Estimating Lake Water Volume Using Scale Analysis

A THESIS

SUBMITTED TO THE FACULTY OF THE

UNIVERSITY OF MINNESOTA

BY

Chelsea O'Neill Delaney

IN PARTIAL FULFILLMENT OF THE REQUIERMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

John Nieber

December 2019

ACKNOWLEDGEMENT

I would first like to thank my advisor Professor John Nieber of the Department of Bioproducts and Biosystems Engineering at the University of Minnesota- Twin Cities. His willingness to give his time so generously has been very much appreciated. He consistently allowed this paper to be my own work but steered me in the right the direction whenever he thought I needed it. Each of the members of my Thesis Committee has provided me extensive guidance throughout this process.

I wish to thank various people for their contribution to this project; Associate Scientist Adam Heathcote for his valuable knowledge on the methods; Hydrologist Jared Trost for his valuable and constructive suggestions during the planning and development of this research work; and Assistant Scientist Kerry Holmberg for her technical support throughout the entirety of this project. Without their passionate participation and input, the work could not have been successfully conducted.

Finally, I must express my very profound gratitude to my parents and to my colleagues for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Author

Chelsea Delaney

Abstract

The volume of a lake is a crucial component in understanding the different biological, chemical, thermal, and hydrologic processes occurring within it. Minnesota has within its border tens of thousands of lakes, but for only a small fraction of those are there any readily available bathymetric information. We applied a previously developed methodology for predicting lake volumes using lake surface area and land surface elevation change for each of the lakes as well as a statistical method to determine total lake volume through the use of bootstrapping for over 40,000 lakes within Central Minnesota spanning from the Twin Cities to Moorhead across 17 HUC-8 watersheds. 816 lakes had known bathymetric data within the watersheds with a range of volumes approximately from 190,000 to 135,000,000 m^3 and a range of surface areas from 64,000 to 21,000,000 m^2. The total lake volumes for both methods calculated was 1,180,000 and 1,200,000 hectare meters. When comparing the known to the predicted volumes of the 816 lakes, the model explained 82% of the variation. The sum difference between the total predicted lake volume and known volumes using the statistical method was less than 2%. These models are not only an accurate way to estimate lake volume, but a good steppingstone to help calculate different processes that require a volume.

TABLE OF CONTENTS

List of Tables

List of Figures

Chapter I: Introduction

Fresh water is a crucial resource to humans and with an ever-changing environment we need to be better prepared to protect it. Because liquid freshwater only accounts for about 0.007% of the total amount of water in the world, humans need to improve ways of monitoring and securing water resources for the future (Calmant, Seyler, & Cretaux, 2008).

One of the most important freshwater bodies are lakes. While the surface area of all lakes cover less than 4% of the of the global landmass, they are home to a wide range of biodiversity and ecosystems (McDonald, Rover, Stets, & Striegl, 2012). The ecosystem functioning of lakes provide tangible ecologic and economic value, yet key information such as lake datasets that contain basic morphological and hydrologic characteristics needed to determine these functions are missing (Crétaux et al., 2016; J. W. Hollister, Milstead, & Urrutia, 2011). Lake volume is a vital component in many lake functions related to the physical, biological, and chemical processes within the lake. For example, the volume of a lake can affect the water residence time which in turn can affect the nutrient dynamics and primary productivity of a lake (Sobek, Nisell, & Folster, 2011). With missing or inaccurate data, scientists' prediction of these functions are not as precise as they could be, making it more difficult to quantify the changes that may occur within these environments (Crétaux et al., 2016; Messager, Lehner, Grill, Nedeva, & Schmitt, 2016; Sobek et al., 2011).

As models become less dependent on full bathymetric data, lake volumes can be better predicted in the future. As the environment continues to change, scientists need to focus more on the importance of freshwater and its role in our society. Not only can scientists better understand the functions that lake volume plays on the overall ecosystem but begin to map lake volumes over different regions. This, in turn, can help us to produce better management and restoration techniques for this valuable resource.

Traditionally, lake volumes were determined from hydromorphology contour maps (bathymetric maps), but this method is expensive, time consuming, and these data are often not available (Cael, Heathcote, & Seekell, 2017; Hayashi & Van Der Kamp, 2000; J. Hollister & Milstead, 2010; Ozesmi & Bauer, 2002). Furthermore, public access to bathymetric data can be restricted due to the data being only available in unpublished tables or paper maps (J. W. Hollister et al., 2011). In order to tackle this lack of information, scientists developed models that required limited data, with broad geographic coverage, that in most areas are available to the public.

Calculating bathymetric data using satellites allows for a greater range of area to be covered while minimizing the need for scientists to go into the field. This is particularly useful in regions that are dominated by water sources or areas in remote locations where surveying is nearly impossible (Abileah & Vignudelli, 2011). While there may be some disadvantages to satellites data such as spatial resolution, temporal resolution, and obstructions of data, overall, satellites are often the best choice when trying to gather data that are already limited due to the lack of money, time, and manpower (Calmant et al., 2008; Lu, Ouyang, Wu, Wei, & Tesemma, 2013; Ozesmi & Bauer, 2002). Utilizing satellite derived topographic and morphologic data, scientists are producing models that can predict volumes ranging from small lakes and ponds to extremely large lakes with limited bathymetric data. Often times, ponds are overlooked and disregarded from the importance they play on the environment. However, these ponds provide important biodiversity to the surrounding landscape due to the close contact they have with the terrestrial environment and a larger littoral zone (Søndergaard, Jeppesen, & Jensen, 2005). Therefore, predicting volumes for these ponds can produce a better understanding of the surrounding processes. Having a model that can predict volumes regardless of size of the waterbody is a crucial step in better understanding the ecosystem as a whole and how the water moves throughout.

Considering a data driven model, the method purposed by Heathcote *et al*. (2015) provided a solution to limited available data to the public by improving previous models. This was accomplished by using terrestrial average change in relief and surface area to predict individual lake volume. Assuming that the surrounding environment around the lake was formed by the same geological process as the lakebed, the topographic relief under the surface of the lake would be a continuation from the surrounding land. For example, Heathcote found that lakes with a larger change in elevation in the surrounding environment will most likely have large changes in elevation below the surface.

While the Heathcote *et al*. (2015) method predicted lake volumes using self-similar scaling, the Cael *et al*. (2017) method developed a model using self-affine surfaces. The Cael *et al*. (2017) method predicted lake volumes on a global scale across the world with vastly different regions and topographic features. Assuming that this model works for self-affine surfaces due to the relationship between the topography and the horizontal scale as explained by the Hurst coefficient, an exponent originally established to estimate future time series, the Cael *et al*. (2017) showed how total volume can be calculated when examining a wide range of lake volumes (Cael et al., 2017; Munshi, 2015). The surface area and Hurst coefficient help determine the volume when the lake surface area is on a scaled level. When scaling a lake, there is a statistical relationship between the volume and area due to the Hurst coefficient allowing for calculating a collection of lake volumes across broad regions.

As water resources and water availability become scarcer on a global scale, scientists need the ability to better manage and counteract changes over these regions. However, producing a model that can predict lake volumes over vast regions has been hard to achieve (Cael et al., 2017). Testing was undergone to see if the Heathcote *et al.* (2015) and the Cael *et al.* (2017) models could achieve predicting lake volumes regardless of the lakes' region and topography within central Minnesota, a lake dominated area, to determine if the models could accurately predict lake volume. By having a region such as Minnesota with small relief and an array of lake sizes, a test was conducted to see if these models would result in accurate lake volume predictions.

We hypothesize using the Heathcote *et al*, (2015) model will significantly predict lake volumes using lake surface area and the surrounding topography based on the size of the lake. Furthermore, we hypothesize that grouping lakes by size or by watershed will result in a better prediction of lake volumes. Overall, we hypothesize that using the

Heathcote *et al.* (2015) model for predicting total lake volume storage for a region is more accurate than using the Cael *et al.* (2017) model.

Lakes are a crucial freshwater body and yet, are not fully researched and understood in regards to the impact they have on ecosystem functions (Crétaux et al., 2016; J. W. Hollister et al., 2011). Continual measurements of lakes across the globe is an essential goal to better understand and track the physical, biological, and chemical changes that are occurring in our world today (Sobek et al., 2011). The problem though is that the vast majority of lakes have not been surveyed and with a lack of lake size and shape information, the impact lakes have on the environment is relatively unknown (Heathcote, del Giorgio, & Prairie, 2015). Further research to determine basic morphological and hydrologic characteristics of lakes must be undertaken in order to better manage and predict changes that may occur and accurately develop strategies to counter negative consequences. This paper provides possible methods to determine these basic morphological characteristics of lake to be used for future management strategies.

Chapter II: Literature Review

2.1 Background of Estimating Lake Volume

Lake volume is a crucial component in understanding the different processes occurring within a lake. Lake volume affects the physical, chemical and biological properties of the lake such as the water residence time which in turn can affect the nutrient dynamics and primary productivity of the lake (Sobek et al., 2011). By knowing lake volume, scientists can have a better understanding of water resource management occurring at different scales (Crétaux et al., 2016; Sobek et al., 2011).

Estimating lake volume can be difficult. Not only is surveying time intensive and expensive in nature, but the number of lakes already surveyed is minimal to the total number of lakes globally (J. Hollister & Milstead, 2010; Sobek et al., 2011). For example, within the state of Minnesota data on lake depth and volume only exists for 2,500 lakes (Minnesota Department of Natural Resources, 2017). Of those 2,500 lakes, only one lake with a surface area under 10^4 m^2 has been surveyed. Having only one lake surveyed creates a dilemma when trying to quantify the geochemical processes of smaller lakes and how they affect the overall hydrological, geochemical, or biological processes in a region.

Methods for estimating lake volume have changed drastically over the past few decades. Bathymetry surveys were conducted to first collect data with the volume being calculated with bathymetric contour maps and planimeters. Although, having access to the bathymetric contour map data, if even available, may be hard to obtain (J. W.

Hollister et al., 2011). Furthermore, obtaining bathymetric data for every lake is implausible and so large gaps exist when looking at lakes within a region (Calmant et al., 2008; J. W. Hollister et al., 2011). These gaps create discrepancies when trying to collect all lake volumes information within a region.

2.2 Satellite Remote Sensing

There have been advancements in helping to determine lake volumes without the need of hydromorphological surveys of individual lakes. Satellite remote sensing is becoming an increasingly developed tool for scientists to use as a way to predict lake volumes due to its ability for global remote sensing even in remote regions of the world. Satellites can monitor lakes over long periods, and can revisit specific locations at temporal intervals from a few months to a few days (Crétaux et al., 2016). Furthermore, there has been a drastic increase in access of free and public satellite data allowing for a greater quantification of the global variation in water body volumes (Abileah & Vignudelli, 2011; Crétaux et al., 2016).

While there may be advancements using remote sensing, there are some downfalls to remote sensing. The accuracy of satellites can be affected by range errors which are due to surface roughness and the ability for the altimeter in the satellite to track the waveforms (Calmant et al., 2008; Crétaux et al., 2016). Furthermore, satellite data measurements may vary from one satellite to another based on the resolution, resulting in several types of inaccuracies occurring, ranging from centimeters to meters. Cloud coverage can also play an issue when attempting to see the surface area of a lake as well as mischaracterization of shadows as waterbodies in algorithm-based land area surveys (Schwab, Leshkevich, & Muhr, 1992). Lastly, the difficulty of separation between land and water due to foliage coverage can play a large role in errors due to the resolution being unable to separate one from the other (Ozesmi & Bauer, 2002).

2.3 Lake surface area and land surface slope methods

Even with these issues, modern analytical methods are outcompeting older methods in calculating lake volumes by abandoning unnecessary assumptions (J. W. Hollister et al., 2011). By continuing to improve satellite remote sensing tools, scientists will continue to improve on the overall quality and resolution of remote freshwater surveys (Calmant et al., 2008; Crétaux et al., 2016).

The original concept of using lake surface area and land surface slope came from Håkanson and Peters (1995) who suggested using an empirical model that calculated lake volume from lake area and maximum slope of the catchment from 95 lakes in Sweden. With the use of a two-dimensional map by means of planimeter, square counting, or computerized GIS-methods, lake area and shoreline length was determined. The catchment area and its relief were determined from topographic and economic maps of the catchment area. From the lake area and maximum slope of the catchment regression model, the lake volume model explained 87% of the variability in volume. While the lake volume model was able to explain a high percentage of the variability in volume, the model requires catchment area data which may not always available in certain locations. Furthermore, during the mid-nineties using GIS-based methods resulted in high errors with landscapes with limited vertical resolution due to GIS not being as developed as today. Sobek *et al*. (2011) improved this concept by using surface area and a static buffer of 50 m around each lake, for a total of 6130 lakes, to calculate lake volume within Sweden. Using the Swedish lake register to derive the geographical and topographical parameters via GIS analysis, the lake volume model explained 92% of the variability in volume.

Heathcote *et al*. (2015) further developed this method to predict lake volume by using the surface area and the terrestrial slope with the terrestrial slope being dependent on the surface area size. This allowed the lake's buffer area to be proportional to the size of the lake rather than a static buffer distance as done by Sobek *et al*. (2011). In doing so, the model explained 95% of the variation in lake volume while the variables of surface area and elevation change uniquely explained 32% and 4% of the variation, respectively. The RSE for the model was 0.222 $\log_{10} m^3$. By not having to rely on full, comprehensive lake datasets that contain basic morphological characteristics, Heathcote *et al*. (2015) has developed a way to determine a lake's volume with limited bathymetric data.

2.4 Cael Method Overview

Using a statistical approach model, Cael *et al*. (2017) has minimalized the need for depth or elevation change of the surrounding buffer to determine lake volumes. By showing the connection between lake area and volume (Mandelbrot, 1975; Renard, Candela, & Bouchaud, 2013), Cael *et al*. (2017) used the surface area of a lake and statistical analysis to find total volume of a group of lakes. He estimated the total volume of lakes globally to be 199,000 km^3, which is lower than previous estimates which on average were 210,000 km^3. Furthermore, he classified the lakes by area and saw that while not encompassing a significant part of the total volume, lakes with 10^4-10^5 m^2 area comprised the majority of the lakes in the world. This model has the capability to estimate a total volume of a group of lakes across a diverse region with limited data assuming that the lake surfaces are self-affine. Self-affine surfaces are surfaces with no permanent scale where the vertical and horizontal scaling is not necessarily equal to one another (Cael et al., 2017; Goodchild, 1988). Self-affinity implies that when observing a landscape, the landscape itself does not display any cues as to what the scale is. This solidifies the idea of characterizing the earth's topography as a self-affine surface resulting in the lakes' volumes being easier to predict.

2.5 Similar Research

Referencing the same lakes within the 17 HUC-8 watersheds, a statistical approach used lake surface area to predict lake volume. In order to examine the relationship between lake attributes and volume, statistical analyses were performed on approximately 800 lakes in the watershed study region. Lake surface area was the most significant predictor of lake volume. A piecewise regression analysis further revealed a log transformed breakpoint regression at 125 hectares surface area yielded the best prediction of lake volume. Surface area delineations were used in the breakpoint regression model relating lake surface area to lake volume of the 800 lakes to estimate lake volume for all of the lakes in the study area (n=30,000). Volumes were estimated with surface areas from the Minnesota Department of Natural Resources (DNR) (Minnesota Department of

Natural Resources, 2017) dataset using breakpoint regression (K. Holmberg, personal communication, December 2018-May 2019; European Commisions Joint Research Centre, 2017; Pekel, Cottam, Gorelick, & Belward, 2016).

2.6 Applying lake volume prediction methods to Minnesota

To determine if volume prediction methods can be applied to a lake dominated region such as Minnesota, the methods by Heathcote *et al*. (2015) and the Cael *et* al. (2017) were used within Central Minnesota spanning from the Twin Cities to Moorhead across 17 Hydrologic Unit Code (HUC)-8 watersheds (Minnesota Department of Natural Resources, 2005; Seaber, P.R., Kapinos, F.P., Knapp, 1987). With only a limited amount of lakes within the region surveyed and majority of the lakes less than 1000 m^2, an attempt was proposed to use these methods within Minnesota to see if they can indeed be used in this location.

Chapter III: Methods

The methods developed by Heathcote *et al*. (2015) and Cael *et al*. (2017) were used to estimate lake volume within Central Minnesota using limited bathymetric data. Previously, lack of bathymetric data prevented the capability to find lake volume from the unavailability of known average depth. However, both methods provided estimates of lake volume without the need of average depth. This allowed for a calculation of total lake volume within the region that had not been previously known.

These estimates of lake volumes were calculated using the data provided by the Minnesota Department of Natural Resources (DNR). The DNR provided hydrography data, without depth or volumes, of 40,054 lakes within Minnesota's 17 central HUC-8 watersheds to be used to test the prediction models (Figure 1) (Department of Natural Resources Division of Fish and Wildlife, 2014). 816 lakes, with known volumes and a shapefile of each lake with corresponding data, was compiled from the DNR morphology dataset of the state (Minnesota Department of Natural Resources, 2017). Due to the size and extensive surveys, Mille Lacs Lake was removed from the study area calculations. These 816 lakes ranged from volumes of 10^4 to greater than 10^7 m^3 with known maximum depths, average depths, and surface areas for each lake (Appendix C). A summary of each lake size and watershed category is listed in Table 1.

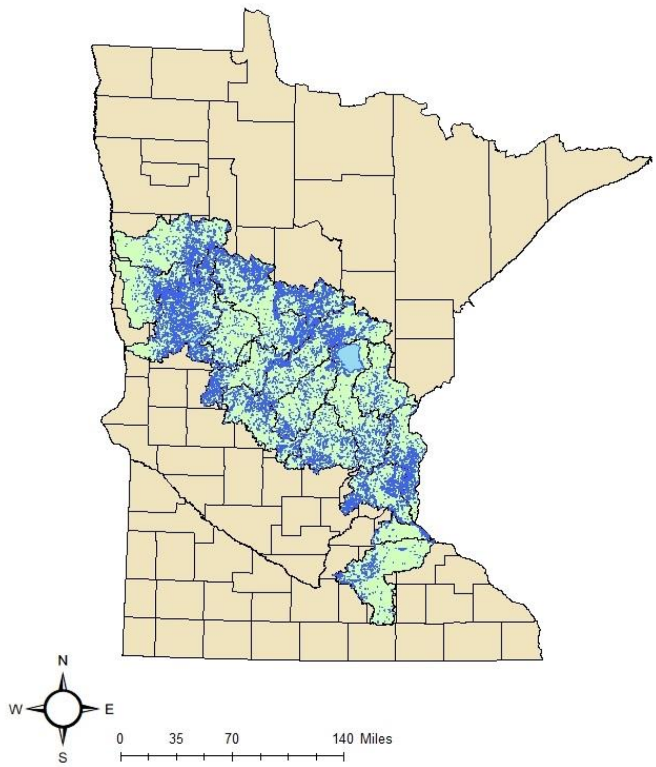

Figure 1. Map of 40,054 lakes contained within 17 HUC-8 watersheds of central Minnesota used in lake volume prediction.

Table 1. Averages of morphology traits from surveyed 816 lakes provided by Minnesota Department of Natural Resources (DNR).

Lake Volume (m^3)	*Number of Lakes*	*Average Size (m^2)*	*Average Max Depth (m)*	*Average Depth (m)*	*Average Volume (m^3)*	*Average Surface Area (m^2)*
10^4	11	124,239	2.3	0.8	55,032	124,156
10^5	192	333,8656	6.7	2.2	530,127	333,926
10^6	436	1,054,611	11.0	4.0	3,653,086	1,054,480
10^7	166	4,477,037	18.9	6.3	25,600,190	4,477,055
$>10^7$	11	25,148,785	31.2	7.9	190,669,424	25,148,967

3.1 Heathcote Method

As volume prediction models continue to advance along diverse regions, the need for comprehensive bathymetric data is no longer required. The Heathcote *et al*. (2015) method found that the average change in elevation between the surrounding terrestrial landscape and the lake surface to be the best predictor of bathymetric properties (Heathcote et al., 2015). The terrestrial buffer surrounding the lake was used because of the assumption that the elevation change surrounding the lake was formed by the same geomorphic process forming the elevation change within the lake and that the slope of the surrounding topography was near to that of the slope of the lake bottom (J. W. Hollister et al., 2011). Due to not being able to calculate the slope occurring under the water because that information is not available, the method uses elevation change surrounding the lake as an independent variable to predict the lake volume. By studying the relationship between the morphology of a lake and the surrounding area, lake volumes can be predicted with limited bathymetric data. The Heathcote *et al*. (2015) method is such a model and testing whether it can predict lake volumes in a lake dominated region will provide further evidence that these predictive models can be used across diverse regions.

The study area of all the lakes, using ArcMap 10.6.1, was projected in the NAD_1983_UTM_Zone_15N coordinate system for all layers. Following the Heathcote *et al*. (2015) method, each lake had a buffer created around the lake using an equation as given in the following:

$$D = 2 \cdot \sqrt{(A / \pi)} \quad \text{(Equation 1)}$$

where D is the buffer distance from the shoreline outward and A is the lake surface area. In order to determine the optimal buffer distance that would result in the best prediction of lake volume, increments of 5% from 0-100% of D were calculated. The 25% buffer resulted in the best prediction of lake volume when compared to the set of known volumes within our research as well.

