A STATISTICAL ANALYSIS OF STREAMFLOW TRENDS FOR THE STATE OF MICHIGAN

By

George H. Wimbrow II

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Civil Engineering

2012

ABSTRACT

A STATISTICAL ANALYSIS OF STREAMFLOW TRENDS FOR THE STATE OF MICHIGAN

By

George H. Wimbrow II

Michigan has a unique landscape that is surrounded by the Great Lakes forming two peninsulas, and encompasses 36,000 miles of inland streams and approximately 11,000 inland lakes. The rare landscape of Michigan makes water its primary commodity and resource. It is imperative to have an understanding of how this resource varies within time and space for water resource management purposes. Therefore, a time series analysis was performed on the USGS streamflow gauging stations found across Michigan in an attempt to identify long-term streamflow trends. Also, the streamflow data were compared to precipitation data of equal length to help identify if a cause-effect relationship exists. Using well-known hydrologic statistical techniques the intent of the study was to provide insight into temporal streamflow trends and their interaction spatially. The streamflow and precipitation data were evaluated on daily, seasonal and annual time scales. The analysis proved to be most accurate at predicting trends based on the annual evaluation. The data identified that the majority of stations in the Lower Peninsula experience an increasing trend, while the stations in the Upper Peninsula display a decreasing trend. The relationship between precipitation and streamflow was found to have a direct correlation when both datasets were found to have increasing trends. In addition to precipitation, elevation and land use were found to have a direct correlation with how trends interacted spatially. Some unique cases do occur where trends in streamflow and precipitation opposed one another. Hypotheses for the opposing trends at these locations are provided however these regions require further study and analysis.

ACKNOWLEDGEMENTS

I would like to thank my advisor Mantha S. Phanikumar and my committee, Susan J. Masten and Shu-Guang Li, for the guidance, knowledge and support. They provided valuable insight that helped me complete my thesis.

I would like to thank Jie Niu for his wisdom, support and help. Jie Niu was a key figure in helping me complete this thesis. He was proficient in areas of academia that I lacked and with his help I was able to complete all of my objectives.

Finally, I would like to thank my family for the love, support, comfort and wisdom. My family has been my support structure throughout this entire process. They have helped me overcome many obstacles throughout this process. My family is the most important thing in my life and they are the reason that I have accomplished so much and will continue to strive for excellence.

TABLE OF CONTENTS

CHAPTER 6

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction

Michigan has a unique landscape that is quite different from anywhere else in the United States. Michigan is a state that is not only surrounded by the Great Lakes forming two peninsulas, but also encompasses 36,000 miles of inland streams and approximately 11,000 inland lakes and ponds. The landscape of the state is predominantly a product of glacial erosion. The varying topography and many bodies of water are due to the numerous glacial advances and retreats spanning the last one million years. The large quantity of surface water makes the state of Michigan an intriguing place to analyze past, current and future hydrological trends. To analyze the hydrology of the area the hydrologic cycle must first be examined. The hydrologic cycle has 4 primary stages. The first stage is precipitation. Precipitation in the state of Michigan is commonly found in two forms: rainfall and snowfall. However, intermediate stages between the two do occur, such as sleet and hail. The next stage is the collection and storage of water. The water can be stored in surface reservoirs such as lakes, ponds, streams, rivers, ditches, detention basins, and retention basins. The water can also be stored below the surface in groundwater basins. The two storage systems are interconnected and do not serve as separate entities. They exist in a state of equilibrium by which the water table fluctuates due to inflow from precipitation or outflow by transpiration and evaporation. The process of evaporation, sublimation, and evapotranspiration replenish the water in the atmosphere by retrieval of water from the surface and sub-surface storage systems. The water that is retrieved then condenses in the atmosphere prior to starting the cycle over. The statistical analysis to be conducted focuses on the two primary components of the hydrologic cycle, precipitation and surficial storage systems (streamflow).

Objective

The intent of this research is to perform a time series analysis on the 147 United States Geological Survey (USGS) gauging stations found across Michigan in an attempt to identify long-term streamflow trends. From the statistical analysis techniques the goal is to provide insight into streamflow trends with respect to time and their spatial relationships. The individual and spatial trends can help identify areas of concern for potentially dangerous drops or increases in streamflow that may have a direct effect on the surrounding area. Also, the exploration of the relationship between streamflow and precipitation will be evaluated to help identify if a cause-effect relationship exists between the two sets of data. Trying to identify if precipitation is the cause of increased streamflow, can help one to understand if increases/decreases are caused by natural processes within the hydrologic cycle or are caused by external factors.

To analyze the streamflow data provided by USGS gauging stations, statistical tests for trend analysis were performed and evaluated. To quantify the analysis an additional statistical technique was used to identify the strength and direction of the trend. The streamflow trends at each gauging location were then compared to precipitation trends for a similar time period. The precipitation trends were identified by testing the data with the same statistical techniques. After examining the relationship between the two trends, hypotheses were derived to explain possible reasons for such correlations at individual gauging locations. The streamflow and precipitation trends were then compared spatially to identify any spatial relationships between the two datasets or possible other factors.

Motivation

The intent of this analysis is to understand how key hydrologic processes have changed with respect to time throughout the state of Michigan. The streamflow trends to be identified will be compared on an individual and cumulative basis (spatially) to investigate how streamflow has changed and its implications with regards to water resource management.

Decreasing trends in streamflow in certain regions may be the cause for re-evaluating water resource management plans. Decreasing trends in water resources may need a particular location to re-evaluate the usage and storage levels of water available. Particular locations may need to develop possible mitigation techniques to sustain the current quantity of water available. A reduction in available water could lead to devastating social and economic implications to a region impacting future governmental rules and regulations. The continuous decreasing trends could also have direct economic implications such as severe spikes in cost and limitations on availability of water.

On the other hand, increasing trends in streamflow may impact floodplains within a particular region. Mitigation techniques may need to be developed to protect cropland and urbanized areas. Also, certain areas may need to be rezoned to protect future development and to protect the water from possible future contamination. In addition to impacting floodplains, increases in streamflow may be a product of increased surface water caused by runoff. This could lead to an increase in pollutants in the water. An increase in the levels of pollutants can be dangerous to the environment and ecology of streams. It also impacts the quality of water for local water usage. Collection and treatment of this water may be imperative to protect the community and the environment in the region. Increases in streamflow trends may also have a direct impact on the hydrologic cycle and the climate by changing the amount and or location of the storage of water. This could lead to a warmer wetter region that could change the landscape of the state.

Increasing and decreasing streamflow rates impact the landscape of the state. Michigan's land use is primarily composed of agriculture and forest. A reduction in streamflow and available water may have serious future implications on the ability to harvest and support plant and animal life. Similarly, increasing trends in streamflow and precipitation may have a positive impact on both the support of vegetation but also on the cost to produce crops within the region.

Literature Review

Streamflow analyses have been conducted in a variety of forms. Analysis has been done on a national level, such as the analysis of streamflow data for Switzerland and its relationship to climatic data. In Switzerland, a relationship between increased streamflow and increased seasonal runoff in the winter, spring and autumn was identified (Birsan et al. 2005). Precipitation was also analyzed but there was not enough evidence to support the conclusion that precipitation was the cause of the variances in the streamflow data (Birsan et al. 2005). The last important observation in this study was the identification of when and where the runoff was most significant. The winter runoff had the most pronounced influence on streamflow of any season; this is mostly likely due to the decrease in days of subzero temperatures (Birsan et al. 2005). It was found that the most substantial increase in runoff was in the mountain basin region, where the ablation zone on glaciers seems to be increasing.

A national level study was also conducted in Turkey. In this study the relationship between precipitation, temperature and streamflow data were examined. From the 30 year period of collected data, a direct relationship between the precipitation and streamflow data were observed (Kalayci and Kahya, 2006). However, during periods of drought, minimal changes were seen in precipitation data while streamflow data decreased significantly (Kalayci and Kahya, 2006). This is to be attributed to the increase in temperature during these periods of drought causing an increase in evapotranspiration counteracting the amount of precipitation at a higher rate (Kalayci and Kahya, 2006). This study was able to successfully identify the hydrologic relationship between streamflow data and climate (Kalayci and Kahya, 2006).

A geographical region study was conducted to observe trends in streamflow data. In the Nordic region, streamflow data were analyzed for three different time periods. From each of the time periods, a distinct increase in winter, spring, and annual streamflow data were observed (Wilson et al. 2010). The increase in streamflow data were compared to air temperature for the same region over the same time periods. The increase in streamflow data were found to be a byproduct of the increase in air temperature in the region (Wilson et al. 2010). This can be seen by the increases in streamflow in the winter and spring months. The increase in streamflow for these two seasons is caused by an increase in snowmelt runoff contributing to greater streamflow due to increase in temperature (Wilson et al. 2010). The intent of this analysis is to help create future projections of climatic and streamflow changes.

Another international study performed on a regional level can be found in Victoria, Australia. The intent of the study was to analyze trends in precipitation in the Yarra River catchment basin.

The Yarra River catchment is the main source of water that supplies the city of Victoria and is crucial for continued development in the region. The precipitation data were evaluated using the Mann-Kendall test similar to most hydrologic statistical evaluations. The data were also evaluated using Sen's Slope Estimator and was evaluated for pre-whitening. Pre-whitening is the process of removing the effects of autocorrelation from the dataset. After an extensive literature review it was determined that removing autocorrelation from large sets of data with small Sen's Slopes has a minimal impact on trend analysis (Yue and Wang 2002, a,b). In fact, it was found that by removing autocorrelation by pre-whitening actually will remove a portion of the trend and provide false results (Barua et al., 2012). The Mann-Kendall test was performed on the precipitation data from 1953-2006 on a monthly and annual basis. From the analysis a decreasing trend in precipitation was observed on both the seasonal and annual level. This is of major concern for if this trend continues major drought may impact the region. It was determined that the drought response plan for this region needs to be amend as the data indicated that future water resources issues are not handled in the current revision (Barua et al., 2012).

Analysis was conducted on the regional level to observe the impact of land use and precipitation on streamflow data. Analysis has been conducted for the Mississippi River Basin, determining that streamflow and baseflow have increased due to increase in precipitation in the basin (Zhang and Schilling, 2006). The gauging stations have also been significantly impacted by the land use in the area. The area has been dominated by agricultural land-use (Zhang and Schilling, 2006). In the recent history, however, the crop has transitioned from perennial crop to seasonal crop (Zhang and Schilling, 2006). This adjustment has led to increased filtration (groundwater recharge), decreased surface water runoff, decreased evapotranspiration and increased baseflow

(Zhang and Schilling, 2006). Therefore, the increase in streamflow is a byproduct of the increase in baseflow contributions to streams (Zhang and Schilling, 2006). It is known that baseflow is a major contributing factor to these streams because of the increase in nitrate levels in the water which is a product of groundwater transport (Zhang and Schilling, 2006).

Similarly, the impact of land use changes in streamflow trends were analyzed in the Great Lakes Region using the VIC hydrologic model. The region was subdivided into five regions. The only region with a significant annual streamflow trend was the Lower Peninsula of Michigan/Northern Wisconsin region (Dazhi and Cherkauer, 2009). It was determined that the highest variations in streamflow data were found to be in the winter months (Dazhi and Cherkauer, 2009). The highest streamflow data were not found at periods of peak precipitation for this region but rather was found in April, due to snowmelt runoff (Dazhi and Cherkauer, 2009). It was also determined that regions with greater topographic relief and regions with more forest cover were found to have greater streamflow trends (Dazhi and Cherkauer, 2009). This information is important and may similarly impact streamflow trends for the state of Michigan.

Streamflow analysis has also been done on a state level. Streamflow data and its relationship to farmland irrigation were analyzed in the state of Indiana (Kumar et al., 2009). This study provided a comparative analysis of statistical types and lengths of studies for streamflow data. The data were analyzed using multiple versions of the Mann-Kendall test for different time series. The Mann-Kendall test provided a trending relationship for a large portion of the sites within the state of Indiana (Kumar et al., 2009). However, when autocorrelation was considered when analyzing the data, a drastic reduction in the number of stations that produced viable trends was found (Kumar et al., 2009). This same effect from autocorrelation cannot be found within the precipitation data. Therefore it is expected that some other source is more directly related to the variations in streamflow. It is important to note that it was identified that a correlation exists between low flow streamflow data and precipitation data (Kumar et al., 2009). This study further divulged into the uniqueness of the streamflow data and found that subsurface tile drains had an impact on high flow stream data. It was observed that high flows were reduced while low flows were increased due to subsurface drainage tiles (Kumar et al., 2009).

This analysis being done on the state of Michigan directly correlates with the previously mentioned studies, but is unique in its regard to be the first to explore the streamflow trends for the entire state of Michigan using statistical techniques, as well as to identify if any relationship between precipitation and streamflow exists.

CHAPTER 2

Study Area

The state of Michigan is approximately 57,022 mi^2 of which 16,439 mi^2 comprises of Michigan's Upper Peninsula. In addition to the land mass of Michigan, the surrounding Great Lakes are approximately 38.575mi^2 in size. The majority of Michigan is dominated by forest cover, cropland and inland lakes and streams (Figure 1). In Michigan there are approximately 36,000 streams and 11,000 lakes (Figure 2). Major urbanization consists of less than 5% of the state's land use.

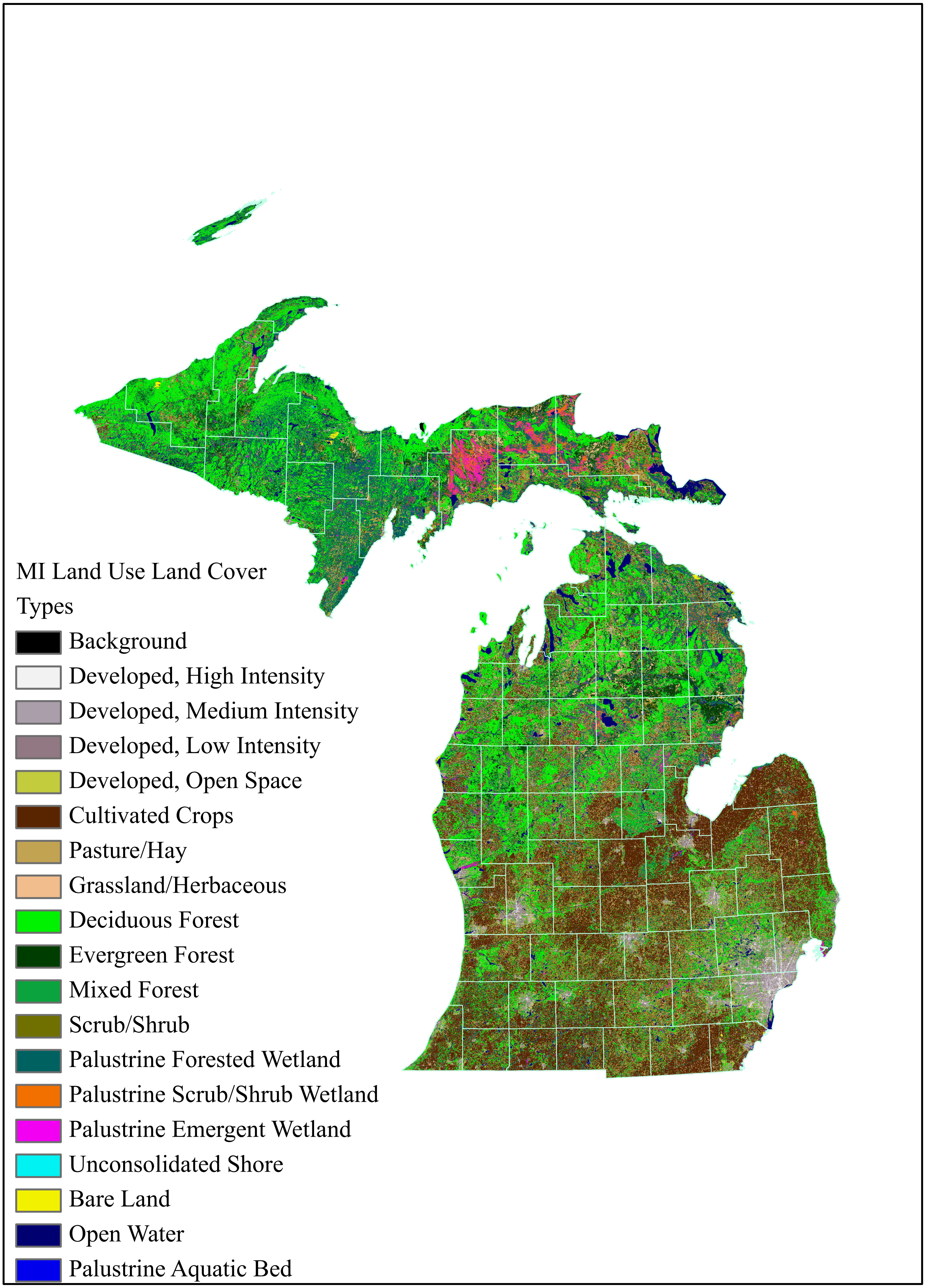


Figure 1. Michigan Land Use and Land Cover (For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of the thesis)

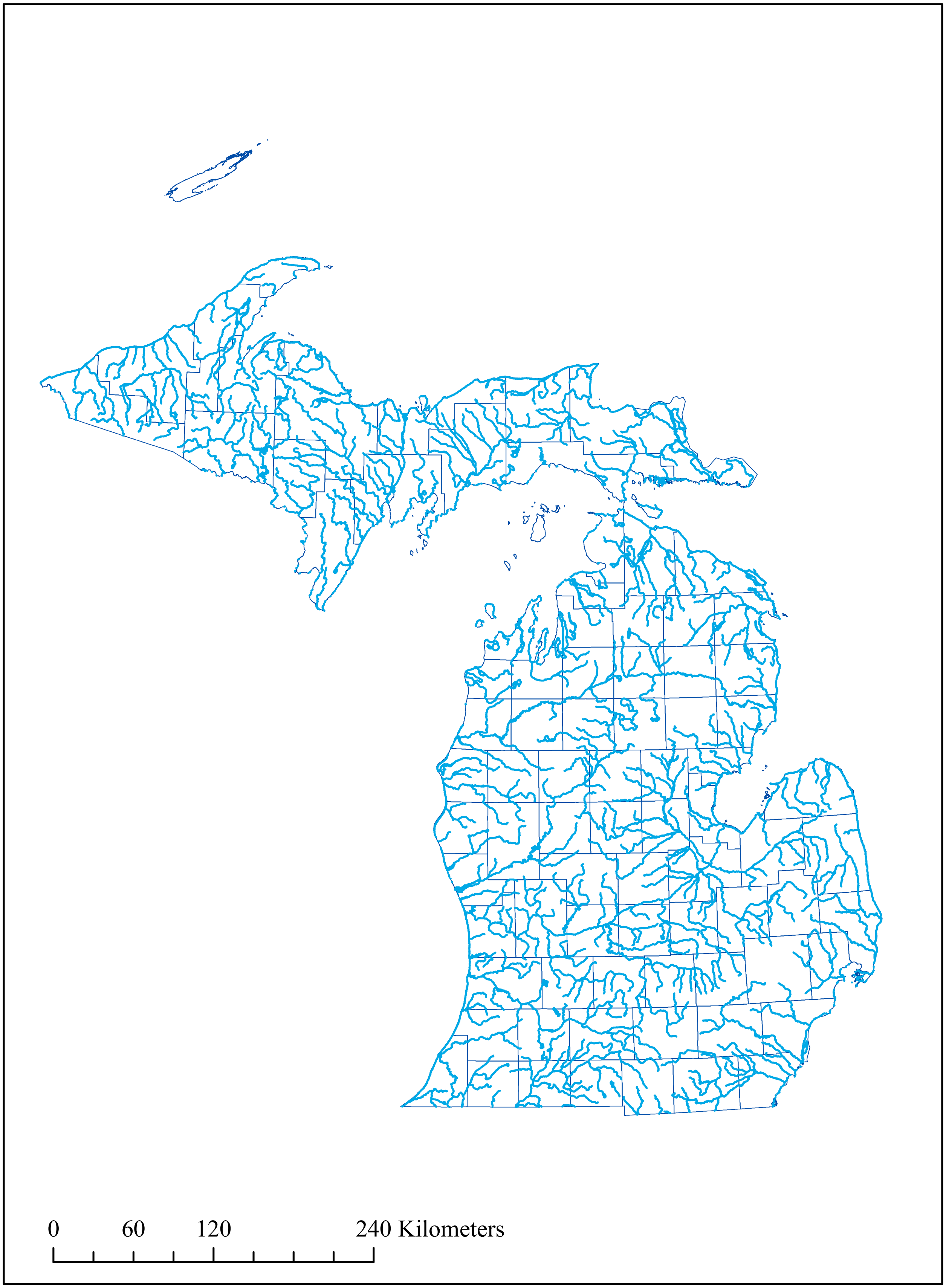


Figure 2. State Map of Michigan with All Major Streams

The terrain of Michigan is subtle with rolling hills that are the remnants of glacial deposits. The geological content of Michigan consists of a mix of moraine and glacial till as well as large deposits of sand and gravel intermixed throughout the state (Figure 3). Along with the geological content, the regression of the glaciers produced low, gradually adjusting topography with many bodies of water formed by glacier movement, glacial lakes and stagnant melting (Figure 4). The Lower Peninsula has a consistent elevation pattern that ranges between 300ft – 600ft above sea level. In the northern central region (Grayling, Michigan and Gaylord, Michigan) elevations do exceed these normal levels and reach a maximum of about 1200ft above sea level. The topography in the Upper Peninsula is substantially different. Maximum elevations can reach between 1800ft – 3000ft above sea level along the central and southern area of the western part of the peninsula. The terrain gradually decreases eastward and where the elevation is about 300ft – 600ft above sea level from the central part of the peninsula eastward.

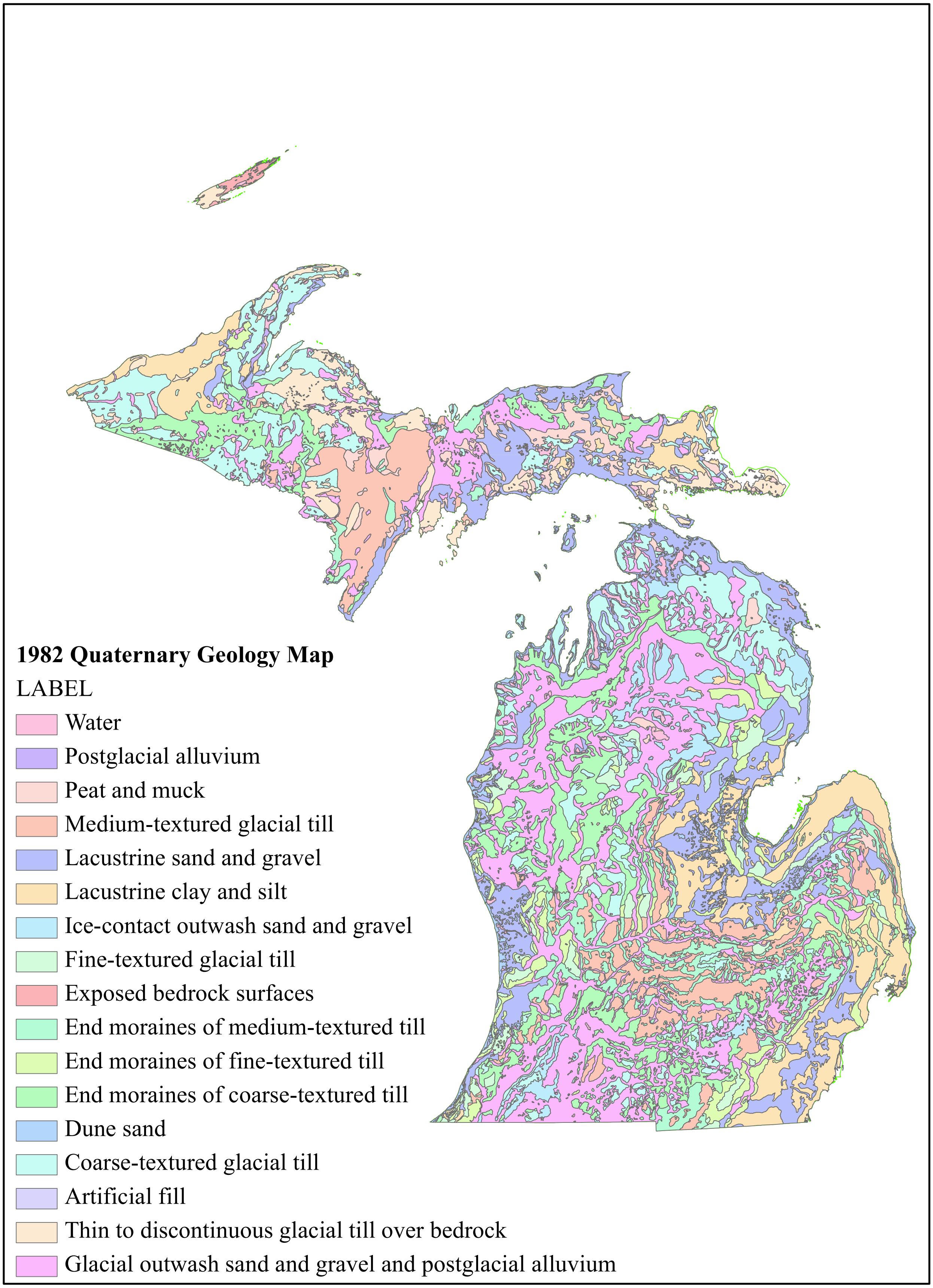


Figure 3. Quaternary Geology Map of Michigan

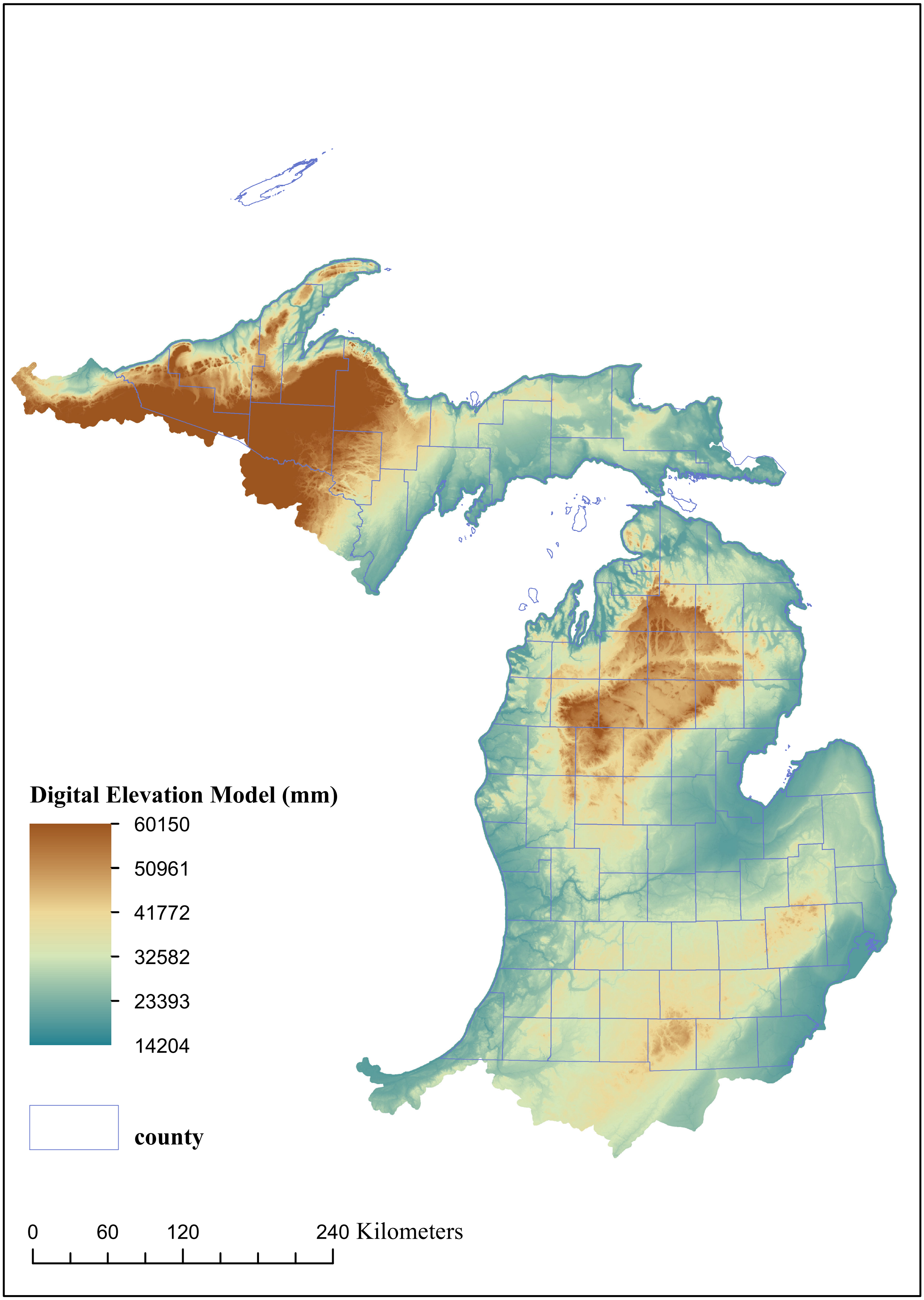


Figure 04. Digital Elevation Map of Michigan

The average annual precipitation is about 31” for the state of Michigan. The peak of the precipitation is in the growing season, when the temperature is about 60℉-80℉ where it reaches about 3.5”-4.0” per month. During the winter season, when the temperature is about 20℉-35℉, the state only receives about 1.5”-2.0” per month. Precipitation is the primary source for replenishment of surface bodies of water. During the winter season the precipitation collected is commonly in the form of snow, this leads to less runoff and even frozen bodies of water that are incapable of receiving recharge. Therefore it is expected to observe minimal streamflow during the winter months and a sharp peak during the spring months due to thawing and snowmelt runoff. The ranges of these peaks vary throughout the state. The western side of Michigan accumulates more snow during the winter months due to lake effect and therefore is expected to see greater streamflow values as runoff increases in the spring months. Similarly the snow accumulation increases linearly with the increase in latitude.

