also meet state standards when the necessary phosphorus reductions are made.

The TMDL (or loading capacity) was first determined in terms of annual loads. In-lake water quality models predict annual averages of water quality parameters based on annual loads. Symptoms of nutrient enrichment normally are the most severe during the summer months; the state eutrophication standards (and, therefore, the TMDL goals) were established with this seasonal variability in mind. The annual loads were then converted to daily loads by dividing the annual loads by 365 days. Section 12 contains for all lakes BATHTUB modeling case data (inputs), diagnostics (results), and segment balances (water and phosphorus budgets) for both the calibrated (benchmark/existing) models and the TMDL scenarios.

System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For this study, the total watershed area was modeled as one tributary to each lake (i.e., segment).

Model Inputs

The input required to run the BATHTUB model includes lake geometry, climate data, and water quality and flow data for runoff contributing to the lake. Observed lake water quality data are also entered into the BATHTUB program in order to facilitate model verification and calibration. The availability of observed lake water quality data is summarized for each lake in Section 3.4. Lake segment inputs are listed in Table 4-1, and tributary inputs are listed in Table 3-4 from Section 3.5. Precipitation rates were estimated at 0.70 m per year and 0.74 m per year for Jail and Kego, respectively, based on the climate data used to develop the HSPF model. Evaporation rates were estimated to be 0.66 m per year based on data from the Minnesota Hydrology Guide (SCS 1992). Precipitation and evaporation rates apply only to the lake surface areas. Average phosphorus atmospheric deposition loading rates were estimated to be

0.24 lb/ac-yr for the Upper Mississippi River Basin (Barr 2007), applied over each lake's surface area (see Section 3.5.1.2: Atmospheric Deposition).

Table 4-1. BATHTUB segment input data

Impaired Lake	Surface area (sq km)	Lake fetch (km)	Mean depth (m)	Total Phosphorus	
				(ppb)	CV (%)
Jail	0.7425	1.421	3.50	53.3	14%
Kego	1.1947	1.940	3.39	33.3	7%

Model Equations

BATHTUB allows a choice among several different phosphorus sedimentation models. The Canfield-Bachmann-Lakes phosphorus sedimentation model (Canfield and Bachmann 1981) best represents the lake water quality response of Minnesota lakes, and was used for this study. However, the Canfield-Bachmann phosphorus sedimentation model tends to under predict the amount of internal loading in shallow, frequently mixing lakes. Therefore, an explicit internal load is added to shallow lakes to improve the lake water quality response of the Canfield-Bachmann phosphorus sedimentation model.

Model Calibration

The models were calibrated to existing water quality data according to Table 4-2, and then were used to determine the phosphorus loading capacity (TMDL) of each lake. For both lakes, the predicted in-lake TP concentration was *lower* than the average observed (monitored) concentration. Therefore, an explicit additional load was added to calibrate the model. Heavily impacted lakes in Minnesota with high phosphorus loading and/or very poor water quality may have greater internal loading on average than that of the lakes in the data set used to derive the Canfield-Bachmann lakes formulation. It is also possible that the watershed model loading estimates did not account for certain hot spots of phosphorus loading such as above average application of lawn fertilizer runoff and/or animal waste. In addition, as stated above, the Canfield-Bachmann phosphorus sedimentation model tends to under predict the amount of internal loading in shallow, frequently mixing lakes.

Table 4-2. Model calibration summary for the impaired lakes

Impaired Lake	P Sedimentation Model	Calibration Mode	Calibration Value
Jail	Canfield & Bachmann, Lakes	Added Internal Load	0.623 mg/m^2-day
Kego	Canfield & Bachmann, Lakes	Added Internal Load	0.096 mg/m^2-day

Determination of Lake Loading Capacity (TMDL)

Using the calibrated existing conditions model as a starting point, the tributary phosphorus concentrations were reduced until the model indicated that the TP state standard was met, to the nearest tenth of a whole number. First, the watershed flow weighted mean TP concentration was reduced to 50 ppb to represent reasonable baseline loading conditions for a northern Minnesota forested watershed. If further reductions were needed, any added internal loads were reduced until the in-lake phosphorus concentration met the lake water quality standard.

4.1.2 Load Allocation Methodology

The LA includes all sources of phosphorus that do not require NPDES Permit coverage: watershed runoff, internal loading (sediment release), and atmospheric deposition. The loading capacity (TMDL) less the MOS and WLA was used to determine the LA for each impaired lake, on an areal basis. Note that the

MOS was distributed proportionately among internal loading and watershed runoff based on existing loads relative to the loading capacity, but not to atmospheric deposition

The TMDLs are based on data from the 10-year period 2003 through 2012. Any activities implemented after 2012, which lead to a reduction in phosphorus loads to the lake may be considered as progress towards meeting a LA.

Natural Background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion (Section 3.5) of this study. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, failing SSTSs and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest natural background sources are a major driver of either of the impairments and/or affect their ability to meet state water quality standards. For the impairments addressed in this study, natural background sources are implicitly included in the LA portion of the TMDL allocation tables and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

4.1.3 Watershed Allocation Methodology

The TMDLs are based on data from the 10- year period 2003 through 2012. Any activities implemented after 2012, which lead to a reduction in phosphorus loads to the lake may be considered as progress towards meeting a WLA.

4.1.3.1 Regulated Construction Stormwater

Construction stormwater is regulated by NPDES Permits for any construction activity disturbing a) one acre or more of soil, b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites where there is construction activities reflects the number of construction sites greater than or equal to one acre expected to be active in the impaired lake subwatershed at any one time.

A categorical WLA was assigned to all construction activity in each impaired lake subwatershed. First, the average annual fraction of the impaired lake subwatershed area under construction activity over the past five years was calculated based on MPCA Construction Stormwater Permit data from January 1, 2007, to October 6, 2012 (Table 4-3), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (atmospheric load, internal load, upstream lakes, and MOS).

Table 4-3. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012)

County	Average Annual Construction Activity Area	
	(ac)	(% county area)
Cass	10,065	0.78%
Crow Wing	324	0.05%

4.1.3.2 Regulated Industrial Stormwater

Industrial stormwater is regulated by NPDES Permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired lake subwatershed for which NPDES Industrial Stormwater Permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired lake subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

4.1.3.3 MS4 Regulated Stormwater

There is no regulated Municipal Separate Storm Sewer Systems (MS4) stormwater in any of the impaired lake or stream subwatersheds.

4.1.3.4 NPDES Permitted Feedlots

There are no NPDES-permitted feedlots in the watershed.

4.1.3.5 Municipal and Industrial Wastewater Treatment Systems

There are no NPDES-permitted WWTFs in the watershed.

4.1.4 Margin of Safety

An explicit 10% MOS was accounted for in the TMDL for each impaired lake. This MOS is sufficient to account for uncertainties in predicting phosphorus loads to lakes and predicting how lakes respond to changes in phosphorus loading. This explicit MOS is considered to be appropriate based on:

- precedence for using an explicit 10% MOS in most other lake TMDLs in Minnesota
- BATHTUB model calibration using added internal load with values typical of very shallow, eutrophic lakes (see Section 3.5.1.2: Internal Loading)
- the generally good agreement between BATHTUB model predicted and observed values indicating that the models reasonably reflect the conditions in the lakes and their subwatersheds
- three or more years of in-lake water quality data used to calibrate the BATHTUB model

4.1.5 Seasonal Variation

In-lake water quality varies seasonally. In Minnesota lakes, the majority of the watershed phosphorus load often enters the lake during the spring. During the growing season months (June through September), phosphorus concentrations may not change drastically if major runoff events do not occur. However, chl-*a* concentration may still increase throughout the growing season due to warmer temperatures fostering higher algal growth rates. In shallow lakes, the phosphorus concentration more frequently increases throughout the growing season due to the additional phosphorus load from internal sources. This can lead to even greater increases in chl-*a* since not only is there more phosphorus but temperatures are also higher. This seasonal variation is taken into account in the TMDL by using the eutrophication standards (which are based on growing season averages) as the TMDL goals. The eutrophication standards were set with seasonal variability in mind. The load reductions are designed so that the lakes and streams will meet the water quality standards over the course of the growing season (June through September).