Topography for each buffer was calculated using a 1/3 arc-second Digital Elevation map (DEM) (~10 m) of Minnesota (U.S. Geological Survey, 2017). Within each lake's buffer, topography was summarized as the minimum, mean, and maximum elevation within the buffer. The mean elevation change was determined by calculating the difference between the mean and minimum elevation within the buffer.

Once the topography was determined, the original Heathcote *et al*. (2015) volume equation, seen in equation 2, was used as a basis for composing an equation for calculating lake volume (V) within the 17 HUC-8 watershed lakes (Equation 3) where lake area is the surface area of an individual lake provided by the DNR morphology dataset of the state and elevation $change_{25,}$ defined as DE_{25} within the equations, is the change within the buffer area defined by 25% of D calculated from equation 1 .

$$\log_{10} V = \log_{10} \text{lake area} \cdot 0.96 + \log_{10} DE_{25} \cdot 0.77 \text{ (Equation 2)}$$

A regression analysis was conducted using the known volumes from the morphology shapefile and the mean elevation change and surface area from the hydrography layer. Once run, coefficients for the volume equation were determined as given in equation 3 to better predict lake volume.

$$\log_{10} V = \log_{10} \text{lake area} \cdot 1.17 + \log_{10} DE_{25} \cdot 0.07 \text{ (Equation 3)}$$

In order to prevent heteroscedasticity, all variables were normalized by $\log_{10}$ transformation before the regression analysis. Due to there being a bias introduced when estimates are being back transformed from regressions, corrections were conducted based on Ferguson (1986) to prevent variables from being underestimated.

$$\hat{Y}\ corr = 10^{\log 10\ \hat{Y}} \cdot \exp(2.65 \cdot s^2)\ \text{(Equation 4)}$$

where $\hat{Y}$ corr is the corrected predicted value, s^2 is the residual variance from the model, and 2.65 is a constant (Ferguson, 1986). This provided a closer estimate to the known volumes from the 816 lakes.

In order to determine if outliers were imbedded within the predicted volumes, the “outlierTest” function within the package “car” within R was run to determine if and how many outliers were present (Fox et al., 2018). Once run, outliers outside of the 95% confidence interval were removed from the data set and further analyzed to see why certain lakes, if any, were outliers in the overall data set.

When calculating individual lake volumes, the surface area alone was not as significant as a predictor when compared to surface area coupled with the elevation change surrounding the lake. This may be due to the wide processes by which a lake can be formed. The processes of a lake can result in unique bathymetric and surrounding features of the lake. Furthermore, lakes that fit the character of a similar formation type and that reside in geographical proximity to one another are generally of the same origin (Branstrator, 2009). This means that lakes that fit those criteria are regionally dependent and that the way in which a lake is formed can have a significant impact on the lake volume. Therefore, when calculating individual lake volumes surface area alone will not be sufficient by itself. Compiling with the other variables will produce a more accurate prediction due to the array of processes in which lakes are formed.

Due to the size range and the variability of lake formation, testing was conducted to determine whether or not pooling the entire project area with one regression analysis provided the most accurate prediction to lake volumes. Further analysis of lake grouping by different methods was conducted to provide improved predictions.

Lakes were categorized by surface area size into the following size ranges: $<10^4$, 10^4-10^5, 10^5-10^6, 10^6-10^7, and $>10^7$ m^2. Due to lack of known volumes of lakes with surface area less than 10^4 m^2, they were given a depth of 0.5 m in order to calculate volume by multiplying the depth and surface area. This depth was chosen because known lake morphology within the region for lakes within a surface area between 10^4-10^5 had an average depth of 0.8 m (Table 1) and we assumed that the average depth of lakes with surface area less than 10^4 m^2 would be smaller than that of lakes with a surface area between 10^4-10^5. The other sizes had their own regression analysis conducted following the Heathcote *et al.* (2015) method (Appendix B).

Lakes were also segregated by watershed to examine whether geographic location played a role in the lake volume relation. Each watershed with its own lakes had a regression analysis conducted following the protocol above (Appendix B).

Using equation 5 as a guideline for lake volume prediction where β_1 and β_2 are the coefficients determined by regression analysis, the volume of the 40,054 lakes with known surface area and elevation change was calculated to find a total sum of water storage for each of the different lake groupings (Table 2 & Appendix B).

$$\log_{10} V = \beta_1 \cdot \log_{10} \text{lake area} + \beta_2 \cdot \log_{10} DE_{25} \text{ (Equation 5)}$$

Each lake was categorized into the appropriate size category based on surface area and watershed based on lake location (Appendix A).

Table 2. Coefficients for each lake grouping (noted by β_1 and β_2) determined by regression analysis.

Lake Groupings	***Surface Area Coefficient β_1***	***Elevation Change$_{25}$ Coefficient β_2***
Size	-	-
10^4-10^5	0.78	0.19
10^5-10^6	1.12	-0.04
10^6-10^7	1.26	0.75
$>10^7$	0.94	0.10
Watersheds	-	-
Buffalo River	1.13	0.19
Cannon River	0.95	-0.04
Crow Wing River	1.18	0.75
Long Prairie River	1.21	0.10
Lower St. Croix River	1.15	0.02
Mississippi River- Brainerd	0.91	0.41
Mississippi River- Lake Pepin	1.05	-0.04
Mississippi River- Sartell	1.22	-0.17
Mississippi River- St. Cloud	1.07	-0.08
Mississippi River- Twin Cities	1.04	0.58
Ottertail River	1.12	0.25
Pine River	1.04	0.54
Redeye River	1.67	0.18
Rum River	1.35	0.78
Sauk River	0.92	0.30
Snake River	1.57	-0.10
Wild Rice River	1.40	-0.30

Lake volumes were predicted using multiple linear regression derived from surface area and elevation changes listed above. In order to determine the strength in relationship between variables (surface area and elevation change), the Pearson's partial correlation coefficient was calculated for the study region (Table 3). The residual standard error (RSE) was calculated in order to assess the predictive power of the regression model. The Akaike information criteria (AIC) (Akaike, 1974) was used in order to determine the most parsimonious model in the regression analysis. The best model was seen to be that of surface area and elevation change, rather than surface area alone, with the lowest AIC score (Table 4). All statistical analysis was conducted using the statistical software R (RStudio Team, 2016) and the "ppcor" package was used to calculate the partial correlation coefficient (Kim, 2015).

Table 3. Pearson partial correlation coefficient tested to determine correlation strength of independent variables to lake volume.

Coefficient Variables	***Lake Volume***
Surface Area	0.90
Elevation Change	0.15

Table 4. Akaike information criteria (AIC) and ΔAIC for the different predictive models tested for determining lake volume.

Model Variables	***AIC***	***ΔAIC***
Surface Area + Elevation Change	317.79	0.0
Surface Area	334.89	17.1

3.2 Cael Method

Estimating the global lake volume can be quite difficult due to high variability and poor documentation of lake volumes (Cael et al., 2017). In order to combat this, Cael *et al*. (2017) developed a volume-area scaling method based on the relationship between lake volume and surface area. In doing so, this allowed for the prediction of lake volumes across diverse regions and topography with limited bathymetric data. To test whether this model can be used in a region-specific area dominated by lakes with limited bathymetric data, the model was applied to Central Minnesota.

Using the DNR morphology dataset of the 816 lakes (Minnesota Department of Natural Resources, 2017), the Cael *et al*. (2015) method was followed. Cael *et al*. (2017) created a regression formula (Equation 6)

$$\log(v) = \zeta \log(a) + \log(\kappa) + \varepsilon \text{ (Equation 6)}$$

that used log transformed surface area (a) and volume (v) to compare known volumes to predicted volumes derived from the formula (ζ is the volume- area scaling exponent, κ is a proportionality coefficient, and ε is the error) (Cael et al., 2017). ζ and κ were determined by the regression analysis from the slope and intercept. To consider the variability in lake volumes within the project area, confidence intervals from a bootstrapping resampling procedure were calculated (Leschinski, 2019). These two procedures were used to account for the different sources of uncertainty within ζ and κ. The bootstrapping procedure using the given data, and the Monte Carlo procedure using sampling from a theoretical distribution with predefined parameters, produce confidence intervals. Due to the Monte Carlo procedure estimating the confidence intervals around the scaling relationship, there is no need for a transformation bias correction (Cael et al., 2017).

Using known volumes from the 816 lakes (Minnesota Department of Natural Resources, 2017), bootstrapping of the variables created 95% confidence intervals. With the parameters known, an equation for predicted lake volumes was created within our project area (Equation 7) was created. The error (ε) within the equation was determined from the root-mean-square error (RMSE) of the residuals of the scaling relationship. The equation was then applied to all the lakes within the project area (40,054) and then summed to determine the total lake volume.

$$\log_{10}(v) = 1.17 \cdot \log_{10}(a) - 0.498 + \varepsilon \text{ (Equation 7)}$$

Like the Heathcote *et al.* (2015) method, this method was conducted with different groupings of the lakes to test which provided the most accurate individual lake volumes. Lakes were pooled by the same surface area size ranges from the Heathcote *et al*. (2015) method. Once again, lakes with surface area less than 10^4 m^2 were given a depth of 0.5 m in order to calculate volume by multiplying the depth and surface area (Boyd, 2004; Shapiro & Wright, 1984). The other sizes had their own regression analyses conducted following equation 8

$$\log_{10} V = \beta_1 \cdot \log_{10} (A) + \beta_2 + \varepsilon \text{ (Equation 8)}$$

where β_1 and β_2 are the coefficients determined by regression analyses from the slope and intercept. Lakes were also categorized by the 17 HUC-8 watersheds in order to examine whether see if geographic location plays a role in lake volume. Each watershed with its own lakes had a regression analysis conducted following the Cael *et al.* (2017) protocol. Using the same format as equation 7, the volume of the 40,054 lakes with known surface area was calculated to find a total sum of water storage for each of the different lake groupings based on location and size.

In order to show the relationship between volume and area, Cael *et al*. (2017) provided background on the relationship by proposing that when scaling self-affine lakes, the volume and area of a lake have a relationship through the use of the Hurst coefficient. Cael *et al*. (2017) provided that the Hurst coefficient is used when scaling or zooming in by a coefficient, *b* for example (*b* can be any number when scaling down), such that when vertically scaling the depth (z) results in b^H while scaling vertically, the length or diameter of the lake (ℓ) is only scaled down by *b* (Figure 2). This results in the landscapes of the normal level and the zoomed in level being statistically identical.

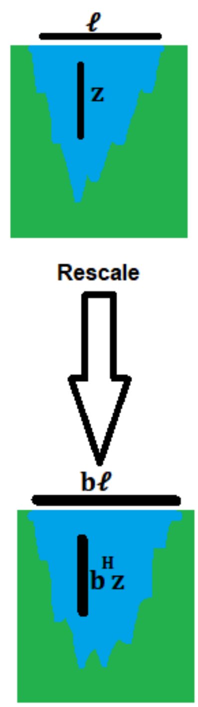

Figure 2. Rescaling of self-affine lakes by a factor of *b* and the Hurst coefficient showing the volume-area relationship.

Cael *et al*. (2017) calculated the Hurst coefficient for all the lakes within his paper and determined the Hurst coefficient for those set of lakes to be H = 0.4 +/- ~0.1. The Hurst coefficient number is based on the value range (0-1) classified into three categories.

These categories provide a prediction for the tendency of a time series by quantifying the data. A Hurst exponent of 0.5 shows no correlation between the data and future observations and a Hurst exponent between 0.5 and 1 indicates with an increase in values will be followed by another increase and vice versa if the values are decreasing. When the Hurst coefficient is below 0.5, it indicates the time series will alternate between a high number and a low number (Cannon, Percival, Caccia, Raymond, & Bassingthwaighte, 1997; Qian & Rasheed, 2004).

The Hurst coefficient is widely established in the hydrology field due to its ability to explain natural phenomena (Munshi, 2017). Scientists have not only used the Hurst coefficient to explain the surface of the Earth but for the Moon, Mars, and Mercury (Fa & Fa, 2017; Rosenburg et al., 2011; Shepard et al., 2001). For example, Fa *et al*. (2017) calculated the Hurst coefficient for cratered terrains and smooth plains on the Moon, Mars, and Mercury and found the Hurst coefficients ranging from 0.65-0.0.91. Using lake volume, a test was conducted to see if the Hurst coefficient for Minnesota's lake volumes would follow the same trend as the Cael *et al*. (2017) Hurst coefficient or the Fa *et al*. (2017) Hurst coefficient.

By using the Hurst coefficient, Cael *et al*. (2017) was able to provide thorough background as to why the relationship between volume area is sound and that predicting lake volume through the use of the regression analysis can significantly predict lake volumes. Furthermore, because of the rescaling and unnecessary need for geographic characteristics of the region where a lake is located, the volume of a lake can be calculated through this method across broad regions (Cael et al., 2017). All statistical analyses are conducted using the statistical software R (RStudio Team, 2016) and the "pracma" package was used to calculate the Hurst coefficient (Borchers, 2019)

Chapter IV: Results

4.1 Heathcote Method

Lake surface area (R^2=0.81, $F_{[1,814]}$ = 3426, $p < 2.2e-16$) and the elevation change of the surrounding terrestrial slope of a lake (R^2=0.013, $F_{[1,814]}$ = 11.06, $p < 0.001$) resulted in the best predictor of lake volume. These variables were further determined as the best predictors based on the Pearson partial correlation coefficient and AIC test (Table 3 and Table 4). Other variables such as mean elevation and maximum elevation that were available for all lakes but did not explain a significant amount of variation when predicting lake volumes, were removed from the model. Lake surface area and the elevation change both were explanatory variables for all lakes, however, surface area had a greater significance than elevation change as seen in the Pearson partial correlation coefficient (Table 3) and regression analysis.

All Lakes Pooled:

Our results supported our use of the terrestrial elevation change and surface area to predict the volume of a lake. When comparing the known and predicted lake volumes, the model explained 82% of the variation in lake volume (R^2 = 0.82, $F_{[1, 812]}$ = 3811, $P < 2.2e-16$) (Figure 3). The surface area and elevation change accounted for 82% and 2% of the variation within the model respectively. The RSE for the model was 0.282 $\log_{10}$ m^3. Furthermore, the predicted total volume with a bias correction compared to the known total volume was 6.4% different than the 16.8% difference with the predicted total volume without a biased correction (Table 5).

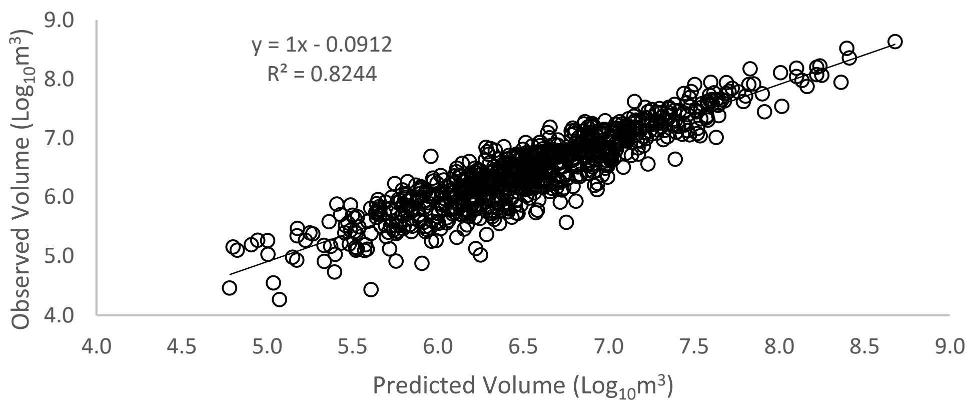

Figure 3. Heathcote method of observed versus predicted lake volumes for a linear regression model (R^2 = 0.82, $F_{[1, 812]}$ = 3811, P < 2.2e-16).

Table 5. Comparison of the percent difference when using and not using the Ferguson *et al*. (1983) method to the 816 observed lake volumes for the Heathcote *et al*. (2015) method.

Comparison	***Volumes (m^3)***	***Percent Difference***
Observed Volumes	8,042,130,358	-
Predicted without bias correction	6,884,440,469	16.8%
Predicted with bias correction	8,641,912,864	6.4 %

Lakes Separated by Size:

Splitting the lake regression analysis by surface area resulted in an 83% explanation of the variation in lake volume (R^2 = 0.83, $F_{[1, 812]}$ = 3835, P < 2.2e-16) (Figure 4). The RSE for the model was 0.281 $\log_{10} m^3$.

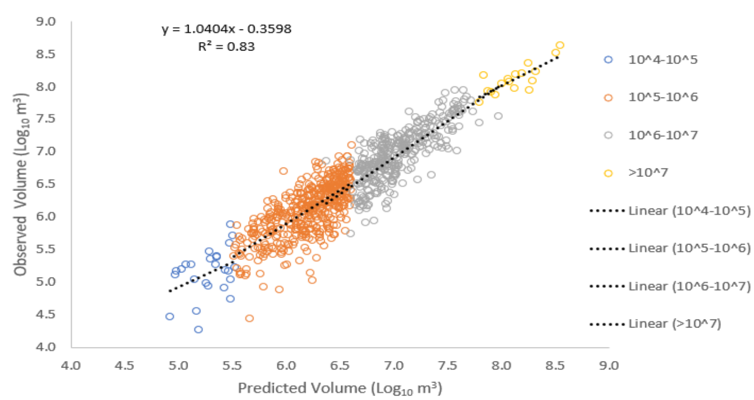

Figure 4. Comparing predicted volumes to known volumes separated by the size of the surface area of the lakes (R^2= 0.83, n=816, $F_{[1, 812]}$ = 3835, P < 2.2e-16).

Table 6. Total predicted volume by each ale size in project area. Regression analysis using surface area and elevation change in terrestrial buffer was conducted for each size.

Size	*Known Volume (m3)*	*Predicted Volume (m3)*	*Percent Difference*
10^4-10^5	4,761,038	4,272,646	10.3%
10^5-10^6	806,186,183	726,584,526	9.9%
10^6-10^7	4,538,884,627	4,478,136,636	1.3%
>10^7	2,692,298,510	2,677,799,591	0.5%
Total	8,042,130,358	7,886,793,399	1.9%

Lake Separated by Watershed:

Grouping the lakes by watershed resulted in the model explaining 84% of the variation in lake volume ($R^2 = 0.84$, $F_{[1, 814]} = 4342$, $P < 2.2e\text{-}16$) (Table 7). The RSE for the model was 0.269 $\log_{10}$ m^3.

Table 7. Total predicted volume by each watershed in project area. Regression analysis using surface area and elevation change in terrestrial buffer was conducted for each watershed (n= 816, $R^2 = 0.84$, F[1, 814] = 4342, P < 2.2e-16)

Watersheds	*Known Volume (m^3)*	*Predicted Volume (m^3)*	*Percent Differences*
Buffalo River	36,350,941	37,246,650	2.4%
Cannon River	220,456,231	242,749,474	9.6%
Crow Wing River	1,359,708,747	1,278,342,131	6.2%
Long Prairie River	952,569,927	837,593,468	12.8%
Lower St. Croix River	203,413,119	165,149,343	20.7%
Mississippi River-Brainerd	624,888,496	676,090,233	7.9%
Mississippi River-Lake Pepin	13,431,687	14,608,058	8.4%
Mississippi River-Sartell	121,815,236	127,774,030	4.8%
Mississippi River- St. Cloud	284,449,132	266,029,558	6.7%
Mississippi River-Twin Cities	332,693,906	317,921,490	4.5%
Ottertail River	2,509,976,730	2,597,468,051	3.4%
Pine River	902,738,899	822,873,334	9.3%
Redeye River	51,419,386	50,341,558	2.1%
Rum River	104,355,324	82,893,697	22.9%
Sauk River	147,591,348	157,164,850	6.3%
Snake River	61,919,196	55,757,269	10.5%
Wild Rice River	114,352,053	104,835,498	8.7%
Total	8,042,130,358	7,834,838,692	2.6%

Comparing the different groupings of lakes, the volumes of each grouping of lakes to the total of the 816 lake volumes were compared. Grouping the lakes by surface area size resulted in the closest prediction to the known total volume of lakes with a 1.9% difference (Table 6). Furthermore, by grouping the lakes by watershed gave a 2.6% difference to the observed volume (Table 7). Pooling all the lakes together with one regression analysis resulted in a difference of 7.5% to the observed volume (Table 8).

Table 8. 816 lakes with known volumes compared to predicted volumes of the same lakes. Predictions were calculated in three variations of the Heathcote *et al*. (2015) method (project area, size of the lake's surface area, and watersheds).