Streamflow Data

To evaluate the streamflow trends in the state of Michigan and determine the significance of these findings, data were analyzed using the Matlab R2011a (The Mathworks Inc., 2011) and Systat-13 Software (Systat Inc., San Jose, CA). The data collected and evaluated was the daily streamflow data from USGS National Weather Information System (NWIS) gauging stations. The state of Michigan has approximately one hundred forty-seven gauging stations with daily streamflow data from the Upper and Lower Peninsula (Figure 5).

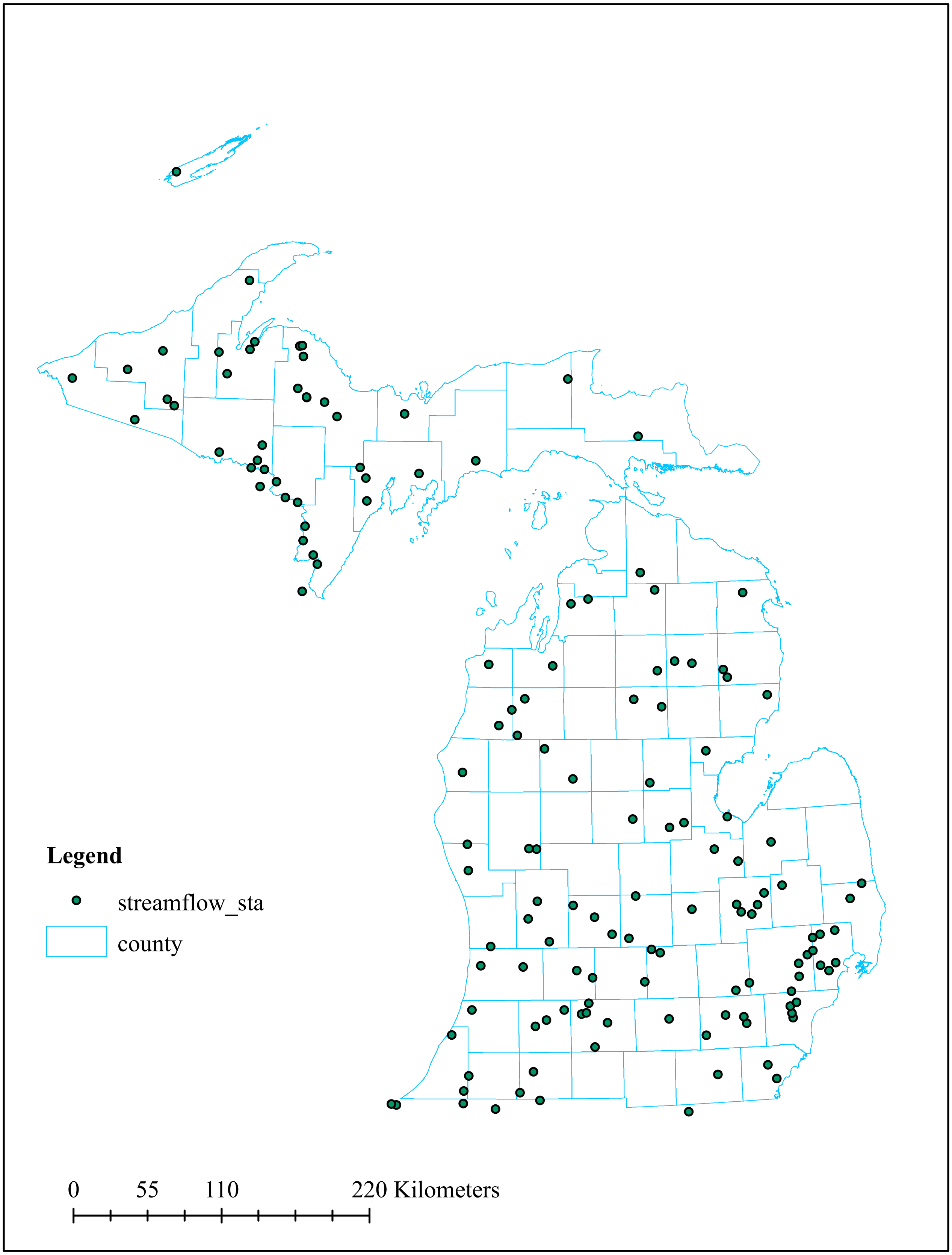


Figure 5. Location of USGS Streamflow Stations

Approximately a third of the stations are from the Upper Peninsula. Each of the stations was analyzed in an attempt to capitalize on the maximum amount of data available. Data were analyzed from the earliest record of daily streamflow data for that station until November 2010. A breakdown of the number of stations for each particular time period can be seen below. For a particular time evaluation period please refer to the details in Table 6.

Table 1. Breakdown of Daily Streamflow Analysis Periods

Time Period of Analysis	Number of Stations
1901-1930	19
1931-1960	69
1961-1990	32
1991-2011	27

It is important to note that the data sets provided by the USGS gauging stations were not always complete. There did arise occasions at nearly every station where single data points, multiple data points or large sections of data were not present. To minimize the impact of these absent data points the data were analyzed without taking the non-existent streamflow data into account. Similarly, issues arose when ice was found in the streams and impacted the streamflow measurement. The ice in these streams cannot be accounted as no streamflow because water may continue to flow however the gauge is incapable of reading and collecting data. Therefore, in the same fashion as the non-existent data, the data impacted by ice were removed from the analysis.

Precipitation Data

The precipitation data were analyzed for the entire state of Michigan using the same statistical techniques as the streamflow data. However, the precipitation data that was collected was scattered across the state of Michigan at 563 different weather stations (Figure 6). The precipitation data were attempted to be collected from January 01, 1901 until April 01, 2011 whenever possible. However, the amount of data available at each location varied.

To make the data comparable to the streamflow data, the precipitation data were interpolated to provide a continuous time series of precipitation data at the streamflow gauging stations. The data were spatially interpolated using Delaunay Triangulation and Veronoi tessellation as implemented in Matlab. The interpolation method used the natural neighbor interpolation and created Theissen Polygons by which the data were interpolated to from the precipitation stations to the gauging streamflow stations. (The Mathworks Inc., 2011). Through the interpolation a larger temporal range of data were created from neighboring stations with different time series of data available. However, multiple gauging station locations fell outside of the region of available precipitation data. When this occurred the interpolation could not be successfully completed with any type of accuracy. Therefore, if the streamflow data for that station was found to have a statistically significant trend, the precipitation data from the closest rain gauge station that had substantial available data were used as an approximation for the precipitation for that streamflow station(i.e., nearest neighbor approximation). For the stations that were not able to be interpolated and no statistically significant streamflow trends were present, the statistically analysis was not performed.

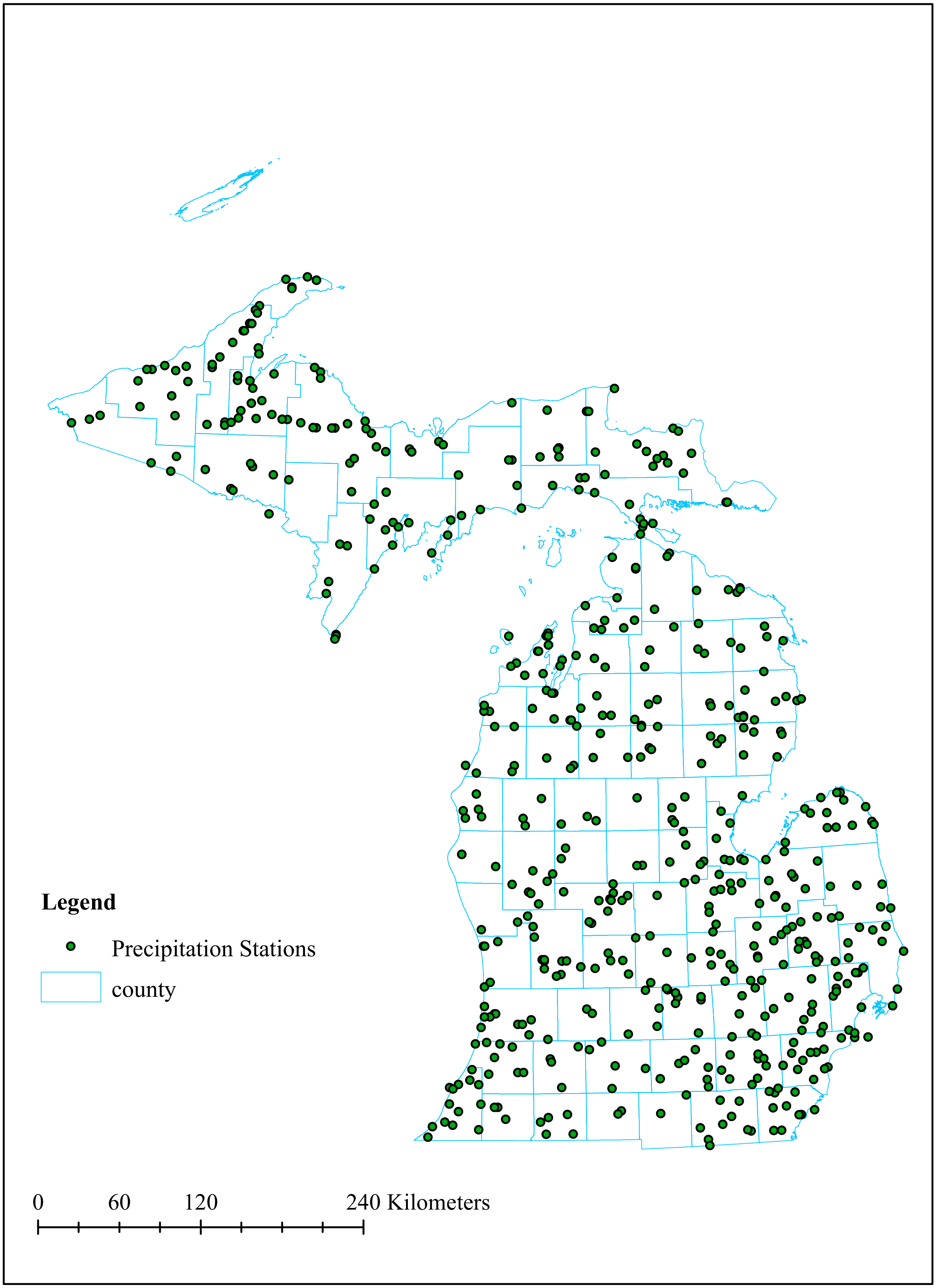


Figure 6. Precipitation Station Location

CHAPTER 3

Methodology

Prior to performing any type of statistical analysis, the terminology and reason for such tests needs to be defined and outlined. The tests to be conducted are time-series analyses on streamflow and precipitation data. A time series is a set of data that has an associated time value. The data should be separated into equal time intervals. A time series consists of four components: trend, seasonality, dependent stochastic component and independent residual component (Shahin et al., 1993). The trend and seasonality components comprise of the systematic pattern that is assumed to be present in every time series analysis. The dependent stochastic component and the independent residual component comprise of the random error or noise that is assumed to be prevalent in all time series data. The intent of the hydrologic analysis in this study is to identify the systematic patterns in streamflow and take into account the possible random error that may influence the data.

Hydrologic time series analyses are based on a common set of assumptions: the series is assumed to be homogenous, stationary, has no shifts, and free from trends, with no periodicity and no persistence (Adeloye and Montaseri, 2002). A time series is considered homogenous as long as the data collection method and the environment in which it is done remain unchanged (Machiwal and Jha, 2012). A time series is assumed stationary if statistical properties such as mean and variance do not change based on the interval of time analyzed (Chen and Rao, 2002). Stationary time series do not occur in any natural setting. Therefore, hydrologic time series analysis is based on the assumption that the data is a weakly stationary time series. Weak stationarity is defined as time series where only first and second order moments are dependent on time. Hydrologic time series are assumed to be free of shifts. Shifts are sudden events that cause peaks or valleys in the data (Shahin et al., 1993). Shifts found in hydrologic data are commonly associated with natural disasters, such as tornados or forest fires, and human changes, such as dams or pumping of water. Hydrologic time series are also assumed to be free of trends. They are expected to not experience any gradual changes in the mean value in the positive or negative direction (Shahin et al., 1993). However, trends do exist in the hydrologic time series and the possible reasons for such trends include climate change, urban development, substantial land-use change, and heavy population growth and increased consumption. A time series is assumed to have no periodicity as long as no recurring events take place over a given time period. However, annual and seasonal cycles are commonly found in streamflow and precipitation data in this region. The final assumption associated with hydrologic time series is that there is no persistence. Persistence is defined as the impact of an event in time successive data within that same time series (Shahin et al., 1993). Two types of persistence can impact data, long-term persistence (LTP) and short-term persistence (STP). Short term persistence, also known as short term autocorrelation, is the impact of a previous event on subsequent data point for small time intervals of analysis. STP can be analyzed in two different formats. The data can be analyzed by including the effect of autocorrelation on the data or by removing the autocorrelation from the data. For this analysis the first approach of adjusting the variance to account for autocorrelation is conducted to evaluate the impact of the STP and to identify existing trends by eliminating the ability of autocorrelation to present falsified trends that may or may not exist. Similar to STP, long term persistence evaluates the impact of previous events on the current data but for larger time intervals. The impact of an event in long term persistence is looking beyond a day. An example of where long term persistence has been identified is in the North Atlantic Oscillation (Haslette and Raftery, 1989). It is looking for events that may have long term effects that are misrepresented as trends. However, this is a common problem associated with LTP as it becomes hard to distinguish the difference between LTP and trends (Hirsch and Slack, 1984). Since rainfall and streamflow time series tend to have smaller autocorrelations at the annual scale, the effect of LTP is not a primary concern and is therefore not evaluated in this study (Hirsch and Slack, 1984).

Statistical Techniques

To identify if trends in streamflow data exist, three statistical techniques were used to determine whether the probability distribution has changed (increased or decreased) in relation to time. The three statistical tests conducted for each station were the Mann-Kendall test (MK), The Modified Mann-Kendall test (MKR – Mann-Kendall-Rao), and the Sen's Slope Estimation. Using the Matlab software with predefined statistical scripts for each test streamflow and precipitation data were processed to determine the presence of any unique trends.

The Mann-Kendall test (Mann, 1945; Kendall, 1955) is a non-parametric statistical test commonly used in trend analysis. This method is used to determine if a linear trend exists with respect to time. This statistical test assumes that the data is independent and randomly ordered.

The Mann-Kendall test is testing the null hypothesis H_o, that there is no trend. If the null hypothesis is rejected a trend is observed in the data. To reject the null hypothesis and identify a trend, the p-value must be less than a predetermined significance level (α) of 0.05. To compare the p-value to the significance level for a particular time series of length n (x_1, x_2,…, x_n) the Mann-Kendall test statistic (S) (also known as the tau statistic) must be determined using:

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\mathrm{sgn}(x_j-x_i) \qquad 3.1$$

Where:

$$\mathrm{sgn}(x)=\begin{cases} 1 & \text{for } x>0 \\ 0 & \text{for } x=0 \\ -1 & \text{for } x<0 \end{cases} \qquad 3.2$$

The distribution of the Mann-Kendall statistic S can be approximated by a normal distribution for large n, with the mean, $\bar{x}$(S), and the variance, Var(S). Here x denotes the data point (streamflow or precipitation value) at times i and j (j > i). If x is assumed to be an independent, identically distributed (iid) random variable with no tied data values, then

$$E(S)=\bar{x}(S)=0 \qquad 3.3$$

$$\mathrm{Var}(S)=\sigma^2(S)=\frac{n(n-1)(2n+5)}{18} \qquad 3.4$$

The correction to the variance when some data are tied is:

$$\sigma^2(S)=\sqrt{\frac{n(n-1)(2n+5)-\sum_{i=1}^{n}[t_i(i)(i-1)(2i+5)]}{18}} \qquad 3.5$$

The above equation estimates the standard deviation of the statistic $\sigma(S)$ with correction for ties in the data denoted by t_i, the number of ties of extent i (i.e., a data set with two tied values will have one tie of extent two with i = 2 and $t_2 = 1$).

With the variance of the test statistic known the z-value can be found using the equations below.

$$z=\begin{cases}\dfrac{S-1}{\sqrt{\sigma(S)}} & \text{for } S>0\\ 0 & \text{for } S=0\\ \dfrac{S+1}{\sqrt{\sigma(S)}} & \text{for } S<0\end{cases} \qquad 3.6$$

The z-value is normally distributed. The significance levels (p-value) at a given site for each trend can be determined from (Douglass et al. 2000).

$$p=2[1-\varphi(|z|)] \qquad 3.7$$

where $\varphi(|z|)$ is the cumulative distribution function (CDF) of a standard normal variate. Once the z-value is known, it is compared to the significance level and the null hypothesis is evaluated. The null hypothesis is to be rejected if the p-value is less than or equal to the significance level ($\alpha=0.05$). If the null hypothesis is rejected, the streamflow data has a statistical trend. If the null hypothesis is not rejected, this doesn’t mean a trend is not present, it means it could not be identified by the Mann-Kendall test.

The Mann-Kendall test was chosen to analyze the streamflow data for a multitude of reasons. First, the data being analyzed does not have a known distribution and the Mann-Kendall test uses a non-parametric method capable of identifying trends in unknown distributions. Secondly, the Mann-Kendall is a simple statistical technique with few assumptions that is easy to compute while providing insight into possible linear statistical trends. The Mann- Kendall test is also robust allowing a trend to be identified while eliminating the impact of outliers on the dataset. The major drawback to the Mann-Kendall test is the trending capabilities of the test. The test is only able to identify linear trends. Trends may exist in the dataset that cannot be identified by this statistical test. It is important to note that when a trend is not found by this test, it does not mean a trend does not exist, rather a linear trend was not observed by this statistical method.

The Modified Mann-Kendall test (Hamed and Rao, 1998) is a superior statistical trending tool compared to the original Mann-Kendall test. The Modified Mann-Kendall test has the same assumptions and performs the same statistical test as the Mann-Kendall test. However, the Modified Mann-Kendall test assumes that the data is autocorrelated. Autocorrelation is the residual effect data has on adjacent data with respect to time. Instances of autocorrelation can been found in the streamflow data when the flow is impacted (overestimated) on certain days by previous events. In many cases, the effect of serial correlation on the dataset is neglected which leads to misidentification of trends when no actual trend is present. Making these datasets independent helps to eliminate improper rejections of the null hypothesis when trending is not present or not of statistical significance. The Modified Mann-Kendall test adjusts the variance as follows:

$$\sigma(S)^{*}=\sigma(S)\frac{n}{n^{*}} \tag{3.9}$$

$$\frac{n}{n^{*}}=1+\frac{2}{n(n-1)(n-2)}\sum_{i=1}^{n-1}(n-i)(n-i-1)(n-i-2)r_{i} \tag{3.10}$$

where n is the length of the time series and r_i is the lag-i significant autocorrelation coefficient and (n/n*) is the adjustment factor on the variance to account for the effects of autocorrelation. The adjustment of the variance allows for a determination of a more appropriate p-value to be compared to the significance level (α) to determine if there is a trend in the streamflow data. A disadvantage, in addition to those of the standard Mann-Kendal test, is that if no autocorrelation is present in the data, the Modified Mann-Kendall assumption of autocorrelation will cause no trend to be identified even though a trend may actually exist.

After identifying streamflow trends with the Modified Mann-Kendall test, the data were analyzed using Sen's Method to determine the direction and slope of the change in the streamflow data. Mann-Kendall test is capable of identifying trends in the data but does not have the ability to recognize the strength and direction of those trends. Sen's Method was chosen instead of a linear regression technique for multiple reasons. Sen's Method similar to the Mann-Kendall test is robust against outliers, whereas linear regression is greatly affected by outliers. Also, Sen's Method doesn't require any assumed distribution. This allows for the slope estimation to be as accurate as possible with minimal assumptions. Therefore, Sen's Slope is calculated to help identify the strength and direction of these trends using the equation below.

$$\beta=\text{median}\left(\frac{x_j-x_i}{t_j-t_i}\right) \qquad 3.11$$

Sen's estimator of slope (β) is defined as the median slope for all the time series data (x_1, $x_2,\ldots,x_n$) analyzed over the time (t_1, $t_2,\ldots,t_n$) for entire time series. The change in the median slope allows for determination of whether the streamflow has increased or decreased and at what significance level.

CHAPTER 4

Results

The streamflow data for all 147 USGS gauging stations in the state of Michigan were analyzed to identify any possible existing trends. The streamflow trends were then compared to trends in precipitation at the same locations. Streamflow and precipitation datasets were evaluated using three statistical tests commonly used in the field of hydrology to identify trends. The three statistical tests used were the Original Mann-Kendall Test, the Modified Mann-Kendall Test (Mann-Kendall-Rao) and Sen's Slope Estimator. Each test provides different and useful insight into existing trends in streamflow data. The data were also analyzed in three different temporal formats. The first analysis is based on daily data, the second is an analysis of seasonal data and the final analysis is of annual data. The data for each is presented and discussed below.

Mann-Kendall Test - Daily Streamflow Results

The Mann-Kendall test was performed on all of Michigan's streamflow data. The results of the test can be found in Table 7. The test rejected the null hypothesis at a 95% confidence level for 136 of the 147 stations. Therefore, the presence of a linear trend was found to exist in about 93% of all streamflow data. The locations where no trend was found were scattered across the state and seem to have no foreseeable correlation to each other. The data also does not be seemed to be impacted by different time periods of analysis for each station. Some stations found trends for 110 years of data while other stations were found to have trends for 50 years and as small as 10 years of data.

Modified Mann-Kendall Test - Daily Streamflow Results

The Modified Mann-Kendall test was conducted on the same set of data to provide greater insight into the existence of streamflow trends as well as to account for the effect of serial correlation on the Mann-Kendall results. The Modified Mann-Kendall test had distinctly different results than the original Mann-Kendall test. This test found 77 of the 147 stations to have a trend with a 95% confidence level. The identification and adjustment to account for the serial correlation present in the calculation of variance and the p-value reduced the number of stations with identifiable trends by 40.4%. Therefore, the Modified Mann-Kendall test found about 52.7% of data to have a linear trend in the state of Michigan. Similar to the Mann-Kendall test a wide variety of periods of analysis were found to have trends.

Sen's Method - Daily Streamflow Results

After successfully narrowing down the data to more properly identify stations that have existing trends, the data were evaluated with the SYSTAT-13 software to determine the strength and direction of these trends. Sen's Slope was calculated for all 77 stations that were found to have trends with the Mann-Kendall-Rao Test. A predetermined significance level of 0.01 for the slope was used to evaluate the data. Of the 77 stations found to have trends with the Mann-Kendall-Rao test, 23 were found to have significant results. The 23 stations have a variety of significant slopes ranging from 0.26 to -1.68. Of the 23 stations that were determined to have strong identifiable trends in either the positive or negative trends, 4 stations had slopes that were significantly greater than the rest of the data. The 4 stations with the most significant slopes can be seen highlighted in grey in Table 2 below.

Table 2. Stations with Significant Trending Slopes

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's Slope**
SAGINAW RIVER AT SAGINAW, MI	1	0	1	0	-1.676
MENOMINEE RIVER AT WHITE RAPIDS DAM NEAR BANAT, MI	1	0	1	0	-0.144
MENOMINEE RIVER AT NIAGARA, WI	1	0	1	0	-0.090
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1	0	1	0.0021	-0.090
MENOMINEE RIVER NEAR VULCAN, MI	1	0	1	0	-0.068
GRAND RIVER AT GRAND RAPIDS, MI	1	0	1	0.0043	-0.048
AU SABLE RIVER NEAR AU SABLE, MI	1	0	1	0	-0.027
AU SABLE RIVER NEAR RED OAK, MI	1	0	1	0	-0.023
PLATTE RIVER AT HONOR, MI	1	0	1	0	-0.003
JUDAY CREEK NEAR SOUTH BEND, IN	1	0	1	0.0119	-0.001
MANISTEE RIVER NEAR MESICK, MI	1	0	1	0	0.016
AU SABLE RIVER NEAR CURTISVILLE, MI	1	0	1	0	0.016
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0	1	0	0.018
TITTABAWASSEE RIVER AT MIDLAND, MI	1	0	1	0.0283	0.018
THORNAPPLE RIVER NEAR CALEDONIA, MI	1	0	1	0.0026	0.018
TRAIL CREEK AT MICHIGAN CITY HARBOR, IN	1	0	1	0	0.018
GRAND RIVER AT PORTLAND, MI	1	0	1	0.0068	0.022
ST. JOSEPH RIVER AT ELKHART, IN	1	0	1	0	0.024
ST. JOSEPH RIVER AT THREE RIVERS, MI	1	0	1	0.0035	0.027
GRAND RIVER AT IONIA, MI	1	0	1	0.0251	0.029
MANISTEE RIVER NEAR WELLSTON, MI	1	0	1	0	0.033
ST. JOSEPH RIVER AT NILES, MI	1	0	1	0	0.047
KALAMAZOO RIVER NEAR NEW RICHMOND, MI	1	0	1	0	0.262

** MK – Mann-Kendall Test

***MKR – Mann-Kendall-Rao Test

Some of the stations seen in the table above and in the appendices are named using neighboring states of Michigan, such as Indiana (IN), Wisconsin (WI) and Ohio (OH). These stations are named based on the nearest neighboring town but the actual gauging stations do fall with the

Michigan State boundaries and were therefore analyzed as streamflow data for the state of Michigan.

Additional information that the Sen’s Slope analysis provided that was insightful is that relationship of positive and negative trends exist throughout the state. Of the 77 stations found to have significant trends based on the Mann-Kendall Rao test, 17 of those stations have negative trends in streamflow, 10 of which were analyzed to be significant. Contrastingly, 52 of the 77 stations were found to have a positive slope or increasing trend in streamflow. However, only 13 of these stations were found to have a significant positive slope. The remaining 8 stations were found to have extremely small slopes that were assumed to be zero when analyzed using Sen’s Method. This is interesting because both Mann-Kendall tests identified a linear trend in the data however a slope of such insignificance would not provide any type of trending unless it has remained constant over the time period evaluated.

It is interesting to note that through the progression of analysis from The Mann-Kendall test to the Modified Mann-Kendall test to Sen’s Method, a reduction of approximately 40% of data that was found to have trends of significance occurred through each evaluation. Another potential note of interest is that the 4 significant data trends found in the streamflow data all comprise of less than 20 years of streamflow except the Saginaw River at Saginaw dataset, which dates back to 1904. However, the Saginaw River at Saginaw data sets includes many gaps in the dataset and the majority of data is from the past decade. To counteract the effects of missing data which may lead to inaccurate results, the data were truncated to allow for evaluation of only continuous datasets.

Continuous Daily Streamflow and Precipitation Results

Upon further analysis, periods of missing data seem to have a drastic impact on the strength of the trends found. Many of the stations have significant time periods of missing data within the scope of the entire dataset. Therefore, the data were truncated to only represent periods of continuous streamflow. The data were truncated to include only data that were considered continuous or having less than a month of missing data. Periods of larger than a month were considered too large to assume potential values and the impact of the missing values could not be neglected. After the data were truncated, datasets were eliminated if less than 17 years of continuous data existed due to the lack of accurate trend representation by data of smaller periods. The cutoff point of 17 years was chosen because the statistical techniques used were no longer robust against outliers on data that were less than this length in the annual analysis. The elimination of stations without a continuous period of streamflow data for an appropriate length of time eliminated 50 stations from the analysis.

The precipitation data that were interpolated to the streamflow gauging stations was evaluated for gaps within each dataset. From the evaluation an additional 5 stations were eliminated under similar circumstances as continuous precipitation data did not exist for comparison. It is important to note that for these 5 stations that were eliminated, almost no data existed that could be analyzed due to the location of the station and the inability to interpolate data using the natural neighbor technique. However, a large portion of the precipitation dataset was missing one or multiple small periods (1 month) of data due to lack of available precipitation data at a given time period. In these instances, the natural neighbor interpolation technique was abandoned and the precipitation data of the closest station was supplemented into the dataset. This secondary technique is not expected to be as accurate as the natural neighbor interpolation technique however; it is satisfactory for such small periods of data and should have minimal impact on the analysis. Therefore the analysis was reduced to 92 stations with complete datasets of both precipitation and streamflow. Of the 55 stations eliminated, 9 of the 23 stations with significant daily non-continuous streamflow trends were eliminated. Of the 9 stations, 3 of the 4 stations that were found to have steepest Sen's Slope for streamflow were removed due to large chunks of missing data and inaccurate representation of streamflow trends without continuous record. The only station that still was available for analysis was the Menominee River at Niagara; however the strength of the trend present in the daily streamflow data decreased with the elimination of gaps of data.

After truncating the data to only stations of continuous periods of streamflow and precipitation, the data were reanalyzed using the Mann-Kendall test, the Modified Mann-Kendall test and Sen's Method. The Mann-Kendall test found that 83 of 92 stations had some sort of trend present in streamflow data as seen in Table 9. The Modified Mann-Kendall test found 59 of the 92 gauging stations rejected the null hypothesis and found an existing linear trend in streamflow data (Table 9). Adjusting the variance to account for the effects of serial correlation reduced the amount of stations with trends by 24, almost one third of the data. Of the 59 stations that rejected the null hypothesis, approximately 41% of the stations had a negative or decreasing trend in streamflow data. The remaining 59% were found to have a positive Sen's Slope relating to an increasing trend in streamflow data.