Critical conditions in these lakes occur during the growing season, which is when the lakes are used for aquatic recreation. Similar to the manner in which the standards take into account seasonal variation, since the TMDL is based on growing season averages, the critical condition is covered by the TMDL.

4.1.6 Future Growth Consideration/Reserve Capacity

The population in this area is expected to increase slightly between 2015 and 2025 (+3.8% in Cass County and +5.4% in Crow Wing County). This population increase will likely be as increased cabin development around the high quality, recreational lakes in this watershed, and as increased urban development to support the cabin and recreation industry in this area.

Potential changes in population and land use over time in impaired lake watersheds could result in changing sources of pollutants. Possible changes and how they may or may not impact TMDL allocations are discussed below.

4.1.6.1 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES Permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL (see Section 4.1.3). One transfer rate was defined for each impaired lake as the total watershed runoff allocation (kg/yr) divided by the watershed area (hectares). In the case of a load transfer, the amount transferred from LA to WLA will be based on the area (hectares; 1 hectare = 2.47 acres) of land coming under permit coverage multiplied by the transfer rate (kg/ha-yr). The MPCA will make these allocation shifts. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment. Individual transfer rates for each lake or stream TMDL are listed in Table 4-4.

Table 4-4. Transfer rates for any future MS4 discharger in the impaired lake watersheds

Impaired Lake	LA to WLA transfer rates	
	(kg/ha-yr)	(kg/ha-day)
Jail	0.085	0.00023
Kego	0.079	0.00022

4.1.7 TMDL Summary

4.1.7.1 Jail Lake

Table 4-5. Jail Lake Phosphorus TMDL and Allocations

Jail Lake Load Component		Existing	Goal		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.5	0.5	0.0014	0.0	0%
	Industrial stormwater (MNR50000)	0.5	0.5	0.0014	0.0	0%
	Total WLA	**1.0**	**1.0**	**0.003**	**0.0**	
Load Allocations*	*Watershed runoff*	*167.7*	*117.1*	*0.320*	*50.6*	*30%*
	Failing septics	*0.2*	*0.0*	*0.000*	*0.2*	*100%*
	Internal load	*169.0*	*10.8*	*0.030*	*158.2*	*94%*
	Total Watershed/In-lake	336.9	127.9	0.350	209.0	62%
	Atmospheric	20.0	20.0	0.055	0.0	0%
	Total LA	**356.9**	**147.9**	**0.405**	**209.0**	
MOS			**16.5**	**0.045**		
TOTAL		**357.9**	**165.4**	**0.453**	**209.0**	**58%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 33 shoreline private on-site septic systems with a 3% failure rate
- An animal pasture is located northeast of the lake would could be contributing phosphorus loads

4.1.7.2 Kego Lake

Table 4-6. Kego Lake Phosphorus TMDL and Allocations

Kego Lake Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.6	0.6	0.0016	0.0	0%
	Industrial stormwater (MNR50000)	0.6	0.6	0.0016	0.0	0%
	Total WLA	**1.2**	**1.2**	**0.003**	**0.0**	
Load Allocations*	*Watershed runoff*	*209.4*	*169.5*	*0.464*	*39.9*	*19%*
	Failing septics	*0.2*	*0.0*	*0.000*	*0.2*	*100%*
	Internal load	*41.9*	*20.4*	*0.056*	*21.5*	*51%*
	Total Watershed/In-lake	251.5	189.9	0.520	61.6	24%
	Atmospheric	32.1	32.1	0.088	0.0	0%
	Total LA	**283.6**	**222.0**	**0.608**	**61.6**	
MOS			**24.8**	**0.068**		
TOTAL		**284.8**	**248.0**	**0.679**	**61.6**	**22%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 30 shoreline private on-site septic systems with a 3% failure rate
- Logging operations occur in the watershed which can cause occasional large phosphorus pulses to lakes

5. Reasonable Assurance

5.1 Non-regulatory

Large internal load reductions (82% in Jail and 51% in Kego) are needed for these lakes to meet water quality standards. These reductions will be achieved through a combination of in-lake management activities, such as alum treatment, fish stocking, and/or aeration. These management activities have been used to successfully improve lake water quality in Minnesota. Shallow lake management forums/workshops are common in the Twin Cities Metropolitan Area of Minnesota where practitioners can share their shallow lake management successes and lessons learned. An example presentation from the April 2014 Minnehaha Creek Watershed District Shallow Lake Forum is available online at:

http://minnehahacreek.org/sites/minnehahacreek.org/files/Shallow%20Lake%20Forum%204.12.14%20McComas.pdf

Alum treatments are particularly effective at managing excessive internal load over long time periods, and have been used in many lakes throughout Minnesota to reduce internal loads. The local SWCD and lake association group will likely lead these efforts with assistance from DNR.

DNR Forestry has developed tools and guidelines for managing stormwater runoff from logging events to protect downstream water bodies (Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers). The SWCD will work with local DNR Forestry staff to ensure that logging operations in these impaired lake watersheds follow these guidelines to prevent further build-up of watershed nutrients in the impaired lakes.

At the local level, the Cass Soil and Water Conservation District (SWCD), Cass Environmental Services, Crow Wing County, the Crow Wing SWCD, The Pine River Watershed Alliance, The Whitefish Property Owners Association (WAPOA) and other local entities currently implement programs that target improving water quality and have been actively involved in projects to improve water quality in the past. Potential state funding of Restoration and Protection projects include Clean Water Fund grants. At the federal level, funding can be provided through Section 319 grants that provide cost-share dollars to implement activities in the watershed. Various other funding and cost-share sources exist, which will be listed in the Pine River WRAPS Report. The implementation strategies described in this plan have demonstrated to be effective in reducing nutrient loading to lakes and streams. There are programs in place within the watershed to continue implementing the recommended activities. Monitoring will continue and adaptive management will be in place to evaluate the progress made towards achieving water quality goals.

5.2 Regulatory

5.2.1 Regulated Construction Stormwater

State implementation of the TMDL will be through action on NPDES Permits for regulated construction stormwater. To meet the WLA for construction stormwater, construction stormwater activities are required to meet the conditions of the Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

5.2.2 Regulated Industrial Stormwater

To meet the WLA for industrial stormwater, industrial stormwater activities are required to meet the conditions of the Industrial Stormwater General Permit or Nonmetallic Mining & Associated Activities General Permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

5.2.3 Subsurface Sewage Treatment Systems Program (SSTS)

SSTS, commonly known as septic systems, are regulated by Minn. R. 7080 and Minn. Stats. 115.55 and 115.56.

These regulations detail:

- Maintenance assessment at least once every three years;
- Removal of material when sludge (settled mass) and scum (floating mass) accumulate to the point of endangering the soil treatment system;
- Minimum technical standards for individual and mid-size SSTS;
- A framework for local administration of SSTS programs and;
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

5.2.4 Feedlot Rules

The Minnesota Pollution Control Agency (MPCA) regulates the collection, transportation, storage, processing and disposal of animal manure and other livestock operation wastes. The MPCA Feedlot Program implements rules governing these activities, and provides assistance to counties and the livestock industry. The feedlot rules apply to most aspects of livestock waste management including the location, design, construction, operation and management of feedlots and manure handling facilities.