Distribution of Lakes	***Volumes (m^3)***	***Percent Difference***
Observed Lakes	8,042,130,358	-
Project Area	8,641,912,864	7.5%
Size	8,099,363,288	1.9%
Watershed	7,834,838,693	2.6%

Using the different groupings of lakes, the total volumes were calculated for the 40, 054 lakes within the region (Table 9). When comparing the three lake groupings, surface size grouping resulted in the highest lake volume with 1,236,436-hectare meters while the model with all the lakes pooled yielded the lowest lake volume with 1,179,284-hectare meters, a 4.7% difference.

Table 9. Comparison of total volume of the 40,054 lakes based on three approaches of the Heathcote *et* al. (2015) method (Mille Lacs Lake not included).

Distribution of Lakes	***Total Volume (hectare meters)***
Project Area	1,179,284
Size	1,236,436
Watershed	1,183,347

When comparing our analysis to research conducted within the same project area using the DNR data to determine lake volume (Nieber et al., 2019), there was a close similarity in the predictions of lake volumes based on watershed grouping (Figure 5) (R^2=0.96, $F_{[1, 15]}$ = 344.4, P < 9.304e-12). The closest prediction was that of the Rum River watershed with a difference of 3%. The difference for the study region between the total volumes sums was 11.5%.

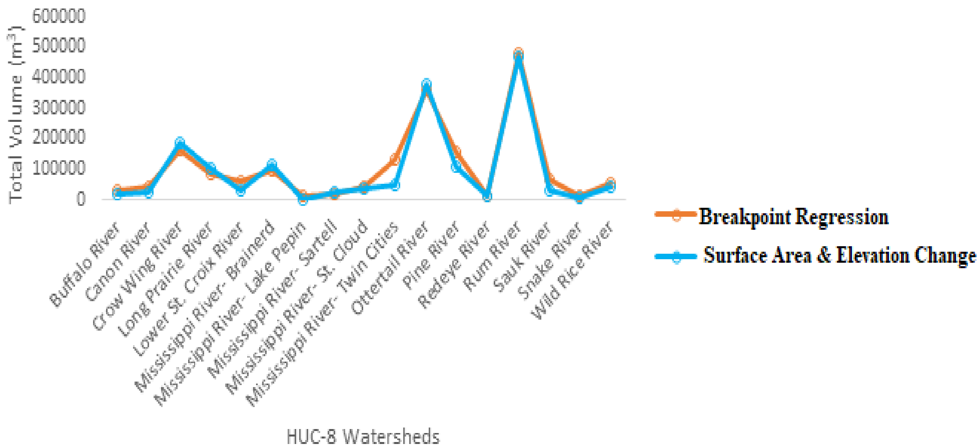

Figure 5. Comparing total lake volumes in 17 HUC-8 watersheds in central Minnesota from the volumes predicted using surface area and elevation change to the volumes estimated using breakpoint regression (Lake Mille Lacs included) (R^2= 0.96, $F_{[1, 15]}$ = 344.4, P < 9.304e-12).

4.2 Cael Method

The Cael *et al.* (2017) method was used to predicted lake volume within our study region of Central Minnesota. The method used surface area which is the most significant variable to determine lake volume as seen in the Pearson partial correlation coefficient (Table 3). Furthermore, to determine if the lakes within the project area were similar to that of the Cael *et al*. (2017) Hurst coefficient (0.4 +/- ~0.1), the Hurst coefficient based on the known volumes of the 816 lakes in the region was calculated,=. This resulted in a coefficient of 0.54.

When comparing the known and predicted lake volumes based on Equation 7, the model explained 82% of the variation in volume for individual lake volumes ($R^2 = 0.82$, $F_{[1, 812]} = 3697$, $P < 2.2e-16$) (Figure 6). Using Equation 7 derived from the Cael *et al*. (2017) paper, the total observed volume from the 816 lakes to the predicted volumes of the same lakes were compared. Our predictions were 1.4% different than that of the observed volume total (Table 10). The RSE for the model was 0.296 log_{10} m^3. After calculating the total volume with the 40,054 lakes by both methods, the difference between the Heathcote *et al*. (2015) and the Cael *et al*. (2017) methods for all the lakes pooled was 3% (Table 11). The project area volumes Hurst coefficient came to be 0.54 which is larger than that of Cael *et al.* (2017) Hurst coefficient.

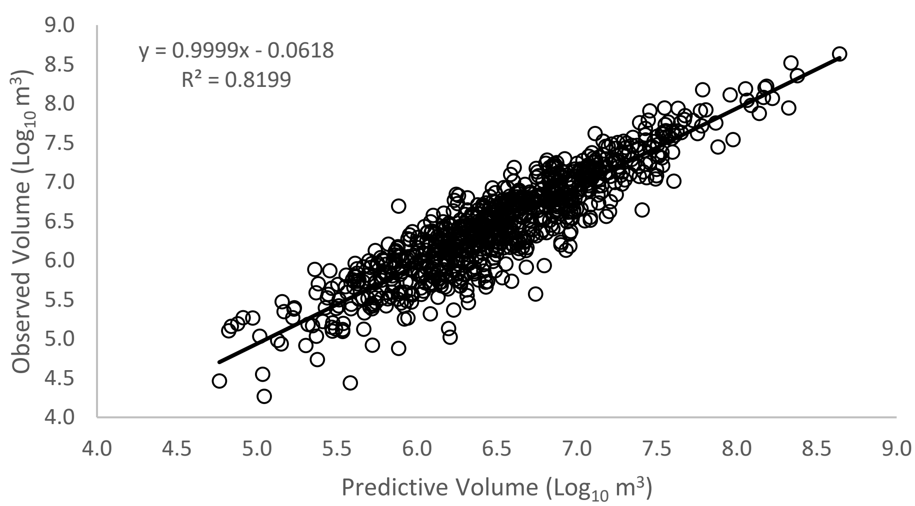

Figure 6. Cael method of observed versus predicted lake volumes for a linear regression model ($R^2 = 0.82$, $F_{[1, 812]} = 3697$, $P < 2.2e-16$).

Table 10. Using the Cael *et* al. (2017) method, percent difference between the 816 observed lake volumes and the predicted volumes of the same lakes within the 17 HUC-8 watersheds.

Comparison	***Total Volume (m^3)***	***Percent Difference***
Observed Volume	8,042,130,358	-
Predicted Volume	7,928,754,557	1.4%

Table 11. Heathcote *et* al. (2015) versus Cael *et* al. (2017) total volume comparison of 17 HUC-8 watersheds in central Minnesota for all lakes pooled.

Methods	***Total Volume (hectare meters)***
Heathcote All Pooled Lakes	1,179,284
Cael All Pooled Lakes	1,211,393

Chapter V: Discussion

5.1 Heathcote Method

While different models have been used to calculate lake and pond volumes, the model developed by Heathcote *et al*. (2015) can accurately predict the volumes of lakes even with limited geographic features and no bathymetric parameters. The ability to accurately predict lake volumes through the use of high-resolution topography data with known bathymetric data of the study area consisting of seventeen HUC-8 watersheds in Central Minnesota same region was achieved.

Based on the Pearson partial coefficient, the surface area of a lake explained a significant amount of variation to the volume. This was observed in the Heathcote *et al*. (2015) method when comparing the lake surface area to the volume. Even in different locations, surface area still plays a significant role in predicting lake volume. When comparing our research to the Heathcote *et al.* (2015) paper, Central Minnesota's surface area has a larger correlation to lake volume than that of buffer elevation as seen in the Pearson partial correlation coefficient (Table 3). This may be because of there being a smaller range of elevation within the project area, being a relatively flat region, resulting in the elevation difference in the buffer having a weaker relationship. The Heathcote *et al*. (2015) method compared 433 lakes selected from five different regions, two of which were situated in a mountainous region. When comparing the five regions, the mountainous region models for predicting volumes produced the most accurate lake volumes as well as the highest R^2 ($R^2 > 0.90$). The regions with less elevation change such as Eastmain region resulted in R^2 similar to the results reported herein for Central Minnesota's R^2 ($R^2 \approx 0.80$). This affirms the hypothesis that when the elevation has a larger range and the elevation change within the Pearson partial coefficient explains a significant amount of variation to the volume, the estimate of lake volume will have a better prediction (Heathcote et al., 2015).

All three groupings of lakes using the Heathcote *et al.* (2015) procedure showed a significant predication in determining lake volume. Determining lake volume by watershed resulted in the best prediction. A reason why the watershed grouping was the best prediction when compared to the known volumes is most likely due to the lakes within a given subregion (or watershed) are almost all formed by the same geomorphic process resulting in the lakes' formation being similar. Thus, the predictions were closer to the known volumes when looking at a specific subregion than an entire region. For example, this can be seen with the outliers removed from the final dataset. When conducting the initial regression analysis, three lake volumes were overpredicted by the model when compared to the known volume. Upon further analysis, it was determined that all three lakes were large in surface area but extremely shallow (all less than 1.5 meters across entire lake). When looking at the location of these lakes, all were located in the Crow Wing River watershed overlaying the ancient Glacial Lake Aitkin. These modern lakes formed over an ancient and larger lakebed that was formed in a broad lowland with low relief topography (Meyer & Boerboom, 2004). This means that they are formed on an ancient (larger) lakebed, and thus overlie flat-lying low-hydraulic-conductivity sediments. These flat sediments mean that the lake will be unlikely to be very deep, and the fact that they are fine-grained and have a low hydraulic conductivity means that they will be likely to pool water, even locally (A. Wickert, personal communication, May 23, 2019). These may be the reasons these lakes have shallow depths. Further research is needed to fully determine why these lakes have larger surface areas but shallow depths.

For future work, determining volume based on groupings of size and location might be a better basis to determine the prediction equations and ultimately lake volumes. Based on data available for future work, scientists can figure which grouping of lakes will provide the best prediction because all three predictive groupings (all lakes pooled, surface area size, and watersheds) provided significant results.

5.1.1 Model Limitations

Despite the fact there are highly accurate predictions for all three groupings only 816 lakes were surveyed with a total of over 40,000 lakes within the area. Having a small sample size could reduce the confidence level of the study while also increasing the margin of error. At this point in time though, the coefficients derived are the best ones with the limited data available. Furthermore, no lake smaller than 1000 m^2 surface area had been surveyed in the project area resulting in a lack of regression analysis occurring for the smallest of water bodies within the project area. Therefore, these volumes were calculated by each lake's known surface area and a best estimated depth based on prior research. Using a depth estimate yields a higher amount of error for the total water storage in all lake groupings. Similarly, when attempting to calculate large lakes such as the Great Lakes the lack of sample lakes to create a regression analysis is limiting. Thus, a large limiting factor on whether the Heathcote *et al*. (2015) can accurately estimate lake volumes falls on amount of sample data whether the lake is small or large.

In addition, using a 1/3 arc-second DEM resulted in no calculations for elevation data of lakes less than 10^4 m^2 due to the lakes being too small for the DEM to pick up the elevation difference. For further research, a better resolution will be used in order to more accurately predict volumes by obtaining the buffer elevations from the smaller lakes.

While this study is only limited to central Minnesota, in an independent study covering the full state calculation were completed to determine if the same approach can accurately predict lake volume across large distances and ecoregions. For example, using surface area and elevation change for lakes greater than 4,047 m^2 across the entire state of Minnesota, Griffin *et al*. (2019) used the Heathcote *et al.* (2015) method to estimate the surface colored dissolved organic matter (CDOM) and dissolved organic carbon (DOC) pools in lake water columns in order to explore the regional variability of DOM pools in the water column across heterogeneous lakes (Griffin et al., 2019). Based on preliminary research, the model explained 82% of the variation in lake volume with over 1,000 lakes of 4,047 m^2 or larger to compare to the prediction (Griffin et al., 2019).

This method could also be used to calculate the volume of wetlands within an area. Due to the large number of wetlands, satellite remote sensing is an advantage in determining the changing coverage of wetlands in seasons and annually (Lehner & Döll, 2004; Minke, Westbrook, & Van Der Kamp, 2010; Ozesmi & Bauer, 2002). Using surface area and elevation change within a buffer method, the variation in wetland volumes through the years in order to determine any change (Hayashi & Van Der Kamp, 2000). This in turn can help scientist understand the fluctuations of wetland volumes (Minke et al., 2010; Ozesmi & Bauer, 2002).

5.2 Cael Method

The method developed by Cael *et al*. (2017) can significantly predict total lake volume within Central Minnesota. A reason why this method might be able to accurately predict individual lake volumes is due to the low relief topography within the project area. Due to the surface area being the variable to explain the highest amount of significance of variation, the Cael *et al. (2015)* method can predict individual lake volume. While that is the case here in Minnesota, in other regions or on a global scale where elevation change plays a stronger role in the calculation of lake volume this method may not be able to significantly predict individual lake volume. This method may only be acceptable to calculate individual lakes with flat regions that have a minimal amount of elevation change. Calculating total volume can be achieved using this method on a global scale with many different types of regions and topographies.

In order to see whether, like the Heathcote *et al*. (2015) method, the Cael *et al*. (2017) method can have its lakes grouped by size and watershed, the lakes were grouped by the same categories. The significance of predicting total lake volumes when comparing to the total volume of known lakes within the region was decreased when splitting into the groups. Meaning that grouping the lakes by surface area size and watershed did not produce any significant results. Therefore, having a larger set of lakes when comprising the Cael *et al*. (2017) model improves the predictability of total lake volume. Even though, the Cael *et al.* (2017) method was unable to significantly predict total lake volume when grouped by surface area and watershed, both the Heathcote *et al*. (2015) and the Cael *et al.* (2017) method were both able to significantly predict volumes when pooling all lakes together.

The distribution of lake abundance at different size intervals creates issues when trying to find the patterns between all lakes. Due to there being asymmetry between size of a lake and the abundance of lakes, the Cael *et al*. (2017) paper proposed using a scaling process to better predict volumes at all different sizes for self-affine surfaces. When observing lakes of different sizes and regions, lake volumes can be determined by scaling down horizontally and vertically by a certain factor (coefficient *b*). This relationship between the change in the horizontal scale and the topographic variations is the Hurst coefficient. As the Hurst coefficient approaches 0.5, this indicates a random series where there is no correlation between the observations and the future observations (Qian & Rasheed, 2004). In regard to our Hurst coefficient being 0.54, future observations to the volumes of these lakes will be hard to predict. As the environment changes and some years are wetter or drier than others there will always be a fluctuation of water levels. This in turn hinders the ability for the Hurst coefficient to predict future trends.

5.2.1 Model Limitations

Nevertheless, the Cael *et al*. (2017) method's scaling is based off an area-volume relationship rather than specific data from the dataset resulting in it only being suitable for predicting the volume of a collection of lakes. This results in the method not being able to derive individual lake volumes due to the lack of specific lake bathymetric data. Thus, without a large dataset, the model will not be able to accurately predict a total volume of a collection of lakes.

The Cael *et al*. (2017) method allows for the ability to predict lake volume over a wide range of areas. Not only can scientists determine the total volume of storage but also see how water storage is correlated with lake size. This in turn can show that while small in total water storage, smaller lakes and ponds make up a large percentage of the total lake abundance. Smaller lakes are a crucial component to study in order to see the overall impact water has on the ecosystem and are key components to the biodiversity (Søndergaard et al., 2005).

By seeing the distribution of lakes and the water storage within each size, scientists can determine the total water storage within an area and better prepare best management practice for larger and smaller lakes by considering conservation and restoration practices for individual lakes as well as overall ecosystem.

However, while both methods provide a significant prediction the Cael *et al*. (2017) method is used to predict a group of lakes rather than individual lakes. Therefore, the Cael *et al*. (2017) method should only be used when looking at the total volume of a group of lakes and to see how the processes as a whole is affected by the total volume. The Heathcote *et al*. (2015) method is better at predicting individual lakes and therefore can be used when calculating individual lake processes. Consequently, one method may be more advantageous than the other depending on what future research questions are being asked.

Chapter VI: Summary and Conclusions

Overall, the Heathcote *et al.* (2015) and the Cael *et al.* (2017) methods provide accurate lake volume predictions using scaling analysis. The hypotheses were correct in stating that both methods would significantly predict lake volumes. The Heathcote *et al.* (2015) method demonstrated that pooling the lakes based on size or by watershed resulted in a better prediction of lake volumes than the project area as a whole. Furthermore, the Heathcote *et al*. (2015) method was more accurate in predicting lake volumes than the Cael *et al*. (2017) method.

As models continue to advance in predictability, the tools to solve, monitor, and predict future changes that may occur due to variations in the environment will advance as well. Not only can scientists begin to accurately predict lake volume but use the predictions in furthering the understanding of the processes within lakes. By significantly predicting individual lake volume, lake processes can now be calculated using these methods.

Using both these methods is a good technique for future research needing the volume of a lake when unknown and limited bathymetric data is given. By having a method that significantly predicts individual lake volumes, scientists can achieve a better understanding of how a lake affects the different biological, chemical and thermal processes occurring within it. This in turn can create better management protocols in protecting these critical human resources.

As the environment continues to change, it is now more important than ever to be able to better predict lake volumes. Volumes are a crucial component in understanding the dynamics of a freshwater ecosystem and by obtaining the volume of a lake, scientists can achieve better management techniques and solutions for the future.

In conclusion:

- The Heathcote et al. (2015) and the Cael et al. (2017) methods provide accurate lake volumes when limited bathymetric data is given
- The Cael *et al*. (2017) method can be used for a variety of lakes spanning across regions and different topographies but is more accurate for predictions of total lake volumes
- The Heathcote *et al*. (2015) method estimated a more accurate prediction of individual lake volumes than the Cael *et al*. (2017) method

Chapter VII: References

Abileah, R., & Vignudelli, S. (2011). A Completely Remote Sensing Approach To Monitoring Reservoirs Water Volume. *Fifteenth International Water Technology Conference*, (1), 59–72.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. https://doi.org/10.1109/TAC.1974.1100705

Borchers, H. W. (2019). *Package "pracma."* Retrieved from http://cran.r-project.org/web/packages/pracma.pdf

Boyd, C. E. (2004). Hydrology of Small Experimental Fish Ponds at Auburn, Alabama. *Transactions of the American Fisheries Society*, *111*(5), 638–644. https://doi.org/10.1577/1548-8659(1982)111<638:hosefp>2.0.co;2

Branstrator, D. K. (2009). Origins of Types of Lake Basins. *Encyclopedia of Inland Waters*, 613–624. https://doi.org/10.1016/b978-012370626-3.00023-5

Cael, B. B., Heathcote, A. J., & Seekell, D. A. (2017). The volume and mean depth of Earth's lakes. *Geophysical Research Letters*, *44*(1), 209–218. https://doi.org/10.1002/2016GL071378

Calmant, S., Seyler, F., & Cretaux, J. F. (2008). Monitoring continental surface waters by satellite altimetry. *Surveys in Geophysics*, *29*(4–5), 247–269. https://doi.org/10.1007/s10712-008-9051-1

Cannon, M. J., Percival, D. B., Caccia, D. C., Raymond, G. M., & Bassingthwaighte, J. B. (1997). Evaluating scaled windowed variance methods for estimating the Hurst coefficient of time series. *Physica A: Statistical Mechanics and Its Applications*, *241*(3–4), 606–626. https://doi.org/10.1016/S0378-4371(97)00252-5

Crétaux, J. F., Abarca-del-Río, R., Bergé-Nguyen, M., Arsen, A., Drolon, V., Clos, G., & Maisongrande, P. (2016). Lake Volume Monitoring from Space. *Surveys in Geophysics*, *37*(2), 269–305. https://doi.org/10.1007/s10712-016-9362-6

Department of Natural Resources Division of Fish and Wildlife. (2014). *DNR Hydrography - Lakes and Open Water*. Retrieved from http://www.mngeo.state.mn.us/committee/standards/mgmg/metadata.htm%0A

European Commisions Joint Research Centre. (2017). Global Surface Water Explorer dataset. Retrieved from https://data.europa.eu/euodp/en/data/dataset/jrc-gswe-global-surface-water-explorer-v1

Fa, C., & Fa, W. (2017). A Comparison of Topographic Roughness of the Moon, Mars, and Mercury. *Lunar and Planetary Science*.

Ferguson, R. I. (1986). River Loads Underestimated by Rating Curves. *Water Resources Research*, *22*(1), 74–76. https://doi.org/10.1029/WR022i001p00074

Fox, J., Weisberg, S., Adler, D., Bates, D., Baud-bovy, G., Ellison, S., … Venables, W. (2018). Package 'car': Companion to Applied Regression. *CRAN Repository*.

https://doi.org/10.1177/0049124105277200

Goodchild, M. F. (1988). Lakes on fractal surfaces: A null hypothesis for lake-rich landscapes. *Mathematical Geology*, *20*(6), 615–630. https://doi.org/10.1007/BF00890580

Griffin, C. G., Delaney, C., Holmberg, K., Olmanson, L. G., Brezonik, P. L., Nieber, J., & Finlay, J. C. (2019). An empirical estimate of dissolved organic matter stocks in northern temperate lakes. *Canadian Journal of Fisheries and Aquatic Sciences*.