The streamflow results were then to be compared to the precipitation results using the same statistical techniques. The precipitation results were inconclusive on a daily analysis. The Mann-Kendall test rejected the null-hypothesis for precipitation for 49 of the 83 stations that found trends in streamflow analysis (Table 9). However, the adjustment of the variance to account for serial correlation was found to be imperative in the analysis of precipitation data. Using the Modified Mann-Kendall test which accounts for the impact of short term serial correlation, the null hypothesis is accepted verifying that no trend in precipitation exists at any gauging station. All 92 stations evaluated had a Sen's Slope value of zero further indicating that no trend is present in precipitation (Table 10). A comparative analysis of an increasing trend in streamflow compared to the non-existent trend in precipitation can be seen in Figure 7 below. It is expected that on a daily analysis of precipitation that no trends exist, because of the high frequency of zero precipitation causing a horizontal trend with sporadic variations representing the infrequent days that the state of Michigan actually has precipitation.

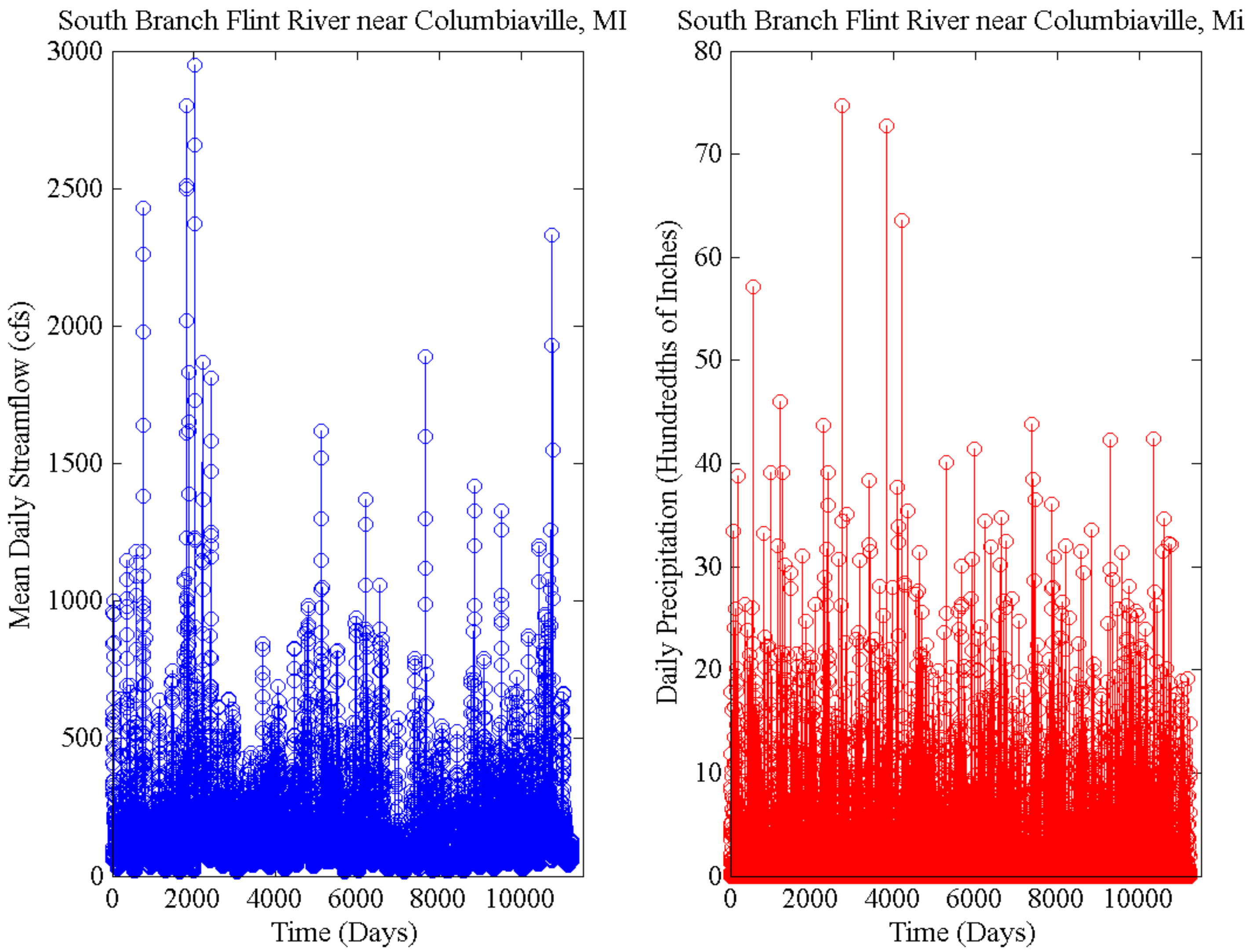


Figure 7. Daily Precipitation and Streamflow Comparison

Continuous Seasonal Streamflow and Precipitation Results

After determining the inability of the statistical techniques to identify a trend in the daily precipitation data due to the high frequency of days without precipitation, the data for both precipitation and streamflow were evaluated on a seasonal basis. The seasons were divided into four equal periods that matched the seasons experienced in Michigan. The period of each season can be seen in the table below.

Table 3. Season Description

SEASON	START DAY	END DAY
SPRING	20 March	20 June
SUMMER	21 June	21 September
AUTUMN	22 September	21 December
WINTER	22 December	19 March

After determining the period of each season the data were segregated into one of the four seasons in chronological order. The mean of the streamflow and precipitation records for each season were then calculated and entered into a new separate record. This new mean record for each season was then evaluated for the length of the given dataset to identify any existing trends. The data were again evaluated using the same three statistical techniques as the daily streamflow and precipitation data.

The results provided a different insight into the comparative analysis of precipitation and streamflow trends. The Mann-Kendall test found significantly less stations that rejected the null-hypothesis that no trend is present. The daily streamflow data found that about 90% of the stations rejected the null-hypothesis compared to the seasonal streamflow analysis which found only 51% (47 of 92 stations) of the data may have some sort of trend present. The values of the Mann-Kendall test conducted on the seasonal streamflow are also much more comparable to the Modified Mann-Kendall test which suggest, averaging the data over seasonal periods reduces the effect of short term persistence on the data.

The Modified Mann-Kendall test had 44 of the 92 stations reject the null-hypothesis that no linear trend is present (Table 11). The adjustment of the variance to account for serial correlation still identifies falsified trends caused by short term persistence; however the impact of the serial correlation is significantly reduced by averaging the data. Of the 47 stations that the Mann-Kendall test suggested could have a trend, only 8 of those stations were found to not have trends by adjusting for auto-correlation. This is substantially different than the impact that auto-correlation had on the daily streamflow data. It is also important to note that 5 stations that did not identify a trend in streamflow using the Mann-Kendall test rejected the null-hypothesis of the Modified Mann-Kendall test after the adjustment for serial correlation. This type of result was not present in any of the daily data analysis. Therefore, it is important to note that the impact of serial correlation can represent false trends, but also infringe on the ability to find trends that do exist in the dataset.

Sen's Slope was then evaluated for all the stations that rejected the null hypothesis after accounting for serial correlation. It was found that of the 44 stations that rejected the null hypothesis, 10 of those stations identified a decreasing trend in streamflow. This is a reduction of 14 stations from the daily streamflow analysis. The reduction is comprised of 3 new stations that didn't have any daily trends but now have an identifiable negative seasonal trend. Therefore. 17

stations that had negative trends in the daily analysis were found to not have trends in the seasonal analysis. The remaining 34 statistical significant seasonal stations identified an increasing trend in streamflow. Of the 34 stations that identified an increasing trend, 30 stations found a similar increasing trend in the daily analysis. However, 5 station that were present in the daily analysis found no trend in the seasonal analysis and similarly 4 stations rejected the null hypothesis under the seasonal analysis that had no trend identified under the daily analysis.

Another unique difference between the daily analysis and the seasonal analysis is the value of the slopes found. Many of the slopes are significantly greater some by an order of magnitude of 10 or even 100. The significant increase in slope is mostly likely due to the elimination of much of the noise in the data allowing for a more identifiable slope that is associated with the dataset. Sen's Slope takes the average of all the slopes between all the data points. The reduction in the number of data points is expected to impact the relationship greatly which causes the slopes to be greater than those found in the daily analysis.

In addition to comparing the seasonal results to the daily results, the seasonal streamflow data were compared to the seasonal precipitation data to help identify if any correlation between the two datasets exists. The precipitation data were again interpolated to the location of the USGS gauging stations so that a direct comparison could be made. The data were then divided into seasons and the mean value for each season was found. The Mann-Kendall, Modified Mann-Kendall and Sen's Method were performed on the new mean seasonal dataset and compared to the mean seasonal streamflow data.

It was found that the Mann-Kendall test for precipitation data had experienced a similar decrease in stations rejecting the null hypothesis as the streamflow data. The interpolated precipitation data at the streamflow gauging station locations found that 24 of these stations rejected the null hypothesis, therefore identifying a trend in precipitation (Table 13). Of those 24 with significant trends in precipitation, all but one of them had trends in streamflow. Therefore the remaining 31 streamflow stations where a trend may exist do not have trends in precipitation at these locations.

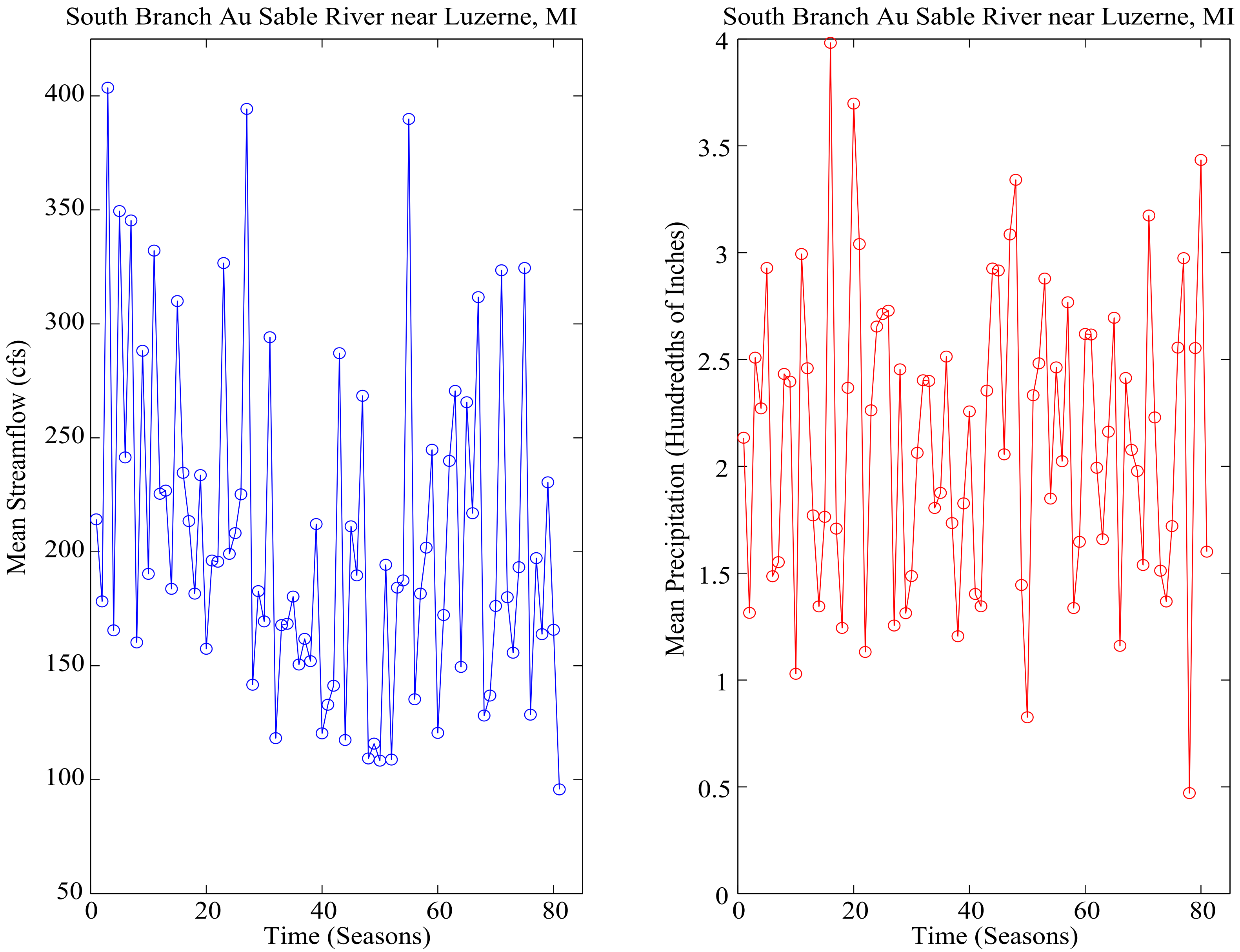
The impact of serial correlation was then evaluated on the precipitation data to see if any trends were a result of prior day's events causing falsified trends. The Mann-Kendall-Rao test found that 29 stations had rejected the null-hypothesis. In addition to the 24 stations that found trends under the Mann-Kendall test, the Mann-Kendall-Rao test found 5 additional stations that found a trend after examining the impact of serial correlation. Of these 29 stations that rejected the null-hypothesis 11 of the stations also had streamflow data that indicates a trend may exist (Table 4). Therefore the remaining 33 stations that may have streamflow trends do not have trends in precipitation.

Table 4. Stations with Trends in Seasonal Streamflow and Precipitation

Station Location	Streamflow Sen's Slope	Precipitation Sen's Slope
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	0.3712	0.00110
FLINT RIVER NEAR FLINT, MI	1.0171	0.00110
RIFLE RIVER NEAR STERLING, MI	0.1673	0.00120
RIVER ROUGE AT DETROIT, MI	0.3044	0.00120
PAINT CREEK AT ROCHESTER, MI	0.0981	0.00140
ST. JOSEPH RIVER AT THREE RIVERS, MI	0.3037	0.00150
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	-0.5591	0.00160
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	0.1626	0.00210
HURON RIVER NEAR HAMBURG, MI	0.3330	0.00240
DOWAGIAC RIVER AT SUMNERVILLE, MI	0.3277	0.00360
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	-0.0144	0.00700

A closer look into the stations that may have trends in both streamflow and precipitation after the effects of serial correlation are accounted for is necessary. Of the 11 stations, two unique cases are present where a negative streamflow trend is paired with a positive precipitation trend. The two unique stations where this occurs are at West Fork Portage Creek in Kalamazoo, Michigan and South Branch Au Sable River near Luzerne, Michigan. An example of one of these unique cases can be seen in Figure 8 below.

These two unique cases where precipitation has increased and streamflow has decreased can be caused by multiple factors. These factors include increased water usage by the local communities. Both of these particular stations are located in regions that have experienced increased development and population growth over the past few decades. The station of West Fork Portage Creek in Kalamazoo was found to have an abundance of high capacity wells nearby. Though the amount withdrawn at these locations may meet well pumping regulations, the cumulative effect of these wells may cause a substantial drop on this first order stream. Secondly, it could be caused by redirection or collection of storm runoff for agricultural use or by municipal collection systems. Both of these regions are marked as high agricultural water use regions in Michigan. Therefore, there is expected to be a decrease in streamflow with an increase in water infiltration and collection for the increase in vegetation per square mile. Also, each city may use municipal collection systems to collect the water, treat the water then re-deposit the water back into a nearby body of water. The deposited water may not be connected to the area where water was being collected causing a decreasing in streamflow. The water may also be treated and then supplied to the local community for water use. The scenario may also be a by-product of protecting the stream. The South Branch Au Sable River is a stream containing a protected species of trout in Michigan. The contaminated runoff may need to be redirect to protect and preserve the quality of water for the trout. However, further investigation needs to be done to see the impact of the decrease in streamflow on the trout in this habitat. This possible contaminated runoff from primarily agricultural waste may need to be redirected from the river systems to the wastewater treatment plant. One other plausible scenario for why a decrease in streamflow and increase in precipitation may be seen along the South Branch Au Sable River is the effect of the dams along the Au Sable River. The dams have been investigated and can have an increasing or decreasing impact on daily streamflow at any given location (Sendek and Zorn, 2001). The specific site would need to be investigated on an individual basis but the use of hydroelectric dams could be cause for the decreasing trend and fluctuations in the trend at this location. For either case, these particular regions need a more rigorous analysis to identify the reason behind this unique relationship. It should also be noted that these two uncommon scenarios are not identifiable when evaluated on an annual basis.



South Branch Au Sable River near Luzerne, MI

South Branch Au Sable River near Luzerne, MI

Figure 8. Seasonal Negative Streamflow and Positive Precipitation Trend Comparison

The remaining 9 stations have positive trends in both streamflow and precipitation. The comparison of streamflow to precipitation can be seen below in Figure 9. This trend is expected as when the amount of water entering the system (precipitation) increases, the storage facilities of these systems should increase in capacity and rate. These 9 stations with a positive relationship between streamflow and precipitation do not have any unique temporal or volume components that are common between them. It is interesting to note that all of the stations are found in the lower half of the Lower Peninsula, but not clustered in any particular area. Also, the Sen's Slope estimate for streamflow in all 9 cases is significantly greater in magnitude than any of the other statistically significant streamflow stations.

It is also possible that during the period of study, multiple trends existed in the streamflow and precipitation data (for example a negative trend followed by a positive trend). These multiple trends could be found within data with an increasing or decreasing trend as well as data with no trend. The point where a break in slope occurs can be identified using more advanced statistical techniques such as Bayesian Change Point Analysis (Seidou and Ouarda, 2007) but these techniques are beyond the scope of the present study.

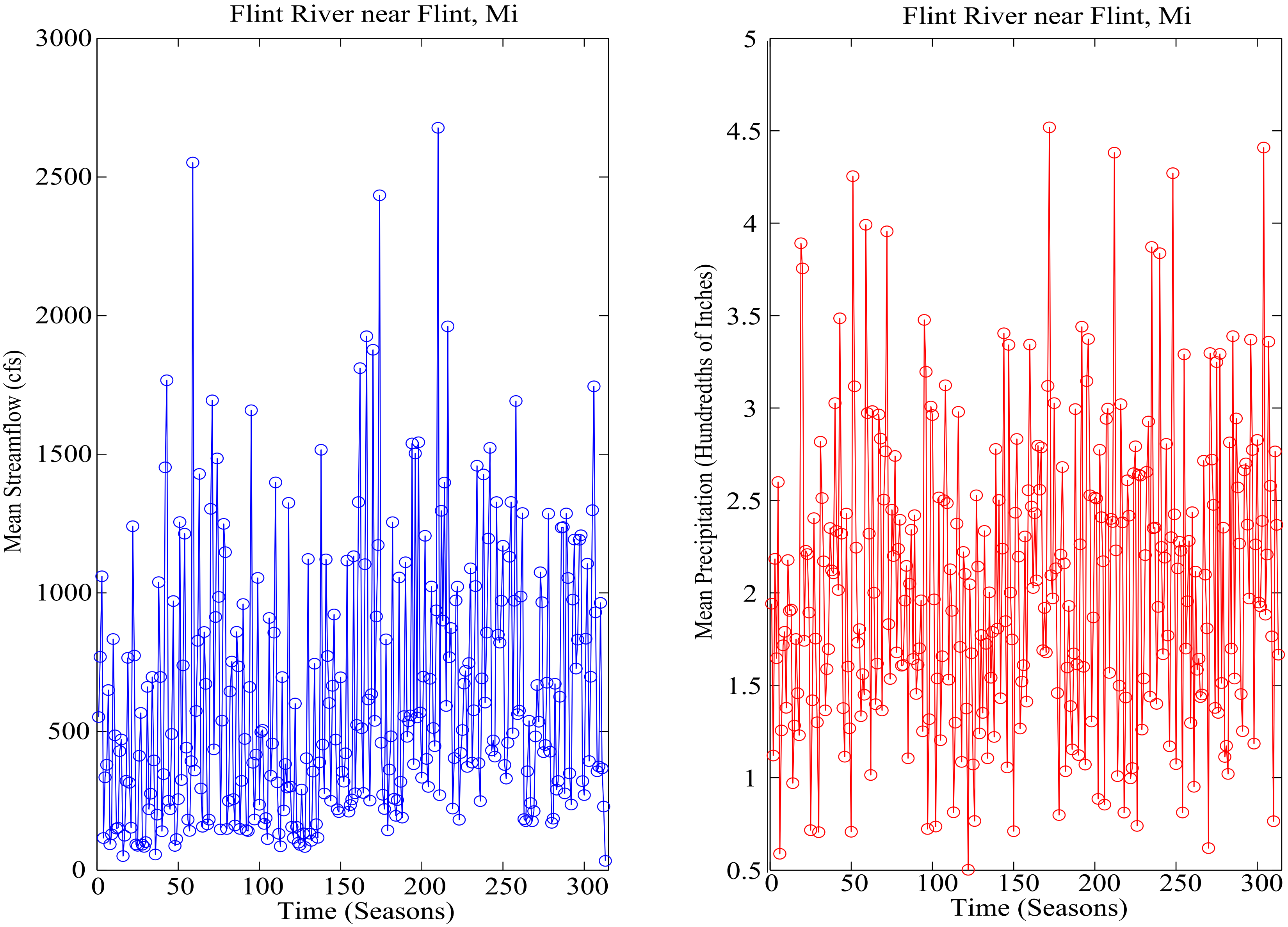


Figure 9. Seasonal Positive Streamflow and Positive Precipitation Trend Comparison

Continuous Annual Streamflow and Precipitation Results

Evaluations of the streamflow and precipitation data were conducted on an annual basis in addition to the seasonal and daily study. The annual analysis was conducted in a similar procedural fashion to the seasonal. The data were dissected into the four seasons shown above in Table 3. The mean for each season was determined. Then the mean of four consecutive seasons was found to represent the annual value. The annual value set is then analyzed using the three statistical test methods used to analyze the daily and seasonal data.

The Mann-Kendall results of the annual streamflow showed even further reduction in the number of stations that rejected the null hypothesis. The number of stations decreased from 47 stations to 43 when analyzed on an annual basis compared to seasonal. The further reduction can be credited to the elimination of serial correlation by taking the mean of such a large dataset. It also can be credited to the reduction in the data size allowing for a greater grasp of possible trends associated with the dataset.

Of the 43 stations that rejected the null-hypothesis of the Mann-Kendall test, all of them rejected the null-hypothesis after the adjustment of the variance for short term persistence. This further illustrates that taking the mean value of the dataset leads to a reduction in the impact of serial correlation. The annual Mann-Kendall-Rao test produced almost identical results to the seasonal analysis. This study found that 47 stations rejected the null hypothesis, 3 more than the seasonal analysis. Also, 4 stations rejected the null hypothesis that the Mann-Kendall test did not reject, that no trend was present. Therefore, serial correlation was removed from the dataset and a trend was found to be in existence.

Of the 43 stations that rejected the null hypothesis, that no trend exists, 8 of those stations were found to have a negative or decreasing trend. Of those 8 stations, 1 station has a negative trend that was found in the seasonal analysis. The remaining 7 stations had no trend present according to either seasonal statistical test. Similarly, the remaining 10 stations with negative trends for the seasonal data do not have any trend present according to either annual statistical test. The remaining 35 stations were found to have positive or increasing trends in streamflow. As opposed to the negative trends, there are more positive trends found in the streamflow data when evaluated on an annual basis. The positive trends also had more stations in common between the seasonal and annual analysis. The seasonal evaluation found 34 positive trending stations of which 33 had similar trends when tested annual. The remaining stations that do not coincide between the two datasets are found to have no trend for the opposing respective temporal analysis.

An additional component of the comparative analysis between the seasonal and annual evaluation is the strength of the slope found. The annual evaluation has slopes that are even greater in magnitude than those found in the seasonal evaluation. The increasing strength of the slopes confirms the idea that increasing the length of the temporal evaluation decreases the noise and effects of short and some long term persistence to provide more accurate results. Therefore the annual evaluation is considered to be the most accurate representation of the streamflow trends in Michigan. However, the results from the seasonal and daily evaluation should be recognized and not discounted.

A comparative analysis was also conducted to evaluate the relationship between annual streamflow trends and annual precipitation trends as it was done in the seasonal study. The precipitation data were tested at the same location as the USGS streamflow gauging stations through interpolation of the available streamflow data. The data were then broken down into annual datasets and the mean values were tested using the same three statistical tests.

The Mann-Kendall test was used to compare the annual streamflow data to the annual precipitation data. The analysis found that of the 43 stations that rejected the null hypothesis for streamflow data, only 11 of those stations also identified possible trends in precipitation data. The comparison between the two datasets was also reviewed after adjusting the variance to account for the effects of autocorrelation. The number of stations slightly increased from the Mann-Kendall test, to 14 stations that have trends in precipitation at significant streamflow locations. This helps identify that precipitation does explain some of the existing trends in streamflow. However, it is not the only source of impact and in fact may not be the most pertinent variable in terms of relationship to streamflow data. Other variables are to be credited for the remaining 70-75% of data that has streamflow trends. This relationship could be directly correlated with one distinctly different variable than precipitation or it may be the combination of a multitude of variables that are unique to each given location.

Further investigation into the stations that have identifiable trends in both precipitation and streamflow is necessary. The Sen's Slope estimations strength and direction of trends were compared for each of the given datasets. Of the 14 stations that have trends in both precipitation and streamflow according to the Mann-Kendall-Rao test, 12 of these stations have positive, increasing trends in both of their respective datasets as seen in Table 4. An example of the increasing trends in streamflow and precipitation can be seen in Figure 10. The positive relationship is much more prominent in the streamflow data as the slopes are almost one hundred times greater than those found in the precipitation data.

Table 5. Stations with Trends in Annual Streamflow and Precipitation

Station Location	Streamflow Sen's	Precipitation Sen's
HURON RIVER NEAR NEW HUDSON, MI	0.54410	-0.00490
TITTABAWASSEE RIVER AT MIDLAND, MI	10.40340	0.00260
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1.43440	0.00380
RIVER ROUGE AT DETROIT, MI	1.09570	0.00420
LOWER RIVER ROUGE AT INKSTER, MI	0.93870	0.00450
FLINT RIVER NEAR FLINT, MI	4.78390	0.00510
MAPLE RIVER AT MAPLE RAPIDS, MI	1.79280	0.00530
RIVER ROUGE AT BIRMINGHAM, MI	0.30370	0.00610
PAINT CREEK AT ROCHESTER, MI	0.43180	0.00710
RIVER ROUGE AT SOUTHFIELD, MI	0.81880	0.00710
PINE RIVER NEAR RUDYARD, MI	-1.98350	0.00730
HURON RIVER AT ANN ARBOR, MI	2.83170	0.01020
HURON RIVER NEAR HAMBURG, MI	1.39750	0.01070
DOWAGIAC RIVER AT SUMNERVILLE, MI	1.29350	0.01580

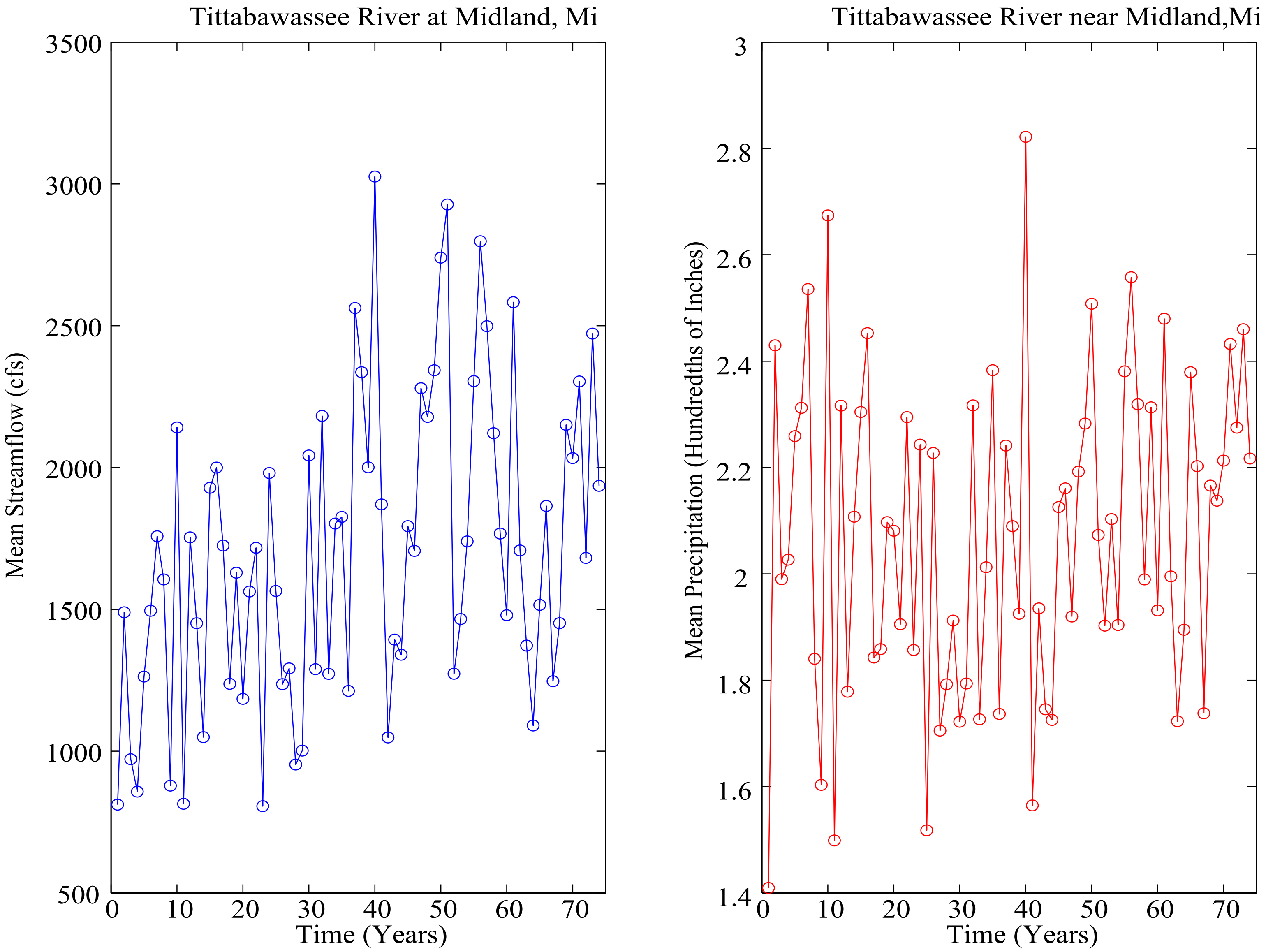


Figure 10. Annual Positive Streamflow and Positive Precipitation Trend Comparison

Of the remaining 2 stations, one of them has a positive trend in precipitation and a negative trend in streamflow. This unique situation arises in the Pine River near Rudyard and the comparison can be seen in Figure 11. This case is quite unique for a multitude of reasons. First it is quite uncommon to see an increase in precipitation and a decrease in streamflow.