There are two primary concerns about feedlots in protecting water:

- Ensuring that manure on a feedlot or manure storage area does not run into water;
- Ensuring that manure is applied to cropland at a rate, time and method that prevents bacteria and other possible contaminants from entering streams, lakes and ground water.

6. Monitoring Plan

6.1 Lake Monitoring

If funding is available, the SWCDs or local organizations will set up a monitoring program to monitor the lakes for phosphorus, chl-*a*, and Secchi depth. If funding is not available for new monitoring programs, additional monitoring of the lakes will be completed in 2022 and 2023 as part of the next MPCA 10-year Intensive Watershed Monitoring cycle for the Pine River Watershed, and these lakes will be considered for inclusion. The SWCD could work with local residents to recruit volunteers for the MPCA Citizen Lake Monitoring Program to help fill the data gap:

https://www.pca.state.mn.us/water/citizen-lake-monitoring-program

The DNR conducts lake and stream surveys to collect information about game fish populations which are then used to evaluate abundance, relative abundance size (length and weight), condition, age and growth, natural reproduction/recruitment, and effects of management actions (stocking and regulations). Other information collected for lake population assessments include basic water quality information (temperature, dissolved oxygen profile, secchi, pH, and alkalinity), water level and for fish disease and parasites. Additional information collected for lake surveys include lab water chemistry (TP, alkalinity, TDS, Chl-a, Conductivity, pH), watershed characteristics, shoreline characteristics, development, substrates and aquatic vegetation. The frequency of sampling depends on importance/use. The most important/heavily used lakes are sampled about every five years. Less important/heavily used lakes are sampled every 7, 10, 12, or 15 years. If there is a management action (regulation or stocking) that needs to be evaluated more quickly, sampling could occur every other year. Full surveys are often only done about every 20 years.

6.2 BMP Monitoring

On-site monitoring of implementation practices should also take place in order to better assess BMP effectiveness. A variety of criteria such as land use, soil type, and other watershed characteristics, as well as monitoring feasibility, will be used to determine which BMPs to monitor. Under these criteria, monitoring of a specific type of implementation practice can be accomplished at one site but can be applied to similar practices under similar criteria and scenarios. Effectiveness of other BMPs can be extrapolated based on monitoring results.

7. Implementation Strategy Summary

7.1 Permitted Sources

7.1.1 Construction Stormwater

The WLAs for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

7.1.2 Industrial Stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES Industrial Stormwater Permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

7.2 Non-Permitted Sources

7.2.1 Adaptive Management

The response of the lakes will be evaluated as management practices are implemented. This evaluation will occur every five years after the commencement of implementation actions; for the next 25 years. Data will be evaluated and decisions will be made as to how to proceed for the next five years. The management approach to achieving the goals should be adapted as new information is collected and evaluated.

7.2.2 Best Management Practices

A variety of BMPs to restore and protect the impaired lakes have been outlined and prioritized in the WRAPS report. Please refer to the WRAPS for more information.

7.3 Education and Outreach

A crucial part in the success of the Restoration and Protection plan that will be designed to clean up the impaired lakes will be participation from local citizens. In order to gain support from these citizens, education and civic engagement opportunities will be necessary. A variety of educational avenues can and will be used throughout the watershed. These include (but are not limited to): press releases, meetings, workshops, focus groups, trainings, websites, etc. Local staff (conservation district, watershed, county, etc.) and board members work to educate the residents of the watersheds about ways to clean up their lakes. Education will continue throughout the watershed as described in the Pine River WRAPS report.

7.4 Technical Assistance

The counties and SWCDs within the watershed provide assistance to landowners for a variety of projects that benefit water quality. Assistance provided to landowners varies from agricultural and rural BMPs to urban and lakeshore BMPs. This technical assistance includes education and one-on-one training. Many opportunities for technical assistance are as a result of educational workshops of trainings. It is important that these outreach opportunities for watershed residents continue. Marketing is necessary to motivate landowners to participate in voluntary cost-share assistance programs.

Programs such as state cost share, Clean Water Legacy funding, Environmental Quality Incentives Program (EQIP), and Conservation Reserve Program (CRP) are available to help implement the best conservation practices that each parcel of land is eligible for to target the best conservation practices per site. Conservation practices may include, but are not limited to stormwater bioretention, septic system upgrades, feedlot improvements, invasive species control, wastewater treatment practices, agricultural and rural BMPs and internal loading reduction. The MDA recently released the Cropland Grazing Exchange program, which serves as a website (www.mda.state.mn.us/cge) to match up livestock farmers with crop farmers who have forage to harvest, which may be an opportunity to encourage livestock management in the watershed. More information about types of practices and implementation of BMPs will be discussed in the Pine River WRAPS report.

7.5 Partnerships

Partnerships with counties, townships, and citizens are one mechanism through which the Cass SWCD and Crow Wing County SWCD will protect and improve water quality. Strong partnerships with state and local government to protect and improve water resources and to bring the impaired lakes into compliance with State standards will continue. A partnership with local government units and regulatory agencies such as cities, townships and counties may be formed to develop and update ordinances to protect the impaired lakes.

7.6 Cost

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25]. A detailed analysis of the cost to implement this TMDL was not conducted. However, as a rough approximation one can use some general results from BMP cost studies across the U.S. For example, a EPA summary of several studies of predominantly developed urban landscapes showed a median cost of approximately $2,200 per pound

TP removed per year (Foraste et al., 2012). Multiplying that by the needed 442 pound reduction for both impaired lakes in this study provides a total cost of approximately $0.97M.

The Pine River Watershed, however, is not an urban landscape. Another way of estimating implementation costs might be to assume specific practices such as an alum treatment for Jail Lake, a cattle enclosure for the pastures near Jail Lake, and money for staff time (LGU or consultant) to work with the DNR to improve logging practices near Kego Lake. Emmons and Olivier Resources, Inc. estimates that an alum treatment for Jail Lake would cost approximately $150,000, while a cattle enclosure would cost approximately $15,000 to $20,000. They estimate staff time to work with the DNR at $75,000 to $80,000.

Alum treatments have the best chance of success when combined with other practices such as no-wake zones, vegetation management, and the removal of undesirable fish species if present.

8. Public Participation

8.1 Steering Committee Meetings

The Pine River Watershed is made up of numerous local partners who have been involved at various levels throughout the project. The steering committee is made up of members representing the DNR, University of Minnesota Extension, Crow Wing County, The Natural Resource Conservation Service, the Cass and Crow Wing SWCDs, Cass County Environmental Services, The Nature Conservancy, The Pine River Watershed Alliance, The Whitefish Area Property Owners Association (WAPOA), and the Board of Water and Soil Resources. The following table outlines the meetings that occurred regarding the Pine River Watershed monitoring, TMDL development, and WRAPS report planning.

Table 8-1. Pine River Watershed Steering Committee Meetings

Date	Location	Meeting Focus
Feb. 1, 2012	MPCA-Brainerd	DNR/MPCA responsibilities
June 3, 2013	MPCA-Brainerd	WRAPS development and component timelines
August 13, 2013	MPCA-Brainerd	WRAPS development and component timelines
April 16, 2014	MPCA-Brainerd	WRAPS development and component timelines
September 16, 2014	MPCA-Brainerd	WRAPS development, Zonation and HSPF models
September 29, 2014	MPCA-Brainerd	Stressor ID and Intensive Watershed Monitoring

8.2 Public Meetings

The MPCA along with the local partners and agencies in the Pine River Watershed recognize the importance of public involvement in the watershed process. The following table outlines the opportunities used to engage the public and targeted stakeholders in the Pine River Watershed.