Hayashi, M., & Van Der Kamp, G. (2000). Simple equations to represent the volume-area-depth relations of shallow wetlands in small topographic depressions. *Journal of Hydrology*, *237*(1–2), 74–85. https://doi.org/10.1016/S0022-1694(00)00300-0

Heathcote, A. J., del Giorgio, P. A., & Prairie, Y. T. (2015). Predicting bathymetric features of lakes from the topography of their surrounding landscape. *Canadian Journal of Fisheries and Aquatic Sciences*, *72*(5), 643–650. https://doi.org/10.1139/cjfas-2014-0392

Hollister, J., & Milstead, W. B. (2010). Using GIS to estimate lake volume from limited data. *Lake and Reservoir Management*, *26*(3), 194–199. https://doi.org/10.1080/07438141.2010.504321

Hollister, J. W., Milstead, W. B., & Urrutia, M. A. (2011). Predicting maximum lake depth from surrounding topography. *PLoS ONE*, *6*(9), 1–6. https://doi.org/10.1371/journal.pone.0025764

Kim, S. (2015). *Package "ppcor."* Retrieved from https://cran.r-project.org/web/packages/ppcor/ppcor.pdf

Lehner, B., & Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. *Journal of Hydrology*, *296*(1–4), 1–22. https://doi.org/10.1016/j.jhydrol.2004.03.028

Leschinski, C. H. (2019). *Package 'MonteCarlo.'* Retrieved from https://cran.r-project.org/web/packages/MonteCarlo/MonteCarlo.pdf

Lu, S., Ouyang, N., Wu, B., Wei, Y., & Tesemma, Z. (2013). Lake water volume calculation with time series remote-sensing images. *International Journal of Remote Sensing*, *34*(22), 7962–7973. https://doi.org/10.1080/01431161.2013.827814

Mandelbrot, B. B. (1975). Stochastic models for the Earth's relief, the shape and the fractal dimension of the coastlines, and the number-area rule for islands. *Proceedings of the National Academy of Sciences*, *72*(10), 3825–3828. https://doi.org/10.1073/pnas.72.10.3825

McDonald, C. P., Rover, J. A., Stets, E. G., & Striegl, R. G. (2012). The regional abundance and size distribution of lakes and reservoirs in the United States and implications for estimates of global lake extent. *Limnology and Oceanography*, *57*(2), 597–606. https://doi.org/10.4319/lo.2012.57.2.0597

Messager, M. L., Lehner, B., Grill, G., Nedeva, I., & Schmitt, O. (2016). Estimating the volume and age of water stored in global lakes using a geo-statistical approach. *Nature Communications*, *7*. https://doi.org/10.1038/ncomms13603

Meyer, G. N., & Boerboom, T. J. (2004). *Geologic atlas of Crow Wing County, Minnesota, C-16*, *Part A, Plate 6, Mineral Endowment*. Retrieved from https://reflections.mndigital.org/catalog/mgs:759

Minke, A. G., Westbrook, C. J., & Van Der Kamp, G. (2010). Simplified volume-area-depth method for estimating water storage of prairie potholes. *Wetlands*, *30*(3), 541–551. https://doi.org/10.1007/s13157-010-0044-8

Minnesota Department of Natural Resources. (2005). What is a Watershed? Retrieved from https://www.dnr.state.mn.us/whaf/key-concepts/ws_def.html

Minnesota Department of Natural Resources. (2017). *Lake Basin Morphology*. Retrieved from http://www.mngeo.state.mn.us/committee/standards/mgmg/metadata.htm%0A

Munshi, J. (2015). *THE HURST EXPONENT OF PRECIPITATION*. (November), 1–17.

Munshi, J. (2017). *THE HURST EXPONENT OF PRECIPITATION : ENGLAND AND WALES 1766-2016*. (March), 1–7.

Nieber, J. L., Delaney, C., Holmberg, H., Lahoud, F., Li, X., Trost, J., & Wilson, B. (2019). *Estimating total terrestrial water storage in Central Minnesota*.

Ozesmi, S. L., & Bauer, M. E. (2002). Satellite remote sensing of wetlands. *Wetlands Ecology and Management*, *10*(5), 381–402. https://doi.org/10.1023/A:1020908432489

Pekel, J., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. *Nature*, *540*(7633), 1–19. https://doi.org/10.1038/nature20584

Qian, B., & Rasheed, K. (2004). Hurst exponent and financial market predictability. *Proceedings of The 2nd IASTED International Conference on Financial Engineering and Applications*, 203–209. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.137.207&rep=rep1&type=pdf

Renard, F., Candela, T., & Bouchaud, E. (2013). Constant dimensionality of fault roughness from the scale of micro-fractures to the scale of continents. *Geophysical Research Letters*, *40*(1), 83–87. https://doi.org/10.1029/2012GL054143

Rosenburg, M. A., Aharonson, O., Head, J. W., Kreslavsky, M. A., Mazarico, E., Neumann, G. A., … Zuber, M. T. (2011). Global surface slopes and roughness of the Moon from the Lunar Orbiter Laser Altimeter. *Journal of Geophysical Research E: Planets*, *116*(2), 1–11. https://doi.org/10.1029/2010JE003716

RStudio Team. (2016). *RStudio: Integrated Development for R. RStudio, Inc.* Retrieved from http://www.rstudio.com/

Schwab, D. J., Leshkevich, G. A., & Muhr, G. C. (1992). Satellite Measurements of Surface Water Temperature in the Great Lakes: Great Lakes Coastwatch. *Journal of Great Lakes Research*, *18*(2), 247–258. https://doi.org/10.1016/S0380-1330(92)71292-1

Seaber, P.R., Kapinos, F.P., Knapp, G. L. (1987). Hydrologic units map. *U.S. Geological Survey Water-Supply Paper, 2294,* 63. Retrieved from http://pubs.usgs.gov/wsp/wsp2294/pdf/wsp_2294.pdf%0Ahttp://pubs.usgs.gov/wsp/wsp229

4/

Shapiro, J., & Wright, D. (1984). Lake restoration by biomanipulation : Round Lake , Minnesota , the first two years. *Freshwater Biology*, *14*, 371–383.

Shepard, M. K., Campbell, B. A., Bulmer, M. H., Farr, T. G., Gaddis, L. R., & Plaut, J. J. (2001). The roughness of natural terrain: A planetary and remote sensing perspective. *Journal of Geophysical Research E: Planets*, *106*(E12), 32777–32795. https://doi.org/10.1029/2000JE001429

Sobek, S., Nisell, J., & Folster, J. (2011). Predicting the volume and depth of lakes from map-derived parameters. *Inland Waters*, *1*, 177–184. https://doi.org/10.5268/IW-1.3.426

Søndergaard, M., Jeppesen, E., & Jensen, J. P. (2005). Pond or lake: does it make any difference? *Archiv Für Hydrobiologie*, *162*(2), 143–165. https://doi.org/10.1127/0003-9136/2005/0162-0143

U.S. Geological Survey. (2017). 1/3rd arc-second Digital Elevation Models (DEMs) - USGS National Map 3DEP Downloadable Data Collection: U.S. Geological Survey. Retrieved from https://viewer.nationalmap.gov/basic/#startUp

Chapter VIII: Appendices

Appendix A. Statistical Overview of Heathcote Method Groupings

	Number of Lakes	Average Volume (m^3)	Average Change in Relief (m)	Average Surface Area (m^2)	R^2	Standard Deviation	p-value
Project Area	816	9,855,552	6.5	1,900,871	0.82	0.28	< 2.2e-16
$10^4 – 10^5$	25	190,442	3.0	63,602	0.15	0.12	1.4e-12
$10^5 – 10^6$	438	1,840,608	6.2	502,066	0.49	0.18	< 2.2e-16
$10^6 – 10^7$	333	13,630,284	7.1	2,732,843	0.61	0.22	< 2.2e-16
> 10^7	20	134,614,926	9.0	20,978,959	0.64	0.17	4.5e-06
Buffalo River	19	1,913,207	7.4	835,064	0.51	0.22	5.8e-04
Cannon River	32	6,889,257	0.19	2,148,533	0.77	0.24	3.3e-11
Crow Wing River	112	12,140,257	7.5	2,205,157	0.75	0.37	< 2.2e-16
Long Prairie River	51	18,677,842	7.4	2,640,334	0.93	0.18	< 2.2e-16
Lower St. Croix River	46	4,422,024	7.3	1,251,052	0.76	0.31	2.7e-15
Mississippi River - Brainerd	60	10,414,808	6.9	1,944,915	0.84	0.18	< 2.2e-16
Mississippi River - Lake Pepin	5	2,686,337	0.20	2,273,945	0.87	0.25	0.02
Mississippi River - Sartell	35	3,480,435	6.1	742,758	0.76	0.27	1.3e-11
Mississippi River - St. Cloud	85	3,346,460	5.9	797,872	0.81	0.27	< 2.2e-16
Mississippi River - Twin Cities	110	3,024,490	5.8	832,856	0.84	0.26	< 2.2e-16

Otter Tail River	82	30,609,472	7.8	5,460,210	0.90	0.22	< 2.2e-16
Pine River	79	11,427,075	6.7	1,708,664	0.77	0.25	< 2.2e-16
Redeye River	8	6,427,423	5.1	1,268,347	0.86	0.20	8.8e-4
Rum River	25	4,174,213	5.4	1,203,361	0.82	0.26	4.1e-10
Sauk River	49	3,012,068	7.2	822,832	0.59	0.28	8.9e-1
Snake River	7	8,845,599	7.4	3,181,901	0.91	0.16	9.3e-4
Wild Rice River	11	10,395,641	8.2	2,569,959	0.91	0.14	6.1e-06

Appendix B. Heathcote *et* al. (2015) Method Individual Regression Equations

Project Area: $\log_{10} V = \log_{10}$ lake area · 1.17 + $\log_{10}$ elevation change_{25} · 0.07

Size:

$10^4 - 10^5$: $\log_{10} V = \log_{10}$ lake area · 0.78 + $\log_{10}$ elevation change_{25} · 0.08

$10^5 - 10^6$: $\log_{10} V = \log_{10}$ lake area · 1.12 + $\log_{10}$ elevation change_{25} · 0.05

$10^6 - 10^7$: $\log_{10} V = \log_{10}$ lake area · 1.26 + $\log_{10}$ elevation change_{25} · 0.08

$> 10^7$: $\log_{10} V = \log_{10}$ lake area · 0.94 + $\log_{10}$ elevation change_{25} · 0.75

Watershed:

Buffalo River: $\log_{10} V = \log_{10}$ lake area · 1.13 + $\log_{10}$ elevation change_{25} · 0.19

Cannon River: $\log_{10} V = \log_{10}$ lake area · 0.95 + $\log_{10}$ elevation change_{25} · -0.04

Crow Wing River: $\log_{10} V = \log_{10}$ lake area · 1.18 + $\log_{10}$ elevation change_{25} · 0.75

Long Prairie River: $\log_{10} V = \log_{10}$ lake area · 1.21 + $\log_{10}$ elevation change_{25} · 0.10

Lower St. Croix River: $\log_{10} V = \log_{10}$ lake area · 1.15 + $\log_{10}$ elevation change_{25} · 0.02

Mississippi River – Brainerd: $\log_{10} V = \log_{10}$ lake area · 0.91 + $\log_{10}$ elevation change_{25} · 0.41

Mississippi River - Lake Pepin: $\log_{10} V = \log_{10}$ lake area · 1.05 + $\log_{10}$ elevation change_{25} ·-0.04

Mississippi River – Sartell: $\log_{10} V = \log_{10}$ lake area · 1.22 + $\log_{10}$ elevation change_{25} · -0.17

Mississippi River - St. Cloud: $\log_{10} V = \log_{10}$ lake area · 1.07 + $\log_{10}$ elevation change25 · -0.08

Mississippi River - Twin Cities: $\log_{10} V = \log_{10}$ lake area · 1.04 + $\log_{10}$ elevation change_{25} · 0.58

Otter Tail River: $\log_{10} V = \log_{10}$ lake area · 1.12 + $\log_{10}$ elevation change_{25} · 0.25

Pine River: $\log_{10} V = \log_{10}$ lake area · 1.04 + $\log_{10}$ elevation change_{25} · 0.54

Redeye River: $\log_{10} V = \log_{10}$ lake area · 1.67 + $\log_{10}$ elevation change_{25} · 0.18

Rum River: $\log_{10} V = \log_{10}$ lake area · 1.35 + $\log_{10}$ elevation change_{25} · 0.78

Sauk River: $\log_{10} V = \log_{10}$ lake area · 0.92 + $\log_{10}$ elevation change_{25} · 0.30

Snake River: $\log_{10} V = \log_{10}$ lake area · 1.57 + $\log_{10}$ elevation change_{25} · -0.10

Wild Rice River: $\log_{10} V = \log_{10}$ lake area · 1.40 + $\log_{10}$ elevation change_{25} · -0.30

Appendix C. Morphological Traits for 816 Lakes

dowlknum	Watershed	Volume (m^3)	Surface Area (m^2)	Elevation Difference (m)	Area (acres)	Max Depth (m)	Average Depth (m)
01002700	Mississippi River- Brainerd	2314736.523	357635.1573	4.279483696	88.37357197	24.4	6.48125
01006500	Rum River	2435737.475	1008690.645	1.931180519	249.2528865	5.49	2.41865
01006900	Mississippi River- Brainerd	3440225.684	1507202.542	2.425540227	372.437859	5.4595	2.28445
01008700	Mississippi River- Brainerd	6200434.714	1683846.84	3.135703397	416.0876158	13.6335	3.68745
01008900	Mississippi River- Brainerd	17763588.6	1750608.567	5.344916457	432.5847978	35.685	10.2785
01009600	Mississippi River- Brainerd	13368302.3	2418633.832	2.039089356	597.6574358	14.5485	5.5327
01009900	Mississippi River- Brainerd	11036614.24	2903409.81	4.510611946	717.4481886	13.42	3.80335
01010500	Mississippi River- Brainerd	3194382.565	1272642.477	2.249836116	314.4768046	4.575	2.5193
01011500	Mississippi River- Brainerd	3563723.205	1758233.666	4.145869895	434.4690007	5.185	2.02825
01012300	Mississippi River- Brainerd	6473765.425	2096817.691	7.671655872	518.1349355	7.625	3.0927
01012500	Mississippi River- Brainerd	13047877.67	1753272.366	10.57510576	433.2430368	18.4525	7.45115
01012900	Mississippi River- Brainerd	5735372.211	1642288.47	5.784250429	405.8183189	11.285	3.4953
01013600	Mississippi River- Brainerd	12385168.79	2695561.614	5.280734606	666.0877809	11.2545	4.70615
01013700	Mississippi River- Brainerd	12738608.05	2564900.423	6.370932513	633.8006976	17.9645	4.9715
01014600	Mississippi River- Brainerd	10532525.81	2546468.734	8.188929971	629.246128	11.895	4.1419
01014700	Mississippi River- Brainerd	11818159.07	3387423.07	8.954289914	837.0504699	9.4245	3.53495
01015700	Mississippi River- Brainerd	16494966.3	2570083.362	5.964126861	635.0814295	23.79	6.42635
01015900	Mississippi River- Brainerd	42740616.46	8105671.445	5.178619156	2002.955034	15.6465	5.27955
01017800	Mississippi River- Brainerd	10669425.79	2118936.764	7.028496645	523.6006773	14.884	5.04165
01018300	Mississippi River- Brainerd	465950.8685	130112.7	0.672897196	32.15154836	11.529	3.5868
01018800	Mississippi River- Brainerd	2464081.623	1298231.65	4.246362842	320.8000272	5.185	1.90015
01020902	Mississippi River- Brainerd	369761.6589	105227.0656	3.833623693	26.00217419	7.93	3.52885
01020903	Mississippi River- Brainerd	4757904.898	809566.863	6.088195055	200.0483285	15.25	5.88345
02000400	Mississippi River- Twin Cities	4552900.774	2233037.141	3.49737273	551.7954946	4.8495	2.04655

02000500	Mississippi River- Twin Cities	1352565.219	1966886.469	1.804191915	486.0282313	1.4945	0.6893
02000600	Mississippi River- Twin Cities	6272237.814	1917638.014	4.192376451	473.8586731	5.795	3.2757
02000800	Mississippi River- Twin Cities	860514.1097	1502294.439	2.728841042	371.2250404	1.4335	0.5734
02000900	Mississippi River- Twin Cities	2065556.749	1361764.447	2.667836949	336.4993232	3.05	1.5189
02001300	Mississippi River- Twin Cities	459580.0574	734783.0451	1.800359712	181.5688447	1.2505	0.62525
02001500	Mississippi River- Twin Cities	545818.8172	1004707.976	0.968706097	248.2687477	3.6295	0.5429
02001600	Mississippi River- Twin Cities	1583315.382	1843722.397	3.296705572	455.5937262	1.6775	0.8601
02002200	Lower St. Croix River	382746.6045	294171.6708	3.855652822	72.69140292	5.917	1.30235
02002600	Lower St. Croix River	6506327.773	2315210.966	5.584052483	572.1010891	12.749	2.8304
02002800	Lower St. Croix River	209389.3794	369829.8992	4.072914563	91.38695832	5.7645	0.5673
02003400	Lower St. Croix River	2708879.226	940135.8755	4.996495271	232.3126341	5.185	2.6535
02003500	Lower St. Croix River	480129.8477	233866.4909	4.800413068	57.78966845	7.015	2.0557
02004200	Mississippi River- Twin Cities	12036817.61	5994375.773	4.001043747	1481.242512	8.235	2.00995
02004500	Mississippi River- Twin Cities	510056.3619	235100.8935	5.715569447	58.09469596	7.2895	2.22345
02005200	Mississippi River- Twin Cities	639649.4765	482906.979	2.114587566	119.3289133	5.795	1.32675
02005300	Mississippi River- Twin Cities	1523543.49	625763.3921	1.464084216	154.6295017	6.71	1.83
02005900	Rum River	538738.2421	746851.5791	3.315684205	184.5510443	2.8975	0.72285
02006500	Rum River	376088.5484	1352835.78	2.540572193	334.2930015	3.05	0.27145
02007000	Rum River	330519.1526	203248.3466	3.481508516	50.22376022	2.44	1.6287
02007200	Mississippi River- Twin Cities	263534.6657	267606.3841	2.104097883	66.12697763	1.525	0.98515
02007501	Mississippi River- Twin Cities	161735.6603	111338.5266	1.878874583	27.51234909	6.1	1.44875

02008400	Mississippi River- Twin Cities	1253643.503	465106.8614	3.840640944	114.9304084	7.93	2.69925
02009100	Rum River	5069148.553	1973694.616	3.476084092	487.7105609	9.7295	2.5742
02010600	Rum River	325111.6169	219262.2454	4.731779958	54.1808808	5.185	1.63785
02012200	Rum River	685874.5833	384179.4223	3.86399272	94.9328027	5.49	1.7873
02076400	Mississippi River- Twin Cities	246334.3219	116409.6966	3.573953235	28.76546248	6.649	1.6714
03000500	Crow Wing River	1449871.968	246395.6488	3.482503888	60.8856908	16.7445	5.8926
03000600	Crow Wing River	187842.948	67970.98264	1.473462002	16.79599559	6.405	2.76635
03000700	Crow Wing River	1786733.886	354781.9795	4.804210134	87.66853638	14.3045	5.04165
03001000	Crow Wing River	13332791.91	1907859.846	12.66281899	471.442435	19.215	6.9967
03001700	Crow Wing River	14728454.91	2339020.299	6.378672769	577.9845031	18.3	6.29825
03002900	Crow Wing River	358581.7439	581122.1521	8.325954038	143.5984111	6.405	0.61915
03003000	Crow Wing River	19097149.97	1558447.682	9.198208589	385.1008088	33.184	12.27015
03004400	Crow Wing River	1173143.644	239585.7603	5.7726	59.20293068	9.76	4.90135
03008200	Crow Wing River	135859.3006	462070.8787	3.866264021	114.1802007	0.61	0.29585
03008800	Crow Wing River	2673789.264	826216.6104	2.555735794	204.1625707	7.625	3.36415
03009200	Crow Wing River	1019402.366	457917.8249	2.832797772	113.1539588	4.575	2.22955
03009600	Crow Wing River	343167.2999	2397554.785	4.756807754	592.4486898	1.952	0.14335
03010100	Otter Tail River	10983966.56	5907764.063	9.051393616	1459.840292	4.2395	1.8605
03010200	Crow Wing River	28083610.28	12736754.33	6.187781671	3147.320536	4.88	2.2082
03010700	Otter Tail River	38008216.71	6945109.857	7.003499476	1716.174021	8.845	5.52965
03012000	Crow Wing River	568615.1181	670001.1913	3.926773455	165.5609	2.6535	0.85095
03012700	Crow Wing River	2053910.422	525311.1136	7.375396884	129.8072031	14.518	3.9162
03013600	Crow Wing River	9135744.249	1734061.976	14.90177148	428.4960462	21.35	5.8194
03015300	Crow Wing River	27073061.57	4773203.511	13.72688148	1179.484274	11.5595	5.6791
03015500	Otter Tail River	29499657.46	4427993.508	7.545592318	1094.181025	20.801	6.67035
03015600	Otter Tail River	12026890.39	1397479.039	7.03721179	345.3245911	21.35	8.61625
03015800	Otter Tail River	58358252.09	6883343.621	10.37576445	1700.911251	28.0295	8.48815