The unique scenario of increase in precipitation to a particular region with a decrease in streamflow is significant as it is counterintuitive. Some possible explanations for this may be because of the increase in population, causing an increase in water usage. Specifically, the increase in groundwater wells located right around the streamflow gauging station. The significant decrease in streamflow that is seen here may be falsified due to the drawdown caused by all the extremely close adjacent groundwater wells. Also, the addition of high capacity wells north of the station along the stream may decrease the streamflow. Since the town of Rudyard is developed on primarily bedrock and has little surface water available a source of usable of water for the community is Pine River. Secondly, the town of Rudyard is identified as a region of heavy water use for agricultural activity. To support this agriculture, some of the surface water runoff may be redirected from Pine River and to irrigation collections ditches. Also, the particular crops grown in this region may require more water than the pre-existing vegetation. Another plausible justification for the decrease in streamflow is to protect the stream. The stream is habitat to a protected species of trout. Water may be redirected to preserve the water quality. These are hypotheses to explain this rare occurrence; however an in-depth analysis of the region should be conducted to develop a concrete explanation as to why streamflow has decreased with an increase in precipitation.

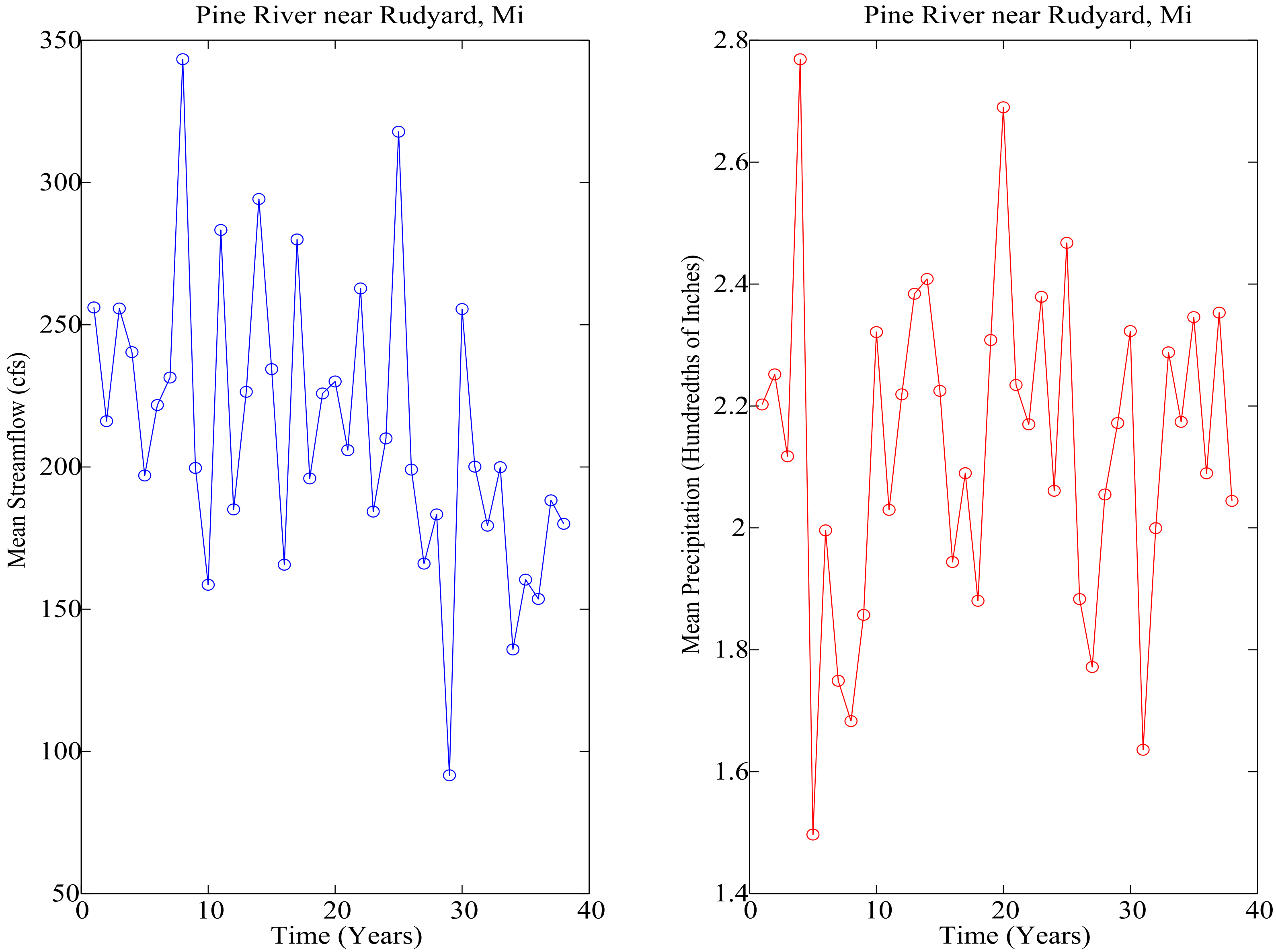


Figure 11. Annual Negative Streamflow and Positive Precipitation Trend Comparison

The final station is also quite a unique scenario. At the Huron River near New Hudson, an uncommon and unique situation is found. The streamflow data are found to have a positive increasing trend while the precipitation at this particular location is found to have a negative decreasing trend as shown in Figure 12. It is quite uncommon to see a decrease in precipitation and an increase in streamflow. This opposes common logic as one would expect that with less water provided to the system, less water would flow through the system. However, the decrease in precipitation at this particular location contradicts the surrounding stations in the area where precipitation is found to be increasing. Therefore, the increase in precipitation along the Huron River and its subsequent watersheds causes an increase in surface water raising the capacity of the entire stream even though at a particular location along the stream precipitation is decreasing. This observation further emphasizes the need for analyses at the watershed scale since statistical trend analyses fail to take spatial dependence of hydrologic processes into account.

Another explanation for this uncommon relationship is the fact that this region has been subjected to substantial land-development in the last 60 years. This community has transformed from an agriculture and rural region towards a more urbanized area. This development has impacted the area watershed and may have increased run-off to surface streams while decreasing infiltration and irrigation storage. These are all possible hypotheses to what is occurring at this particular location, but to get a true understanding of what is happening in this watershed, this location should be analyzed on an individual basis accounting for all possible components to determine a proper explanation for why such a scenario exists.

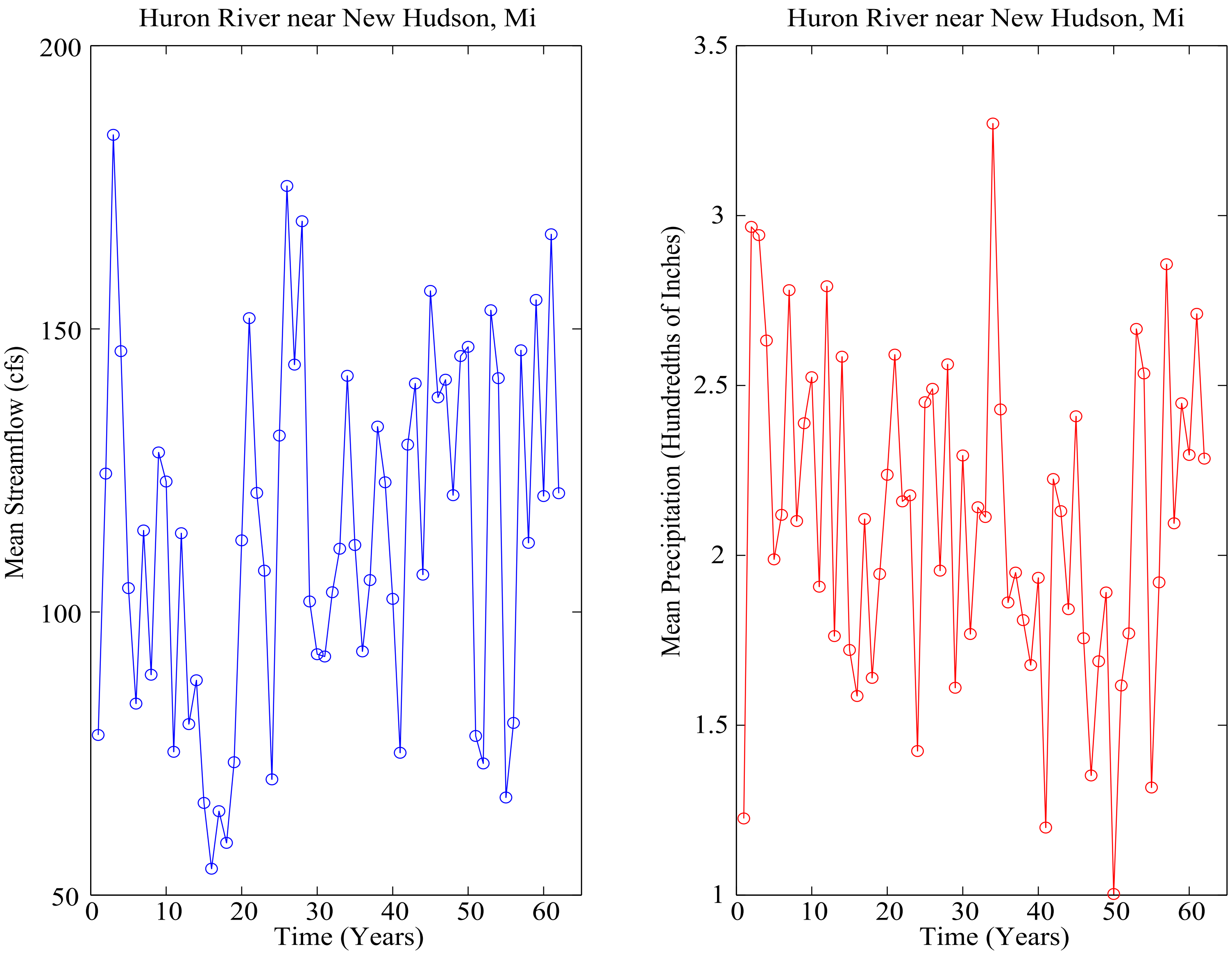


Figure 12. Annual Positive Streamflow and Negative Precipitation Trend Comparison

Evaluation of Persistence

The effects of short term and long term persistence were identified as possible causes of falsification of trends. If short term or long term persistence were present in the data an event was expected to affect subsequent days, seasons or even years. The evaluation conducted in this research identified that short term persistence plays in key role in distinguishing whether a trend exists or is falsely identified due to the effects of serial correlation. After collecting the data and conducting two different statistical tests, one without regards to serial correlation the other accounting for the effects of autocorrelation, it can be seen that short term persistence is present and may skew results. The lag associated with the autocorrelation on a daily scale can be seen in the autocorrelation plot (Figure 13). Therefore the Mann-Kendall-Rao test provides more accurate results by adjusting the variance so that the effects of autocorrelation are accounted for providing a true representation of trends.

Long term persistence (LTP) was not accounted for in the analysis for three primary reasons. The first reason is that the effects of LTP were expected to be reduced by averaging data. The second reason LTP was not accounted for was that based on most hydrologic statistical analyses the streamflow and precipitation data had very small autocorrelation values and were only of concern for short-term persistence (Hirsch and Slack, 1984). Most time series records for hydrology indicate that effects of long term persistence are minimal and hard to identify (Capodaglio and Moisello, 1990). Thirdly, based on multiple sources, accounting for LTP was avoided because it commonly eliminates actual trends in the data that existing tests are unable to distinguish from LTP (Hirsch and Slack, 1984). The assumptions made regarding the effects of LTP and the decision to not include it in the analysis can be seen in Figure 14 and Figure 15 below. As seen in the comparison of all of the three figures below, the degree of correlation decreases as the evaluation progresses from daily to seasonal to annual as expected. Therefore, not accounting for the effects of LTP seems to be reasonable in the evaluation of streamflow data.

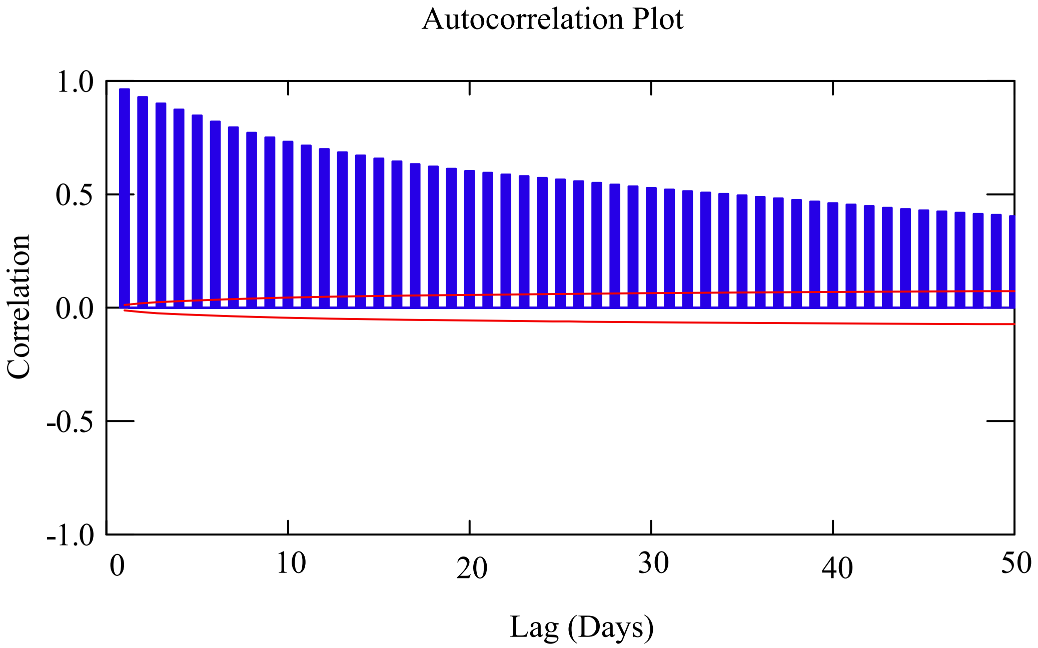


Figure 13. Autocorrelation plot of Daily Streamflow

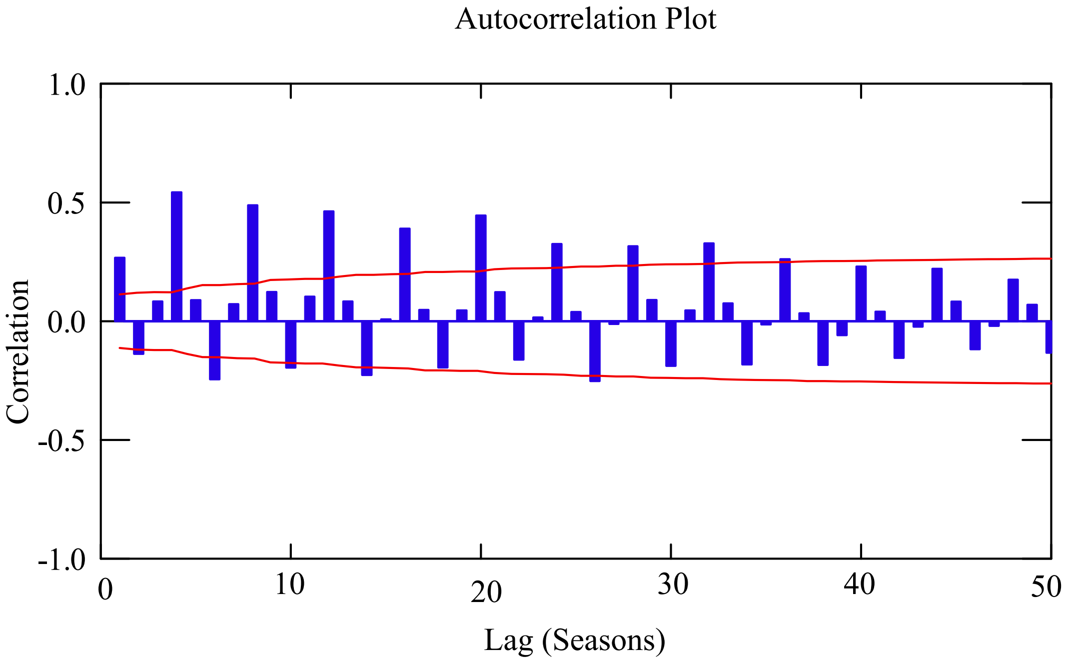


Figure 14. Autocorrelation plot of Seasonal Streamflow

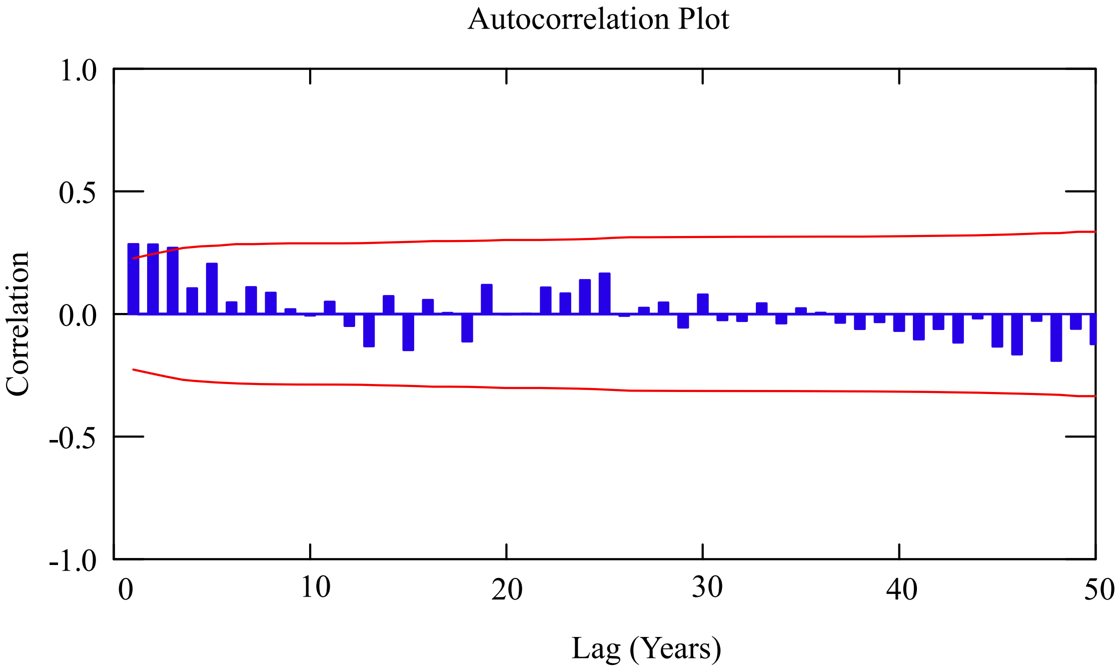


Figure 15. Autocorrelation plot of Annual Streamflow

CHAPTER 5

Spatial Variability of Temporal Trends

Spatial Variability of Temporal Trends in Daily Streamflow and Precipitation

A spatial variability of temporal trends was examined to determine possible locations and reasons for trends in streamflow data. The streamflow and precipitation data for viable station were analyzed on a daily, seasonal and annual basis. Each different temporal period was analyzed in two formats, the first was identifying any trend regardless of the Mann-Kendall and Mann-Kendall Rao test results. The second analysis only includes those stations that have trends that were identified by rejecting the null hypothesis of the Modified Mann-Kendall Test.

As stated above no trends in daily precipitation for any station were found to exist due to the high frequency of zero precipitation days. Therefore no spatial interaction exists between streamflow and precipitation.

Daily streamflow also did not have many distinguishable trends but not due to lack of stations with significant data. For the most part, the data shows stations of increasing and decreasing trends scattered throughout the Lower Peninsula with no real association to geographic location in either spatial analysis. However, southeast Michigan, near Detroit, has almost all stations in the area indicating a positive trend or an increase in streamflow in the analysis of all stations and significant stations. This would seem to be a byproduct of the development of land use (Figure 1) in the region decreasing infiltration rates and increasing surface runoff deposits into nearby streams. The other region that has an identifiable trend is the Upper Peninsula. The peninsula has all but two stations identifying a decreasing trend in precipitation when comparing all stations with observable trends (Figure 16). Upon elimination of the stations that fail to have an identifiable linear trend according to the Mann-Kendall-Rao test, all stations in the Upper Peninsula have a decreasing trend in streamflow as seen in Figure 17.

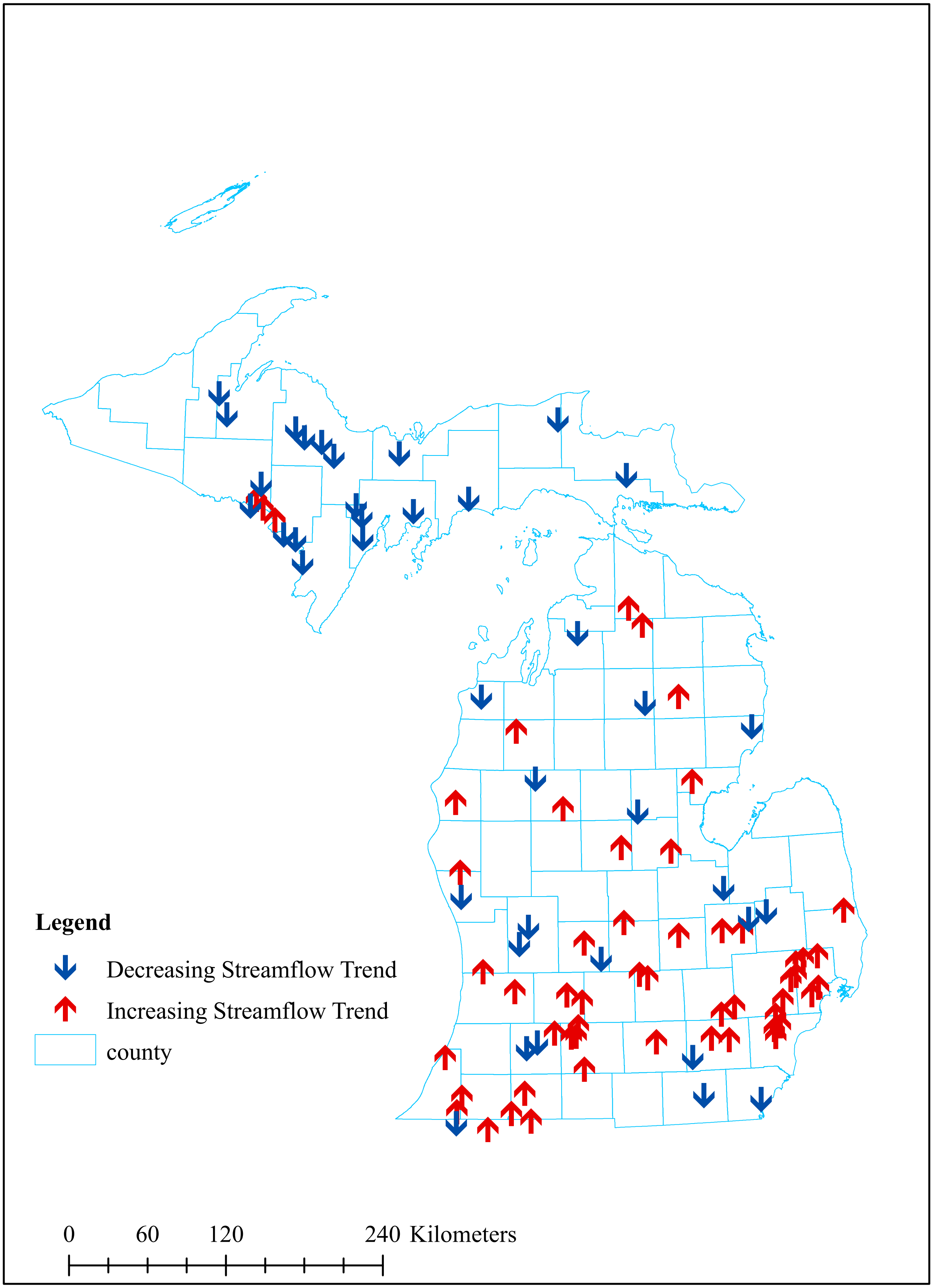


Figure 16. Spatial Variability of Temporal Trends in Daily Streamflow

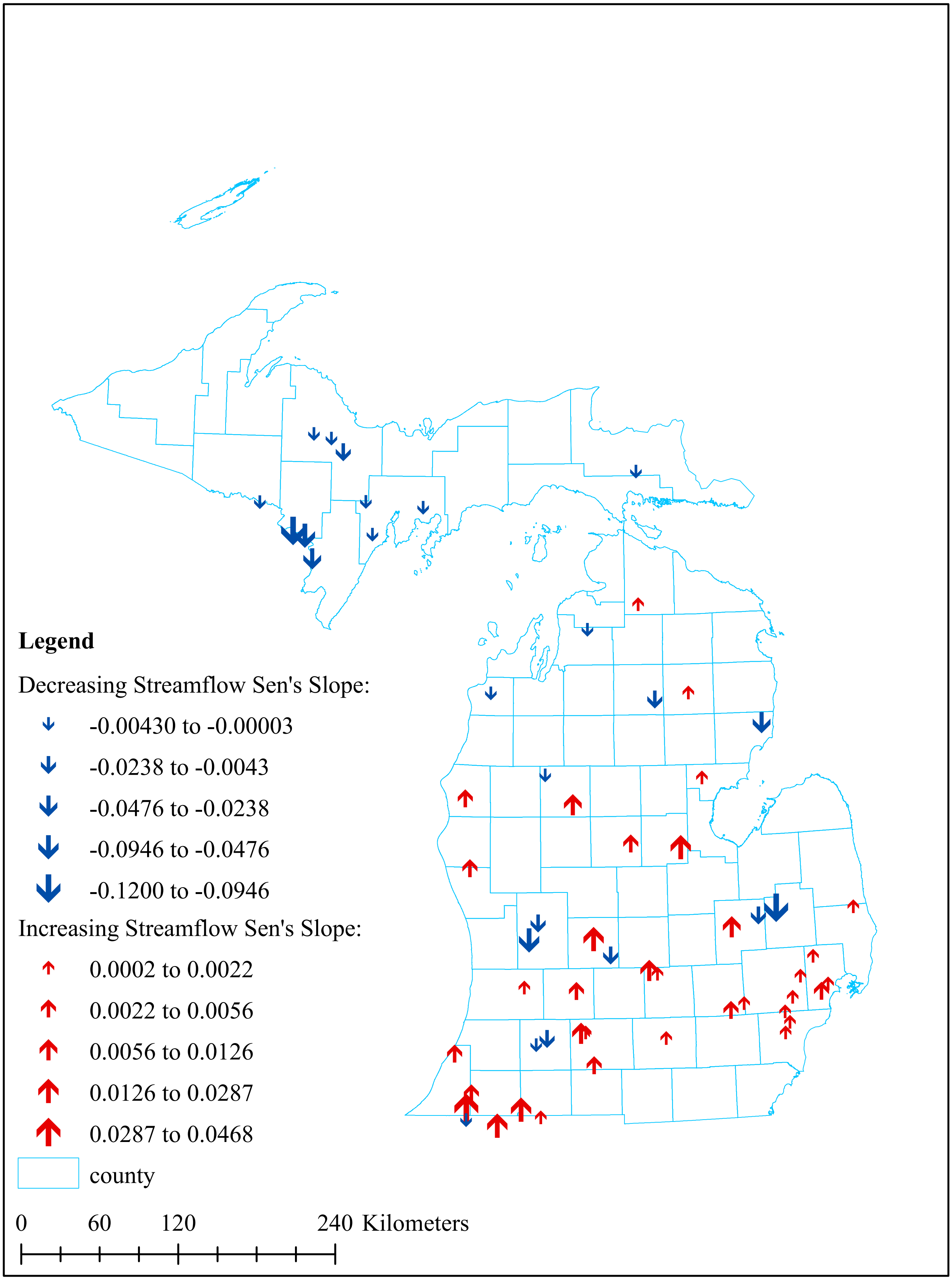


Figure 17. Spatial Variability of Significant Temporal Trends in Daily Streamflow

Spatial Variability of Temporal Trends in Seasonal Precipitation

A seasonal spatial evaluation of precipitation trends was able to identify spatial relationships unlike the daily precipitation assessment. The complete set of seasonal precipitation data identified no spatial trends to exist in the Upper Peninsula of Michigan (Figure 18). This data is without regards to the results of the Mann-Kendall and Mann-Kendall Rao test results. It is merely to identify if there is increasing or decreasing slope that is consistent throughout the region. In the Lower Peninsula, almost all of the stations with available slopes have a positive increasing relationship in precipitation. There are only seven stations that are randomly scattered throughout the Lower Peninsula with decreasing relationships. These seven stations are scattered around the perimeter of the state as well. It can be clearly stated that central Lower Michigan has experienced an increasing spatial trend in precipitation.