Public Notice

An opportunity for public comment on the draft Pine River Watershed TMDL Report was provided via a public notice in the State Register from April 10, 2017 through May 10, 2017. There were four comment letters received and responded to as a result of the public comment period.

Table 8-2. Pine River Watershed Public Meetings

Date	Location	Meeting Focus
Aug 24, 2011	Pine River	WRAPS Process-what to expect
May 6, 2013	MPCA-Brainerd	Greet new Project manager and discuss WRAPS
June 4, 2013	MPCA-Brainerd	Individual discussions with Citizens
June 11, 2013	MPCA Brainerd	What is to come, discuss ideas for CE
June 16, 2013	Ideal Corners	PRWA Board meeting
June 24, 2013	Crow Wing Co. Land Services	Education and Outreach
July 30, 2013	Cass County Land Services	HSPF Modelling
Aug. 3, 2013	Fifty Lakes	TMDLS, Water quality
Oct. 15, 2013	Ideal Corners	PRWA Board Meeting
Dec. 17, 2013	Ideal Corners	PRWA Board Meeting
Dec. 11, 2013	MPCA-Brainerd	Zonation Model presentation
Feb. 6, 2014	MPCA-Brainerd	Zonation model survey planning
Feb. 18, 2014	MPCA-Brainerd	Zonation Model survey planning
March 3, 2014	Backus	HSPF Scenarios
March 24, 2014	MPCA-Brainerd	Zonation Model survey planning
April 18, 2014	Central Lakes College	Zonation Survey-Technical
April 26, 2014	Warehouse-Pine River	Zonation Survey-General public
June 14, 2014	Lake Washburn Town Hall	Water quality/TMDLs/Pipeline
June 21, 2014	Warehouse-Pine River	Zonation Survey/Water Quality
June 23, 2014	Crow Wing Co. Land Services	HSPF Model scenarios
August 2, 2014	Fifty Lakes, MN	Water Quality/Pipeline/TMDLs

9. Literature Cited

Barr Engineering (Twaroski, C., N. Czoschke, and T. Anderson). June 29, 2007. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds – Atmospheric Deposition: 2007 Update. Technical memorandum prepared for the Minnesota Pollution Control Agency. http://www.pca.state.mn.us/index.php/view-document.html?gid=3958

Canfield, D. and R. Bachmann, 1981. Prediction of Total Phosphorus Concentrations, Chlorophyll- *a*, and Secchi Depths in Natural and Artificial Lakes. *Canadian Journal of Fisheries and Aquatic Science* 38:414-423.

Foraste, A., Goo, R., Thrash, J., and L. Hair. June 2012. Measuring the Cost-Effectiveness of LID and Conventional Stormwater Management Plans Using Life Cycle Costs and Performance Metrics. Presented at Ohio Stormwater Conference. Toledo, OH.

Minnesota Pollution Control Agency (MPCA). 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared by Barr Engineering. http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/phosphorus/detailed-assessments-of-phosphorus-sources-to-minnesota-watersheds.html

Heiskary, S. and Wilson, B. 2005. Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria (Third Edition). Prepared for the Minnesota Pollution Control Agency. http://www.pca.state.mn.us/index.php/view-document.html?gid=6503

Minnesota Pollution Control Agency (MPCA). 2014. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. Wq-iw1-04, 52 pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=16988

Minnesota Pollution Control Agency (MPCA). July 2013. 2012 SSTS Annual Report: Subsurface Sewage Treatment Systems in Minnesota. Wq-wwists1-51, 39 pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=19690

Nürnberg, G. K. 1988. The prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. Can. J. Fish. Aquat. Sci. 45: 453-462.

Nürnberg, G.K. 1996. Trophic state of clear and colored, soft- and hard-water lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake Reserv. Manage. 12: 432-447.

Soil Conservation Service (SCS). 1992. Hydrology Guide for Minnesota.

Walker, W. W., 1999. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. Prepared for Headquarters, U.S. Army Corps of Engineers, Waterways Experiment Station Report W-96-2. http://wwwalker.net/bathtub/, Walker 1999 (October 30, 2002).

10. Lake Summaries

10.1 Jail Lake (18-0415-00)

10.1.1 Physical Characteristics

Jail Lake (DNR Lake ID 18-0415-00) is located in Crow Wing County with portions of its watershed located in Crow Wing County (48%) and Cass County (52%). Table 10-1 summarizes the lake's physical characteristics, and Figure 10-1 illustrates the available bathymetry.

Table 10-1. Jail Lake Physical Characteristics

Characteristic	Value	Source
Lake total surface area (acre)	184	DNR 24k
Percent lake littoral surface area	67%	Calculated from DNR depth contours
Lake volume (acre-feet)	2,108	
Mean depth (feet)	11.5	Lake volume ÷ surface area
Maximum depth (feet)	22	DNR Lake Finder
Watershed area, including lake surface (acre)	3,606	HSPF subbasin 98*
Watershed area: Lake area	20: 1	Calculated

* HSPF subbasin 98 was expanded to include the portion of HSPF subbasin 99 that drains to Jail Lake. HSPF subbasin 99 is identified as downstream of Jail Lake in the HSPF model developed for the TMDL.

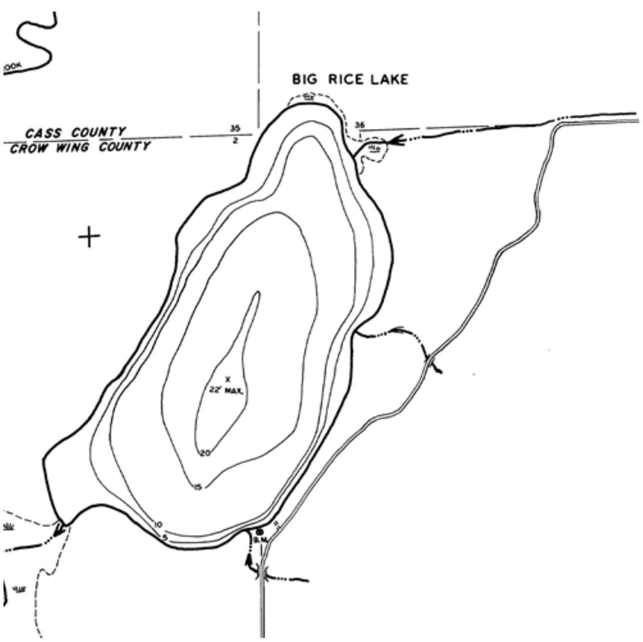


Figure 10-1. Jail Lake Bathymetry (DNR)

10.1.2 Water Quality

Water quality monitoring data were available for Jail Lake from 2005-2012, which were used to determine whether Jail Lake meets water quality standards. The lake does not meet the NLF lake water quality standard for TP, Chl-a, or Secchi (Table 10-2). Figure 10-2 shows the 2011 aerial photography, and annual growing season mean trends in TP, Chl-a, and Secchi are illustrated in Figure 10-3 through Figure 10-5.

Table 10-2. 10-year Growing Season Mean TP, Chl-*a*, and Secchi for Jail Lake, 2003-2012.

Parameter	Growing Season Mean (June – September)	Growing Season CV (June – September)	NLF Lake Standard
Total phosphorus (µg/L)	53	14%	< 30
Chlorophyll-*a* (µg/L)	29	22%	< 9
Secchi transparency (m)	1.3	4%	> 2

*CV, coefficient of variation, defined in BATHTUB as the standard error divided by the mean.