03015900	Otter Tail River	33263766.48	3986305.862	15.28753134	985.0376308	21.35	8.35395
03016600	Otter Tail River	2723279.653	974581.3752	3.972976744	240.8243025	14.518	2.79685
03017700	Otter Tail River	570651.9257	141756.1025	6.490902849	35.02869578	8.8755	4.0321
03018900	Otter Tail River	11301101.94	1637443.783	6.899273168	404.6211707	19.825	6.9113
03019500	Otter Tail River	34872938.36	15335624.58	8.190171601	3789.515361	6.3745	2.27835
03021300	Otter Tail River	2450084.16	937970.3543	4.422636358	231.7775222	4.575	2.6169
03023400	Otter Tail River	9317665.762	1185238.53	4.641665975	292.878819	15.25	7.87205
03025800	Otter Tail River	3560059.26	622092.9671	9.279227172	153.7225199	16.7445	5.73095
03026500	Otter Tail River	6199450.44	1294312.06	9.477477829	319.8314753	8.906	4.9105
03027300	Otter Tail River	928330.4751	192827.4409	10.05341713	47.64869835	11.285	4.819
03028600	Otter Tail River	35873415.52	7215971.892	10.51653049	1783.105487	8.54	4.9776
03028700	Otter Tail River	8293802.071	1459436.049	12.2916126	360.6345017	22.509	5.8133
03029100	Buffalo River	2184604.775	936557.6906	4.095473325	231.4284454	7.015	2.3363
03029300	Otter Tail River	11785800.54	4838058.224	8.174612297	1195.510223	5.49	2.44
03030400	Wild Rice River	5732387.014	2110493.872	9.472325571	521.5143932	12.5355	3.35195
03031300	Buffalo River	3406745.68	892440.6374	7.531505302	220.5268841	8.7535	3.94975
03032300	Wild Rice River	38597394.95	6061170.8	8.422452324	1497.747923	11.285	6.50565
03035000	Otter Tail River	7290300.429	1689846.373	10.0105535	417.5701325	10.675	4.37675
03035100	Buffalo River	1347010.976	829536.551	3.074468085	204.9829459	3.66	1.62565
03035200	Buffalo River	1909460.43	942398.1729	8.023419832	232.87166	8.5095	1.99775
03035700	Otter Tail River	2203791.552	541620.6271	9.350022075	133.8373717	7.93	4.0748
03035800	Otter Tail River	1538164.798	580072.9929	5.111662727	143.3391582	7.259	2.6535
03035900	Otter Tail River	25142007.33	5151261.37	8.233554267	1272.904406	15.067	4.8861
03036000	Otter Tail River	395204.5475	271644.7658	5.724078701	67.12488348	5.49	1.4579
03037100	Otter Tail River	2116704.5	286195.5367	2.876579203	70.72045727	21.96	7.4054
03037401	Otter Tail River	2527020.087	742032.4364	3.835815911	183.3602083	9.0585	3.4099
03037402	Otter Tail River	1229681.837	456573.6749	1.862806617	112.8218121	13.115	2.6962
03037700	Otter Tail River	761080.4466	625258.6224	6.694792854	154.5047704	3.05	1.2139

03038100	Otter Tail River	56842616.27	12412220.97	6.292004221	3067.126597	25.01	4.58415
03038300	Otter Tail River	9002553.186	1654064.024	6.99804878	408.7281216	18.605	5.45035
03038600	Otter Tail River	3521787.557	867161.5081	3.149870075	214.2802753	9.3635	4.06565
03038700	Otter Tail River	15860355.7	4766577.713	5.192406843	1177.847004	10.37	3.3306
03042800	Buffalo River	743921.0529	488851.6921	4.801143402	120.7978838	3.05	1.525
03043000	Buffalo River	640485.1472	449666.8685	4.309041835	111.1151031	5.795	1.4274
03047100	Wild Rice River	1628172.58	1003600.476	8.145193675	247.9950785	3.05	1.62565
03047500	Otter Tail River	39172211.73	7487372.942	7.607832453	1850.170147	13.115	5.23685
03048400	Otter Tail River	633876.1916	337383.4005	4.893797089	83.36925389	7.2895	1.88185
03048600	Otter Tail River	3606003.772	1131482.782	6.933841203	279.5954845	16.4395	3.24825
03050000	Otter Tail River	8459950.324	2092284.989	5.968776778	517.0148803	9.15	4.0931
03050300	Otter Tail River	6088058.102	1531542.732	5.560866091	378.452451	9.15	4.07175
03050600	Otter Tail River	12693291.91	4318971.75	17.74981191	1067.241162	10.37	2.94325
03057500	Otter Tail River	6068763.134	2106794.547	9.193633212	520.6002702	7.93	2.8853
03057600	Otter Tail River	128951977.6	14799913.3	11.50543206	3657.138222	22.7835	8.723
03057900	Buffalo River	4445841.846	1771083.229	8.733999884	437.6441968	7.93	2.77245
03058800	Otter Tail River	13529634.96	3941663.915	8.097439127	974.0063654	8.845	3.57155
03060200	Otter Tail River	10259626.39	1479317.312	5.927710843	365.5472687	10.675	3.79725
03063100	Buffalo River	4151470.877	2011285.349	8.878795798	496.9994334	4.575	2.0679
03063500	Otter Tail River	578819.1925	503581.4112	7.923375939	124.4376767	2.44	1.19255
03063800	Otter Tail River	2658340.209	848803.3457	7.743354238	209.7438745	8.235	3.1354
03064500	Buffalo River	676684.3281	521033.9287	4.865418245	128.7502877	3.66	1.2993
03064600	Buffalo River	653326.2156	449752.5627	5.922866385	111.1362786	2.44	1.4213
03064700	Buffalo River	1723236.836	1183988.778	3.425182301	292.5699988	2.44	1.4579
03064800	Buffalo River	2403036.174	927206.7781	6.499806534	229.1177846	5.795	3.1781
05000700	Mississippi River- St. Cloud	2040489.826	517929.0893	7.102411308	127.9830652	6.1	3.965
05001300	Mississippi River- Sartell	11428060.83	5303838.17	7.446816955	1310.606954	5.7645	2.15635
10001800	Mississippi River- Twin Cities	2637233.475	430456.2281	9.143626764	106.3680505	15.128	6.13355

10004401	Mississippi River- Twin Cities	4429621.078	583248.5375	6.602436207	144.1238524	25.925	7.59145
10004402	Mississippi River- Twin Cities	1605794.581	592590.4224	4.770326764	146.4322824	10.2785	2.7145
10004500	Mississippi River- Twin Cities	2649212.667	671288.6716	6.713514925	165.8790433	11.224	3.9528
10004800	Mississippi River- Twin Cities	2011115.615	686666.3077	4.455214043	169.6789399	12.4745	3.02865
10005300	Mississippi River- Twin Cities	6497604.496	1080152.423	7.965222275	266.9114766	12.2	5.41985
11000600	Pine River	2735345.811	665212.4112	1.552494977	164.3775666	15.4025	4.1175
11003700	Pine River	4285518.695	491806.5385	9.02262469	121.5280423	18.3	8.72605
11005300	Pine River	5253191.66	910166.7949	6.222160489	224.907113	21.655	5.77975
11005400	Pine River	441843.7965	110126.9006	7.062032556	27.21294979	7.625	4.10225
11005900	Pine River	42112741.99	6435312.47	8.724568558	1590.200343	31.9945	6.5514
11010100	Pine River	3216375.995	2478520.273	6.241367255	612.4556975	4.575	1.2993
11010200	Pine River	7943838.668	1450005.783	4.308563183	358.3042321	13.725	5.4839
11011400	Pine River	937546.2286	455930.1194	2.656745226	112.6627861	6.1	2.05875
11011600	Pine River	1850010.96	405106.0998	3.262398757	100.1038973	18.2085	4.57195
11011700	Pine River	854174.3437	439818.7662	2.326462021	108.681584	3.05	1.9459
11019900	Pine River	6913153.8	1471841.846	4.743314743	363.7000408	17.019	4.7031
11021600	Crow Wing River	721134.2891	637028.5422	4.864137931	157.4131809	3.6295	1.1346
11021800	Crow Wing River	11275174.7	1707098.085	7.784045877	421.8331235	16.47	6.6124
11022200	Crow Wing River	3223468.909	1002752.92	7.758161667	247.7856428	7.93	3.27875
11022600	Crow Wing River	902956.3555	937871.4785	5.839877036	231.7530895	7.564	0.9638
11023200	Pine River	9376998.269	2378822.785	5.787224711	587.8199117	9.15	4.3798
11023700	Pine River	6717732.14	522142.3204	9.241989427	129.0241773	32.025	12.8832
11024200	Pine River	5927597.074	1170390.738	3.827995607	289.2098497	17.324	5.124
11024600	Pine River	1388800.285	456697.5026	7.010103229	112.8524106	7.93	3.0439
11025000	Pine River	23561315.95	3898402.937	6.598268741	963.3163448	18.3	6.4477
11030400	Crow Wing River	19468579.97	3617994.679	13.55758865	894.0259552	17.385	5.38935

11030700	Pine River	3487435.744	2083687.123	4.009098294	514.8903014	3.965	1.67445
11030801	Pine River	5422934.296	2938651.514	7.050902428	726.1566033	5.7645	1.8483
11030802	Pine River	737444.6828	713004.2684	5.877969259	176.1871917	3.66	1.037
11032000	Crow Wing River	4999317.313	829661.6195	12.85699608	205.013851	11.895	6.0451
11032400	Crow Wing River	1922092.305	1056255.466	3.626792137	261.0064097	5.185	1.82085
11035000	Pine River	3585467.198	737219.6948	5.745373691	182.1709541	7.625	4.87085
11035100	Pine River	5047938.807	1014359.12	7.216958414	250.6535972	11.285	5.1972
11035300	Pine River	1833583.432	532979.5109	1.873538287	131.7021054	9.76	3.44345
11035500	Pine River	3577242.001	755674.9771	7.097035678	186.7313535	12.81	4.7397
11035800	Pine River	6493495.138	1053480.39	6.023049935	260.3206735	15.555	6.37755
11036000	Pine River	750410.1863	408993.4332	3.195526286	101.0644783	4.27	1.8361
11036100	Pine River	5783492.682	891551.5135	6.734642835	220.3071768	14.5485	6.4965
11036700	Pine River	5143140.743	1780463.595	4.142027722	439.9621359	8.235	2.8914
11041100	Pine River	41351362.67	6525299.571	7.52966035	1612.43664	23.7595	6.34705
11045400	Pine River	3250493.314	576643.7562	11.77212493	142.4917753	14.64	5.6425
11046300	Pine River	2678975.946	646318.4875	4.849581604	159.7087764	8.845	4.15105
11050000	Crow Wing River	918082.1395	586421.5089	5.707978212	144.9079107	5.185	1.5677
13001201	Lower St. Croix River	6802409.363	1974588.124	9.428021343	487.9313516	8.235	3.63255
13001202	Lower St. Croix River	1720759.879	1845501.143	6.142092541	456.033264	2.44	0.97295
13001300	Lower St. Croix River	1851495.295	781794.752	8.19337898	193.1856904	9.15	2.5254
13001900	Lower St. Croix River	548957.1174	528867.9183	6.442205993	130.6861087	2.44	1.04005
13002700	Lower St. Croix River	17131159.81	3380455.008	9.035973274	835.3286242	32.1165	5.0996
13002800	Lower St. Croix River	10463915.6	1840021.648	7.166268529	454.6792511	10.3395	4.7214
13002900	Lower St. Croix River	655888.0448	566423.999	8.675788727	139.9664183	2.135	1.159
13003100	Lower St. Croix River	3654888.457	3220040.541	9.660249378	795.6893462	6.405	1.13155
13003201	Lower St. Croix River	7426528.167	3032148.424	11.19236293	749.2601929	12.2	2.4522
13003300	Lower St. Croix River	1791387.17	680677.5135	4.444781261	168.1990766	7.015	2.96155
13003500	Lower St. Croix River	2792142.326	574054.8347	9.433447099	141.8520389	8.845	4.8556

13004101	Lower St. Croix River	2015980.979	912456.319	9.059103105	225.4728668	4.27	2.21125
13004102	Lower St. Croix River	20386983.97	6410312.178	10.81989974	1584.022636	8.845	3.172
13005300	Lower St. Croix River	5142167.421	881496.8104	5.562357454	217.8226056	14.3045	5.84075
13005400	Lower St. Croix River	782838.3639	149852.135	2.590409956	37.02926898	16.47	5.3131
13006800	Lower St. Croix River	6334725.289	1290224.998	5.054350257	318.8215402	14.823	4.9898
13006901	Lower St. Croix River	14616826.36	5991503.002	4.445261183	1480.532635	7.198	2.44305
13006902	Lower St. Croix River	23935209.78	6388597.052	9.437469846	1578.656712	12.2	3.7515
13007300	Lower St. Croix River	3535278.082	906649.4791	3.279801325	224.0379654	16.043	3.96195
13007400	Lower St. Croix River	540992.705	190249.2909	2.999738014	47.01162359	6.1	2.85785
13007900	Lower St. Croix River	705808.7637	212706.0893	3.267755682	52.56081934	12.932	3.3855
13008301	Lower St. Croix River	1675868.523	1100763.356	3.52603128	272.0045489	2.745	1.525
13008302	Lower St. Croix River	10248750.22	1810666.068	3.817613581	447.4253295	16.7445	5.6669
14002100	Buffalo River	972524.9437	800518.2905	13.99225119	197.8123775	5.185	1.7385
14003000	Buffalo River	1678667.902	538503.7013	9.294076752	133.0671625	6.1	3.12015
14004900	Buffalo River	2132440.318	639208.4627	15.34620649	157.951851	10.98	4.1663
14010000	Buffalo River	2977906.299	465209.3761	5.926433505	114.9557403	11.59	6.7588
15006800	Crow Wing River	5897078.015	2028283.766	10.8538489	501.1998338	16.165	2.9097
15007900	Wild Rice River	2565976.508	930875.8787	4.086456645	230.0244391	4.88	2.76025
18001800	Rum River	9745511.303	2160374.717	7.435727411	533.8402186	12.81	4.51705
18002000	Rum River	27608122.36	4095252.399	7.463470524	1011.958906	25.62	6.6978
18002800	Rum River	12246000.39	1986064.846	5.914183451	490.7673113	16.47	6.1732
18003400	Mississippi River- Brainerd	61159850.24	9388249.99	6.520382557	2319.887095	21.35	6.52395
18003800	Mississippi River- Brainerd	27101220.09	3642974.4	13.67608862	900.1985787	16.47	7.39015
18004101	Mississippi River- Brainerd	1737790.14	424480.7658	4.442764579	104.8914816	10.675	4.4835
18004102	Mississippi River- Brainerd	7643078.069	1582490.029	8.974363511	391.0418022	21.899	5.2765
18004400	Mississippi River- Brainerd	4452995.095	666595.0683	3.910851522	164.7192286	13.6945	6.71
18005000	Mississippi River- Brainerd	6293893.341	1160782.966	3.851028807	286.8357177	11.285	5.4534
18009000	Mississippi River- Brainerd	37245221.91	4463943.722	6.969920912	1103.064516	18.91	8.35395

18009301	Mississippi River- Brainerd	23713768.19	2697919.315	12.74742903	666.6703816	102.358	8.79925
18009302	Mississippi River- Brainerd	13590600.95	2164047.516	11.99718895	534.747787	15.25	6.2891
18009600	Mississippi River- Brainerd	19877727.79	3218819.222	10.401229	795.3875518	14.335	6.18235
18010400	Mississippi River- Brainerd	15295652.32	2820296.995	7.814610511	696.9105648	12.81	5.42595
18013600	Mississippi River- Brainerd	34446467.26	5240263.953	10.94662644	1294.897423	14.335	6.57885
18014500	Mississippi River- Brainerd	5531107.905	1617110.133	10.80446377	399.5966156	7.015	4.19375
18015500	Mississippi River- Brainerd	5828195.447	1531519.363	1.289394603	378.4466765	7.93	3.86435
18016500	Mississippi River- Brainerd	6887492.067	1990085.595	7.764449573	491.7608602	9.4245	3.46785
18018000	Pine River	1980169.593	1220646.215	2.571530394	301.6282485	3.233	1.62565
18018300	Pine River	3662843.502	969348.477	11.8091738	239.5312252	11.285	3.782
18018400	Mississippi River- Brainerd	6042895.123	971207.5644	8.229764317	239.9906157	19.4895	6.35925
18018500	Pine River	8268736.705	1669912.402	8.144561034	412.6443411	10.37	5.12705
18018600	Mississippi River- Brainerd	1634500.375	664486.879	6.405508911	164.1982837	6.71	2.46135
18019500	Pine River	1246970.873	1099340.118	3.505066778	271.6528592	4.8495	1.1346
18020300	Pine River	6883320.902	2916683.036	7.345991956	720.7280742	3.965	2.36375
18020500	Pine River	1215363.48	471558.8168	5.175018951	116.5247213	7.625	2.5803
18020800	Pine River	911697.8859	179881.9142	8.844709898	44.44978902	12.749	5.01725
18021100	Pine River	4898591.217	717589.7676	8.032276533	177.3202933	14.64	6.83505
18021200	Pine River	13760828.56	2424866.049	8.189003901	599.1974501	11.7425	5.68215
18021300	Pine River	1380031.841	453910.9937	7.410223525	112.1638492	7.625	3.0439
18021800	Pine River	1547267.295	474139.5366	8.634982639	117.1624311	6.71	3.3428
18022400	Mississippi River- Brainerd	2606034.819	982806.4703	9.416751012	242.8567678	5.185	2.65655
18022500	Pine River	5272018.32	1254778.757	4.166766441	310.0625835	8.235	4.20595
18022600	Pine River	5623959.469	1546492.63	5.198677478	382.1466513	10.614	3.6417
18022701	Pine River	1063444.269	440200.9866	6.098320361	108.7760327	7.93	2.64435
18022702	Pine River	2272826.855	355418.6507	4.892441453	87.82586127	14.9145	6.527
18023100	Pine River	1378163.192	783860.9217	8.926838152	193.6962521	6.1	1.75985
18024200	Mississippi River- Brainerd	17530981.13	3538758.203	8.489098511	874.4461956	10.98	4.9593

18024300	Mississippi River- Brainerd	8960717.381	2932591.656	5.603185897	724.6591798	8.235	3.05915
18025100	Mississippi River- Brainerd	13765693.84	3731340.371	5.287162478	922.0342858	16.7445	3.69355
18026100	Pine River	2149526.981	1309470.185	6.250269978	323.5771297	5.1545	1.24745
18026600	Pine River	5471623.54	1334904.675	4.309063587	329.8621289	9.15	3.843
18026800	Pine River	609600.6214	200442.7263	7.590301831	49.53047633	9.15	3.0073
18026900	Pine River	4498826.605	940485.9312	9.100743608	232.3991348	21.35	6.0756
18027000	Pine River	2622711.782	520104.5464	6.5912388	128.5206323	15.86	5.5998
18027100	Pine River	3104781.68	1045200.33	5.092283126	258.2746263	7.625	3.3245
18027800	Pine River	771176.5565	89248.53659	7.045066991	22.05379368	20.801	8.6681
18028400	Pine River	2736915.329	675287.1744	4.676388661	166.8670948	8.845	4.13885
18028700	Pine River	3342292.402	1434130.674	5.061983033	354.3814073	10.98	2.33325
18028800	Pine River	4848475.058	974565.5904	8.161288895	240.820402	21.35	4.9532
18029300	Pine River	3989033.518	1198412.451	9.265991733	296.1341659	6.1	3.3428
18029400	Pine River	16036764.88	1736301.9	8.232789584	429.0495433	23.729	9.31775
18029600	Pine River	6845708.023	1415530.55	11.07746096	349.7852165	10.675	4.82815
18029700	Pine River	12695604.65	1818737.106	11.25958125	449.4197264	16.775	7.09735
18029800	Pine River	5513945.964	974799.903	5.285524365	240.8783019	19.825	5.73095
18030200	Pine River	1337224.865	188139.0562	9.476896887	46.49017326	18.3	7.4847
18030500	Crow Wing River	52049064.21	10419952.83	4.40298757	2574.826419	22.753	4.99895
18030800	Crow Wing River	227790256.3	33861612.95	6.680764507	8367.386786	31.72	6.7344
18031000	Pine River	331651940.8	31226616.86	16.1609918	7716.265072	41.602	10.6384
18031100	Pine River	19325984.87	3471505.682	5.023877683	857.8277357	30.5	6.54225
18031400	Pine River	925891.5811	598426.4318	7.36457346	147.8743917	3.965	1.5494
18031500	Pine River	80779846.53	5516056.112	10.28872108	1363.04715	36.6	14.66135
18033800	Crow Wing River	6208103.731	1768681.727	4.725094836	437.0507727	10.98	3.5136
18034000	Crow Wing River	2079688.807	784839.8527	4.547295724	193.9381512	12.2915	2.6535
18034200	Crow Wing River	3056848.244	857427.4907	4.296746653	211.8749472	15.982	3.5685
18035100	Pine River	2807592.711	1098234.456	4.894076797	271.3796442	10.187	2.55895