After eliminating stations that do not have viable trends according to the Modified Mann-Kendall Test, the results became very distinct. All stations with decreasing trends in precipitation were eliminated except for one in northwest region of the Upper Peninsula (Figure 19). All other significant stations that presented viable trends have an increase in precipitation. This result is expected as much of Michigan is subjected to the same climate. The increasing trend depicted by the data is in accordance with the expected increase in precipitation according to the Great Lakes Integrated Sciences Assessment (GLISA). GLISA predicts that the precipitation found in Michigan should stay fairly stable if not increase (*Climate Change in the Great Lakes Region*, 2012). The interpolated precipitation data identifies the majority of stations as having no trend, and those stations with trends tend to have an increasing trend. In addition to the expected increase in precipitation is an increase in temperature. The increase in temperature will drastically change the climate of Michigan. First, the change in temperature will increase the length and decrease the snowfall intensity of winters in the region. Much of the precipitation may convert from snowfall to rain due to the increase in temperature. The change in the type of precipitation could lead to an increase in the overall amount of precipitation. Secondly, the increase in temperature will lead to greater evaporation and transpiration rates throughout the region as time progresses. Changing the relative importance/magnitude of key components of the hydrologic cycle could have serious implications on the water availability and lake levels in the region. Thirdly, this will lead to an increase in the length of the growing season, increasing crop production and potentially reducing streamflow further in some regions. The only location with a decrease in precipitation is in a region of higher elevation in the northwestern region of the Upper Peninsula. It may receive less precipitation due to its location not being on the leeward side of the elevated landscape.

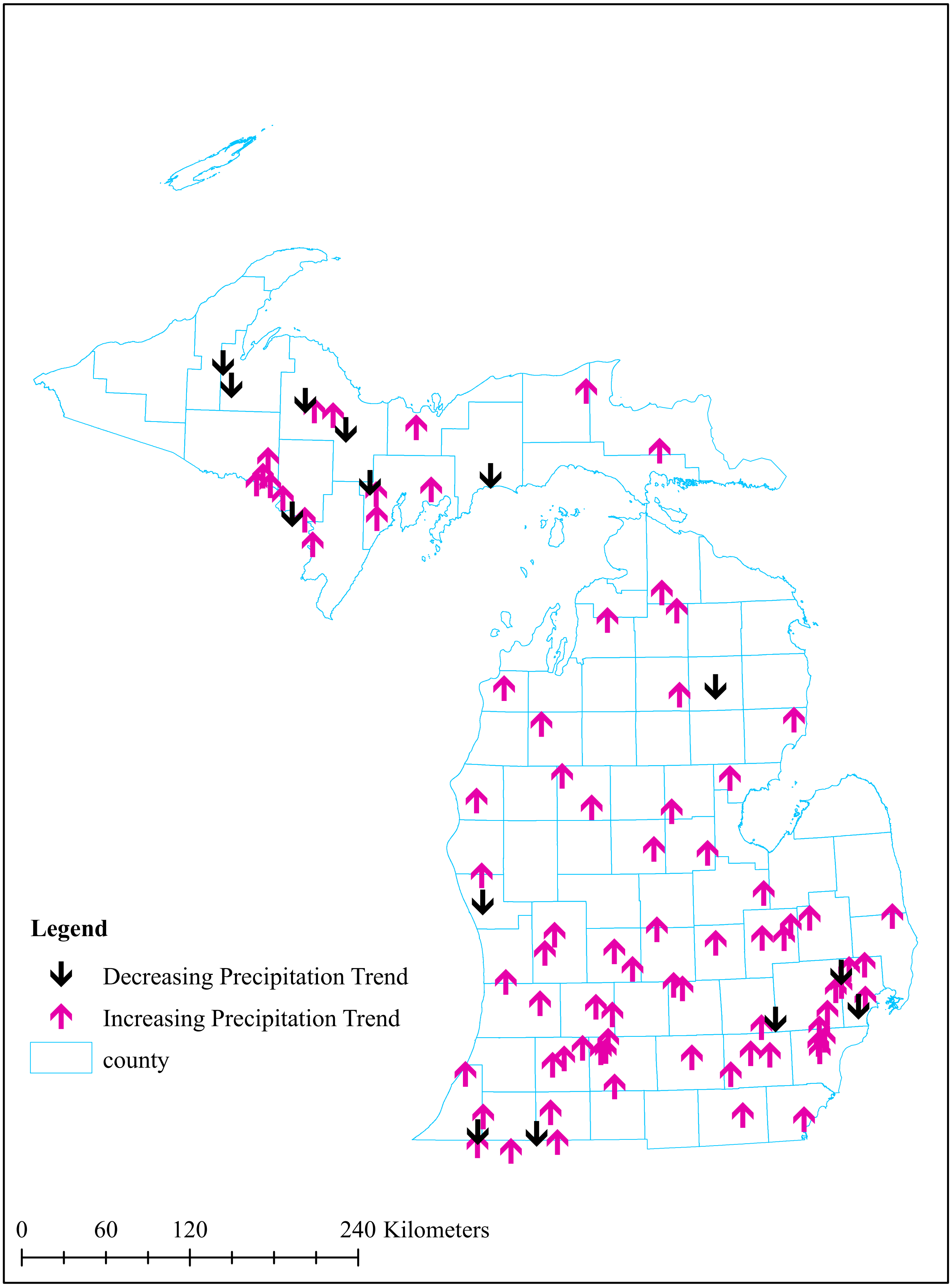


Figure 18. Spatial Variability of Temporal Trends in Seasonal Precipitation

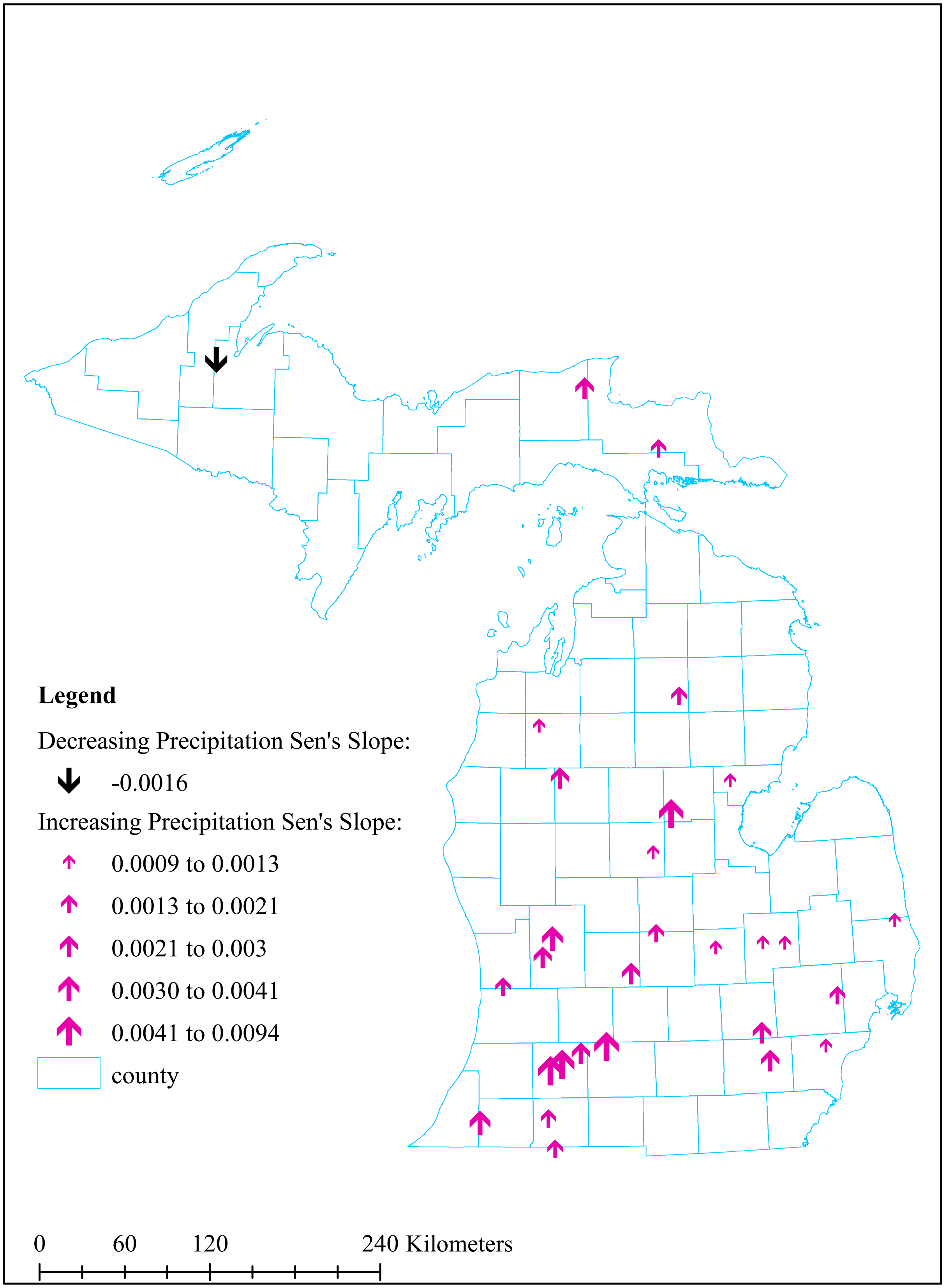


Figure 19. Spatial Variability of Significant Temporal Trends in Seasonal Precipitation

Spatial Variability of Temporal Trends in Seasonal Streamflow

Examination of the spatial variation of seasonal streamflow trends without regards to the Mann-Kendall or Mann-Kendall-Rao results produced similar spatial relations to those found in the daily analysis. The state is well defined by a mixture of increasing and decreasing trends for stations across the Lower Peninsula with a strong identifiable increasing trend in the Detroit Region (Figure 20). The Upper Peninsula is still dominated by decreasing streamflow trends however; multiple stations of increasing trends can be found at the seasonal time scale.

The spatial analysis of viable trending stations produced much different results. A significant decrease in stations from the daily to seasonal analysis is noticeable. With the reduction in stations three unique spatial regions are identifiable. It seems as though, the Western region of the Upper Peninsula has experienced a decrease in streamflow (Figure 21). This is to be expected as a decrease in precipitation was found in this region, and decreasing the input is expected to decrease the streamflow. Similarly, a strip heading east from Traverse City to Alpena has also experienced a decrease in streamflow. A common attribute between these two regions of decreasing streamflow trends, is the increased elevation in comparison to all other locations in the state (Figure 4). The decrease in streamflow could be a byproduct of drawdown from water use. The streams found located at these high elevation points tend to be first order streams that are groundwater fed. These first order streams are commonly small in magnitude and experience a decrease in streamflow due to any minor impact on the watershed. Therefore the decrease in streamflow could be a by-product of several factors in the area.

Meanwhile, all the stations in the southern half of the Lower Peninsula have experienced an increase in streamflow (Figure 21). This is an expected result as all of the Lower Peninsula has experienced an increase in precipitation causing the streams and streamflow to increase to accommodate for the increase in capacity.

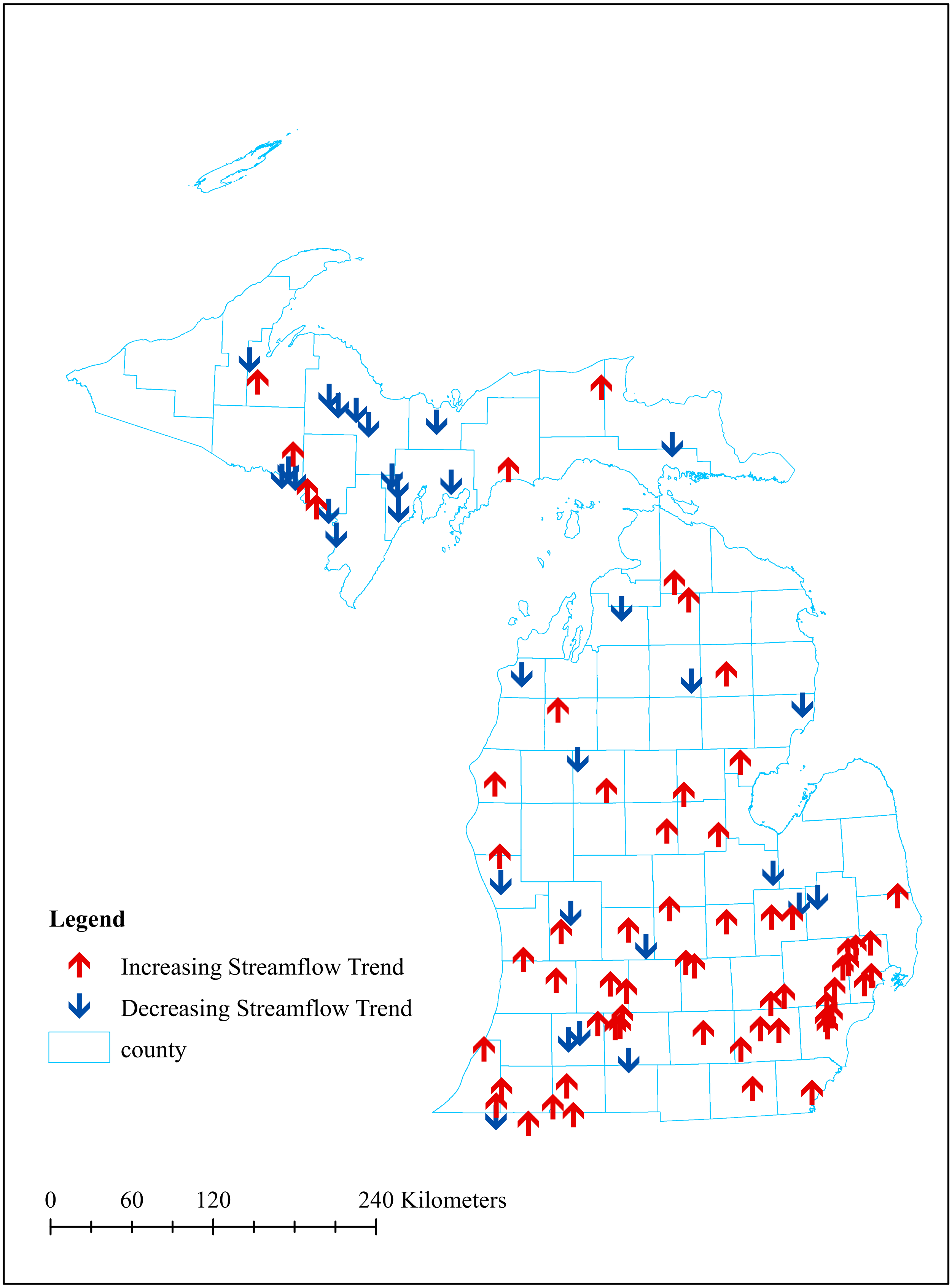


Figure 20. Spatial Variability of Temporal Trends in Seasonal Streamflow

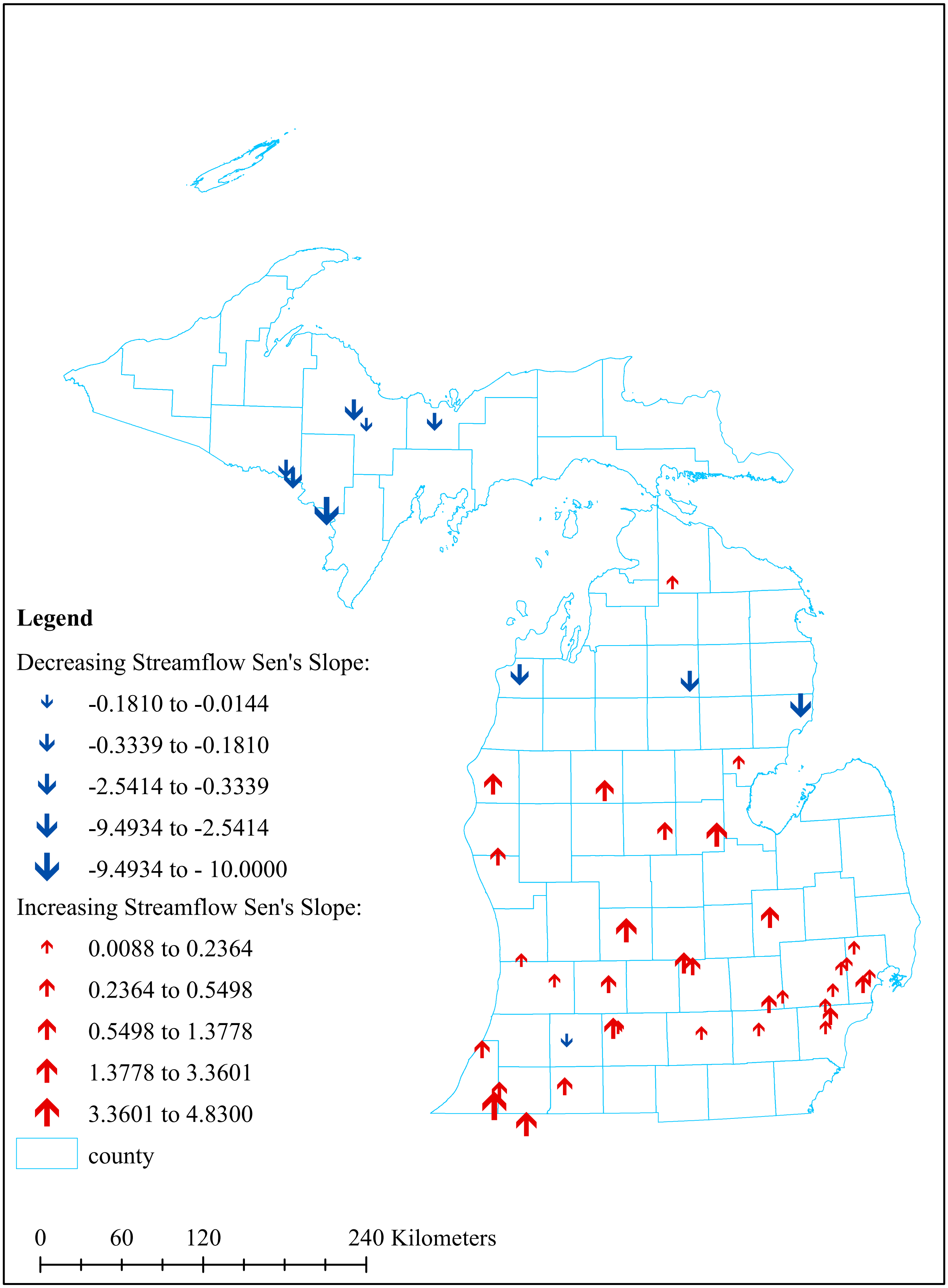


Figure 21. Spatial Variability of Significant Temporal Trends in Seasonal Streamflow

Spatial Variability of Temporal Trends in Annual Precipitation

Evaluation of spatial trends was also conducted based on the annual precipitation for all stations regardless of whether or not they rejected the null hypothesis or identified a trend using the Mann-Kendall-Rao statistical analysis. The annual precipitation spatial relationship between stations prior to testing for a trend with the Modified Mann-Kendall test produced similar results to the seasonal analysis with a few minor variations. Similar to the seasonal analysis the majority of the Upper Peninsula experiences an even mixture of increasing and decreasing trends. However, the eastern half of the region is subjected to only increasing trends in precipitation which was not identifiable in the seasonal analysis (Figure 22). This seems to further illustrate the impact that the elevation has on precipitation in the region. In regards to the Lower Peninsula, the majority of the region has experienced an increase in precipitation with the exception of seven stations again. These seven stations with decreasing trends are not the same seven as in the seasonal analysis. Four of the seven are same; however, the remaining three are different stations that had trends that were very close to zero in previous analyses. The averaging of the data changed the slope slightly causing the trend to change from increasing to decreasing. Similarly the three stations that were previously decreasing in trend and now are increasing experienced a similar reversal due to the small negative slope identified that was found to be close to zero. The station locations of the few decreasing precipitation trends seem to be randomly scattered throughout and have no real distinct characteristics that are common between them.

Annual precipitation after evaluation of the Modified Mann-Kendall test found different trends than that of the seasonal analysis. First and foremost the number of decreasing precipitation stations increased from one to five. Even with the increase in stations with decreasing precipitation, the precipitation analysis seems to directly coincide with the expectations for the region based on the predicted warming climate. The State is still primarily dominated by increasing precipitation. Three of the stations with decreasing trend are found in the western part of the Upper Peninsula (Figure 23). The other two are found on opposite sides of Lower Michigan. It is still safe to state though that the Lower Peninsula and the eastern part of the Upper Peninsula have predominantly experienced an increase in precipitation.

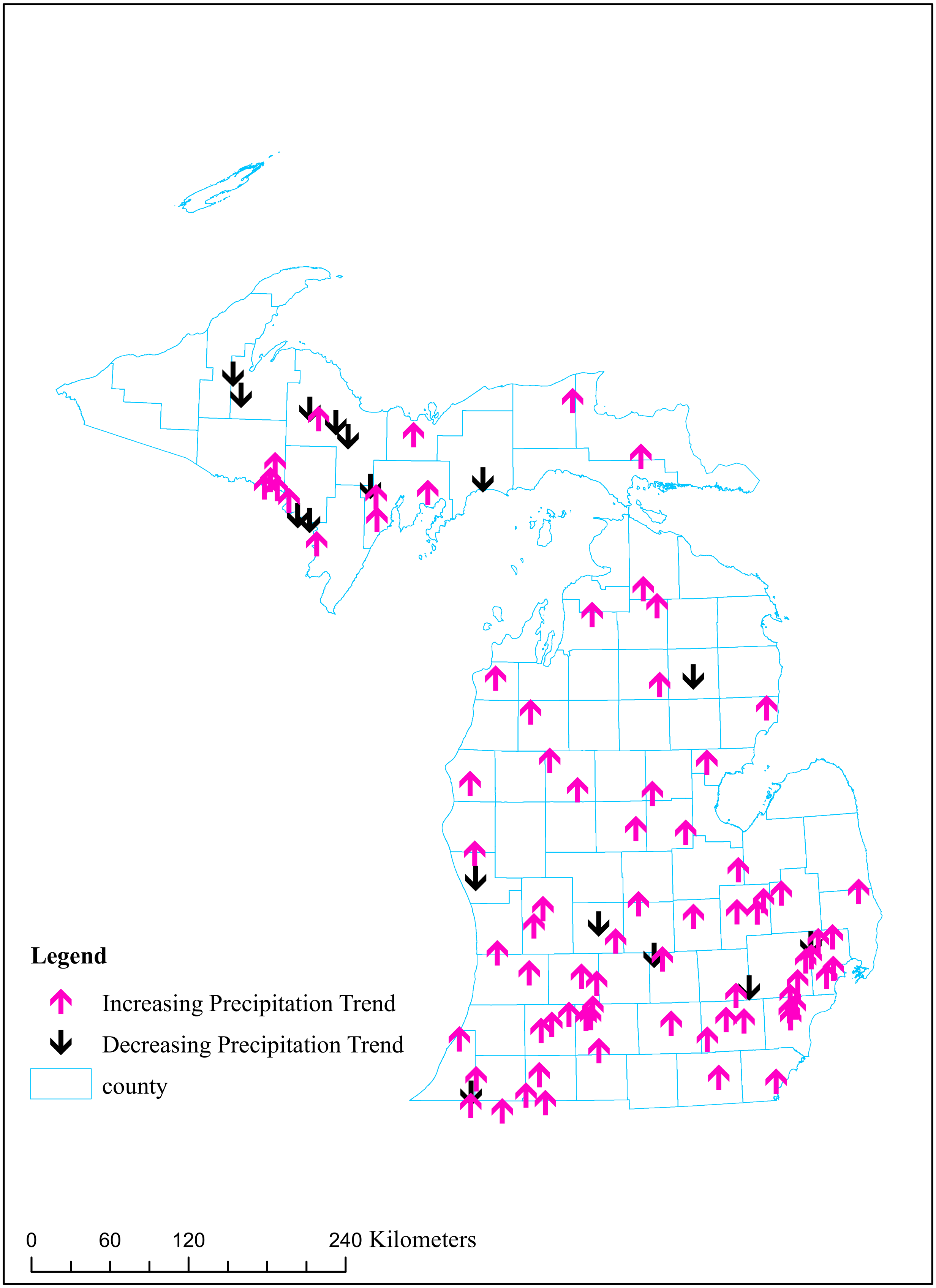


Figure 22. Spatial Variability of Temporal Trends in Annual Precipitation

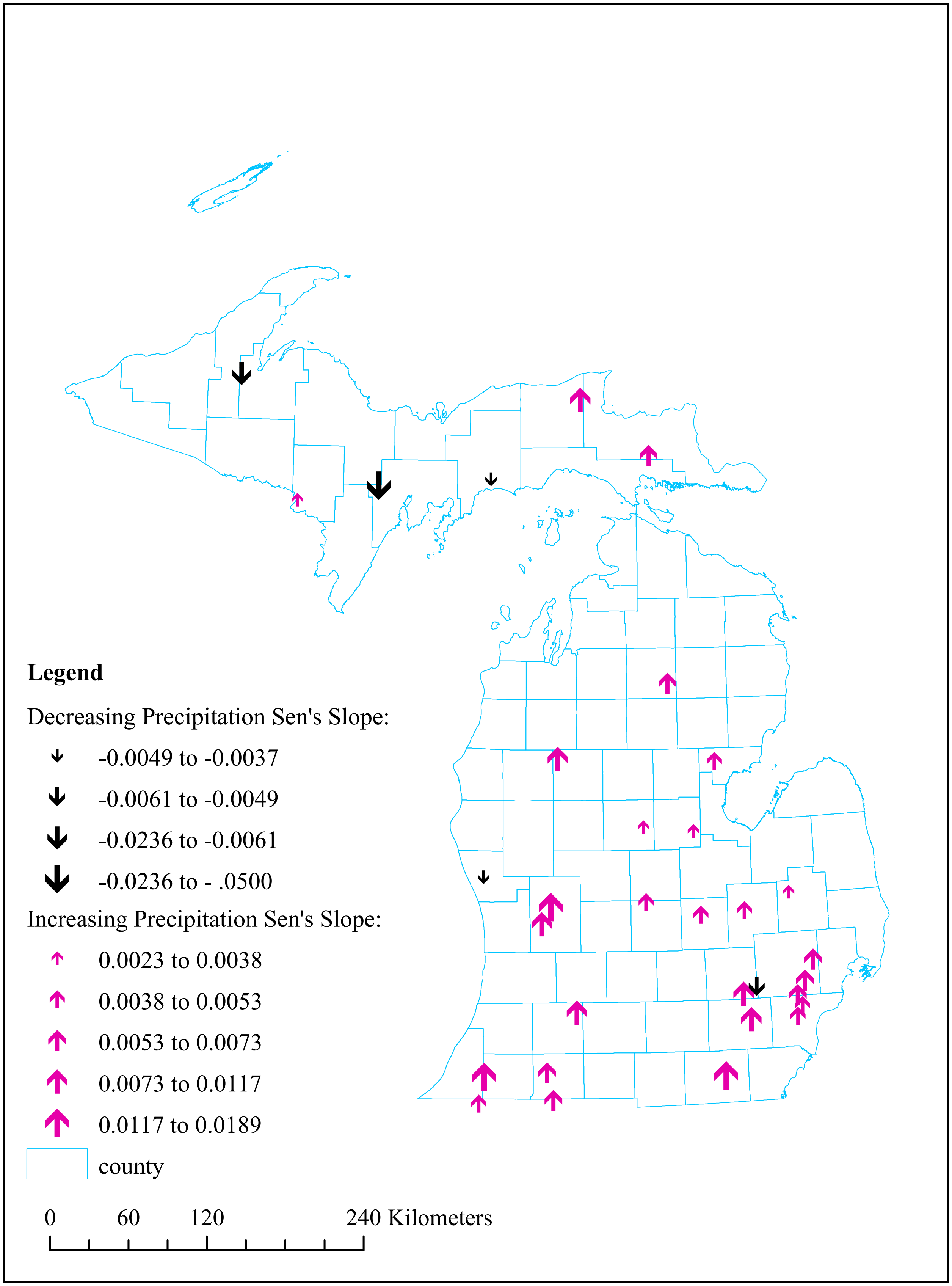


Figure 23. Spatial Variability of Significant Temporal Trends in Annual Precipitation

Spatial Variability of Temporal Trends in Annual Streamflow

A spatial analysis of all annual streamflow data found that the southeastern region of the Lower Peninsula is experiencing an increase in streamflow while the rest of the Lower Peninsula is composed of a mixture of increasing and decreasing trends. The Upper Peninsula is quite the opposite of the Lower Peninsula. The Upper Peninsula stations are almost all experiencing a decreasing trend in streamflow with the exception of two stations.

After identifying the stations where linear trends may exist, there was a significant reduction in the number of stations with significant trends. From this two strong identifiable trends are prevalent in Michigan. The first spatial trend can be seen in the southern half of the Lower Peninsula (Figure 24) where all of the stations but one have increasing trend in streamflow. The second spatial trend is that all the stations in the Upper Peninsula experience a decrease in streamflow. There is one decreasing trend found north of Cadillac, but it is the only station that has a trend in the upper half of the Lower Peninsula and cannot be used to make a generalized statement for the entire region.

The spatial relationship between precipitation and streamflow are consistent with a few contradictory stations. The majority of the Lower Peninsula has stations where precipitation and streamflow are experiencing increasing trends. The Detroit Metro region again is composed of all stations with increasing streamflow trends. This directly correlates with the heavy urbanization of the region that can be seen in Figure 1. Therefore, it is expected that land use impacts streamflow trends along with elevation and precipitation.

The western region of the Upper Peninsula experiences a decreasing trend in streamflow and precipitation. A few stations are contradictory in the region to the overall decreasing trend but the area is primarily represented by a decrease in streamflow. The eastern part of the Upper Peninsula has one station that experiences an increase in streamflow and a decrease in precipitation as discussed above.