Figure 10-2. Aerial photograph of Jail Lake (Google Earth, April 2011)

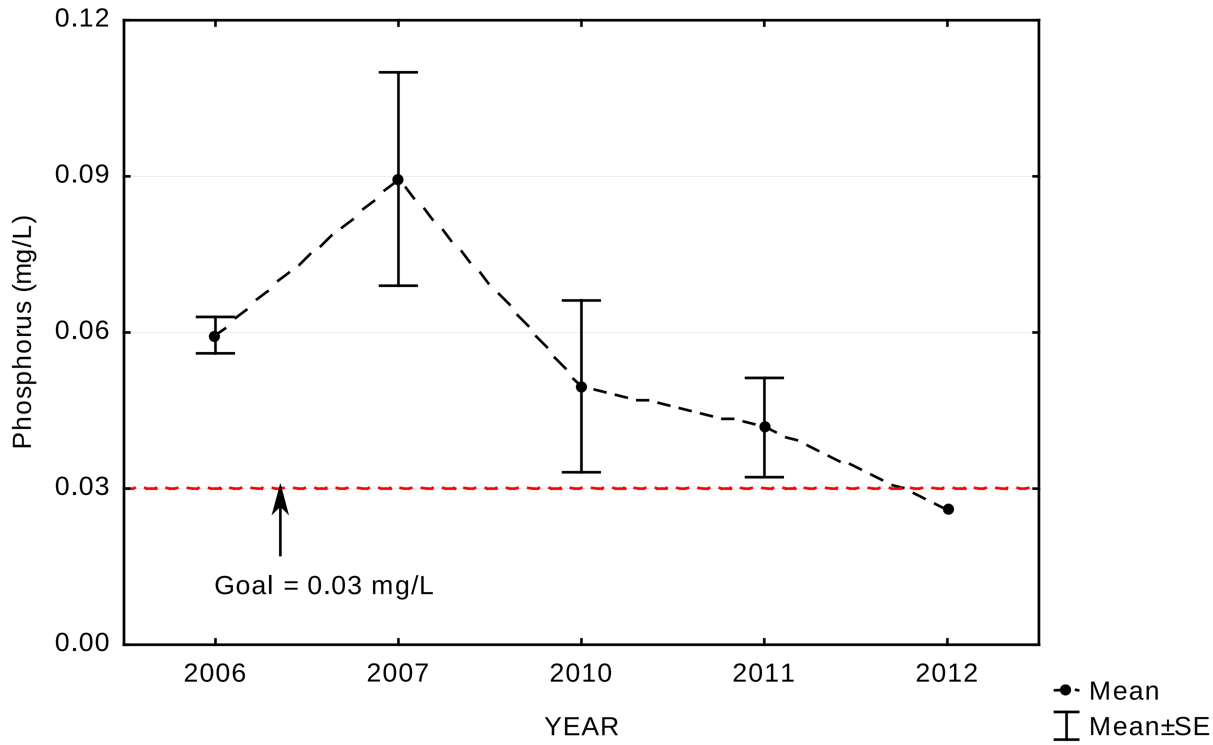


Figure 10-3. Growing Season Means ± SE of Total Phosphorus for Jail Lake by Year.
Note that TP data is collected in units of mg/L, which are equivalent to 1,000 µg/L.

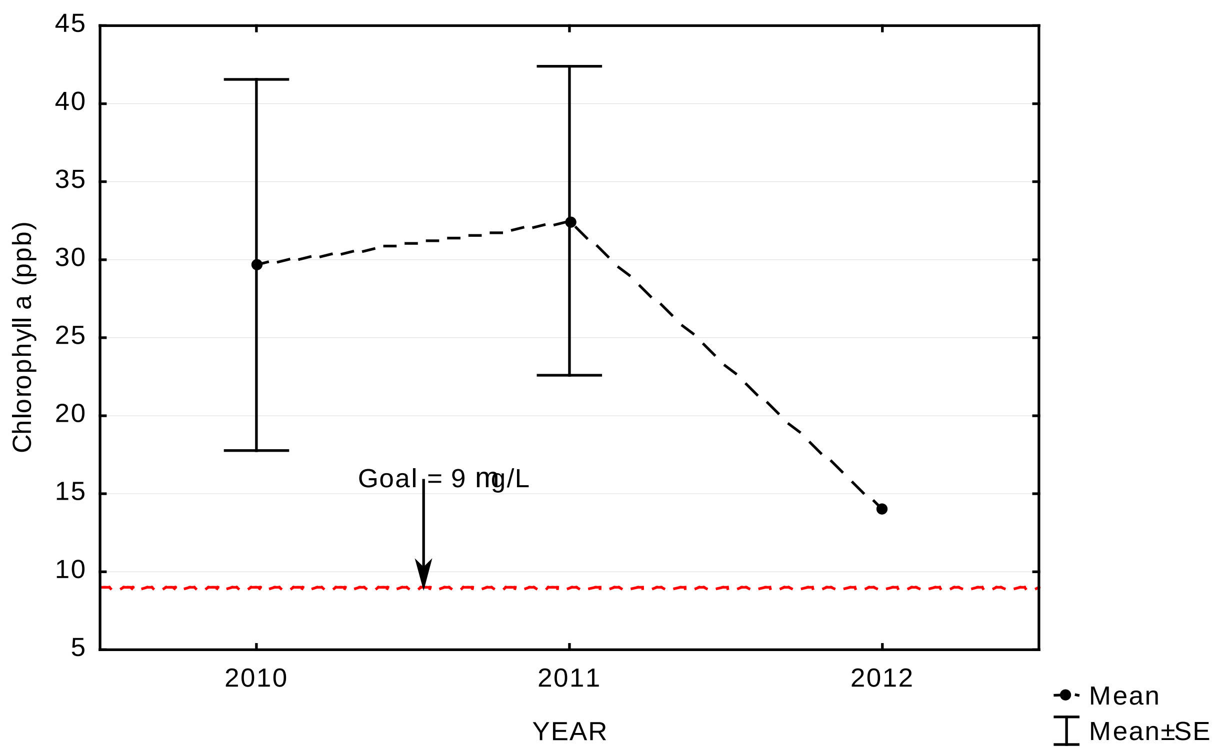


Figure 10-4. Growing Season Means ± SE of Chlorophyll-*a* for Jail Lake by Year.