18035200	Pine River	17835271.62	2795362.096	7.86780092	690.7490171	19.1845	6.40195
18035400	Pine River	5409602.732	732440.8166	4.923546817	180.9900674	17.08	7.3505
18035500	Pine River	11466680.6	1363252.081	6.25893261	336.8669256	21.35	8.45765
18035600	Pine River	1996311.347	854142.1908	5.817430293	211.0631319	12.2	2.41865
18035800	Pine River	2192499.512	489688.9021	5.911720448	121.004763	14.335	4.4835
18035900	Pine River	5330889.565	515869.3541	7.532532118	127.4740935	25.315	10.3456
18036100	Pine River	6551625.177	768007.567	7.932375613	189.7788028	23.485	8.8694
18036400	Pine River	8528787.754	914242.8478	12.60285926	225.9143277	19.215	9.5038
18036600	Pine River	1338759.97	1199384.75	8.406976744	296.3744261	3.05	1.1163
18037100	Mississippi River- Brainerd	5019654.287	1076093.599	4.783431316	265.9085192	12.81	4.52315
18037200	Crow Wing River	117288309.9	24864167.61	5.79558137	6144.069622	27.45	4.72445
18037300	Crow Wing River	37647092.58	6677776.767	5.000917091	1650.114575	15.555	5.64555
18037400	Crow Wing River	3267810.226	1235970.064	5.763577887	305.4148542	9.455	2.6474
18037500	Crow Wing River	40060387.56	5211319.172	5.601669582	1287.745012	24.7355	7.6982
18037600	Crow Wing River	7169780.86	1758599.724	7.069294178	434.5594556	12.2	4.0809
18037700	Crow Wing River	9787426.15	1605202.792	8.516666667	396.6542483	14.03	6.1061
18037800	Pine River	41784265.39	2804899.317	7.17264402	693.1057156	30.5	14.9206
18037900	Crow Wing River	5008390.264	1672282.665	3.801766139	413.2300459	7.93	3.02255
18038600	Crow Wing River	2365890.358	2084246.252	1.866253813	515.0284651	4.6665	1.11935
18038701	Crow Wing River	15105.5778	385666.7808	3.313511763	95.300337	1.0675	0.0915
18038702	Crow Wing River	1629142.138	709551.0446	3.236524537	175.3338815	8.7535	2.70535
18038703	Crow Wing River	105614.2699	471828.4223	6.871267969	116.5913423	2.318	0.2501
18038800	Crow Wing River	738989.7213	317745.0939	3.407162898	78.51652263	8.235	2.32715
18039600	Crow Wing River	2808639.669	633124.9912	6.773469934	156.4485925	19.215	4.4408
18039700	Crow Wing River	808133.7529	260666.4791	5.47458665	64.41208976	12.2	3.1049
18039900	Crow Wing River	2911354.859	887483.1186	5.739957052	219.3018546	7.015	3.28485
18040200	Crow Wing River	331780.144	161029.4135	4.627739614	39.79123465	5.49	2.0618
18040300	Crow Wing River	13082486.08	2266147.28	7.758353607	559.977188	11.895	5.77975

18040700	Crow Wing River	2896809.734	660957.2508	8.602715202	163.3260936	13.725	4.38895
18040900	Crow Wing River	1838609.229	515946.9549	10.78668885	127.4932691	14.7925	3.5685
18041200	Pine River	12290075.95	2410719.888	6.999864084	595.7018577	12.81	5.1057
18041400	Pine River	1922824.058	992573.6919	8.660568052	245.2703008	2.8365	1.9398
18043900	Mississippi River- Brainerd	4938690.619	250502.4036	19.92693216	61.900492	78.812	19.7396
19000300	Mississippi River- Twin Cities	629158.8929	330145.683	11.39252891	81.58077494	4.575	1.9093
19000600	Cannon River	17642584.72	5500649.124	1.095848755	1359.24	15.25	3.20860014
19002300	MS- Lake Pepin	395778.3838	257663.3484	0.004379562	63.67	2.195999942	1.537199988
19002600	MS- Lake Pepin	4127413.768	2146047.961	0.002108889	530.3	5.185	1.924549983
19003400	Mississippi River- Twin Cities	96211.8496	56458.14974	2.893984962	13.95111263	2.2875	1.13765
19005000	Mississippi River- Twin Cities	522542.7464	187291.0626	11.12814012	46.28062948	9.76	2.6108
19008000	Mississippi River- Twin Cities	524663.5484	414156.5729	5.667386796	102.3403179	2.44	1.2688
21001600	Sauk River	11218926.21	2696543.931	5.611352065	666.3305167	9.15	4.1663
21004100	Long Prairie River	2075389.358	434263.5992	5.34839547	107.3088723	13.6945	4.78545
21004900	Long Prairie River	5149334.877	704903.9988	10.75222816	174.1855715	13.115	7.3139
21005100	Long Prairie River	2590144.029	615606.9086	5.088259274	152.11978	9.76	4.21205
21005200	Long Prairie River	16072487.94	2589224.719	8.605839559	639.8113619	19.215	6.2159
21005300	Long Prairie River	2746035.4	556269.0194	4.26254459	137.4570682	9.455	4.94405
21005400	Long Prairie River	15224877.67	1686758.025	10.28915663	416.8069851	18.3	9.03715
21005500	Long Prairie River	1509652.491	446100.2239	8.285586021	110.233766	7.93	3.38855
21005600	Long Prairie River	45004701.93	7288230.045	6.488117169	1800.960866	25.8945	6.2342
21005700	Long Prairie River	150482761.4	10542529.02	8.867887418	2605.115655	48.556	14.2862
21007300	Long Prairie River	4689264.267	1366123.352	8.869100716	337.576432	17.9035	3.7271
21007600	Long Prairie River	15516140.22	2586993.744	7.399766063	639.2600761	13.359	6.01765
21008000	Long Prairie River	24169305.68	4249194.271	6.118519443	1049.998771	18.91	5.69435
21008300	Long Prairie River	166801221.9	23165411.92	13.50815921	5724.29795	30.5	7.2102

21008500	Long Prairie River	32001770.66	3716511.533	8.306372149	918.3700001	24.4	8.62235
21009200	Long Prairie River	41668975.58	9916571.81	7.059612926	2450.43826	9.15	4.20595
21009400	Long Prairie River	3890348.022	867898.0286	5.758051794	214.4622734	10.065	4.4896
21009500	Long Prairie River	1274227.791	457908.3256	4.545454545	113.1516115	12.81	2.7877
21010100	Long Prairie River	1353834.984	351097.6601	3.332375754	86.75812124	17.2325	3.89485
21010200	Long Prairie River	5182599.659	1184033.209	5.438887273	292.5809778	12.2	4.38285
21010300	Long Prairie River	6619595.862	981546.8081	5.715775968	242.5454984	15.86	6.7527
21010500	Long Prairie River	333981.0067	187648.5951	2.509776812	46.36897768	8.662	1.7812
21010600	Long Prairie River	33252104.42	3102458.339	10.53670616	766.6341514	33.855	10.7299
21010800	Long Prairie River	16329833.11	1664938.907	8.929732928	411.4153636	37.515	9.821
21011100	Long Prairie River	1219270.748	407928.5299	4.621674572	100.801335	14.701	2.99205
21012000	Long Prairie River	1353204.856	559429.2554	4.319857398	138.2379796	9.7905	2.4217
21012300	Long Prairie River	154303964.1	17914772.7	10.72635536	4426.836741	32.2995	8.6254
21013000	Long Prairie River	2397472.394	474219.7749	6.611659614	117.1822584	16.47	5.063
21014000	Long Prairie River	6034265.859	1066089.241	9.215182207	263.4363887	10.675	5.6669
21014401	Long Prairie River	13753450.89	3001992.542	7.523806799	741.8085122	18.5135	4.76715
21014402	Long Prairie River	9613960.451	2567814.221	8.535650107	634.5207126	9.4245	3.85215
21015000	Long Prairie River	4842833.651	715333.9493	8.756717075	176.7628684	18.178	6.7771
21015100	Long Prairie River	4797063.297	1243885.197	12.49364583	307.3707261	12.505	3.8613
21015700	Long Prairie River	1675676.168	511108.6287	9.091895636	126.2976927	12.1695	3.2818
21018000	Long Prairie River	9355623.109	1822292.798	7.083015737	450.298357	12.2	5.13925
21055100	Long Prairie River	1229234.98	347859.7037	7.19410484	85.95800479	15.7685	3.538
25001400	MS- Lake Pepin	4209297.386	3358405.208	2.2487E-05	829.88	5.795	1.253550041
25001700	MS- Lake Pepin	4409048.647	5017252.124	0.997277295	1239.79	3.294000058	0.878400035
25001900	MS- Lake Pepin	290148.5831	590355.4149	0.00511509	145.88	1.0675	0.491050004
27001600	Mississippi River- Twin Cities	13557571.85	1380880.938	10.4834565	341.2231108	26.4435	9.83015
27001800	Mississippi River- Twin Cities	893740.9699	214201.2283	3.652711954	52.93027622	9.455	4.06565

27001900	Mississippi River- Twin Cities	3433331.634	814376.3229	4.703565946	201.2367719	10.004	4.1541
27003100	Mississippi River- Twin Cities	17077540.45	1697300.922	8.089552239	419.4121918	27.45	10.07415
27003501	Mississippi River- Twin Cities	995116.3526	273721.71	6.800402936	67.63810756	7.625	3.63865
27003700	Mississippi River- Twin Cities	539263.7165	161772.9361	3.20499699	39.97496309	7.625	3.4953
27003800	Mississippi River- Twin Cities	186162.3808	41499.3082	3.989051095	10.25470238	14.7315	4.2273
27003900	Mississippi River- Twin Cities	3961693.2	662845.4551	5.545925149	163.792679	15.555	5.9841
27004000	Mississippi River- Twin Cities	1042305.527	452276.6548	4.390535872	111.7599953	9.455	2.30885
27004201	Mississippi River- Twin Cities	421761.8618	580187.5173	3.057920169	143.3674578	2.44	0.84485
27004202	Mississippi River- Twin Cities	1126748.709	282883.8202	3.786211581	69.90211431	13.3895	4.7702
27004203	Mississippi River- Twin Cities	244187.8235	139373.722	3.083122718	34.43999674	6.71	1.8422
27005200	Mississippi River- Twin Cities	134683.3507	115230.3841	5.135135135	28.47404803	1.83	0.976
27009501	Mississippi River- Twin Cities	959702.5533	675357.1205	7.172574427	166.8843789	4.88	1.4213
27009800	Mississippi River- Twin Cities	1722465.775	738417.677	10.46433255	182.4669818	9.455	2.3363
27010000	Mississippi River- Twin Cities	333493.3694	103980.7973	2.892566468	25.69421459	7.808	3.21165
27010200	Mississippi River- Twin Cities	242410.6401	180738.2356	5.32363213	44.66139064	8.2045	1.342
27010400	Mississippi River- Twin Cities	18028361.08	3744326.206	9.832492184	925.2431554	14.518	4.79765
27010700	Mississippi River- Twin Cities	1351302.926	405386.1654	6.720109048	100.1731031	11.285	3.44955
27011101	Mississippi River- Twin Cities	3806310.38	1198679.441	5.22426767	296.2001406	10.797	3.1781

27011102	Mississippi River- Twin Cities	582211.5135	229317.8489	1.992859976	56.66567453	6.71	2.54065
27011600	Mississippi River- Twin Cities	2449609.852	1479059.039	8.009891869	365.4834481	3.355	1.7141
27011700	Mississippi River- Twin Cities	3890774.702	615490.1664	9.553095238	152.0909324	17.324	6.32875
27011800	Mississippi River- Twin Cities	5964177.881	962043.5644	9.60382013	237.726142	18.605	6.20675
27012500	Mississippi River- Twin Cities	2849218.389	1639073.357	5.954509296	405.0238471	2.44	1.74155
27013301	Mississippi River- Twin Cities	1828200.263	760200.244	4.217422321	187.8495713	8.906	2.40645
27013303	Mississippi River- Twin Cities	1435449.127	463821.0818	7.022241758	114.6126854	9.2415	3.0988
27013304	Mississippi River- Twin Cities	2943987.08	672510.2046	7.781313749	166.1808907	11.834	4.38285
27013306	Mississippi River- Twin Cities	969286.0087	347524.0099	6.480253353	85.87505303	8.4485	2.7938
27013307	Mississippi River- Twin Cities	329467.6095	171531.4638	4.088661754	42.38634779	7.564	1.92455
27013308	Mississippi River- Twin Cities	86933.072	59008.2203	3.028475712	14.58124879	5.0325	1.4762
27013309	Mississippi River- Twin Cities	9236485.231	2313017.878	10.71375797	571.5591651	10.248	3.99855
27013310	Mississippi River- Twin Cities	28237253.1	3301914.848	6.186395555	815.9209281	31.232	8.56135
27013311	Mississippi River- Twin Cities	5569683.805	1233028.177	7.337982682	304.687898	12.9625	4.52315
27013312	Mississippi River- Twin Cities	3439036.885	802178.0597	9.566994194	198.2225155	12.0475	4.29135
27013313	Mississippi River- Twin Cities	6279013.4	1312811.448	11.23199358	324.4027736	18.666	4.7885
27013314	Mississippi River- Twin Cities	13299784.54	3331733.006	7.633336989	823.2891555	10.675	3.9955
27013315	Mississippi River- Twin Cities	4681780.389	1266323.105	11.15153689	312.915254	7.442	3.7027

27013800	Mississippi River- Twin Cities	186555.4678	36938.62818	3.963581184	9.127733807	16.5005	5.0569
27013900	Mississippi River- Twin Cities	1522890.071	364613.142	8.945545102	90.09786954	13.2675	4.18155
27014100	Mississippi River- Twin Cities	648309.2765	216409.535	6.226484018	53.47596069	6.2525	2.99815
27015100	Mississippi River- Twin Cities	108246.2831	45315.62299	0.899917287	11.1977343	5.6425	2.3912
27016000	Mississippi River- Twin Cities	4828524.266	1153327.15	8.489020974	284.9933453	10.675	4.1724
27016200	Mississippi River- Twin Cities	256346.3242	175766.6381	1.73898111	43.43288216	1.4335	0.96685
27018100	Mississippi River- Twin Cities	3067990.095	698988.0438	6.87488824	172.7237072	13.0845	4.39505
27018200	Mississippi River- Twin Cities	1356067.882	580087.2614	6.364381448	143.342684	11.529	2.33935
27069300	Mississippi River- Twin Cities	127487.3965	30905.3455	1.396853147	7.636877188	8.54	4.1297
29000200	Crow Wing River	1670303.243	429959.8293	5.762949956	106.2453876	10.37	3.88875
29000300	Crow Wing River	1899667.923	280585.8234	4.522003578	69.33426693	19.825	6.78015
29002500	Crow Wing River	5525165.216	940502.8486	10.1288561	232.4033152	19.825	6.1122
29003200	Crow Wing River	3299803.546	536225.8107	11.89705209	132.5042835	18.3	6.161
29003601	Crow Wing River	19808129.4	1936489.053	12.16696865	478.5168662	24.4	10.2297
29003602	Crow Wing River	7888579.013	1102583.861	8.176997216	272.4544057	16.775	7.14005
29004500	Crow Wing River	2800781.891	709037.3235	7.255546661	175.2069383	12.2	3.95585
29007200	Crow Wing River	11097787.55	2035452.595	15.65935871	502.97129	9.15	5.56625
29007400	Crow Wing River	1033399.234	206578.9822	15.48465687	51.0467782	10.98	5.0081
29007700	Crow Wing River	9007277.956	2603767.874	6.403650064	643.4050539	9.15	3.5075
29007800	Crow Wing River	2693554.154	1783160.238	5.023374652	440.6284907	3.05	1.5128
29008500	Crow Wing River	3819329.908	896151.6089	7.213893519	221.4438852	10.675	4.3554
29008600	Crow Wing River	3441054.534	2112528.894	4.740102186	522.0172582	4.575	1.63785
29008700	Crow Wing River	1553686.499	591852.3126	8.653524659	146.2498915	6.405	2.6291

29008800	Crow Wing River	2812552.343	911392.0704	5.503619442	225.2098852	9.76	3.05915
29008900	Crow Wing River	1473910.61	1150546.085	6.041405634	284.3061293	3.111	1.28405
29009000	Crow Wing River	532662.2321	731629.4447	6.370937402	180.789573	1.525	0.8052
29009100	Crow Wing River	5552300.897	1054691.781	9.387875739	260.6200148	12.2	5.32225
29009200	Crow Wing River	7091772.052	1619228.866	7.467862244	400.1201666	10.675	4.3859
29009300	Crow Wing River	6718196.09	1374243.459	8.234608713	339.5829541	10.675	4.89525
29009700	Crow Wing River	369513.0434	331177.0225	3.539442634	81.83562449	1.22	1.1163
29009800	Crow Wing River	1235515.966	709120.9049	11.06185674	175.2275917	9.638	1.7446
29010101	Crow Wing River	17380175.16	1533978.562	10.05256544	379.0543577	29.28	11.34295
29010102	Crow Wing River	1908772.033	1168086.666	8.33378929	288.6405012	10.065	1.6348
29010103	Crow Wing River	5858705.875	1091307.403	7.841279336	269.6679322	15.2195	5.37715
29011000	Crow Wing River	2711441.791	528687.0329	8.293553171	130.6414109	10.37	5.1362
29011701	Crow Wing River	6129739.022	2194577.685	11.25062179	542.291956	29.28	3.2513
29011702	Crow Wing River	3118119.159	432771.2819	10.49174631	106.9401127	20.13	7.4908
29014300	Crow Wing River	4348751.734	1389611.478	6.688611357	343.3804743	7.259	3.13235
29014500	Crow Wing River	83182.756	181003.0925	4.943657984	44.72683822	5.7035	0.46055
29014600	Crow Wing River	22062944.8	6056802.849	20.53966557	1496.668578	15.25	3.78505
29014800	Crow Wing River	11454331.02	1858096.336	9.976595017	459.145604	16.775	6.1732
29014900	Crow Wing River	2079326.511	744880.7958	9.651299406	184.0640532	6.71	2.8487
29015000	Crow Wing River	12513297.21	1657243.445	7.700753433	409.5137737	24.4	7.56095
29015101	Crow Wing River	15387440.88	2710719.145	10.59329971	669.8332883	20.7095	5.68825
29015102	Crow Wing River	9053918.507	2581029.922	5.824766128	637.7863834	10.6445	3.37025
29015103	Crow Wing River	27516.1183	138319.8944	3.46541904	34.17959026	1.83	0.91805
29015104	Crow Wing River	4460807.48	797553.2325	10.57001571	197.0796958	17.751	5.5876
29015105	Crow Wing River	1465393.725	318941.5798	8.941348974	78.81218074	16.165	4.6055
29016100	Crow Wing River	87668589.57	7794708.097	14.70697233	1926.114318	39.345	11.2606
29016200	Crow Wing River	6400074.772	1378128.69	6.324442648	340.5430157	8.54	4.65125
29016400	Crow Wing River	436219.9073	459396.0501	10.09759314	113.5192362	3.05	0.9516

29017000	Crow Wing River	1165434.978	301405.2593	8.19302072	74.47886157	12.505	3.87045
29017200	Crow Wing River	1474401.134	411788.8428	9.808418861	101.7552391	7.625	3.64475
29017800	Crow Wing River	2548980.434	1255722.885	6.075381625	310.2958825	7.93	2.0313
29018000	Crow Wing River	21326506.61	2594752.339	8.238057525	641.1772666	35.075	8.2289
29018400	Crow Wing River	14917105.54	1361160.026	8.060738653	336.3499674	25.62	10.9739
29018500	Crow Wing River	88185983.92	6616945.307	11.14681492	1635.082794	41.175	13.34375
29018600	Crow Wing River	1964903.045	317382.5647	4.213496721	78.42693972	15.25	6.31045
29018800	Crow Wing River	2378325.321	377019.9008	5.656646909	93.16364641	16.47	6.31655
29024200	Crow Wing River	53983147.87	6647244.589	7.580483039	1642.56991	23.18	8.1313
29024300	Crow Wing River	70257490.77	8482598.956	10.63379326	2096.095851	26.5045	8.29295
29024700	Crow Wing River	340448.6604	407241.4995	6.200773746	100.6315661	4.5445	0.8357
29024800	Crow Wing River	376072.7004	249774.4646	4.921226959	61.72061435	9.577	1.5067
29025000	Crow Wing River	4287294.888	1737409.023	10.67415062	429.3231194	4.4225	2.47965
29025400	Crow Wing River	14634540.49	2190354.901	8.687233978	541.2484834	18.605	6.79235
29025600	Crow Wing River	11345324.85	1713962.513	5.404331603	423.5293605	23.4545	6.62765
29027700	Crow Wing River	1207550.218	383797.577	8.286956522	94.83844667	20.2215	3.15065
30003500	Rum River	1168958.838	547187.4806	4.106676899	135.2129711	7.625	2.1655
30004300	Rum River	3533105.435	1433519.754	6.218231603	354.2304456	9.15	2.5193
30004400	Rum River	995536.6076	590549.1475	3.419774149	145.9278724	3.66	1.6409
30007200	Rum River	2260212.441	1544216.632	3.69282152	381.5842399	3.05	1.464
30008000	Rum River	1753738.265	1094369.916	4.73365031	270.4246955	2.5925	1.6043
30010701	Rum River	180903.5899	269135.1104	6.220698925	66.50473412	3.355	1.41215
30013500	Rum River	3583734.644	982036.8024	6.707532667	242.6665787	14.274	3.66305
30013600	Rum River	16951727.42	3370562.237	8.279839713	832.8840673	8.54	5.03555
30013800	Rum River	3830462.874	1662596.74	7.201216978	410.8366017	5.185	2.3546
30014300	Rum River	825115.0547	634654.7575	6.602611426	156.826606	3.2025	1.31455
33000900	Snake River	2549570.602	1668115.51	4.474241466	412.2003195	3.355	1.5372
33001500	Snake River	1460373.418	916124.4781	3.634031957	226.3792886	3.355	1.59515