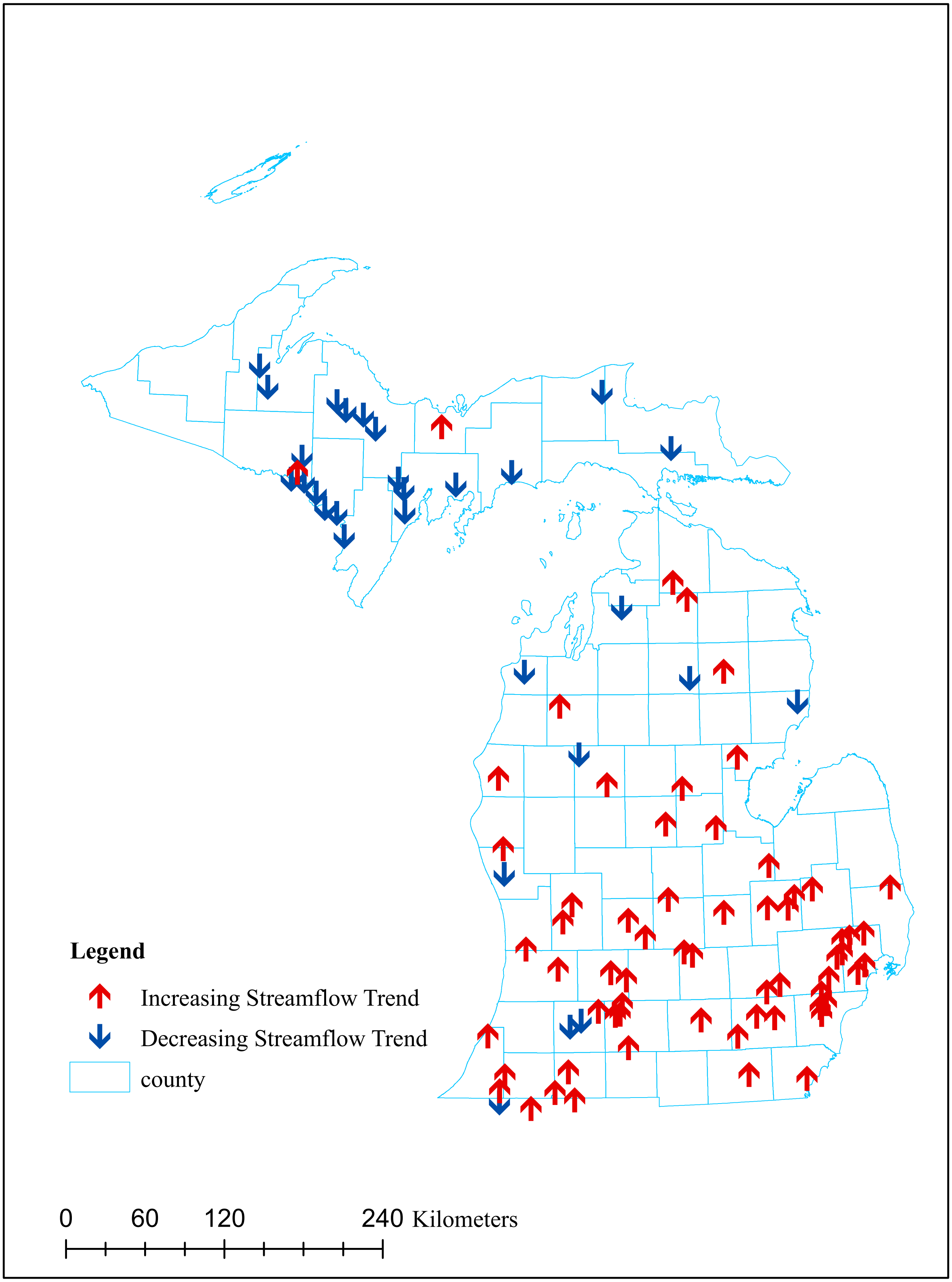


Figure 24. Spatial Variability of Temporal Trends in Annual Streamflow

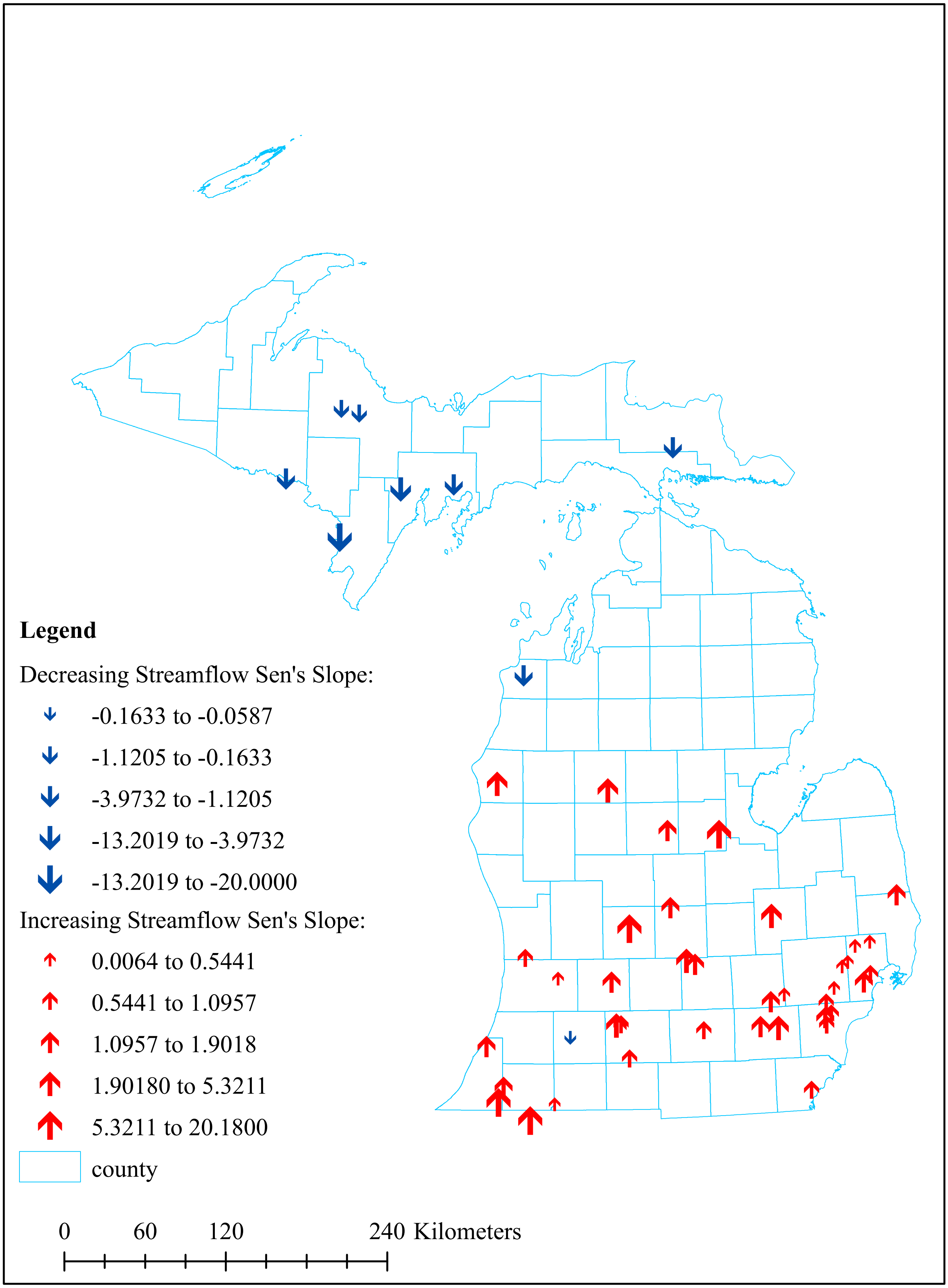


Figure 25. Spatial Variability of Significant Temporal Trends in Annual Streamflow

These results indicate that precipitation is a major factor in explaining streamflow trends. It is important to note that other factors do play an influential part in streamflow rates in the state of Michigan. This can be seen by the large number of stations where trends exist for either precipitation or streamflow but not both. The combination of precipitation, land use, elevation and many other factors dependent on location compromise the unique streamflow trends that are found all over the state.

CHAPTER 6

Conclusion

Daily Streamflow and daily precipitation values for varying time periods were analyzed using three statistical tests, The Mann-Kendall Test (MK), The Mann-Kendall-Rao Test (MKR) and Sen's Slope Estimator. It was found that the original data needed to be modified to accurately portray any trends in the data. Therefore each streamflow gauging station dataset was truncated (eliminating 55 stations from analysis) to only represent a period of continuous flow that was required to be greater than 17 years to obtain reliable results based on trend analysis. After such modification the following results were found.

- Streamflow:
    - MK – 83 of the 92 streamflow stations were found to have an existing trend.
    - MKR – 59 of the 92 streamflow stations were found to have an existing trend after adjusting the variance to account for the effects of serial correlation.
    - Sen's slope – 24 of the 59 stations that the MKR test found to have an existing trend were decreasing.
- Precipitation:
    - The precipitation data was evaluated using similar techniques but was found to have no trend for both (MK and MKR) analyses and a Sen's slope of zero was found due to the high frequency of days without precipitation.

Similar to the daily analysis, a seasonal analysis was conducted on both precipitation and streamflow to diminish the effects of short-term persistence as well as to provide average values of precipitation that could properly produce trends to analyze and compare. The calendar year was divided into four equal length seasons that correspond to the seasons experienced in Michigan. The seasonal analysis found significantly different results for both streamflow and precipitation.

- Streamflow
    - MK – 47 of the 92 streamflow stations were found to have an existing trend.
    - MKR – 44 of the 92 streamflow station were found to have an existing trend adjusting the variance to account for the effects of serial correlation.
    - Sen’s – 11 of the 44 stations that the MKR test found to have an existing trend were decreasing.
- Precipitation with Respect to Streamflow
    - MK – 24 of the 92 stations had trends in precipitation while 23 of the 24 gauging locations where precipitation trends were found had trends in precipitation and streamflow.
    - MKR – 29 of 92 stations had trends in precipitation while 11 of 29 gauging locations where precipitation trends were found had trends in precipitation and streamflow after adjusting the variance to account for the effects of serial correlation.
    - Sen’s Slope – 9 of the 11 stations have an increasing trend in both precipitation and streamflow. This is expected because as the amount of precipitation increases the amount of storage in the surface water (streamflow) is expected to increase. The 2 other stations experienced an increase in streamflow and a decrease in precipitation. These locations are West Fork Portage Creek at Kalamazoo,

Michigan and Au Sable River near Luzerne, Michigan. This unique location needs a site-specific analysis to determine the cause of such a relationship but possible explanations for such results can include increased water usage, irregularities caused by hydro-electric damming, redirection of water runoff for agricultural purposes or even protection of the water quality by rerouting contaminated water to water treatment facilities.

The seasonal analysis produced a reduction of stations with trends from those found in the daily analysis of about 41%. In addition, the slopes are significantly greater for the seasonal analysis than the daily analysis. The reduction of noise from the data has allowed for a more distinguishable slope.

The annual analysis was conducted in the same format for the streamflow and precipitation data. The two datasets were compared to each other as well as the different temporal analyses. The annual analysis results can be see below.

- Streamflow
    - MK – 43 of the 92 streamflow stations were found to have an existing trend, a further reduction of stations with trends from the seasonal analysis.
    - MKR – 47 of the 92 streamflow station were found to have an existing trend adjusting the variance to account for the effects of serial correlation. An increase in stations that were found to have trends from the seasonal analysis.

    - Sen's – 8 of the 47 of the stations that the MKR test found to have an existing trend were decreasing. A continued decrease in stations with decreasing trends as the analysis progresses from a daily to an annual evaluation.
- Precipitation with Respect to Streamflow
    - MK – 11 of the 43 gauging locations where streamflow trends were found had trends in precipitation and streamflow.
    - MKR – 14 of 47 gauging locations where streamflow trends were found had trends in precipitation and streamflow after adjusting the variance to account for the effects of serial correlation.
    - Sen's Slope – 12 of the 14 stations have an increasing trend in both precipitation and streamflow. This is expected because as the amount of precipitation increases streamflow is expected to increase. The 2 other stations experienced unique scenarios.
        - One location is the Huron River near New Hudson, Michigan where an increase in streamflow and a decrease in precipitation are found. This unique scenario may be caused by increased precipitation on the Huron River at other gauging locations causing an increase in streamflow that does not directly correlate with this location. Also this location has experienced extensive development which may lead to an increase in run-off and a decrease in infiltration leading to an increase in storage capacity.
        - The second unique scenario can be found on the Pine River near Rudyard, Michigan. This location has an increase in precipitation and a decrease in streamflow. One possible explanation for is an increase in water usage.

> The region is dominated by bedrock allowing for little water infiltration. Therefore this region is forced to obtain water from surface bodies of water. In Rudyard the primary surface water source is Pine River. Also, agricultural activity in the region may be redirecting water runoff to store for irrigation purposes. Finally, the site may be impacted directly by a multiple nearby groundwater wells giving an inaccurate representation of streamflow data along the Pine River. These are all plausible explanations but a site specific analysis would need to be conducted to provide concrete evidence as to why such unique trends exist.

Some of the stations that were found to have trends based on the seasonal evaluation do not have trends based on the annual evaluation and vice versa. This is primarily a result of the reduction of some of the noise in the data. Some of the stations have weak slopes and by reducing some of the noise the trend may either appear or disappear. Therefore, the annual analysis provides the most accurate representations of actual trends in streamflow.

The spatial relationship was analyzed using the daily, seasonal and annual data to determine if any of the data interacted forming trends spatially in Michigan. It was found that for the most part the Lower Peninsula experiences an increase in streamflow and precipitation. This coincides with the expected increase in precipitation according to climate research for the region. The precipitation is expected to increase and in association with an increase in precipitation would be an increase in capacity or streamflow in surface bodies of water.

The Detroit Metro Region in particular is the only region that experiences an increase in streamflow in every analysis conducted. The increase in streamflow in this area seems to directly correlate with the increased development and urbanization of the area over the period analyzed. Therefore, it is expected increasing development has a direct impact on streamflow trends, as the infiltration decreases and runoff increases affecting the ratio of surface water to groundwater.

The only regions of decreasing streamflow in the Lower Peninsula are the areas of high altitude. These regions are expected to get less precipitation due to the elevation. In addition to the effects of decreased precipitation, the effect of pumping on these first order streams will reduce the streamflow. These streams are small streams that are primarily groundwater fed and will be impacted by any withdrawal from the stream.

The Upper Peninsula has experienced the opposite effect of the majority of the Lower Peninsula. The majority of the Upper Peninsula has a decreasing streamflow and precipitation trend except for locations of lower elevation (Eastern part of the Upper Peninsula). This coincides with regions of high elevation in the Lower Peninsula further establishing that a relationship exists between streamflow and topography.

These spatial relationships help identify that precipitation is not the only environmental component that impacts streamflow. In addition to precipitation, such characteristics as elevation, contamination, dams, agriculture, urbanization and climate all have an impact on streamflow trends; however precipitation is still identifiable as one of the major driving factor.

The statistical findings in these analyses provide insight into some important identifiable trends in streamflow and precipitation. The effects of increasing and decreasing streamflow trends can have a significant impact on the future of Michigan. The trends can affect climate, water resource management, as well as the current political and economic state of Michigan's water. Further analysis is required for a more in-depth analysis into additional relationships and mitigation techniques for possible future problems.

Recommendations

The analysis conducted was to provide insight into general spatial and temporal trends of streamflow and its relationship to precipitation for the State of Michigan. This information can help identify areas of future problems that can have social, economic, environmental and ecological implications. Further investigation into possible additional causes and unique case by case analyses need to be conducted to provide a more in-depth analysis on a given location.

Also, additional future work to be conducted on this data can include a more in-depth trend analysis using Bayesian Change Point Analysis (Seidou and Ouarda, 2007). This will provide the insight into interior trends within each dataset (that is, points in time when slopes changed) that may or may not currently have an overall trending pattern. Additional tests can also be performed based on wavelet (Kang and Liu 2007) and cross-wavelet (Labat 2010) analyses to better identify spatial and temporal trends in the datasets.

APPENDICES

Table 6. Station Description

Station ID	Station Location	Start Date	End Date
04184500	BEAN CREEK AT POWERS, OH	1-Oct-40	29-Nov-10
04101000	ST. JOSEPH RIVER AT ELKHART, IN	1-Oct-47	29-Nov-10
04095300	TRAIL CREEK AT MICHIGAN CITY, IN	1-Jun-69	30-Sep-09
04095380	TRAIL CREEK AT MICHIGAN CITY HARBOR, IN	1-Oct-94	29-Nov-10
04101370	JUDAY CREEK NEAR SOUTH BEND, IN	1-Oct-92	29-Nov-10
04099750	PIGEON RIVER NEAR SCOTT, IN	1-Jun-68	29-Nov-10
04099000	ST. JOSEPH RIVER AT MOTTVILLE, MI	1-Dec-23	29-Nov-10
04101500	ST. JOSEPH RIVER AT NILES, MI	1-Oct-30	29-Nov-10
04176000	RIVER RAISIN NEAR ADRIAN, MI	1-Oct-53	29-Nov-10
04101800	DOWAGIAC RIVER AT SUMNERVILLE, MI	1-Oct-60	29-Nov-10
04097500	ST. JOSEPH RIVER AT THREE RIVERS, MI	9-May-53	29-Nov-10
04176500	RIVER RAISIN NEAR MONROE, MI	1-Sep-37	29-Nov-10
04096405	ST. JOSEPH RIVER AT BURLINGTON, MI	1-Oct-62	29-Nov-10
04175600	RIVER RAISIN NEAR MANCHESTER, MI	1-Jan-70	29-Nov-10
04102500	PAW PAW RIVER AT RIVERSIDE, MI	1-Oct-51	29-Nov-10
04174518	MALLETTS CREEK AT ANN ARBOR, MI	1-Apr-99	29-Nov-10
04106400	WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	10-Sep-59	29-Nov-10
04103500	KALAMAZOO RIVER AT MARSHALL, MI	1-Oct-48	29-Nov-10
04168580	ECORSE RIVER AT DEARBORN HEIGHTS, MI	1-Jul-02	29-Nov-10
04109000	GRAND RIVER AT JACKSON, MI	1-Apr-35	29-Nov-10
04106000	KALAMAZOO RIVER AT COMSTOCK, MI	24-Apr-31	29-Nov-10
04174500	HURON RIVER AT ANN ARBOR, MI	1-Jan-14	29-Nov-10
04173500	MILL CREEK NEAR DEXTER, MI	1-Mar-52	29-Nov-10
04168000	LOWER RIVER ROUGE AT INKSTER, MI	1-Jun-47	29-Nov-10
04105500	KALAMAZOO RIVER NEAR BATTLE CREEK, MI	27-Jul-37	29-Nov-10
04105000	BATTLE CREEK AT BATTLE CREEK, MI	30-Oct-30	29-Nov-10
04167000	MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	1-Oct-30	29-Nov-10
04105700	AUGUSTA CREEK NEAR AUGUSTA, MI	1-Oct-64	29-Nov-10

Table 6. Station Description cont'd

Station ID	Station Location	Start Date	End Date
04102700	SOUTH BRANCH BLACK RIVER NEAR BANGOR, MI	1-Jun-66	29-Nov-10
04166500	RIVER ROUGE AT DETROIT, MI	1-Oct-30	29-Nov-10
04104945	WANADOGA CREEK NEAR BATTLE CREEK, MI	1-Oct-94	29-Nov-10
04166100	RIVER ROUGE AT SOUTHFIELD, MI	1-Apr-58	29-Nov-10
04172000	HURON RIVER NEAR HAMBURG, MI	1-Oct-51	29-Nov-10
04170500	HURON RIVER NEAR NEW HUDSON, MI	20-Aug-48	29-Nov-10
04111000	GRAND RIVER NEAR EATON RAPIDS, MI	1-Oct-50	29-Nov-10
04166000	RIVER ROUGE AT BIRMINGHAM, MI	1-Jun-50	29-Nov-10
04117000	QUAKER BROOK NEAR NASHVILLE, MI	1-Aug-54	29-Nov-10
04164000	CLINTON RIVER NEAR FRASER, MI	1-Jun-47	29-Nov-10
04161820	CLINTON RIVER AT STERLING HEIGHTS, MI	1-Oct-78	29-Nov-10
04117500	THORNAPPLE RIVER NEAR HASTINGS, MI	1-Oct-44	29-Nov-10
04164500	NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	1-Jun-47	29-Nov-10
04161000	CLINTON RIVER AT AUBURN HILLS, MI	1-May-35	29-Nov-10
04108600	RABBIT RIVER NEAR HOPKINS, MI	1-Oct-65	29-Nov-10
04108660	KALAMAZOO RIVER NEAR NEW RICHMOND, MI	1-Apr-94	29-Nov-10
04161540	PAINT CREEK AT ROCHESTER, MI	1-Oct-59	29-Nov-10
04161800	STONY CREEK NEAR WASHINGTON, MI	1-Jul-58	29-Nov-10
04112500	RED CEDAR RIVER AT EAST LANSING, MI	31-Aug-02	29-Nov-10
04113000	GRAND RIVER AT LANSING, MI	1-Mar-01	29-Nov-10
04108800	MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1-Oct-60	29-Nov-10
04161580	STONY CREEK NEAR ROMEO, MI	1-Oct-64	29-Nov-10
04118000	THORNAPPLE RIVER NEAR CALEDONIA, MI	1-Oct-51	30-Sep-94
04164100	EAST POND CREEK AT ROMEO, MI	1-Sep-58	29-Nov-10
04114498	LOOKING GLASS RIVER NEAR EAGLE, MI	1-Aug-44	29-Nov-10
04164300	EAST BRANCH COON CREEK AT ARMADA, MI	1-Oct-58	29-Nov-10
04114000	GRAND RIVER AT PORTLAND, MI	20-Aug-52	29-Nov-10
04119000	GRAND RIVER AT GRAND RAPIDS, MI	1-Mar-83	29-Nov-10

Table 6. Station Description cont'd

Station ID	Station Location	Start Date	End Date
04116000	GRAND RIVER AT IONIA, MI	19-Mar-31	29-Nov-10
04148440	THREAD CREEK NEAR FLINT, MI	1-Jan-70	31-Dec-83
04148300	SWARTZ CREEK AT FLINT, MI	1-Jan-70	31-Dec-83
04144500	SHIAWASSEE RIVER AT OWOSSO, MI	1-Mar-31	29-Nov-10
04148140	KEARSLEY CREEK NEAR DAVISON, MI	1-Oct-65	29-Nov-10
04148500	FLINT RIVER NEAR FLINT, MI	18-Aug-32	29-Nov-10
04116500	FLAT RIVER AT SMYRNA, MI	1-Oct-50	30-Sep-86
04159900	MILL CREEK NEAR AVOCA, MI	1-Apr-63	29-Nov-10
04118500	ROGUE RIVER NEAR ROCKFORD, MI	1-Feb-52	29-Nov-10
04115000	MAPLE RIVER AT MAPLE RAPIDS, MI	1-Aug-44	29-Nov-10
04147500	FLINT RIVER NEAR OTISVILLE, MI	1-Oct-52	29-Nov-10
04159492	BLACK RIVER NEAR JEDDO, MI	1-Mar-44	29-Nov-10
04146063	SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	1-Mar-80	29-Nov-10
04122100	BEAR CREEK NEAR MUSKEGON, MI	1-Oct-65	29-Nov-10
04151500	CASS RIVER AT FRANKENMUTH, MI	1-Mar-08	29-Nov-10
04157000	SAGINAW RIVER AT SAGINAW, MI	11-Mar-04	30-Sep-09
04121944	LITTLE MUSKEGON RIVER NEAR OAK GROVE, MI	1-Oct-95	29-Nov-10
04121970	MUSKEGON RIVER NEAR CROTON, MI	1-Oct-95	29-Nov-10
04150800	CASS RIVER AT WAHJAMEGA, MI	1-Oct-68	30-Sep-94
04122200	WHITE RIVER NEAR WHITEHALL, MI	1-Aug-57	29-Nov-10
04155500	PINE RIVER NEAR MIDLAND, MI	31-May-34	29-Nov-10
04156000	TITTABAWASSEE RIVER AT MIDLAND, MI	1-Apr-36	29-Nov-10
04154000	CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1-Oct-30	29-Nov-10
04157065	SAGINAW RIVER AT WEADOCK ROAD AT ESSEXVILLE, MI	1-Oct-96	30-Sep-04
04152238	SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	1-Jan-87	29-Nov-10
04121500	MUSKEGON RIVER AT EVART, MI	17-Nov-30	29-Nov-10
04122500	PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1-Aug-39	29-Nov-10
04142000	RIFLE RIVER NEAR STERLING, MI	13-Jan-37	29-Nov-10

Table 6. Station Description cont'd

Station ID	Station Location	Start Date	End Date
04124500	EAST BRANCH PINE RIVER NEAR TUSTIN, MI	1-Jul-52	29-Nov-10
04125460	PINE RIVER AT HIGH SCHOOL BRIDGE NR HOXEYVILLE, MI	1-Jul-52	29-Nov-10
04125550	MANISTEE RIVER NEAR WELLSTON, MI	1-Oct-96	29-Nov-10
04124200	MANISTEE RIVER NEAR MESICK, MI	1-Dec-96	29-Nov-10
442409084274001	LAKE ST HELEN AT ST HELEN, MI	1-Oct-43	29-Nov-10
442805084411001	HIGGINS LAKE NEAR ROSCOMMON, MI	1-Oct-76	29-Nov-10
04124000	MANISTEE RIVER NEAR SHERMAN, MI	1-Jul-03	29-Nov-10
04137500	AU SABLE RIVER NEAR AU SABLE, MI	1-Aug-87	29-Nov-10
04137005	AU SABLE RIVER NEAR CURTISVILLE, MI	1-Oct-96	29-Nov-10
04136900	AU SABLE RIVER NEAR MC KINLEY, MI	1-Oct-96	29-Nov-10
04135700	SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	1-Oct-66	29-Nov-10
04126970	BOARDMAN R ABOVE BROWN BRIDGE ROAD NR MAYFIELD, MI	10-Sep-97	29-Nov-10
04136500	AU SABLE RIVER AT MIO, MI	9-Jul-52	29-Nov-10
04126740	PLATTE RIVER AT HONOR, MI	27-Mar-90	29-Nov-10
04136000	AU SABLE RIVER NEAR RED OAK, MI	1-Oct-08	29-Nov-10
450415085153501	INTERMEDIATE LAKE AT CENTRAL LAKE, MI	13-Oct-01	29-Nov-10
04127800	JORDAN RIVER NEAR EAST JORDAN, MI	1-Oct-66	29-Nov-10
04133501	THUNDER BAY RIVER AT HERRON ROAD NEAR BOLTON, MI	1-Apr-45	29-Nov-10
04069416	PESHTIGO RIVER AT PORTERFIELD, WI	1-Jun-98	29-Nov-10
04128990	PIGEON RIVER NEAR VANDERBILT, MI	1-Oct-50	29-Nov-10
04127997	STURGEON RIVER AT WOLVERINE, MI	1-Apr-42	29-Nov-10
04067500	MENOMINEE RIVER NEAR MC ALLISTER, WI	28-Mar-45	29-Nov-10
04066800	MENOMINEE RIVER AT KOSS, MI	1-Jul-13	29-Nov-10
04066030	MENOMINEE RIVER AT WHITE RAPIDS DAM NEAR BANAT, MI	1-Oct-98	29-Nov-10
04066003	MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	1-Oct-49	29-Nov-10
04065722	MENOMINEE RIVER NEAR VULCAN, MI	1-Dec-87	29-Nov-10
04059500	FORD RIVER NEAR HYDE, MI	1-Oct-54	29-Nov-10
04065106	MENOMINEE RIVER AT NIAGARA, WI	1-Oct-92	29-Nov-10

Table 6. Station Description cont'd

Station ID	Station Location	Start Date	End Date
04064500	PINE RIVER BELOW PINE R POWERPLANT NR FLORENCE, WI	1-Oct-23	29-Nov-10
04063500	MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	1-Jan-14	29-Nov-10
04059000	ESCANABA RIVER AT CORNELL, MI	1-Sep-03	29-Nov-10
04057510	STURGEON RIVER NEAR NAHMA JUNCTION, MI	1-Oct-66	29-Nov-10
04063000	MENOMINEE RIVER NEAR FLORENCE, WI	1-Jan-14	29-Nov-10
04060993	BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1-Feb-14	29-Nov-10
04058940	ESCANABA RIVER NEAR ST. NICHOLAS, MI	1-Oct-89	29-Nov-10
04062000	PAINT RIVER NEAR ALPHA, MI	7-Jun-52	29-Nov-10
04056500	MANISTIQUE RIVER NEAR MANISTIQUE, MI	26-Mar-38	29-Nov-10
04060500	IRON RIVER AT CASPIAN, MI	1-Apr-48	29-Nov-10
04062500	MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	20-Aug-44	29-Nov-10
04127918	PINE RIVER NEAR RUDYARD, MI	1-Apr-72	29-Nov-10
04037500	CISCO BRANCH ONTONAGON R AT CISCO LAKE OUTLET, MI	1-Oct-44	29-Nov-10
04058100	MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	1-Jul-61	29-Nov-10
04044724	AU TRAIN RIVER AT FOREST LAKE, MI	1-Oct-93	29-Nov-10
04033000	MIDDLE BRANCH ONTONAGON RIVER NEAR PAULDING, MI	15-Jun-42	29-Nov-10
04033500	BOND FALLS CANAL NEAR PAULDING, MI	1-Jul-42	29-Nov-10
04058200	SCHWEITZER CREEK NEAR PALMER, MI	1-Oct-60	29-Nov-10
04057814	GREENWOOD RELEASE NEAR GREENWOOD, MI	1-Oct-72	29-Nov-10
04057812	GREENWOOD AFTERBAY NEAR GREENWOOD, MI	26-Mar-99	29-Nov-10
04057800	MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	24-Jun-59	29-Nov-10
04031000	BLACK RIVER NEAR BESSEMER, MI	1-Oct-00	29-Nov-10
04045500	TAHQUAMENON RIVER NEAR PARADISE, MI	7-Aug-53	29-Nov-10
04040500	STURGEON RIVER NEAR SIDNAW, MI	1-Apr-43	29-Nov-10
04036000	WEST BRANCH ONTONAGON RIVER NEAR BERGLAND, MI	19-Jul-42	13-Oct-09
04043275	YELLOW DOG RIVER NEAR BIG BAY, MI	1-Dec-04	29-Nov-10
04040000	ONTONAGON RIVER NEAR ROCKLAND, MI	1-Jun-42	29-Oct-09
04041500	STURGEON RIVER NEAR ALSTON, MI	1-Oct-42	29-Nov-10