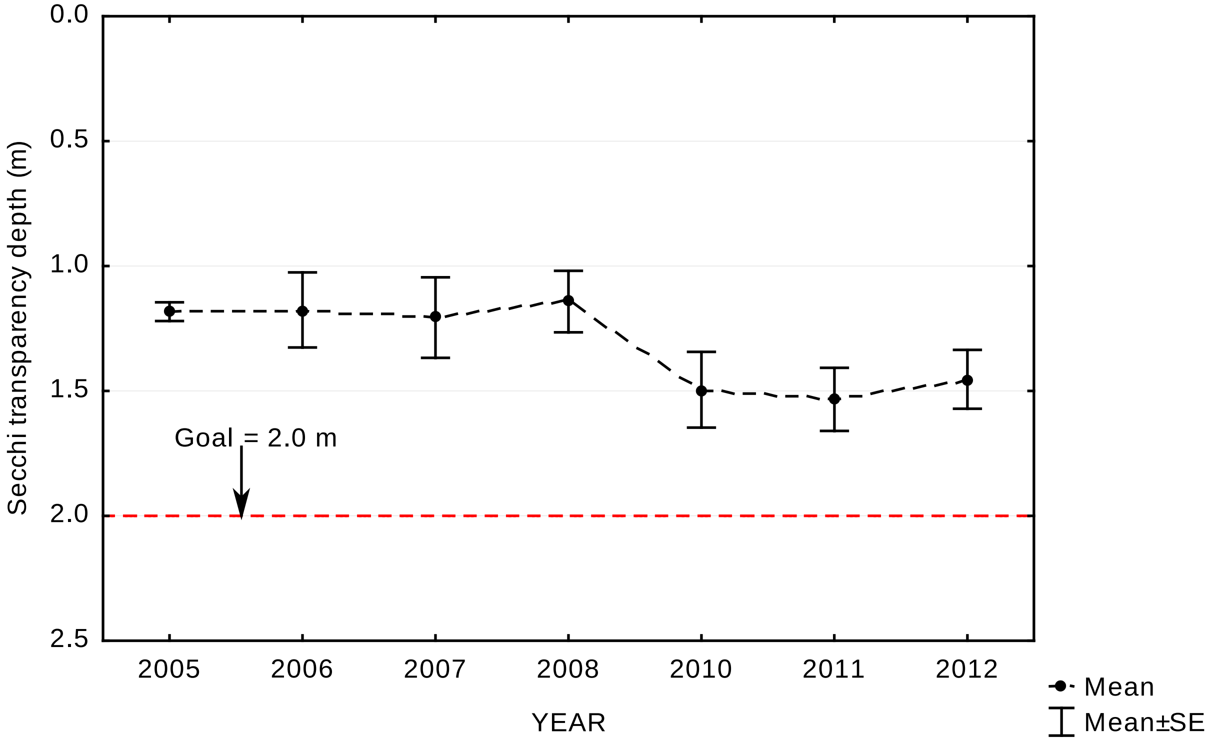


Figure 10-5. Growing Season Means ± SE of Secchi Transparency for Jail Lake by Year.

10.1.3 Fish and Aquatic Plants

The most recent DNR fisheries survey in Jail Lake was conducted in 1998. The aquatic plant community was diverse and abundant and submergent plants grew to a depth of 10 feet. Northern pike was the most abundant gamefish and the catch was above average compared to similar type lakes. The catch of bluegill and perch were above average and the catch of black crappie was average. Other species sampled included black bullhead, brown bullhead, bowfin (dogfish), golden shiner, pumpkinseed and white sucker, all at average rates.

The MPCA staff (Greg VanEeckhout) visited Jail Lake on June 1, 2017 and observed abundant curly-leaf pondweed with mats of this aquatic invasive species growing at the lake surface. At that time, approximately 25% to 40% of the lake area had some degree of curly-leaf pondweed growth, likely in the preferred growing depths of 4 to 12 feet of water. The plant was creating large monospecific beds, although not all plants had reached the surface at the time of the visit. The plant was surfacing in much of its range and some was seen flowering and producing the annual turions (vegetative buds), which are the main source of reproduction for the plant. Peak growth likely occurs in mid-June with plant senescence in late June to early July. There did not appear to be a robust aquatic plant community except for the curly-leaf pondweed. A limited amount of filamentous algae was also growing at the lake surface.

10.2 Kego Lake (18-0293-00)

10.2.1 Physical Characteristics

Kego Lake (DNR Lake ID 18-0293-00) is located in Crow Wing County with portions of its watershed located in Crow Wing County (62%) and Cass County (38%). Table 10-3 summarizes the lake's physical characteristics, Figure 10-7 shows the 2011 aerial photography, and Figure 10-6 illustrates the available bathymetry.

Table 10-3. Kego Lake Physical Characteristics

Characteristic	Value	Source
Lake total surface area (acre)	295	DNR 24k
Percent lake littoral surface area	63%	Calculated from DNR depth contours
Lake volume (acre-feet)	3,286	
Mean depth (feet)	11.1	Lake volume ÷ surface area
Maximum depth (feet)	20	DNR Lake Finder
Watershed area, including lake surface (acre)	5,600	HSPF subbasin 262
Watershed area: Lake area	19: 1	Calculated

Figure 10-6. Kego Lake Bathymetry (DNR)

10.2.2 Water Quality

Water quality monitoring data were available for Kego Lake from 1997 to 2011. Only data from the most recent 10 years (2003 through 2012) were used to determine whether Kego Lake meets water quality standards. The lake does not meet the NLF lake water quality standard for TP or Chl-a, and just meets the standard for Secchi transparency depth (Table 10-4).

Table 10-4. 10-year Growing Season Mean TP, Chl-*a*, and Secchi for Kego Lake, 2003-2012.

Parameter	Growing Season Mean (June – September)	Growing Season CV (June – September)	NLF Lake Standard
Total phosphorus (µg/L)	33	7%	< 30
Chlorophyll-*a* (µg/L)	10	19%	< 9
Secchi transparency (m)	2.0	7%	> 2

*CV, coefficient of variation, defined in BATHTUB as the standard error divided by the mean.

Figure 10-7. Aerial photograph of Kego Lake (Google Earth, April 2011)

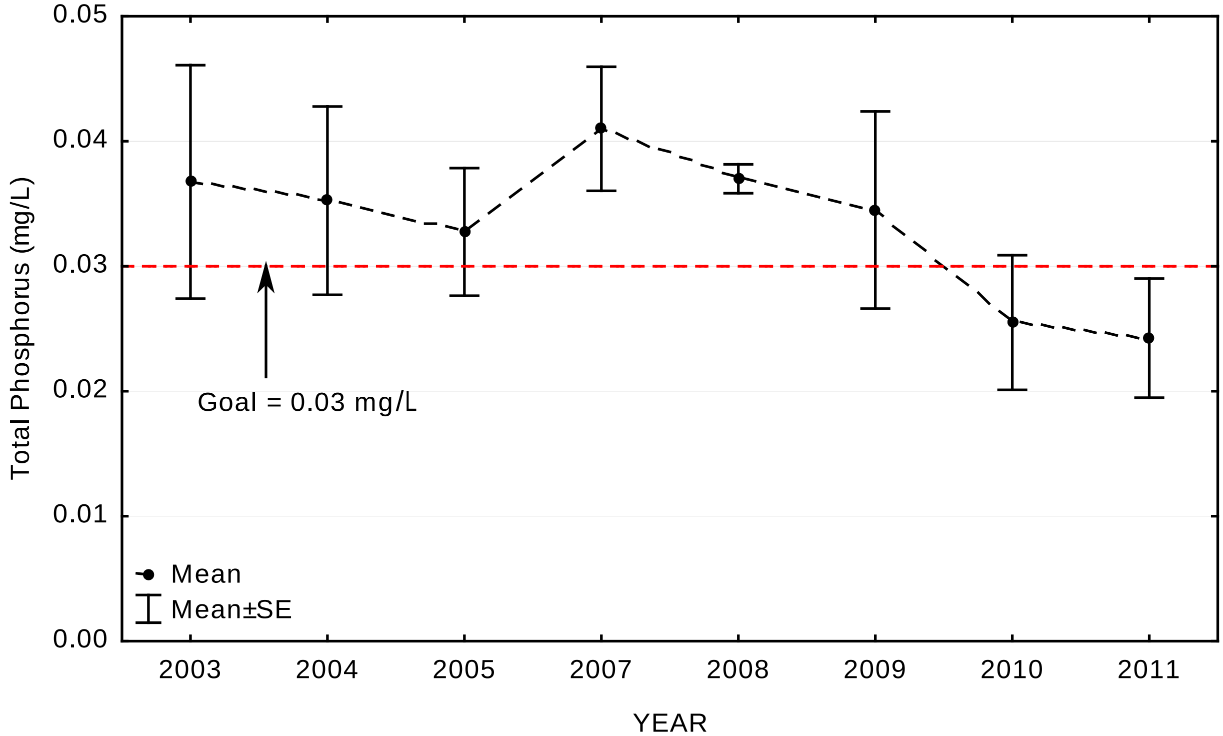


Figure 10-8. Growing Season Means ± SE of Total Phosphorus for Kego Lake by Year.