33002800	Snake River	13461372.34	5095972.946	9.713202668	1259.242339	4.331	2.64435
33003200	Rum River	3615465.962	724350.0279	6.753581822	178.99079	14.5485	5.0264
33003600	Snake River	2193587.704	2046772.787	7.750003363	505.7685703	2.8975	1.0736
33004000	Snake River	5127640.776	2644590.219	10.14631513	653.492475	5.185	1.9459
40000100	Cannon River	5163821.575	1686001.323	0.004058076	416.62	7.93	3.065250058
40000200	Cannon River	6957135.486	3640471.1	0.000439018	899.58	3.05	1.912349994
40000900	Cannon River	1663776.265	490114.7813	0.006825939	121.11	9.15	3.397700105
40003100	Cannon River	27457015.74	5489924.954	0.004391312	1356.59	9.546499767	5.005049953
40003300	Cannon River	7200863.586	1088887.658	0.000348505	269.07	20.37400093	6.618500233
40003900	Cannon River	1846745.287	288540.8629	0.014221754	71.3	18.3	6.405
40005100	Cannon River	1711780.461	313226.6871	0.000242777	77.4	16.165	5.468650093
40005600	Cannon River	1538965.407	683635.4554	0.009677419	168.93	9.729499884	2.253949959
40006300	Cannon River	13220132.95	3203653.418	2.3725E-05	791.64	15.43299953	4.129699988
40009201	Cannon River	13197878.54	2624750.607	5.7885E-05	648.59	11.285	5.0325
40009202	Cannon River	4840981.129	1770944.839	0.002404878	437.61	7.32	2.735850081
40009203	Cannon River	1530005.738	2060092.73	0.005867375	509.06	1.83	0.744200017
40009204	Cannon River	3556068.569	2650448.145	0.001347361	654.94	2.44	1.342000029
44000600	Wild Rice River	10663811.61	2974319.491	14.86470666	734.9703525	7.93	3.9223
44001400	Wild Rice River	17265543.18	4556459.226	8.917986448	1125.925595	8.357	3.78505
44002300	Wild Rice River	9490494.117	3909135.144	7.477046379	965.9683311	4.88	2.4522
44003800	Wild Rice River	10272472.87	2493149.2	12.81067196	616.0705841	13.0845	4.12665
44004500	Wild Rice River	11618778.55	2559638.563	6.902700348	632.5004634	8.845	4.60245
44008000	Wild Rice River	5212604.253	1091800.32	4.763932082	269.7897346	12.2	4.88
44016900	Wild Rice River	1304417.807	578900.5875	4.725054277	143.0494505	8.3875	2.30275
47004200	Mississippi River- St. Cloud	2208000.385	621859.0891	9.267995663	153.6647274	8.845	3.5563
47009500	Mississippi River- St. Cloud	5321290.884	2141066.789	6.348409879	529.0691257	5.185	2.4888
47009600	Mississippi River- St. Cloud	545123.5428	151221.3285	3.040668348	37.36760407	12.688	3.60815
48001200	Rum River	4544572.452	2362375.465	2.19820831	583.7556904	3.965	1.9215

49000500	Mississippi River- Sartell	3863586.014	568408.0155	1.732978723	140.4566795	19.215	6.87165
49002400	Mississippi River- Sartell	3657311.022	765710.511	6.685233295	189.2111879	9.15	4.8983
49003500	Mississippi River- Brainerd	2776650.481	738457.7339	2.839489769	182.47688	7.015	3.7637
49005600	Mississippi River- Brainerd	1549374.258	514269.5756	3.739923869	127.0787797	5.185	2.9829
49007900	Long Prairie River	83586077.38	10962041.44	9.619778738	2708.779433	19.825	7.67685
49008100	Mississippi River- Brainerd	4277059.853	719033.9705	9.002740168	177.6771636	17.9645	6.0756
49008400	Mississippi River- Sartell	265046.7347	181905.6093	5.600479616	44.94985499	2.44	1.4579
49012700	Crow Wing River	32888034.46	5803282.737	14.23531344	1434.022395	15.86	5.673
49013100	Long Prairie River	1361610.946	402622.8658	12.57413914	99.49027684	5.49	3.26655
49013300	Long Prairie River	1956456.457	740832.6585	9.850419852	183.0637367	5.49	2.64435
49013600	Long Prairie River	649801.9883	171239.0914	4.259316292	42.314101	7.015	3.8003
49013700	Long Prairie River	29349399.83	4709777.986	7.612182116	1163.811486	12.81	6.2403
56003100	Redeye River	1473525.617	984162.8649	6.11067644	243.1919402	5.856	1.5006
56006600	Long Prairie River	3561025.96	1980302.139	7.457603503	489.3433156	5.185	1.7995
56006900	Redeye River	2466441.503	799481.0193	2.309028354	197.5560623	9.7295	3.08965
56007000	Redeye River	533690.9937	424067.6226	1.769409748	104.7893916	1.83	1.25965
56011400	Redeye River	19295765.77	2832792.588	5.932073609	699.9982931	16.165	6.8198
56011601	Redeye River	8420691.517	1635502.018	5.396321125	404.14135	13.115	5.1789
56011602	Redeye River	10608070.74	1712088.952	8.923988154	423.0663936	14.3045	6.3623
56013000	Otter Tail River	94990973.05	19124080.93	9.73317837	4725.663313	21.533	4.96845
56013800	Otter Tail River	57126384.19	8033424.8	8.20874	1985.1025	26.5045	7.1187
56014001	Redeye River	5426885.061	1088913.78	5.668798439	269.0764551	14.9145	4.9898
56014100	Otter Tail River	75302216.88	21180346.29	4.843906819	5233.777551	19.825	3.55935
56014200	Otter Tail River	62631296.65	8418569.765	6.281512375	2080.273893	21.9295	7.4481
56020000	Redeye River	3194314.645	669765.4015	4.571333941	165.502635	13.0845	4.7763
56021200	Otter Tail River	2874582.518	685474.4497	3.793253453	169.3844254	7.93	4.19985
56023800	Otter Tail River	81010992.78	10277094.7	11.33474077	2539.525407	20.923	7.89035
56023900	Otter Tail River	158483011.1	22723004.68	9.461835871	5614.97674	32.94	7.0455

56024000	Otter Tail River	16898032.73	5244404.331	3.431174596	1295.920533	19.3065	3.18115
56024100	Otter Tail River	6422170.11	1434196.864	2.828226067	354.3977631	15.5245	4.4835
56024200	Otter Tail River	431127873.4	56956462.83	8.20695574	14074.24847	34.0075	7.57925
56024300	Otter Tail River	44132091.89	6571181.679	10.01282874	1623.774355	18.3	6.72525
56029800	Otter Tail River	5375172.754	1809217.29	3.367928656	447.0673284	7.625	2.99205
56030600	Otter Tail River	4573513.928	762271.4051	6.22862714	188.3613663	13.9995	6.0085
56031000	Otter Tail River	8152353.294	2341071.786	3.338410639	578.4914367	8.845	3.4709
56032800	Otter Tail River	61848494.96	5394458.409	7.585387948	1332.999703	33.245	11.6632
56035800	Otter Tail River	10235508.71	1029452.942	9.299387654	254.3833619	27.389	10.0772
56036000	Otter Tail River	57067346.51	4858142.189	10.7341854	1200.473079	41.724	11.7608
56038300	Otter Tail River	88196359.15	30492412.68	7.990442748	7534.839267	18.483	2.88225
56038500	Otter Tail River	110429336.4	18271421.21	7.13634613	4514.966507	27.45	6.13355
56038601	Otter Tail River	22641044.21	4013274.489	3.668413309	991.7017236	12.81	5.6486
56038602	Otter Tail River	18957117.21	2415410.82	4.983508418	596.8610122	18.91	7.8568
56038603	Otter Tail River	7388025.281	2270403.707	6.799421837	561.0289741	9.15	3.2574
56038700	Otter Tail River	20246084.75	2758464.086	12.13917924	681.6313202	22.57	7.46335
56038802	Otter Tail River	48539522.4	5215514.025	9.117705503	1288.781583	39.0095	9.31775
56047500	Otter Tail River	30592300.08	3434568.981	6.857766132	848.7004783	24.705	9.03105
56053200	Otter Tail River	12854529.92	2512325.526	7.93574403	620.8091574	23.119	5.0996
56072700	Otter Tail River	1286666.405	240134.6499	15.93916756	59.33856427	13.6945	6.1305
56074701	Otter Tail River	120053008.5	22312728.66	13.30418789	5513.595327	14.03	5.3863
56074702	Otter Tail River	16925168.95	3137812.621	13.72408013	775.3703847	14.64	5.35885
56074900	Otter Tail River	28184390.31	5715401.872	8.387746298	1412.30656	16.6835	4.91965
56075900	Otter Tail River	19447395.84	4402165.653	10.09057462	1087.798823	14.1825	4.4225
56076001	Otter Tail River	44883184.98	7689915.771	7.691791418	1900.21957	19.947	5.8377
56076002	Otter Tail River	10286959.24	7411444.068	4.556571775	1831.407714	2.745	1.3908
56078400	Otter Tail River	22442780.78	3103309.832	12.79698686	766.8445599	22.204	7.32915
56084600	Otter Tail River	539420.6683	274625.0661	3.844487427	67.86133172	5.49	2.074

56087700	Otter Tail River	20956362.05	2959201.47	14.0733042	731.2346081	22.8445	7.1004
56091500	Otter Tail River	10642613.18	4057622.203	8.779576117	1002.660282	6.405	2.623
56092000	Otter Tail River	132366.458	125824.2236	8.389216328	31.09184277	4.026	1.05225
56094100	Buffalo River	474226.2979	536239.4992	8.135149024	132.507666	4.9105	0.8845
56095001	Buffalo River	3149947.773	847344.6585	8.544736631	209.3834251	18.605	3.721
56098200	Otter Tail River	4950926.265	2073463.993	8.797446679	512.364111	5.185	2.4034
56103900	Buffalo River	679402.8261	635396.4551	9.209737058	157.0098834	3.5685	1.07055
58011900	Snake River	15660856.91	3744545.5	10.87881344	925.2973442	9.76	4.18765
58014200	Snake River	21465794.37	6157184.415	5.256675439	1521.473404	7.015	3.50445
61002900	Sauk River	742657.09	822035.9385	1.520623314	203.1295042	3.66	0.90585
62000500	Mississippi River- Twin Cities	18549.9991	47839.06856	3.595647194	11.82129129	1.0675	0.38735
62000600	Mississippi River- Twin Cities	409094.4988	340391.0424	3.227994012	84.11245837	3.538	1.22
62000700	Mississippi River- Twin Cities	5522041.151	951058.165	8.528040641	235.0115906	12.627	5.8133
62001001	Mississippi River- Twin Cities	29148.5755	27603.5972	2.106280193	6.820997415	1.525	1.05835
62001002	Mississippi River- Twin Cities	365290.7966	296705.0863	4.949462226	73.31742353	1.525	1.2322
62001100	Mississippi River- Twin Cities	108204.1727	90906.66698	3.832004556	22.46352662	2.44	1.3054
62001200	Mississippi River- Twin Cities	148310.7912	86709.47019	3.394230769	21.42637671	5.124	1.71105
62001300	Mississippi River- Twin Cities	5683566.599	800016.9784	7.26134594	197.6885006	27.755	7.1126
62001600	Mississippi River- Twin Cities	668068.0252	347068.6995	7.017337032	85.76254339	3.965	1.9947
62002700	Mississippi River- Twin Cities	611032.941	389641.3817	5.3301156	96.28248225	2.745	1.57075
62002800	Mississippi River- Twin Cities	670390.776	256745.4215	3.24968254	63.44317533	7.32	2.61385
62003801	Mississippi River- Twin Cities	12087952.51	1590083.433	13.65323999	392.9181732	17.6595	7.6128

62003802	Mississippi River- Twin Cities	1490153.763	856408.8643	7.009638362	211.6232391	2.745	1.74155
62003900	Mississippi River- Twin Cities	652819.4758	131226.2707	0.672897196	32.42671768	10.065	4.8678
62004600	Mississippi River- Twin Cities	12580583	2457382.035	9.969245808	607.2323252	17.5985	5.12705
62004700	Mississippi River- Twin Cities	185565.8168	280444.3118	7.910968775	69.29929865	5.1545	0.63135
62005400	Mississippi River- Twin Cities	2325159.555	296443.5856	7.890220601	73.25280529	17.385	7.85375
62005500	Mississippi River- Twin Cities	527256.6208	288531.6316	7.568419334	71.29771889	4.88	1.94285
62005600	Mississippi River- Twin Cities	5022026.393	1517425.136	11.84319791	374.9639172	11.285	3.3245
62005700	Mississippi River- Twin Cities	1496631.775	470135.9881	6.891470098	116.1731327	13.1455	3.25435
62006100	Mississippi River- Twin Cities	6259785.559	1821154.152	6.782522486	450.0169915	8.54	3.4404
62006700	Mississippi River- Twin Cities	2603952.561	698600.3199	5.359885641	172.6278986	7.32	3.3916
62006900	Mississippi River- Twin Cities	323966.3442	153730.1352	4.023381295	37.9875437	4.88	2.1106
62007100	Mississippi River- Twin Cities	288084.7176	258846.1059	4.828462305	63.96226574	3.904	1.11325
62007300	Mississippi River- Twin Cities	1180796.275	598046.4609	9.238624382	147.7804988	9.15	1.9764
62007501	Mississippi River- Twin Cities	281317.5933	180038.2344	3.167339252	44.48841659	3.355	1.66225
62007502	Mississippi River- Twin Cities	82524.9508	79818.0009	4.073001159	19.72345756	2.135	1.1346
62007800	Mississippi River- Twin Cities	4447341.378	857568.7782	8.227790433	211.9098601	13.115	5.20025
62008200	Mississippi River- Twin Cities	995640.5535	173297.0375	4.685731132	42.82263057	22.2345	5.7523
66000800	Cannon River	16325731.77	6447653.995	0.007189496	1593.25	4.635999942	2.534550128
66001000	Cannon River	3286684.615	2646279.883	0.003963695	653.91	1.525	1.241350052

66001400	Cannon River	1168675.041	257865.6912	0.072395527	63.72	18.20850023	4.535349965
66001500	Cannon River	719822.3592	260981.7707	0.039267016	64.49	15.25	2.760250058
66001800	Cannon River	7948430.546	2558786.847	0.041060939	632.29	11.55950047	3.107949872
66002700	Cannon River	5624717.874	3389566.002	0.047384781	837.58	4.27	1.659200017
66002900	Cannon River	7452372.235	1259138.907	0.038250708	311.14	14.335	5.923100023
66003200	Cannon River	3227364.776	1605549.817	0.029053863	396.74	3.05	2.009950047
66003800	Cannon River	17569579.27	3544277.323	0.009040468	875.81	15.37200047	4.95930007
66003900	Cannon River	14171654.55	2757123.281	0.021355643	681.3	15.15850023	5.142300186
66004500	Cannon River	637437.7856	726127.4479	1.028263373	179.43	1.555499971	0.878400035
66004700	Cannon River	2131530.602	713703.5987	0.028820589	176.36	8.235	2.989000058
66005200	Cannon River	9880945.42	3583612.768	1.012952599	885.53	12.77950047	2.760250058
66005500	Cannon River	12119763.61	3854387.931	2.435742972	952.44	9.363500233	3.147599907
71001300	Mississippi River- St. Cloud	1459673.191	1216103.605	9.415514831	300.5057454	5.185	1.464
71001600	Mississippi River- St. Cloud	3135333.341	1994711.24	7.531865919	492.903882	3.05	1.5982
71002200	Rum River	321701.5518	248163.4412	8.511638521	61.32252181	1.83	1.2993
71002300	Rum River	395345.1419	230280.216	9.05079122	56.90348061	2.135	1.7202
71004000	Rum River	1033891.626	259567.0463	7.176446195	64.14041398	12.2	4.1602
71004600	Mississippi River- St. Cloud	75807.21	250754.1643	3.070529434	61.96270344	1.525	0.30195
71005500	Mississippi River- St. Cloud	3275429.152	1464593.003	6.423810864	361.9088126	4.575	2.2448
71005700	Mississippi River- St. Cloud	1943823.535	642542.1124	4.549244754	158.7756138	5.49	3.12625
71006700	Mississippi River- St. Cloud	5821004.869	1872554.709	6.719612019	462.7183456	6.1	3.1659
71006900	Mississippi River- St. Cloud	1453158.418	739986.2936	5.113922275	182.8545954	7.625	2.0496
71008100	Mississippi River- St. Cloud	2742401.68	685960.696	5.154111141	169.5045795	10.004	4.2151
71008200	Mississippi River- St. Cloud	5278807.66	1026545.414	5.261399211	253.664896	13.9995	5.124
71009600	Mississippi River- St. Cloud	1004286.402	341328.8414	3.700861863	84.34419355	6.71	2.9463
71012300	Mississippi River- St. Cloud	938191.4403	311792.306	7.688669951	77.04555671	10.37	3.0134
71012600	Mississippi River- St. Cloud	519199.158	347214.9743	5.519511776	85.79868868	2.135	1.49755
71013500	Mississippi River- St. Cloud	54732.6811	92216.13787	2.487425697	22.78710392	1.525	0.59475

71014100	Mississippi River- St. Cloud	2274494.121	1444280.784	5.729489938	356.889554	2.44	1.57685
71014500	Mississippi River- St. Cloud	1483098.092	625175.9637	7.191804074	154.484345	4.575	2.4095
71014600	Mississippi River- St. Cloud	6296643.734	1636406.14	6.88922376	404.3647634	7.625	3.8552
71014700	Mississippi River- St. Cloud	1097264.976	651193.8288	4.608866222	160.9134995	3.05	1.68665
71015300	Mississippi River- St. Cloud	1708811.874	455623.5123	3.582136507	112.5870218	7.625	3.75455
71015800	Mississippi River- St. Cloud	764595.7877	436645.6419	5.157230183	107.8974879	6.405	1.75375
71015900	Mississippi River- St. Cloud	2167846.59	704195.0412	6.999242383	174.0103843	7.93	3.08355
71016700	Mississippi River- St. Cloud	541089.2929	144813.8438	3.829463266	35.78428012	13.0845	3.74235
73000100	Mississippi River- St. Cloud	250304.8968	101726.3288	3.692164179	25.13712329	6.71	2.4644
73000200	Mississippi River- St. Cloud	167022.8078	98526.16545	2.876518219	24.3463457	5.185	1.69885
73000300	Mississippi River- St. Cloud	654868.4807	319290.0429	2.965387607	78.89828785	4.575	2.29665
73000400	Mississippi River- St. Cloud	1065644.311	277480.4307	9.174191825	68.56690768	9.15	3.94365
73000500	Mississippi River- St. Cloud	298243.0592	59727.45431	2.70565046	14.75897538	10.675	4.99895
73000600	Mississippi River- St. Cloud	1259416.25	311920.7317	4.368669818	77.07729138	9.15	4.1236
73000700	Mississippi River- St. Cloud	388963.8598	90835.42706	1.132253006	22.44592286	9.15	4.2883
73000800	Mississippi River- St. Cloud	249455.7836	69377.09292	2.587135378	17.14345301	7.625	3.599
73001100	Mississippi River- St. Cloud	504167.7262	151462.067	4.194548637	37.42709186	9.15	3.74235
73001200	Mississippi River- St. Cloud	316024.0907	120573.5838	3.168738899	29.79438142	8.54	2.623
73001500	Mississippi River- St. Cloud	3123948.93	371310.1924	3.964821008	91.75274675	15.25	7.1614
73002200	Mississippi River- St. Cloud	154243.9711	82190.0698	2.255211623	20.30960855	4.575	1.8788
73002300	Mississippi River- St. Cloud	2172044.272	452883.2015	3.142857143	111.9098763	8.235	3.9711
73003500	Mississippi River- St. Cloud	2018530.611	813478.8833	10.92115277	201.0150098	3.66	2.5864
73003700	Mississippi River- St. Cloud	8983287.367	3048651.588	5.413107693	753.3382135	5.551	2.97985
73003800	Sauk River	2860868.14	728058.0463	7.57584094	179.9070613	9.76	4.12665
73004300	Sauk River	455457.3983	144561.5713	4.915131579	35.72194222	7.2895	3.1537
73004400	Sauk River	622900.4611	206821.3896	10.06076459	51.10667836	6.405	3.01645
73005100	Sauk River	3504829.008	880884.9599	5.206025866	217.6714141	9.15	3.9589
73005500	Sauk River	15204878.09	2632630.557	6.306377354	650.5371782	10.37	5.79805