Table 6. Station Description cont'd

Station ID	Station Location	Start Date	End Date
04043140	GOMANCHE CREEK AT INDIAN ROAD NEAR L'ANSE, MI	1-Oct-07	29-Nov-10
04043238	SALMON TROUT RIVER NEAR BIG BAY, MI	2-Dec-04	29-Nov-10
04043244	EAST BRANCH SALMON TROUT RIVER NEAR DODGE CITY, MI	1-Oct-05	29-Nov-10
04043150	SILVER RIVER NEAR L'ANSE, MI	1-Oct-01	29-Nov-10
04043050	TRAP ROCK RIVER NEAR LAKE LINDEN, MI	1-Oct-66	29-Nov-10
04001000	WASHINGTON CREEK AT WINDIGO, MI	1-Oct-64	30-Sep-03
04176605	OTTER CREEK AT LA SALLE, MI	1-Oct-87	29-Nov-10

Table 7. Daily Streamflow Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
SAGINAW RIVER AT SAGINAW, MI	1	0	1	0	-1.676
MENOMINEE RIVER AT WHITE RAPIDS DAM NEAR BANAT, MI	1	0	1	0	-0.143637
MENOMINEE RIVER AT NIAGARA, WI	1	0	1	0	-0.090444
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1	0	1	0.0021	-0.09
MENOMINEE RIVER NEAR VULCAN, MI	1	0	1	0	-0.068349
GRAND RIVER AT GRAND RAPIDS, MI	1	0	1	0.0043	-0.048
AU SABLE RIVER NEAR AU SABLE, MI	1	0	1	0	-0.02739
AU SABLE RIVER NEAR RED OAK, MI	1	0	1	0	-0.023
PLATTE RIVER AT HONOR, MI	1	0	1	0	-0.003478
JUDAY CREEK NEAR SOUTH BEND, IN	1	0	1	0.0119	-0.001091
MANISTEE RIVER NEAR MESICK, MI	1	0	1	0	0.015554
AU SABLE RIVER NEAR CURTISVILLE, MI	1	0	1	0	0.016125
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0	1	0	0.018
TITTABAWASSEE RIVER AT MIDLAND, MI	1	0	1	0.0283	0.018
THORNAPPLE RIVER NEAR CALEDONIA, MI	1	0	1	0.0026	0.018
TRAIL CREEK AT MICHIGAN CITY HARBOR, IN	1	0	1	0	0.018424
GRAND RIVER AT PORTLAND, MI	1	0	1	0.0068	0.022
ST. JOSEPH RIVER AT ELKHART, IN	1	0	1	0	0.024
ST. JOSEPH RIVER AT THREE RIVERS, MI	1	0	1	0.0035	0.027
GRAND RIVER AT IONIA, MI	1	0	1	0.0251	0.029
MANISTEE RIVER NEAR WELLSTON, MI	1	0	1	0	0.033431
ST. JOSEPH RIVER AT NILES, MI	1	0	1	0	0.047
KALAMAZOO RIVER NEAR NEW RICHMOND, MI	1	0	1	0	0.262609
ONTONAGON RIVER NEAR ROCKLAND, MI	1	0	1	0.0032	-7.00E-03
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	1	0	1	0	-0.002
SAGINAW RIVER AT WEADOCK ROAD AT ESSEXVILLE, MI	1	0	1	0.0193	-0.001563
MANISTEE RIVER NEAR SHERMAN, MI	1	0	1	0.0011	-0.001

Table 7. Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
GOMANCHE CREEK AT INDIAN ROAD NEAR L'ANSE, MI	1	0	1	0.0083	-9.57E-04
SALMON TROUT RIVER NEAR BIG BAY, MI	1	0	1	0.0022	-1.93E-04
ESCANABA RIVER NEAR ST. NICHOLAS, MI	1	0	1	0	-2.11E-05
EAST POND CREEK AT ROMEO, MI	1	0	1	0	0
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	1	0	1	0	0
JORDAN RIVER NEAR EAST JORDAN, MI	1	0	1	0	0
QUAKER BROOK NEAR NASHVILLE, MI	1	0	1	0.0019	0
FLINT RIVER NEAR FLINT, MI	1	0	1	0.011	0
IRON RIVER AT CASPIAN, MI	1	0	1	0.0144	0
CISCO BRANCH ONTONAGON R AT CISCO LAKE OUTLET, MI	1	0	1	0.0185	0
KEARSLEY CREEK NEAR DAVISON, MI	1	0	1	0.184	0
GREENWOOD AFTERBAY NEAR GREENWOOD, MI	1	0	1	0	1.09E-04
RIFLE RIVER NEAR STERLING, MI	1	0	1	0	0.001
STURGEON RIVER AT WOLVERINE, MI	1	0	1	0	0.001
HURON RIVER NEAR NEW HUDSON, MI	1	0	1	0	0.001
RIVER ROUGE AT BIRMINGHAM, MI	1	0	1	0	0.001
PINE RIVER AT HIGH SCHOOL BRIDGE NR HOXEYVILLE, MI	1	0	1	0	0.001
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	1	0	1	0.0175	0.001
PAINT CREEK AT ROCHESTER, MI	1	0	1	0.0183	0.001
MILL CREEK NEAR DEXTER, MI	1	0	1	0.0246	0.001
RIVER RAISIN NEAR MANCHESTER, MI	1	0	1	0.03	0.001
PIGEON RIVER NEAR SCOTT, IN	1	0	1	0.0347	0.001
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	1	0	1	0	0.002
GRAND RIVER AT JACKSON, MI	1	0	1	0	0.002
LOWER RIVER ROUGE AT INKSTER, MI	1	0	1	0	0.002
RIVER ROUGE AT SOUTHFIELD, MI	1	0	1	0.0027	0.002
RIVER ROUGE AT DETROIT, MI	1	0	1	0.0032	0.002

Table 7. Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
LOOKING GLASS RIVER NEAR EAGLE, MI	1	0	1	0.0121	0.002
BATTLE CREEK AT BATTLE CREEK, MI	1	0	1	0.0295	0.002
RED CEDAR RIVER AT EAST LANSING, MI	1	0	1	0.044	0.002
HURON RIVER NEAR HAMBURG, MI	1	0	1	0	0.003
WHITE RIVER NEAR WHITEHALL, MI	1	0	1	0	0.003
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0	1	0	0.003
ROGUE RIVER NEAR ROCKFORD, MI	1	0	1	0.0028	0.003
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0	1	0.0042	0.003
THORNAPPLE RIVER NEAR HASTINGS, MI	1	0	1	0.011	0.003
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0	1	0	0.004
PAW PAW RIVER AT RIVERSIDE, MI	1	0	1	0	0.004
CLINTON RIVER AT AUBURN HILLS, MI	1	0	1	0.0019	0.004
PINE RIVER NEAR MIDLAND, MI	1	0	1	0.0194	0.004
HURON RIVER AT ANN ARBOR, MI	1	0	1	0.0011	0.005
CLINTON RIVER NEAR FRASER, MI	1	0	1	0.0035	0.005
SHIAWASSEE RIVER AT OWOSSO, MI	1	0	1	0.0194	0.005
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	1	0	1	0	0.007
KALAMAZOO RIVER AT MARSHALL, MI	1	0	1	0	0.007
MUSKEGON RIVER AT EVART, MI	1	0	1	0.0102	0.007
GRAND RIVER AT LANSING, MI	1	0	1	0.0017	0.008
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1	0	1	0.0033	0.008
GRAND RIVER NEAR EATON RAPIDS, MI	1	0	1	0.0026	0.009
KALAMAZOO RIVER AT COMSTOCK, MI	1	0	1	0	0.012
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	1	0	0	0.054	N/A
RIVER RAISIN NEAR ADRIAN, MI	1	0	0	0.0552	N/A
FLAT RIVER AT SMYRNA, MI	1	0	0	0.0565	N/A
RIVER RAISIN NEAR MONROE, MI	1	0	0	0.0583	N/A

Table 7. Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
BLACK RIVER NEAR JEDDO, MI	1	0	0	0.0658	N/A
STONY CREEK NEAR ROMEO, MI	1	0	0	0.0742	N/A
GREENWOOD RELEASE NEAR GREENWOOD, MI	1	0	0	0.0787	N/A
STONY CREEK NEAR WASHINGTON, MI	1	0	0	0.0809	N/A
STURGEON RIVER NEAR NAHMA JUNCTION, MI	1	0	0	0.0879	N/A
FLINT RIVER NEAR OTISVILLE, MI	1	0	0	0.1019	N/A
PIGEON RIVER NEAR VANDERBILT, MI	1	0.0013	0	0.1132	N/A
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	1	0	0	0.1267	N/A
MENOMINEE RIVER NEAR MC ALLISTER, WI	1	0	0	0.1376	N/A
CASS RIVER AT FRANKENMUTH, MI	1	0	0	0.1486	N/A
MUSKEGON RIVER NEAR CROTON, MI	1	0.0025	0	0.1488	N/A
EAST BRANCH SALMON TROUT RIVER NEAR DODGE CITY, MI	1	0	0	0.1516	N/A
THUNDER BAY RIVER AT HERRON ROAD NEAR BOLTON, MI	1	0	0	0.1594	N/A
TRAIL CREEK AT MICHIGAN CITY, IN	1	0	0	0.1895	N/A
CASS RIVER AT WAHJAMEGA, MI	1	0	0	0.1908	N/A
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	1	0	0	0.1973	N/A
RABBIT RIVER NEAR HOPKINS, MI	1	0	0	0.2076	N/A
LITTLE MUSKEGON RIVER NEAR OAK GROVE, MI	1	0	0	0.2114	N/A
MIDDLE BRANCH ONTONAGON RIVER NEAR PAULDING, MI	1	0	0	0.2254	N/A
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	1	0	0	0.2319	N/A
MILL CREEK NEAR AVOCA, MI	1	0	0	0.2372	N/A
SCHWEITZER CREEK NEAR PALMER, MI	1	0	0	0.2685	N/A
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0	0	0.2735	N/A
WEST BRANCH ONTONAGON RIVER NEAR BERGLAND, MI	1	0	0	0.2929	N/A
ESCANABA RIVER AT CORNELL, MI	1	0	0	0.3139	N/A
PINE RIVER BELOW PINE R POWERPLANT NR FLORENCE, WI	1	0	0	0.34	N/A
BOND FALLS CANAL NEAR PAULDING, MI	1	0	0	0.3489	N/A

Table 7. Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
EAST BRANCH COON CREEK AT ARMADA, MI	1	0	0	0.4127	N/A
AU SABLE RIVER NEAR MC KINLEY, MI	1	0	0	0.4258	N/A
BEAR CREEK NEAR MUSKEGON, MI	1	0	0	0.4315	N/A
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1	0	0	0.4408	N/A
AU SABLE RIVER AT MIO, MI	1	0.338	0	0.4422	N/A
TRAP ROCK RIVER NEAR LAKE LINDEN, MI	1	0	0	0.4465	N/A
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	1	0	0	0.4814	N/A
PINE RIVER NEAR RUDYARD, MI	1	0	0	0.4829	N/A
STURGEON RIVER NEAR ALSTON, MI	1	0	0	0.4866	N/A
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	1	0	0	0.4999	N/A
TAHQUAMENON RIVER NEAR PARADISE, MI	1	0.0044	0	0.5397	N/A
PAINT RIVER NEAR ALPHA, MI	1	0	0	0.5452	N/A
SOUTH BRANCH BLACK RIVER NEAR BANGOR, MI	1	0.0063	0	0.5541	N/A
SWARTZ CREEK AT FLINT, MI	1	0	0	0.564	N/A
FORD RIVER NEAR HYDE, MI	1	0	0	0.6115	N/A
SILVER RIVER NEAR L'ANSE, MI	1	0	0	0.6215	N/A
OTTER CREEK AT LA SALLE, MI	1	0	0	0.6313	N/A
MALLETTS CREEK AT ANN ARBOR, MI	1	0	0	0.6337	N/A
PESHTIGO RIVER AT PORTERFIELD, WI	1	0.021	0	0.6344	N/A
ECORSE RIVER AT DEARBORN HEIGHTS, MI	1	0	0	0.6496	N/A
CLINTON RIVER AT STERLING HEIGHTS, MI	1	0.0401	0	0.7089	N/A
WASHINGTON CREEK AT WINDIGO, MI	1	0	0	0.7171	N/A
YELLOW DOG RIVER NEAR BIG BAY, MI	1	0.0033	0	0.7358	N/A
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	1	0	0	0.7562	N/A
STURGEON RIVER NEAR SIDNAW, MI	1	0.0057	0	0.839	N/A
MENOMINEE RIVER NEAR FLORENCE, WI	1	0	0	0.8552	N/A
BLACK RIVER NEAR BESSEMER, MI	1	0.0262	0	0.867	N/A

Table 7. Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
MENOMINEE RIVER AT KOSS, MI	1	0.0455	0	0.8923	N/A
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	0	0.0512	0	0.2659	N/A
AUGUSTA CREEK NEAR AUGUSTA, MI	0	0.3437	0	0.7411	N/A
AU TRAIN RIVER AT FOREST LAKE, MI	0	0.1122	0	0.807	N/A
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.6585	0	0.8853	N/A
BOARDMAN R ABOVE BROWN BRIDGE ROAD NR MAYFIELD, MI	0	0.7879	0	0.9176	N/A
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.5778	0	0.9284	N/A
THREAD CREEK NEAR FLINT, MI	0	0.6794	0	0.9355	N/A
BEAN CREEK AT POWERS, OH	1	0	0	0.3585	N/A
LAKE ST HELEN AT ST HELEN, MI	1	0	1	0	0
HIGGINS LAKE NEAR ROSCOMMON, MI	1	0	1	0	0
INTERMEDIATE LAKE AT CENTRAL LAKE, MI	0	0.2853	0	0.7001	N/A

Table 8. Daily Precipitation Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
BEAN CREEK AT POWERS, OH	0	1.000	0	1.000	0
ST. JOSEPH RIVER AT ELKHART, IN	1	0.001	0	0.943	0
TRAIL CREEK AT MICHIGAN CITY, IN	0	1.000	0	1.000	0
TRAIL CREEK AT MICHIGAN CITY HARBOR, IN	0	0.111	0	0.933	0
JUDAY CREEK NEAR SOUTH BEND, IN	1	0.001	0	0.943	0
PIGEON RIVER NEAR SCOTT, IN	0	1.000	0	1.000	0
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0.000	0	0.869	0
ST. JOSEPH RIVER AT NILES, MI	1	0.001	0	0.943	0
RIVER RAISIN NEAR ADRIAN, MI	1	0.000	0	0.827	0
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.000	0	0.828	0
ST. JOSEPH RIVER AT THREE RIVERS, MI	1	0.000	0	0.797	0
RIVER RAISIN NEAR MONROE, MI	1	0.000	0	0.845	0
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.000	0	0.820	0
RIVER RAISIN NEAR MANCHESTER, MI	1	0.000	1	0.000	0
PAW PAW RIVER AT RIVERSIDE, MI	1	0.000	0	0.861	0
MALLETTS CREEK AT ANN ARBOR, MI	1	0.000	0	0.777	0
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	1	0.000	0	0.755	0
KALAMAZOO RIVER AT MARSHALL, MI	1	0.000	0	0.809	0
ECORSE RIVER AT DEARBORN HEIGHTS, MI	1	0.000	0	0.840	0
GRAND RIVER AT JACKSON, MI	1	0.000	0	0.558	0
KALAMAZOO RIVER AT COMSTOCK, MI	1	0.000	0	0.782	0
HURON RIVER AT ANN ARBOR, MI	1	0.000	0	0.699	0
MILL CREEK NEAR DEXTER, MI	1	0.000	0	0.800	0
LOWER RIVER ROUGE AT INKSTER, MI	1	0.000	0	0.817	0
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	1	0.000	0	0.735	0
BATTLE CREEK AT BATTLE CREEK, MI	1	0.000	0	0.753	0
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	1	0.000	0	0.677	0

Table 8. Daily Precipitation Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen
AUGUSTA CREEK NEAR AUGUSTA, MI	1	0.000	0	0.834	0
SOUTH BRANCH BLACK RIVER NEAR BANGOR, MI	1	0.000	0	0.862	0
RIVER ROUGE AT DETROIT, MI	1	0.000	0	0.710	0
WANADOGA CREEK NEAR BATTLE CREEK, MI	1	0.000	0	0.767	0
RIVER ROUGE AT SOUTHFIELD, MI	1	0.000	0	0.707	0
HURON RIVER NEAR HAMBURG, MI	1	0.000	0	0.797	0
HURON RIVER NEAR NEW HUDSON, MI	1	0.000	0	0.813	0
GRAND RIVER NEAR EATON RAPIDS, MI	1	0.000	0	0.720	0
RIVER ROUGE AT BIRMINGHAM, MI	1	0.000	0	0.704	0
QUAKER BROOK NEAR NASHVILLE, MI	1	0.000	0	0.827	0
CLINTON RIVER NEAR FRASER, MI	1	0.000	0	0.709	0
CLINTON RIVER AT STERLING HEIGHTS, MI	1	0.000	0	0.714	0
THORNAPPLE RIVER NEAR HASTINGS, MI	1	0.000	0	0.804	0
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	1	0.000	0	0.713	0
CLINTON RIVER AT AUBURN HILLS, MI	1	0.000	0	0.719	0
RABBIT RIVER NEAR HOPKINS, MI	1	0.000	0	0.813	0
KALAMAZOO RIVER NEAR NEW RICHMOND, MI	1	0.000	0	0.885	0
PAINT CREEK AT ROCHESTER, MI	1	0.000	0	0.728	0
STONY CREEK NEAR WASHINGTON, MI	1	0.000	0	0.747	0
RED CEDAR RIVER AT EAST LANSING, MI	1	0.000	0	0.637	0
GRAND RIVER AT LANSING, MI	1	0.000	0	0.715	0
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1	0.000	0	0.773	0
STONY CREEK NEAR ROMEO, MI	1	0.000	0	0.763	0
THORNAPPLE RIVER NEAR CALEDONIA, MI	1	0.000	0	0.832	0
EAST POND CREEK AT ROMEO, MI	1	0.000	0	0.832	0
LOOKING GLASS RIVER NEAR EAGLE, MI	1	0.000	0	0.693	0
EAST BRANCH COON CREEK AT ARMADA, MI	1	0.000	0	0.822	0

Table 8. Daily Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
GRAND RIVER AT PORTLAND, MI	1	0.000	0	0.892	0
GRAND RIVER AT GRAND RAPIDS, MI	1	0.000	0	0.681	0
GRAND RIVER AT IONIA, MI	1	0.000	0	0.799	0
THREAD CREEK NEAR FLINT, MI	1	0.000	0	0.723	0
SWARTZ CREEK AT FLINT, MI	1	0.000	0	0.812	0
SHIAWASSEE RIVER AT OWOSSO, MI	1	0.000	0	0.854	0
KEARSLEY CREEK NEAR DAVISON, MI	1	0.000	0	0.749	0
FLINT RIVER NEAR FLINT, MI	1	0.000	0	0.921	0
FLAT RIVER AT SMYRNA, MI	1	0.000	0	0.806	0
MILL CREEK NEAR AVOCA, MI	1	0.000	0	0.897	0
ROGUE RIVER NEAR ROCKFORD, MI	1	0.000	0	0.848	0
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.000	0	0.878	0
FLINT RIVER NEAR OTISVILLE, MI	1	0.000	0	0.784	0
BLACK RIVER NEAR JEDDO, MI	1	0.000	0	0.850	0
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	1	0.000	0	0.818	0
BEAR CREEK NEAR MUSKEGON, MI	1	0.000	0	0.685	0
CASS RIVER AT FRANKENMUTH, MI	1	0.000	0	0.895	0
SAGINAW RIVER AT SAGINAW, MI	0	0.512	0	0.986	0
LITTLE MUSKEGON RIVER NEAR OAK GROVE, MI	1	0.000	0	0.789	0
MUSKEGON RIVER NEAR CROTON, MI	1	0.000	0	0.835	0
CASS RIVER AT WAHJAMEGA, MI	1	0.000	0	0.889	0
WHITE RIVER NEAR WHITEHALL, MI	1	0.000	0	0.686	0
PINE RIVER NEAR MIDLAND, MI	1	0.000	0	0.836	0
TITTABAWASSEE RIVER AT MIDLAND, MI	1	0.000	0	0.802	0
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0.000	0	0.798	0
SAGINAW RIVER AT WEADOCK ROAD AT ESSEXVILLE, MI	1	0.000	0	0.887	0
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	1	0.000	0	0.802	0

Table 8. Daily Precipitation Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen
MUSKEGON RIVER AT EVART, MI	1	0.000	0	0.835	0
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1	0.000	0	0.845	0
RIFLE RIVER NEAR STERLING, MI	0	0.768	0	0.990	0
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	1	0.000	0	0.780	0
PINE RIVER AT HIGH SCHOOL BRIDGE NR HOXEYVILLE, MI	1	0.000	0	0.823	0
MANISTEE RIVER NEAR WELLSTON, MI	1	0.000	0	0.853	0
MANISTEE RIVER NEAR MESICK, MI	1	0.000	0	0.871	0
LAKE ST HELEN AT ST HELEN, MI	1	0.000	0	0.467	0
HIGGINS LAKE NEAR ROSCOMMON, MI	1	0.000	0	0.442	0
MANISTEE RIVER NEAR SHERMAN, MI	1	0.000	0	0.852	0
AU SABLE RIVER NEAR AU SABLE, MI	1	0.000	0	0.866	0
AU SABLE RIVER NEAR CURTISVILLE, MI	1	0.000	0	0.460	0
AU SABLE RIVER NEAR MC KINLEY, MI	1	0.000	0	0.465	0
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	1	0.000	0	0.463	0
BOARDMAN R ABOVE BROWN BRIDGE ROAD NR MAYFIELD, MI	1	0.000	0	0.861	0
AU SABLE RIVER AT MIO, MI	1	0.000	0	0.507	0
PLATTE RIVER AT HONOR, MI	1	0.000	0	0.865	0
AU SABLE RIVER NEAR RED OAK, MI	1	0.000	0	0.481	0
INTERMEDIATE LAKE AT CENTRAL LAKE, MI	1	0.000	0	0.769	0
JORDAN RIVER NEAR EAST JORDAN, MI	1	0.000	0	0.797	0
THUNDER BAY RIVER AT HERRON ROAD NEAR BOLTON, MI	1	0.000	0	0.572	0
PESHTIGO RIVER AT PORTERFIELD, WI	1	0.000	0	0.809	0
PIGEON RIVER NEAR VANDERBILT, MI	1	0.000	0	0.565	0
STURGEON RIVER AT WOLVERINE, MI	1	0.000	0	0.550	0
MENOMINEE RIVER NEAR MC ALLISTER, WI	1	0.000	0	0.939	0
MENOMINEE RIVER AT KOSS, MI	1	0.002	0	0.953	0
MENOMINEE RIVER AT WHITE RAPIDS DAM NEAR BANAT, MI	1	0.002	0	0.960	0

Table 8. Daily Precipitation Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	0	0.684	0	0.993	0
MENOMINEE RIVER NEAR VULCAN, MI	1	0.000	0	0.944	0
FORD RIVER NEAR HYDE, MI	1	0.000	0	0.885	0
MENOMINEE RIVER AT NIAGARA, WI	1	0.000	0	0.924	0
PINE RIVER BELOW PINE R POWERPLANT NR FLORENCE, WI	1	0.000	0	0.926	0
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	1	0.000	0	0.895	0
ESCANABA RIVER AT CORNELL, MI	1	0.003	0	0.960	0
STURGEON RIVER NEAR NAHMA JUNCTION, MI	1	0.021	0	0.967	0
MENOMINEE RIVER NEAR FLORENCE, WI	1	0.000	0	0.899	0
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1	0.000	0	0.905	0
ESCANABA RIVER NEAR ST. NICHOLAS, MI	1	0.000	0	0.878	0
PAINT RIVER NEAR ALPHA, MI	1	0.000	0	0.934	0
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.484	0	0.993	0
IRON RIVER AT CASPIAN, MI	1	0.000	0	0.722	0
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	1	0.000	0	0.909	0
PINE RIVER NEAR RUDYARD, MI	1	0.000	0	0.944	0
CISCO BRANCH ONTONAGON R AT CISCO LAKE OUTLET, MI	1	0.000	0	0.851	0
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	1	0.000	0	0.774	0
AU TRAIN RIVER AT FOREST LAKE, MI	1	0.000	0	0.850	0
MIDDLE BRANCH ONTONAGON RIVER NEAR PAULDING, MI	1	0.000	0	0.876	0
BOND FALLS CANAL NEAR PAULDING, MI	1	0.000	0	0.843	0
SCHWEITZER CREEK NEAR PALMER, MI	1	0.000	0	0.777	0
GREENWOOD RELEASE NEAR GREENWOOD, MI	1	0.000	0	0.789	0
GREENWOOD AFTERBAY NEAR GREENWOOD, MI	1	0.000	0	0.787	0
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	1	0.000	0	0.808	0
BLACK RIVER NEAR BESSEMER, MI	0	1.000	0	1.000	0
TAHQUAMENON RIVER NEAR PARADISE, MI	1	0.000	0	0.953	0

Table 8. Daily Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen**
STURGEON RIVER NEAR SIDNAW, MI	1	0.000	0	0.745	0
WEST BRANCH ONTONAGON RIVER NEAR BERGLAND, MI	1	0.000	0	0.679	0
YELLOW DOG RIVER NEAR BIG BAY, MI	1	0.000	0	0.751	0
ONTONAGON RIVER NEAR ROCKLAND, MI	1	0.000	0	0.842	0
STURGEON RIVER NEAR ALSTON, MI	1	0.000	0	0.768	0
GOMANCHE CREEK AT INDIAN ROAD NEAR L'ANSE, MI	1	0.000	0	0.624	0
SALMON TROUT RIVER NEAR BIG BAY, MI	1	0.000	0	0.761	0
EAST BRANCH SALMON TROUT RIVER NEAR DODGE CITY, MI	1	0.000	0	0.775	0
SILVER RIVER NEAR L'ANSE, MI	1	0.000	0	0.641	0
TRAP ROCK RIVER NEAR LAKE LINDEN, MI	1	0.000	0	0.699	0
WASHINGTON CREEK AT WINDIGO, MI	0	1.000	0	1.000	0
OTTER CREEK AT LA SALLE, MI	0	1.000	0	1.000	0

Table 9. Continuous Daily Streamflow Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	1	0.0000	1	0.0003	-0.12000
MENOMINEE RIVER AT NIAGARA, WI	1	0.0000	1	0.0000	-0.09460
MENOMINEE RIVER NEAR VULCAN, MI	1	0.0000	1	0.0000	-0.06830
GRAND RIVER AT GRAND RAPIDS, MI	1	0.0000	1	0.0073	-0.04760
AU SABLE RIVER NEAR AU SABLE, MI	1	0.0000	1	0.0000	-0.02740
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	1	0.0000	1	0.0000	-0.02380
GRAND RIVER AT PORTLAND, MI	1	0.0001	1	0.0381	-0.01100
KALAMAZOO RIVER AT COMSTOCK, MI	1	0.0000	1	0.0063	-0.00770
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	1	0.0000	1	0.0000	-0.00770
FLINT RIVER NEAR OTISVILLE, MI	1	0.0000	1	0.0056	-0.00690
ROGUE RIVER NEAR ROCKFORD, MI	1	0.0000	1	0.0000	-0.00620
ESCANABA RIVER AT CORNELL, MI	1	0.0000	0	0.0678	-0.00510
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	1	0.0000	0	0.2447	-0.00440
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	1	0.0000	1	0.0000	-0.00430
PLATTE RIVER AT HONOR, MI	1	0.0000	1	0.0000	-0.00350
STURGEON RIVER NEAR NAHMA JUNCTION, MI	1	0.0000	1	0.0000	-0.00250
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1	0.0000	1	0.0000	-0.00250
PINE RIVER NEAR RUDYARD, MI	1	0.0000	1	0.0000	-0.00210
CASS RIVER AT FRANKENMUTH, MI	1	0.0000	0	0.1896	-0.00170
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	1	0.0000	1	0.0000	-0.00130
FORD RIVER NEAR HYDE, MI	1	0.0000	1	0.0413	-0.00110
JUDAY CREEK NEAR SOUTH BEND, IN	1	0	1	0.0048	-0.00110
STURGEON RIVER NEAR ALSTON, MI	1	0.0000	0	0.2018	-0.00093
TAHQUAMENON RIVER NEAR PARADISE, MI	1	0.0161	0	0.2826	-0.00089
JORDAN RIVER NEAR EAST JORDAN, MI	1	0.0000	1	0.0000	-0.00045
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	1	0.0000	0	0.0914	-0.00037
RIVER RAISIN NEAR MANCHESTER, MI	0	0.11	0	0.3711	-0.00035