Note that TP data is collected in units of mg/L, which are equivalent to 1,000 µg/L.

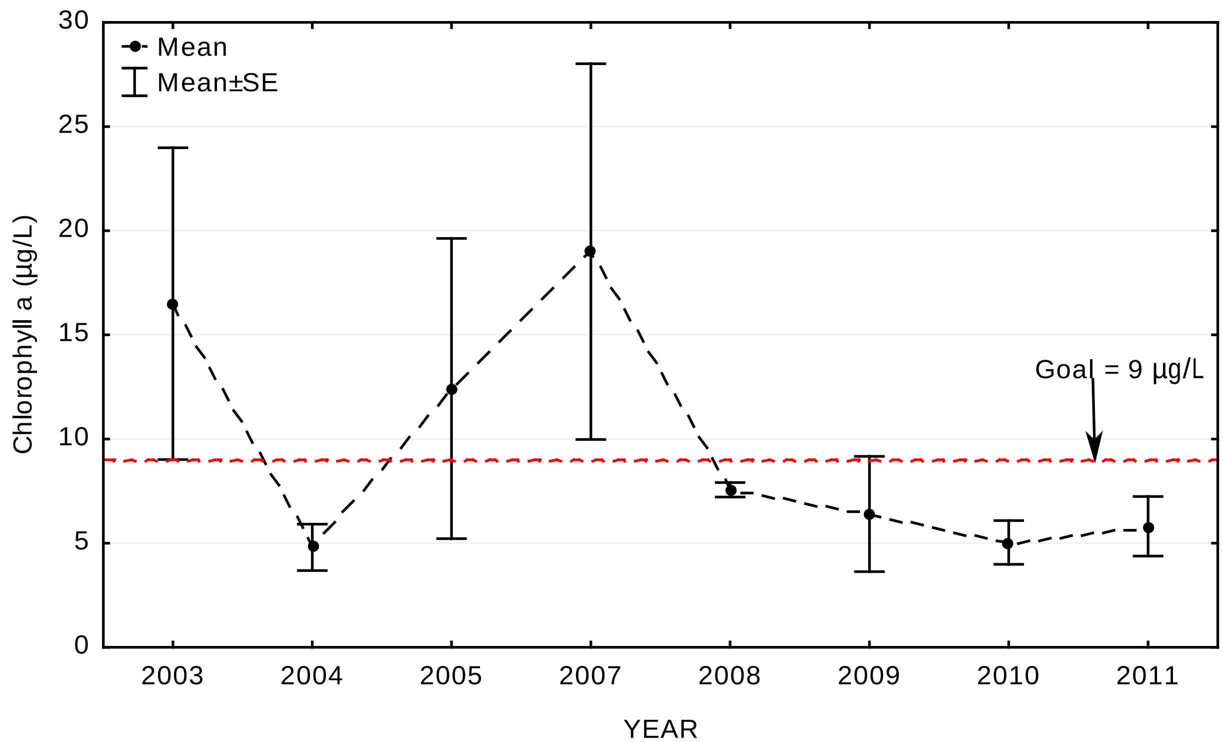


Figure 10-9. Growing Season Means ± SE of Chlorophyll-*a* for Kego Lake by Year.

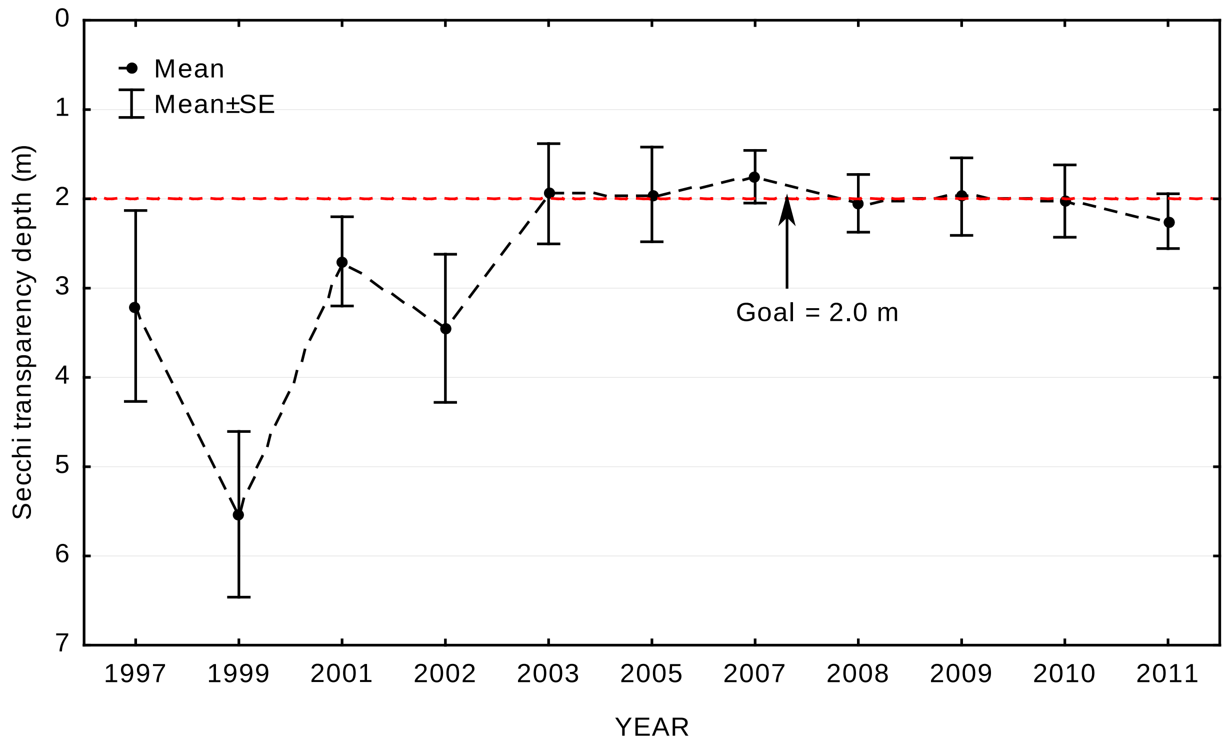


Figure 10-10. Growing Season Means ± SE of Secchi Transparency for Kego Lake by Year.

10.2.3 Fish and Aquatic Plants

The most recent DNR fisheries survey in Kego Lake was conducted in 2003. The aquatic plant community was abundant, consisted of 29 species with flat-stem pondweed the most abundant, and grew to a depth of 12 feet. The catch of northern pike, yellow perch, and largemouth bass was above average, and the catch of bluegill and black crappie was below average, compared to other similar type lakes. Other fish species sampled included black bullhead, bowfin (dogfish), brown bullhead, golden shiner, hybrid sunfish, pumpkinseed, white sucker, and yellow bullhead.