73006400	Mississippi River- Sartell	3122602.756	789257.0178	8.110311751	195.0296565	8.54	3.96195
73007000	Mississippi River- Sartell	2242922.103	391090.0399	3.547082862	96.64045349	16.47	5.74315
73007200	Mississippi River- Sartell	619497.5559	148479.4741	3.995960762	36.69007708	9.455	4.1785
73007600	Sauk River	1716114.519	756880.9894	3.844890032	187.0293656	6.1	2.3119
73008200	Sauk River	1345779.474	241250.3013	5.475694444	59.61424773	16.775	6.12135
73008300	Sauk River	1405190.003	792777.1692	5.884774092	195.8995048	4.941	1.86355
73008500	Sauk River	1413439.057	736433.4688	12.91879627	181.9766732	5.185	1.9215
73008600	Sauk River	1672162.921	873920.417	8.380741847	215.950438	4.941	1.96115
73008700	Sauk River	781650.4431	384756.7623	5.795098039	95.07546652	12.261	2.14415
73008800	Sauk River	1741386.504	440944.4812	9.39904221	108.9597542	10.675	4.02905
73008900	Sauk River	902267.9297	518446.6804	6.512305699	128.1109647	6.4965	1.85135
73009100	Mississippi River- Sartell	758300.1697	291631.3049	12.99707412	72.06366484	10.98	2.6047
73009200	Mississippi River- Sartell	1900700.873	920130.4465	16.46219289	227.369185	12.139	2.0679
73009700	Mississippi River- Sartell	1492796.191	413088.3091	13.5909696	102.0763442	18.3	3.8308
73009800	Mississippi River- Sartell	922269.4924	461735.7807	4.859171491	114.0973962	5.4595	2.0008
73009900	Mississippi River- Sartell	743606.8946	107397.7576	4.519966015	26.53856386	16.775	6.93265
73010000	Mississippi River- Sartell	2550756.967	430738.8687	5.347485157	106.4378925	14.4875	5.9292
73010100	Mississippi River- Sartell	562879.1326	153762.1476	2.379343943	37.99545415	9.455	3.6661
73010200	Mississippi River- Sartell	12510277.4	993733.4225	13.03983984	245.5568764	37.332	12.60565
73010400	Mississippi River- Sartell	1211152.072	470498.2704	9.362752647	116.2626546	12.2	2.684
73010500	Mississippi River- Sartell	125399.1678	125495.0725	5.303346528	31.01050777	3.66	1.0004
73010600	Mississippi River- Sartell	17314007.13	2255373.448	6.877926102	557.3149162	21.35	8.0398
73010700	Mississippi River- Sartell	3692668.362	618003.7992	6.306854391	152.7120646	14.03	5.9841
73010900	Mississippi River- Sartell	641516.9369	231888.3357	6.446864439	57.30085566	6.405	2.7694
73011700	Mississippi River- Sartell	8858076.734	1680558.936	8.127638191	415.2751571	11.59	5.2765
73011800	Mississippi River- Sartell	6137344.194	1177891.597	7.438201235	291.0633523	12.2	5.16365
73012200	Mississippi River- Sartell	829879.1616	162228.1398	3.897940913	40.08744637	12.383	4.80375
73012300	Mississippi River- Sartell	1906468.045	724722.9999	2.95255102	179.0829533	8.357	2.6352

73012500	Mississippi River- Sartell	375242.2652	189839.5229	4.114037627	46.91036772	7.625	2.0191
73012600	Mississippi River- Sartell	448409.9342	329675.2177	4.056099456	81.46452043	8.235	1.36335
73012700	Mississippi River- Sartell	461984.4537	443348.9018	6.909701037	109.5538995	3.66	1.0431
73012800	Mississippi River- Sartell	8458823.758	954025.6701	4.659903477	235.7448771	24.705	8.87855
73013301	Sauk River	7905921.847	1773794.123	10.50752398	438.3140734	21.35	4.5689
73013302	Sauk River	954684.935	332887.9271	7.216184701	82.25839822	10.675	3.08355
73013303	Sauk River	595507.9572	545799.1203	6.317542001	134.8698998	9.2415	1.1407
73013304	Sauk River	826400.5822	1203577.724	5.433766521	297.4105326	4.209	0.75945
73013600	Mississippi River- Sartell	4033160.095	436877.5743	2.849979617	107.9547996	21.35	9.1378
73013800	Mississippi River- Sartell	14020282.56	2361244.09	7.61457476	583.4761215	19.215	5.94445
73013900	Sauk River	5990017.45	1971309.286	8.329812855	487.1211332	10.37	3.0439
73014100	Sauk River	1612917.295	220474.8587	8.857939162	54.48052407	16.4395	7.3261
73014700	Sauk River	7074459.527	1263546.011	8.8746878	312.2290191	10.675	5.6059
73015000	Sauk River	6307989.458	1125965.945	6.33057274	278.2322443	23.119	5.74315
73015100	Sauk River	1665904.489	650102.9635	5.693753309	160.6439408	6.1	2.61995
73015600	Sauk River	604977.4485	895879.648	9.52196265	221.3766822	6.1	0.6832
73015700	Sauk River	10896457.28	2538414.01	12.16080516	627.2557622	17.385	4.29745
73015900	Sauk River	7531522.214	1852147.627	9.604490901	457.675646	9.15	4.10835
73016600	Mississippi River- Sartell	1312312.714	243339.5234	3.685395538	60.13050576	15.25	5.3985
73016700	Mississippi River- Sartell	343151.0274	227076.4649	1.400783021	56.11181647	7.2285	1.5128
73017200	Mississippi River- Sartell	2796525.628	477943.903	3.927778986	118.1025105	12.2	5.85905
73018300	Sauk River	7025078.149	508140.0485	5.681764769	125.5641405	32.025	13.8409
73019300	Mississippi River- Sartell	494752.1464	118604.4611	1.164926931	29.30780061	10.37	4.17545
73019900	Mississippi River- Sartell	1713465.582	846974.3217	4.567154999	209.2919128	3.05	2.0252
73021500	Sauk River	1539898.371	392859.6116	3.841539839	97.07772419	12.2	3.92535
73022600	Sauk River	953971.9165	382468.6726	3.605773896	94.51006725	10.675	2.1289
73023100	Sauk River	2294005.698	373576.7383	6.212793109	92.31282243	18.3	6.1488
73023300	Sauk River	5584013.142	824987.4514	8.02304194	203.8588389	13.42	6.9967

73024100	Sauk River	617820.2149	384811.6255	7.964063362	95.08902351	4.88	1.60735
73024400	Sauk River	692338.275	149880.6223	4.474957983	37.03630834	10.5225	4.6238
73024900	Sauk River	2720413.287	344991.8887	12.92279502	85.24935226	17.08	7.9727
73025100	Sauk River	295374.7693	292639.7073	8.941596485	72.31284649	2.867	1.00955
73027300	Sauk River	1380455.294	834044.1358	5.134650856	206.0967943	3.66	1.65615
73061100	Mississippi River- St. Cloud	156848.0805	34597.7057	3.35451505	8.549279264	9.638	4.5384
73075200	Mississippi River- St. Cloud	35634.2846	47025.89285	1.354661792	11.62035119	1.525	0.75945
74001900	Cannon River	277811.2909	139535.6094	0.045901639	34.48	4.361500058	1.991650064
74002300	Cannon River	1723002.517	395337.4039	0.022260937	97.69	8.235	4.361500058
77000700	Mississippi River- Brainerd	7629360.776	1090756.462	18.16466507	269.5317915	17.385	7.13395
77000900	Mississippi River- Brainerd	1528927.395	1035085.171	2.406869353	255.7751159	1.83	1.47925
77002200	Mississippi River- Brainerd	3757295.686	382515.2204	6.870507265	94.52156946	24.4	9.83625
77002300	Mississippi River- Brainerd	17885412.88	3589293.464	8.705949211	886.9337306	13.725	4.9898
77002400	Mississippi River- Brainerd	5859102.273	496332.1324	11.753391	122.6463409	23.79	11.81875
77002600	Mississippi River- Brainerd	2193150.582	523455.6602	9.06584517	129.3487106	7.93	4.2761
77002700	Mississippi River- Brainerd	15347144.59	1605285.288	9.550615213	396.6746336	19.215	9.60445
77002900	Mississippi River- Brainerd	1502915.365	248170.8224	3.078605323	61.32434573	11.895	6.0634
77003200	Mississippi River- Brainerd	4653649.623	703791.7383	4.142110137	173.910726	18.91	7.03635
77003400	Mississippi River- Brainerd	5134498.658	662045.9579	6.243952201	163.595119	20.435	7.87815
77003500	Mississippi River- Brainerd	3927794.243	964467.0348	9.049344833	238.3249945	8.845	4.07785
77004600	Long Prairie River	3103829.328	691976.3089	5.153674078	170.9910698	7.625	4.4896
77005000	Long Prairie River	1852705.544	673949.0572	5.656981383	166.5364389	5.185	2.7511
77006300	Mississippi River- Brainerd	3985738.663	1187811.383	4.844204322	293.514585	6.405	3.41295
77006600	Long Prairie River	1888958.721	871549.8155	9.081642538	215.3646496	4.27	2.16855
77006700	Long Prairie River	3952896.286	952307.1098	9.088577629	235.3202117	7.93	4.1968
77007600	Long Prairie River	999313.0728	505678.4125	7.028693529	124.955857	6.405	1.97945
77008800	Long Prairie River	2805292.006	468554.8156	7.997630332	115.7824164	11.895	5.95055
77009500	Sauk River	995877.8773	210115.0943	2.588632949	51.92057054	13.725	4.7458

77009600	Sauk River	719364.9731	209390.768	3.671343639	51.74158559	8.8145	3.4404
77010500	Long Prairie River	4156476.638	820127.481	8.328935131	202.657914	9.3025	5.10265
77012000	Long Prairie River	6290663.491	584050.8346	3.282673267	144.3221043	25.62	10.7848
77012800	Long Prairie River	1281067.986	488880.6728	3.111868367	120.8050452	7.2895	2.623
77013800	Long Prairie River	1259742.068	338219.2575	4.964636542	83.57579864	10.37	3.9406
77014900	Sauk River	3050495.941	930967.7817	12.31505498	230.0471491	10.98	4.7763
77015001	Sauk River	4173091.907	2086767.098	10.49313544	515.6513797	5.795	2.2509
77016000	Sauk River	2496375.092	561163.8991	9.514472714	138.6666193	7.625	4.453
77016300	Sauk River	1335628.688	471509.6392	8.834786685	116.5125693	5.795	2.8365
77016400	Sauk River	3803568.987	1122869.497	12.888367	277.4670954	7.747	3.2879
77018100	Sauk River	6512031.468	1571406.417	5.298630634	388.302982	7.015	4.148
77018200	Sauk River	1067952.261	489995.915	7.32112274	121.0806275	4.88	2.18075
77019500	Sauk River	306672.101	275826.5872	3.280272714	68.15823405	2.135	1.11325
77035700	Sauk River	1327467.534	419877.9656	7.572524347	103.7541049	8.845	3.1659
77035800	Sauk River	1144184.593	249648.0367	5.816874195	61.68937334	10.065	4.59025
80003400	Crow Wing River	4474738.183	2155125.546	4.843908948	532.5431202	4.575	2.0801
80003800	Crow Wing River	507924.3531	93055.08136	7.386857143	22.99441138	17.4765	5.4656
80003900	Crow Wing River	2095517.79	460922.5811	3.72009435	113.8964502	14.3655	4.5506
81001401	Cannon River	7925021.335	2625479.041	0.014166691	648.77	7.625	3.019499884
81001500	Cannon River	737929.6932	496306.4716	0.00261458	122.64	2.44	1.488400035
82001400	Lower St. Croix River	1046013.818	552896.1126	12.15992037	136.6236048	8.845	1.89405
82002100	Lower St. Croix River	584874.6567	412475.6412	7.272851956	101.9249507	6.71	1.44265
82002300	Lower St. Croix River	817892.923	177215.1095	9.547633682	43.79080724	13.6945	4.62075
82002500	Lower St. Croix River	214466.3145	164628.8173	3.669883527	40.68066671	2.6535	1.30845
82003100	Lower St. Croix River	233980.2965	492516.7138	11.52770533	121.7035304	1.9825	0.4758
82003300	Lower St. Croix River	133685.804	162759.975	8.446561108	40.21886572	6.405	0.8235
82003400	Lower St. Croix River	293082.5259	189059.2123	9.641397154	46.71754879	8.235	1.6714
82004400	Lower St. Croix River	559953.3088	202755.2966	4.784351145	50.10192492	10.37	2.867

82004600	Lower St. Croix River	7361483.645	821710.6599	15.00891736	203.0491261	20.2215	8.97005
82004900	Lower St. Croix River	13954694.06	1849560.327	17.86335249	457.0363102	20.13	7.55485
82005200	Mississippi River- Twin Cities	24172208.84	7281199.806	10.04299518	1799.223656	15.25	3.54105
82005900	Lower St. Croix River	1117654.306	306978.6046	6.783367933	75.8560652	7.625	3.7454
82008000	Lower St. Croix River	514356.4903	371603.9375	8.419165197	91.82533273	10.2785	1.4518
82008700	Mississippi River- Twin Cities	141593.4466	110000.3017	8.668475803	27.18166651	4.819	1.82695
82009100	Mississippi River- Twin Cities	478547.5381	422680.3905	4.544982057	104.4465991	4.6665	1.22
82009200	Mississippi River- Twin Cities	1009270.201	234254.4848	6.608831575	57.88554383	12.505	4.41335
82010100	Lower St. Croix River	1450222.35	635599.0375	9.89854315	157.0599426	7.32	2.28445
82010300	Lower St. Croix River	806588.9125	352622.6791	7.990463215	87.13496162	4.4225	2.28445
82010400	Lower St. Croix River	2466700.137	618152.7106	7.722950108	152.7488613	11.834	3.96195
82010600	Lower St. Croix River	15408095.69	1039309.039	8.950268817	256.8188565	38.735	14.84435
82011800	Lower St. Croix River	1137005.449	255576.7304	8.054316752	63.15438546	10.37	4.453
82012200	Mississippi River- Twin Cities	890166.312	710247.4772	7.02836455	175.5059738	8.9975	1.25355
82013000	Mississippi River- Twin Cities	263693.8249	214956.3647	5.342857143	53.1168745	7.625	1.22915
82015300	Mississippi River- Twin Cities	530649.5927	538793.2569	7.130172414	133.1387133	4.697	1.0065
82016200	Lower St. Croix River	263934.007	119700.6742	1.566744731	29.57868076	7.8995	2.21125
82016300	Mississippi River- Twin Cities	5978631.257	1735912.665	2.753897955	428.9533614	8.54	3.44955
86006600	Mississippi River- St. Cloud	2013131.509	403962.7302	7.158984234	99.82136454	15.8295	4.9898
86006700	Mississippi River- St. Cloud	241383.2086	69180.67153	4.9	17.09491623	10.492	3.49225
86006800	Mississippi River- St. Cloud	392161.1655	132925.9803	3.528767123	32.84672506	11.102	2.9524
86006900	Mississippi River- St. Cloud	1345414.658	388671.5565	6.890943219	96.04283324	10.0345	3.4648
86007000	Mississippi River- St. Cloud	2609653.087	447966.5808	7.074374255	110.6949528	12.2	5.88345
86007100	Mississippi River- St. Cloud	126756.6056	110988.7482	7.838464971	27.42591695	2.745	1.14375

86007200	Mississippi River- St. Cloud	488817.0138	368496.1155	14.92289253	91.05737318	8.2045	1.32675
86007300	Mississippi River- St. Cloud	1184929.462	835139.6195	17.68997594	206.3674943	14.0605	1.79645
86007302	Mississippi River- St. Cloud	920604.8581	146323.1323	5.397121743	36.15723343	17.9035	6.29825
86009400	Mississippi River- St. Cloud	157682.1098	126554.7985	5.309278351	31.27237175	2.745	1.24745
86009500	Mississippi River- St. Cloud	1077026.288	396228.0662	6.23004151	97.91008744	15.86	2.7206
86013900	Mississippi River- St. Cloud	698060.9312	517425.6987	5.704873027	127.8586747	4.636	1.35115
86014000	Mississippi River- St. Cloud	1699903.26	334740.6098	7.468569543	82.71620608	12.2	5.08435
86014600	Mississippi River- St. Cloud	5103050.283	912672.3949	7.028760096	225.5262603	18.178	5.55405
86014700	Mississippi River- St. Cloud	639310.3576	146027.103	7.61191912	36.08408299	10.065	4.38285
86014800	Mississippi River- St. Cloud	3311107.613	772400.3499	8.018444322	190.8642831	11.529	4.38895
86015200	Mississippi River- St. Cloud	1079172.928	807884.3001	7.038984287	199.6325582	2.5925	1.30845
86015300	Mississippi River- St. Cloud	590017.8421	173315.9457	5.778233438	42.82730288	8.113	3.2452
86015600	Mississippi River- St. Cloud	8442026.746	793318.6843	7.442801727	196.0333161	30.988	10.70245
86016300	Mississippi River- St. Cloud	2776219.246	946407.7025	4.255879953	233.8624363	10.3395	3.74235
86016400	Mississippi River- St. Cloud	758004.2083	370780.9425	6.534249822	91.62196625	7.32	2.04655
86016800	Mississippi River- St. Cloud	2969236.736	566459.9022	5.487255925	139.9752902	14.9145	5.5083
86017100	Mississippi River- St. Cloud	881621.7213	238475.1148	2.616450032	58.92848422	12.383	3.7027
86017600	Mississippi River- St. Cloud	793982.3945	290648.7678	7.091893721	71.82087465	7.32	2.73585
86018300	Mississippi River- St. Cloud	1542461.955	393953.5066	5.800864048	97.34803153	11.59	4.03515
86020800	Mississippi River- St. Cloud	1778313.589	1185208.245	6.43838115	292.8713355	3.355	1.50365
86021100	Mississippi River- St. Cloud	587225.3679	406061.5438	5.668734003	100.3399927	2.745	1.44875
86021200	Mississippi River- St. Cloud	1900845.74	1007841.452	5.610042889	249.0430465	2.4705	1.88795
86021300	Mississippi River- St. Cloud	1417140.018	1101579.047	4.964862385	272.2061107	2.44	1.2871
86022300	Mississippi River- St. Cloud	2779292.032	563666.3535	11.23441616	139.2849893	9.455	5.1057
86022700	Mississippi River- St. Cloud	28496935.68	3198260.468	11.74952539	790.3073729	30.5	9.0036
86022900	Mississippi River- St. Cloud	2097922.554	1132089.497	4.447572164	279.7454071	9.15	1.85745
86023000	Mississippi River- St. Cloud	1754055.423	612507.3399	5.758888234	151.3538599	4.575	2.93715
86023300	Mississippi River- St. Cloud	31511400.2	4127765.321	8.892550367	1019.993024	20.618	7.6433

86023400	Mississippi River- St. Cloud	4448787.111	900313.0201	5.032502031	222.4721923	10.37	5.15145
86023800	Mississippi River- St. Cloud	976545.0436	241055.356	3.427725531	59.56607571	15.25	4.0565
86023900	Mississippi River- St. Cloud	1087513.192	201176.0678	5.627827279	49.71168899	12.4745	5.41375
86024700	Mississippi River- St. Cloud	224297.7911	61131.12257	1.721325404	15.10582936	11.224	3.6722
86025100	Mississippi River- St. Cloud	11281025.07	2415979.564	17.22637429	597.0015517	22.448	4.8861
86025201	Mississippi River- St. Cloud	45407023.22	6718270.73	10.02633565	1660.120852	21.35	6.77405
86025202	Mississippi River- St. Cloud	29891511.15	6062790.26	2.225490196	6.10836225	15.25	4.93185
86028600	Mississippi River- St. Cloud	873382.2612	192763.2157	4.163232323	47.63282794	10.98	4.53535
86032000	Mississippi River- St. Cloud	144934.1201	31967.06231	0.346581876	7.899233125	9.455	4.5384