11. BATHTUB Model Supporting Files

Table 11-1. Jail Lake calibrated BATHTUB model water and phosphorus mass balance summary

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Local P Load from HSPF	13.8493	2.6632	7.09E-02	0.10	0.19
PRECIPITATION				0.7425	0.5197	0.00E+00	0.00	0.70
TRIBUTARY INFLOW				13.8493	2.6632	7.09E-02	0.10	0.19
***TOTAL INFLOW				14.5918	3.1830	7.09E-02	0.08	0.22
ADVECTIVE OUTFLOW				14.5918	2.6929	7.09E-02	0.10	0.18
***TOTAL OUTFLOW				14.5918	2.6929	7.09E-02	0.10	0.18
***EVAPORATION					0.4901	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Local P Load from HSPF	168.9	47.2%	5.70E+02	85.1%	0.14	63.4	12.2
PRECIPITATION				20.0	5.6%	9.97E+01	14.9%	0.50	38.4	26.9
INTERNAL LOAD				169.0	47.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				168.9	47.2%	5.70E+02	85.1%	0.14	63.4	12.2
***TOTAL INFLOW				357.8	100.0%	6.70E+02	100.0%	0.07	112.4	24.5
ADVECTIVE OUTFLOW				143.6	40.1%	1.66E+03		0.28	53.3	9.8
***TOTAL OUTFLOW				143.6	40.1%	1.66E+03		0.28	53.3	9.8
***RETENTION				214.2	59.9%	1.65E+03		0.19		

Overflow Rate (m/yr)	3.6	Nutrient Resid. Time (yrs)	0.3873
Hydraulic Resid. Time (yrs)	0.9650	Turnover Ratio	2.6
Reservoir Conc (mg/m3)	53	Retention Coef.	0.599

Table 11-2. Jail Lake calibrated BATHTUB model observed and predicted in-lake TP concentration

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Jail Lake

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	53.3	0.27	54.7%	53.3	0.14	54.7%

Table 11-3. Jail Lake TMDL goal BATHTUB model water and phosphorus mass balance summary

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Local P Load from HSPF	13.8493	2.6632	7.09E-02	0.10	0.19
PRECIPITATION				0.7425	0.5197	0.00E+00	0.00	0.70
TRIBUTARY INFLOW				13.8493	2.6632	7.09E-02	0.10	0.19
***TOTAL INFLOW				14.5918	3.1830	7.09E-02	0.08	0.22
ADVECTIVE OUTFLOW				14.5918	2.6929	7.09E-02	0.10	0.18
***TOTAL OUTFLOW				14.5918	2.6929	7.09E-02	0.10	0.18
***EVAPORATION					0.4901	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: Predicted TOTAL P — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	Load %Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Local P Load from HSPF	133.2	80.5%	3.55E+02	78.0%	0.14	50.0	9.6
PRECIPITATION				20.0	12.1%	9.97E+01	21.9%	0.50	38.4	26.9
INTERNAL LOAD				12.2	7.4%	0.00E+00		0.00		
TRIBUTARY INFLOW				133.2	80.5%	3.55E+02	78.1%	0.14	50.0	9.6
***TOTAL INFLOW				165.3	100.0%	4.54E+02	100.0%	0.13	51.9	11.3
ADVECTIVE OUTFLOW				80.8	48.8%	4.56E+02		0.26	30.0	5.5
***TOTAL OUTFLOW				80.8	48.8%	4.56E+02		0.26	30.0	5.5
***RETENTION				84.6	51.2%	4.62E+02		0.25		

Overflow Rate (m/yr)	3.6	Nutrient Resid. Time (yrs)	0.4713
Hydraulic Resid. Time (yrs)	0.9650	Turnover Ratio	2.1
Reservoir Conc (mg/m3)	30	Retention Coef.	0.512

Table 11-4. Jail Lake TMDL goal BATHTUB model observed and predicted in-lake TP concentration

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Jail Lake

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	30.0	0.24	30.1%	53.3	0.14	54.7%

Table 11-5. Kego Lake calibrated BATHTUB model water and phosphorus mass balance summary

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Trib 1	21.4678	3.8567	1.49E-01	0.10	0.18
PRECIPITATION				1.1947	0.8841	0.00E+00	0.00	0.74
TRIBUTARY INFLOW				21.4678	3.8567	1.49E-01	0.10	0.18
***TOTAL INFLOW				22.6625	4.7408	1.49E-01	0.08	0.21
ADVECTIVE OUTFLOW				22.6625	3.9523	1.49E-01	0.10	0.17
***TOTAL OUTFLOW				22.6625	3.9523	1.49E-01	0.10	0.17
***EVAPORATION					0.7885	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Trib 1	210.8	74.0%	8.89E+02	77.5%	0.14	54.7	9.8
PRECIPITATION				32.1	11.3%	2.58E+02	22.5%	0.50	36.4	26.9
INTERNAL LOAD				41.9	14.7%	0.00E+00		0.00		
TRIBUTARY INFLOW				210.8	74.0%	8.89E+02	77.5%	0.14	54.7	9.8
***TOTAL INFLOW				284.8	100.0%	1.15E+03	100.0%	0.12	60.1	12.6
ADVECTIVE OUTFLOW				131.6	46.2%	1.27E+03		0.27	33.3	5.8
***TOTAL OUTFLOW				131.6	46.2%	1.27E+03		0.27	33.3	5.8
***RETENTION				153.2	53.8%	1.33E+03		0.24		

Overflow Rate (m/yr)	3.3	Nutrient Resid. Time (yrs)	0.4734
Hydraulic Resid. Time (yrs)	1.0247	Turnover Ratio	2.1
Reservoir Conc (mg/m3)	33.3	Retention Coef.	0.538

Table 11-6. Kego Lake calibrated BATHTUB model observed and predicted in-lake TP concentration

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Segname 1

Variable		Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P	MG/M3	33.3	0.25	34.3%	33.3	0.07	34.3%

Table 11-7. Kego Lake TMDL goal BATHTUB model water and phosphorus mass balance summary

Overall Water & Nutrient Balances

Overall Water Balance						**Averaging Period =**	**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Trib 1	21.4678	3.8567	1.49E-01	0.10	0.18
PRECIPITATION				1.1947	0.8841	0.00E+00	0.00	0.74
TRIBUTARY INFLOW				21.4678	3.8567	1.49E-01	0.10	0.18
***TOTAL INFLOW				22.6625	4.7408	1.49E-01	0.08	0.21
ADVECTIVE OUTFLOW				22.6625	3.9523	1.49E-01	0.10	0.17
***TOTAL OUTFLOW				22.6625	3.9523	1.49E-01	0.10	0.17
***EVAPORATION					0.7885	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:	**Predicted TOTAL P**	**Outflow & Reservoir Concentrations**					
	Load		**Load Variance**			**Conc**	**Export**
Trb Type Seg Name	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1 1 1 Trib 1	192.8	77.7%	7.44E+02	74.2%	0.14	50.0	9.0
PRECIPITATION	32.1	13.0%	2.58E+02	25.8%	0.50	36.4	26.9
INTERNAL LOAD	23.1	9.3%	0.00E+00		0.00		
TRIBUTARY INFLOW	192.8	77.7%	7.44E+02	74.2%	0.14	50.0	9.0
***TOTAL INFLOW	248.1	100.0%	1.00E+03	100.0%	0.13	52.3	10.9
ADVECTIVE OUTFLOW	118.5	47.8%	1.01E+03		0.27	30.0	5.2
***TOTAL OUTFLOW	118.5	47.8%	1.01E+03		0.27	30.0	5.2
***RETENTION	129.6	52.2%	1.05E+03		0.25		

Overflow Rate (m/yr)	3.3	Nutrient Resid. Time (yrs)	0.4896
Hydraulic Resid. Time (yrs)	1.0247	Turnover Ratio	2.0
Reservoir Conc (mg/m3)	30.0	Retention Coef.	0.522

Table 11-8. Kego Lake TMDL goal BATHTUB model observed and predicted in-lake TP concentration

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:	**1**	**Segname 1**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	30.0	0.24	30.1%	33.3	0.07	34.3%