Table 9. Continuous Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.2187	0	0.6430	-0.00034
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	0	0.0512	0	0.3219	-0.00030
OTTER CREEK AT LA SALLE, MI	1	2.855E-07	0	0.3415	-0.00027
RIVER RAISIN NEAR ADRIAN, MI	0	0.6954	0	0.8372	-0.00025
AU TRAIN RIVER AT FOREST LAKE, MI	0	0.0890	0	0.7936	-0.00020
GREENWOOD RELEASE NEAR GREENWOOD, MI	1	0.0000	1	0.0000	-0.00019
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	1	0.0000	1	0.0000	-0.00017
STURGEON RIVER NEAR SIDNAW, MI	1	0.0116	0	0.3893	-0.00016
SCHWEITZER CREEK NEAR PALMER, MI	1	0.0000	1	0.0318	-0.00013
ESCANABA RIVER NEAR ST. NICHOLAS, MI	1	0.0000	1	0.0000	-0.00003
BEAR CREEK NEAR MUSKEGON, MI	1	0.0000	0	0.1250	-0.00003
ST. JOSEPH RIVER AT THREE RIVERS, MI	0	0.8045	0	0.9242	0.00000
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.5778	0	0.8261	0.00000
AUGUSTA CREEK NEAR AUGUSTA, MI	0	0.3437	0	0.6743	0.00000
PIGEON RIVER NEAR VANDERBILT, MI	1	0.0013	0	0.1132	0.00000
MILL CREEK NEAR DEXTER, MI	0	0.3709	0	0.3988	0.00000
EAST BRANCH COON CREEK AT ARMADA, MI	1	0.0000	0	0.0813	0.00004
STONY CREEK NEAR ROMEO, MI	1	0.0000	0	0.0680	0.00005
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	1	0.0000	0	0.0754	0.00010
QUAKER BROOK NEAR NASHVILLE, MI	1	0.0000	0	0.0701	0.00010
PAINT RIVER NEAR ALPHA, MI	1	0.0000	0	0.4436	0.00025
EAST POND CREEK AT ROMEO, MI	1	0.0000	1	0.0025	0.00026
KEARSLEY CREEK NEAR DAVISON, MI	1	0.0000	0	0.2584	0.00035
MANISTEE RIVER NEAR SHERMAN, MI	1	0.0003	0	0.4952	0.00042
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1	0.0000	0	0.0713	0.00046
SHIAWASSEE RIVER AT OWOSSO, MI	1	0.0000	0	0.7573	0.00052
STONY CREEK NEAR WASHINGTON, MI	1	0.0000	0	0.0816	0.00056

Table 9. Continuous Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen's
RABBIT RIVER NEAR HOPKINS, MI	1	0.0000	1	0.0252	0.00057
RIVER ROUGE AT BIRMINGHAM, MI	1	0.0000	1	0.0000	0.00059
HURON RIVER AT ANN ARBOR, MI	1	0.0149	0	0.7852	0.00065
STURGEON RIVER AT WOLVERINE, MI	1	0.0000	1	0.0000	0.00070
PAINT CREEK AT ROCHESTER, MI	1	0.0000	1	0.0067	0.00076
AU SABLE RIVER AT MIO, MI	1	0.0003	1	0.0106	0.00082
RIFLE RIVER NEAR STERLING, MI	1	0	1	4.2E-07	0.00090
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	1	0.0000	1	0.0491	0.00100
HURON RIVER NEAR NEW HUDSON, MI	1	0.0000	1	0.0009	0.00100
MENOMINEE RIVER NEAR FLORENCE, WI	1	0.0002	0	0.7242	0.00120
PIGEON RIVER NEAR SCOTT, IN	1	1.0106E-05	1	0.007	0.00130
BLACK RIVER NEAR JEDDO, MI	1	0.0000	1	0.0169	0.00160
BATTLE CREEK AT BATTLE CREEK, MI	1	0.0000	1	0.0080	0.00170
RIVER ROUGE AT SOUTHFIELD, MI	1	0.0000	1	0.0000	0.00170
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.0000	0	0.1072	0.00180
GRAND RIVER AT JACKSON, MI	1	0	1	3.14E-05	0.00200
RIVER ROUGE AT DETROIT, MI	1	0.0000	1	0.0000	0.00200
LOWER RIVER ROUGE AT INKSTER, MI	1	0.0000	1	0.0000	0.00200
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	1	0.0000	0	0.5399	0.00210
RED CEDAR RIVER AT EAST LANSING, MI	1	0.0000	1	0.0173	0.00220
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.0000	1	0.0013	0.00280
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.0000	1	0.0000	0.00280
WHITE RIVER NEAR WHITEHALL, MI	1	0.0000	1	0.0000	0.00280
THORNAPPLE RIVER NEAR HASTINGS, MI	1	0.0000	1	0.0066	0.00310
HURON RIVER NEAR HAMBURG, MI	1	0.0000	1	0.0012	0.00310
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0.0000	1	0.0000	0.00360
PAW PAW RIVER AT RIVERSIDE, MI	1	0.0000	1	0.0000	0.00370

Table 9. Continuous Daily Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
CLINTON RIVER NEAR FRASER, MI	1	0.0000	1	0.0039	0.00520
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1	0.0000	1	0.0239	0.00560
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	1	0.0000	1	0.0000	0.00700
MUSKEGON RIVER AT EVART, MI	1	0.0000	1	0.0039	0.00700
FLINT RIVER NEAR FLINT, MI	1	0.0000	1	0.0011	0.00850
GRAND RIVER AT LANSING, MI	1	0.0000	1	0.0022	0.01260
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0	1	0.000327	0.01790
TITTABAWASSEE RIVER AT MIDLAND, MI	1	0.0000	1	0.0013	0.01820
ST. JOSEPH RIVER AT ELKHART, IN	1	0	1	4.29E-06	0.02410
GRAND RIVER AT IONIA, MI	1	0.0000	1	0.1470	0.02870
ST. JOSEPH RIVER AT NILES, MI	1	0	1	0.000833	0.04680

Table 10. Daily Continuous Precipitation Analysis

	MK		MKR		
Station Location	H	P	H	P	Sen's
TAHQUAMENON RIVER NEAR PARADISE, MI	1	0.0000	0	0.6682	0
MANISTIQUE RIVER NEAR MANISTIQUE, MI	1	0.0000	0	0.8588	0
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	1	0.0116	0	0.7226	0
ESCANABA RIVER NEAR ST. NICHOLAS, MI	1	0.0490	0	0.8298	0
ESCANABA RIVER AT CORNELL, MI	1	0.0000	0	0.7854	0
FORD RIVER NEAR HYDE, MI	1	0.0225	0	0.8968	0
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1	0.0000	0	0.7275	0
PAINT RIVER NEAR ALPHA, MI	1	0.0000	0	0.6489	0
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	1	0.0000	0	0.6108	0
MENOMINEE RIVER AT NIAGARA, WI	1	0.0173	0	0.8111	0
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	1	0.0000	0	0.7990	0
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0.0050	0	0.8914	0
PIGEON RIVER NEAR SCOTT, IN	1	0.0000	0	0.6747	0
ST. JOSEPH RIVER AT NILES, MI	1	0.0000	0	0.7259	0
KALAMAZOO RIVER AT COMSTOCK, MI	1	0.0000	0	0.7219	0
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	1	0.0001	0	0.6596	0
GRAND RIVER AT JACKSON, MI	1	0.0000	0	0.7930	0
AU SABLE RIVER NEAR AU SABLE, MI	1	0.0000	0	0.6582	0
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.0000	0	0.7528	0
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.0000	0	0.6762	0
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.0003	0	0.7838	0
PAW PAW RIVER AT RIVERSIDE, MI	1	0.0000	0	0.8609	0
BATTLE CREEK AT BATTLE CREEK, MI	1	0.0000	0	0.8201	0
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	1	0.0000	0	0.8342	0
MANISTEE RIVER NEAR SHERMAN, MI	1	0.0003	0	0.8522	0
RED CEDAR RIVER AT EAST LANSING, MI	1	0.0000	0	0.8718	0
GRAND RIVER AT LANSING, MI	1	0.0001	0	0.8973	0

Table 10. Daily Continuous Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
GRAND RIVER AT IONIA, MI	1	0.0000	0	0.7014	0
THORNAPPLE RIVER NEAR HASTINGS, MI	1	0.0000	0	0.8752	0
PIGEON RIVER NEAR VANDERBILT, MI	1	0.0000	0	0.8227	0
MUSKEGON RIVER AT EVART, MI	1	0.0000	0	0.5330	0
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1	0.0000	0	0.7636	0
RIFLE RIVER NEAR STERLING, MI	1	0.0000	0	0.8786	0
SHIAWASSEE RIVER AT OWOSSO, MI	1	0.0000	0	0.7450	0
STURGEON RIVER AT WOLVERINE, MI	1	0.0000	0	0.6642	0
AU SABLE RIVER AT MIO, MI	1	0.0000	0	0.7176	0
KEARSLEY CREEK NEAR DAVISON, MI	1	0.0001	0	0.7913	0
CASS RIVER AT FRANKENMUTH, MI	1	0.0000	0	0.7458	0
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	1	0.0001	0	0.7367	0
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0.0000	0	0.4406	0
TITTABAWASSEE RIVER AT MIDLAND, MI	1	0.0000	0	0.6610	0
BLACK RIVER NEAR JEDDO, MI	1	0.0001	0	0.8994	0
PAINT CREEK AT ROCHESTER, MI	1	0.0001	0	0.8431	0
RIVER ROUGE AT BIRMINGHAM, MI	1	0.0000	0	0.8454	0
RIVER ROUGE AT SOUTHFIELD, MI	1	0.0042	0	0.9060	0
RIVER ROUGE AT DETROIT, MI	1	0.0000	0	0.8875	0
LOWER RIVER ROUGE AT INKSTER, MI	1	0.0000	0	0.7502	0
HURON RIVER NEAR NEW HUDSON, MI	1	0.0074	0	0.9334	0
HURON RIVER NEAR HAMBURG, MI	1	0.0000	0	0.7204	0
HURON RIVER AT ANN ARBOR, MI	1	0.0000	0	0.7202	0
RIVER RAISIN NEAR MANCHESTER, MI	1	0.0000	0	0.7172	0
OTTER CREEK AT LA SALLE, MI	1	0.0151	0	0.7932	0
STURGEON RIVER NEAR SIDNAW, MI	0	0.5446	0	0.9809	0
STURGEON RIVER NEAR ALSTON, MI	0	0.3415	0	0.9705	0

Table 10. Daily Continuous Precipitation Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen's
AU TRAIN RIVER AT FOREST LAKE, MI	0	0.1731	0	0.8758	0
STURGEON RIVER NEAR NAHMA JUNCTION, MI	0	0.1594	0	0.9030	0
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	0	0.2291	0	0.9161	0
GREENWOOD RELEASE NEAR GREENWOOD, MI	0	0.3764	0	0.9163	0
SCHWEITZER CREEK NEAR PALMER, MI	0	0.2852	0	0.9196	0
MENOMINEE RIVER NEAR VULCAN, MI	0	0.9426	0	0.9947	0
ST. JOSEPH RIVER AT THREE RIVERS, MI	0	0.6938	0	0.9679	0
ST. JOSEPH RIVER AT ELKHART, IN	0	0.5622	0	0.9756	0
JUDAY CREEK NEAR SOUTH BEND, IN	0	0.1697	0	0.9168	0
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	0	0.5965	0	0.9679	0
GRAND RIVER AT PORTLAND, MI	0	0.6405	0	0.9523	0
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.7593	0	0.9673	0
ROGUE RIVER NEAR ROCKFORD, MI	0	0.1356	0	0.9001	0
GRAND RIVER AT GRAND RAPIDS, MI	0	0.2288	0	0.9132	0
AUGUSTA CREEK NEAR AUGUSTA, MI	0	0.1869	0	0.8918	0
PLATTE RIVER AT HONOR, MI	0	0.6576	0	0.9610	0
JORDAN RIVER NEAR EAST JORDAN, MI	0	0.8931	0	0.9932	0
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	0	0.0667	0	0.8962	0
PINE RIVER NEAR RUDYARD, MI	0	0.9289	0	0.9955	0
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	0	0.0804	0	0.8850	0
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	0	0.0634	0	0.8623	0
QUAKER BROOK NEAR NASHVILLE, MI	0	0.9017	0	0.9849	0
FLINT RIVER NEAR OTISVILLE, MI	0	0.6170	0	0.9461	0
BEAR CREEK NEAR MUSKEGON, MI	0	0.1156	0	0.9062	0
RABBIT RIVER NEAR HOPKINS, MI	0	0.2047	0	0.9284	0
WHITE RIVER NEAR WHITEHALL, MI	0	0.7340	0	0.9831	0
FLINT RIVER NEAR FLINT, MI	0	0.2503	0	0.9704	0

Table 10. Daily Continuous Precipitation Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen's
STONY CREEK NEAR ROMEO, MI	0	0.5739	0	0.9771	0
STONY CREEK NEAR WASHINGTON, MI	0	0.1026	0	0.9369	0
CLINTON RIVER NEAR FRASER, MI	0	0.3428	0	0.9714	0
EAST POND CREEK AT ROMEO, MI	0	0.7620	0	0.9890	0
EAST BRANCH COON CREEK AT ARMADA, MI	0	0.3718	0	0.9660	0
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	0	0.1971	0	0.9580	0
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	0	0.1974	0	0.9364	0
MILL CREEK NEAR DEXTER, MI	0	0.0580	0	0.8776	0
RIVER RAISIN NEAR ADRIAN, MI	0	0.3671	0	0.9453	0

Table 11. Seasonal Streamflow Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
ESCANABA RIVER NEAR ST. NICHOLAS, MI	1	0	0	0.0537	-0.0165
MENOMINEE RIVER AT NIAGARA, WI	0	0.6693	0	0.7932	0.1298
MENOMINEE RIVER NEAR VULCAN, MI	1	0.0031	1	0.0031	-9.4934
STURGEON RIVER NEAR ALSTON, MI	0	0.7782	0	0.7775	-0.0329
AU SABLE RIVER NEAR AU SABLE, MI	1	0.008	1	9.50E-04	-2.5414
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.9742	0	0.9742	0.0126
STURGEON RIVER NEAR SIDNAW, MI	0	0.6973	0	0.6973	0.032
MANISTEE RIVER NEAR SHERMAN, MI	0	0.286	0	0.2134	0.1136
ST. JOSEPH RIVER AT MOTTVILLE, MI	0	0.5249	0	0.5249	2.2784
STONY CREEK NEAR ROMEO, MI	0	0.4107	0	0.4124	0.0111
BEAR CREEK NEAR MUSKEGON, MI	0	0.4215	0	0.4157	-0.0086
AU SABLE RIVER AT MIO, MI	0	0.7918	0	0.7522	0.0447
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	1	0.032	0	0.0612	-0.2454
MENOMINEE RIVER NEAR FLORENCE, WI	0	0.0658	1	0.0444	-0.3565
SCHWEITZER CREEK NEAR PALMER, MI	0	0.0534	1	0.0014	-0.3472
PLATTE RIVER AT HONOR, MI	1	1.95E-04	1	0	-0.3339
FORD RIVER NEAR HYDE, MI	1	0.0376	0	0.1219	-0.634
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	0	0.4882	0	0.395	-0.1204
PAINT RIVER NEAR ALPHA, MI	1	0.0061	1	0.0027	-0.2251
AU TRAIN RIVER AT FOREST LAKE, MI	1	0	1	0.0067	-0.181
ESCANABA RIVER AT CORNELL, MI	0	0.1773	0	0.1602	-0.0017
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	1	0	1	0	-0.0247
BLACK RIVER NEAR JEDDO, MI	1	0.0056	0	0.0599	0.2953
MILL CREEK NEAR DEXTER, MI	0	0.0666	1	0.0022	0.0088
EAST POND CREEK AT ROMEO, MI	1	0.0059	1	0.0098	0.0270
STURGEON RIVER AT WOLVERINE, MI	0	0.0525	1	0.0196	0.057
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	0	0.0866	0	0.0866	-5.2637

Table 11. Seasonal Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
STONY CREEK NEAR WASHINGTON, MI	1	0.017	1	0.0109	0.0609
RIVER ROUGE AT BIRMINGHAM, MI	1	0	1	0	0.0731
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0	1	0	0.3712
RABBIT RIVER NEAR HOPKINS, MI	1	0.0107	1	0.0107	0.1112
HURON RIVER NEAR NEW HUDSON, MI	1	0.0039	1	0.0039	0.1148
CASS RIVER AT FRANKENMUTH, MI	0	0.0935	0	0.1036	-0.2944
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	0	0.8374	0	0.8788	0.0554
JORDAN RIVER NEAR EAST JORDAN, MI	0	0.0632	0	0.0953	-0.0447
FLINT RIVER NEAR OTISVILLE, MI	0	0.8905	0	0.8905	-0.1782
FLINT RIVER NEAR FLINT, MI	1	3.78E-06	1	1.00E-04	1.0171
GREENWOOD RELEASE NEAR GREENWOOD, MI	0	0.1777	0	0.12	-0.0418
RIFLE RIVER NEAR STERLING, MI	1	0.0191	1	0.0088	0.1673
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	1	0.0104	1	0.0268	0.1744
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	1	9.94E-04	0	0.2834	0.21122
JUDAY CREEK NEAR SOUTH BEND, IN	0	0.2019	0	0.2019	-0.0755
KEARSLEY CREEK NEAR DAVISON, MI	0	0.3731	0	0.3558	0.0590
STURGEON RIVER NEAR NAHMA JUNCTION, MI	0	0.8235	0	0.7886	-0.0819
GRAND RIVER AT JACKSON, MI	1	1.08E-06	1	7.78E-06	0.1963
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	0	0.9518	0	0.9281	-0.0137
RIVER ROUGE AT DETROIT, MI	1	0	1	0	0.3044
RIVER ROUGE AT SOUTHFIELD, MI	1	1.23E-05	1	1.23E-05	0.2006
BATTLE CREEK AT BATTLE CREEK, MI	1	0.0011	1	7.28E-04	0.2234
PIGEON RIVER NEAR VANDERBILT, MI	0	0.7176	0	0.5732	0.0053
SHIAWASSEE RIVER AT OWOSSO, MI	0	0.4362	0	9.85E-02	0.0085
LOWER RIVER ROUGE AT INKSTER, MI	1	0	1	0	0.2364
RED CEDAR RIVER AT EAST LANSING, MI	1	3.4E-05	1	0.0073	0.3035
PAINT CREEK AT ROCHESTER, MI	1	0.0017	1	0.0041	0.0981

Table 11. Seasonal Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.01	0	0.0572	0.3265
ST. JOSEPH RIVER AT THREE RIVERS, MI	1	0.0197	1	0.0049	0.3037
EAST BRANCH COON CREEK AT ARMADA, MI	1	0.0011	0	0.0595	0.0153
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	0	0.0711	1	0.0242	-0.5591
PIGEON RIVER NEAR SCOTT, IN	0	0.4306	0	0.3851	0.2146
PINE RIVER NEAR RUDYARD, MI	0	0.0505	0	0.086	-0.3111
WHITE RIVER NEAR WHITEHALL, MI	1	0.0271	1	0.033	0.336
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1	0.0036	1	0.0417	0.1626
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	0	0.0534	0	0.0534	0.2284
PAW PAW RIVER AT RIVERSIDE, MI	1	0.0168	1	0.002	0.3541
HURON RIVER NEAR HAMBURG, MI	1	3.25E-04	1	1.08E-04	0.3330
HURON RIVER AT ANN ARBOR, MI	0	0.0047	0	0.5642	0.1911
THORNAPPLE RIVER NEAR HASTINGS, MI	1	0.0015	1	0	0.4299
GRAND RIVER AT GRAND RAPIDS, MI	0	0.7662	0	0.7096	1.9355
CLINTON RIVER NEAR FRASER, MI	1	1.64E-04	1	1.10E-04	0.5498
TAHQUAMENON RIVER NEAR PARADISE, MI	0	0.8621	0	0.863	0.037
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	0	0.3539	0	0.3539	-0.1072
AUGUSTA CREEK NEAR AUGUSTA, MI	0	0.3808	0	0.3586	0.0135
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1	0.0017	1	0	0.7159
GRAND RIVER AT PORTLAND, MI	0	0.8424	0	0.8424	-0.04486
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	1	0	1	0	0.7623
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.0038	1	0	0.3277
RIVER RAISIN NEAR ADRIAN, MI	0	0.7857	0	0.7857	0.2056
OTTER CREEK AT LA SALLE, MI	0	0.6925	0	0.6249	0.0428
MUSKEGON RIVER AT EVART, MI	1	0.0015	1	0.0013	0.8989
ROGUE RIVER NEAR ROCKFORD, MI	0	0.2729	0	0.137	-0.4286
RIVER RAISIN NEAR MANCHESTER, MI	0	0.653	0	0.653	0.0839

Table 11. Seasonal Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	1	2.71E-04	1	0.0039	-0.0144
GRAND RIVER AT LANSING, MI	1	1.44E-04	1	0	1.3778
TITTABAWASSEE RIVER AT MIDLAND, MI	1	1.31E-04	1	2.01E-04	2.0720
ST. JOSEPH RIVER AT ELKHART, IN	1	0.0173	1	0.0173	2.8664
GRAND RIVER AT IONIA, MI	1	0.0015	1	0.0125	3.3601
ST. JOSEPH RIVER AT NILES, MI	1	3.81E-07	1	3.68E-07	4.83
QUAKER BROOK NEAR NASHVILLE, MI	0	0.1339	0	0.1339	0.0347
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.0167	0	0.014	-2.0427
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	0	0.4737	0	0.4737	0.1483
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.1885	0	0.07	0.1787
KALAMAZOO RIVER AT COMSTOCK, MI	0	0.9292	0	0.9292	-0.112

Table 12. Seasonal Precipitation Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
STURGEON RIVER NEAR SIDNAW, MI	0	0.1659	0	0.1829	-0.00080
STURGEON RIVER NEAR ALSTON, MI	1	0.0077	1	0.0077	-0.00160
AU TRAIN RIVER AT FOREST LAKE, MI	0	0.3089	0	0.2093	0.00490
TAHQUAMENON RIVER NEAR PARADISE, MI	1	0.0010	1	0.0005	0.00270
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.1159	0	0.1596	-0.00083
STURGEON RIVER NEAR NAHMA JUNCTION, MI	0	0.4181	0	0.3473	0.00095
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	0	0.7787	0	0.7580	-0.00025
GREENWOOD RELEASE NEAR GREENWOOD, MI	0	0.5744	0	0.5164	0.00075
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	0	0.6841	0	0.6841	-0.00140
SCHWEITZER CREEK NEAR PALMER, MI	0	0.8338	0	0.8094	0.00027
ESCANABA RIVER NEAR ST. NICHOLAS, MI	0	0.5749	0	0.5749	-0.00290
ESCANABA RIVER AT CORNELL, MI	0	0.6897	0	0.6730	0.00028
FORD RIVER NEAR HYDE, MI	0	0.7704	0	0.7712	0.00022
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	0	0.7514	0	0.7395	0.00024
PAINT RIVER NEAR ALPHA, MI	0	0.6720	0	0.6489	0.00036
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	0	0.2660	0	0.2460	0.00082
MENOMINEE RIVER NEAR FLORENCE, WI	0	0.2072	0	0.1752	0.00049
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	0	0.1054	0	0.1165	0.00063
MENOMINEE RIVER AT NIAGARA, WI	0	0.5615	0	0.5615	-0.00250
MENOMINEE RIVER NEAR VULCAN, MI	0	0.9206	0	0.9206	0.00034
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	0	0.4839	0	0.5347	0.00054
ST. JOSEPH RIVER AT THREE RIVERS, MI	0	0.1445	0	0.1445	0.00790
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0.0015	1	0.0008	0.00150
PIGEON RIVER NEAR SCOTT, IN	0	0.6382	0	0.6382	-0.00062
ST. JOSEPH RIVER AT ELKHART, IN	1	0.0289	1	0.0074	0.00160
JUDAY CREEK NEAR SOUTH BEND, IN	0	0.7315	0	0.7315	0.00180
ST. JOSEPH RIVER AT NILES, MI	0	0.1069	0	0.1592	0.00092

Table 12. Seasonal Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
KALAMAZOO RIVER AT COMSTOCK, MI	0	0.5519	0	0.5331	-0.00180
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	1	0.0010	1	0.0020	0.00360
GRAND RIVER AT PORTLAND, MI	0	0.2667	0	0.2667	0.00290
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.1455	1	0.0000	0.00830
ROGUE RIVER NEAR ROCKFORD, MI	0	0.2041	0	0.2041	0.00440
GRAND RIVER AT GRAND RAPIDS, MI	0	0.2132	0	0.2850	0.00370
AUGUSTA CREEK NEAR AUGUSTA, MI	1	0.0165	1	0.0152	0.00290
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	0	0.0530	1	0.0362	0.00940
PLATTE RIVER AT HONOR, MI	1	0.0337	1	0.0337	0.00700
JORDAN RIVER NEAR EAST JORDAN, MI	0	0.6098	0	0.6468	0.00059
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1	0.0102	1	0.0140	0.00210
GRAND RIVER AT JACKSON, MI	0	0.5513	0	0.5057	0.00033
PINE RIVER NEAR RUDYARD, MI	0	0.5967	0	0.6877	0.00079
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	0	0.4385	0	0.4836	0.00280
AU SABLE RIVER NEAR AU SABLE, MI	0	0.2527	1	0.0135	0.00300
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.0208	1	0.0003	0.00140
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	0	0.7721	0	0.7932	0.00059
QUAKER BROOK NEAR NASHVILLE, MI	0	0.1676	0	0.1676	0.00780
FLINT RIVER NEAR OTISVILLE, MI	0	0.1877	0	0.0757	0.00440
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.0008	1	0.0008	0.00410
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.0226	1	0.0423	0.00240
PAW PAW RIVER AT RIVERSIDE, MI	0	0.1540	0	0.0924	0.00120
BEAR CREEK NEAR MUSKEGON, MI	0	0.7110	0	0.7110	-0.00038
BATTLE CREEK AT BATTLE CREEK, MI	0	0.3735	0	0.3448	0.00054
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	0	0.7777	0	0.6963	0.00017
MANISTEE RIVER NEAR SHERMAN, MI	1	0.0264	1	0.0324	0.00092
RABBIT RIVER NEAR HOPKINS, MI	1	0.0250	1	0.0002	0.00280

Table 12. Seasonal Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
RED CEDAR RIVER AT EAST LANSING, MI	0	0.2454	0	0.2117	0.00059
GRAND RIVER AT LANSING, MI	0	0.1838	0	0.2378	0.00072
GRAND RIVER AT IONIA, MI	1	0.0176	1	0.0122	0.00190
THORNAPPLE RIVER NEAR HASTINGS, MI	0	0.3910	0	0.3892	0.00059
PIGEON RIVER NEAR VANDERBILT, MI	0	0.0984	0	0.0626	0.00120
MUSKEGON RIVER AT EVART, MI	1	0.0013	1	0.0013	0.00160
WHITE RIVER NEAR WHITEHALL, MI	0	0.7500	0	0.7133	-0.00029
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	0	0.5738	0	0.5442	0.00034
RIFLE RIVER NEAR STERLING, MI	1	0.0115	1	0.0002	0.00120
SHIAWASSEE RIVER AT OWOSSO, MI	1	0.0075	1	0.0035	0.00130
STURGEON RIVER AT WOLVERINE, MI	0	0.0662	0	0.0156	0.00099
AU SABLE RIVER AT MIO, MI	0	0.2292	0	0.2218	0.00072
KEARSLEY CREEK NEAR DAVISON, MI	0	0.2561	1	0.0367	0.00120
FLINT RIVER NEAR FLINT, MI	1	0.0268	1	0.0291	0.00110
CASS RIVER AT FRANKENMUTH, MI	0	0.2632	0	0.2794	0.00061
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	1	0.0207	1	0.0084	0.00790
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0.0189	1	0.0249	0.00110
TITTABAWASSEE RIVER AT MIDLAND, MI	0	0.1162	0	0.1433	0.00077
BLACK RIVER NEAR JEDDO, MI	0	0.0755	1	0.0309	0.00100
PAINT CREEK AT ROCHESTER, MI	0	0.0873	1	0.0174	0.00140
STONY CREEK NEAR ROMEO, MI	0	0.5933	0	0.5833	-0.00058
STONY CREEK NEAR WASHINGTON, MI	0	0.7728	0	0.7501	0.00026
CLINTON RIVER NEAR FRASER, MI	0	0.7302	0	0.6682	-0.00019
EAST POND CREEK AT ROMEO, MI	0	0.9456	0	0.9480	0.00006
EAST BRANCH COON CREEK AT ARMADA, MI	0	0.1193	0	0.1474	0.00140
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	0	0.2524	0	0.2524	0.00074
RIVER ROUGE AT BIRMINGHAM, MI	0	0.0624	0	0.0590	0.00130

Table 12. Seasonal Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
RIVER ROUGE AT SOUTHFIELD, MI	1	0.0214	0	0.0518	0.00180
RIVER ROUGE AT DETROIT, MI	1	0.0080	1	0.0009	0.00120
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	0	0.4075	0	0.2840	0.00170
LOWER RIVER ROUGE AT INKSTER, MI	0	0.1508	0	0.0702	0.00097
HURON RIVER NEAR NEW HUDSON, MI	0	0.2862	0	0.3150	-0.00078
HURON RIVER NEAR HAMBURG, MI	1	0.0007	1	0.0000	0.00240
MILL CREEK NEAR DEXTER, MI	0	0.1425	0	0.1425	0.00760
HURON RIVER AT ANN ARBOR, MI	1	0.0002	1	0.0001	0.00240
RIVER RAISIN NEAR MANCHESTER, MI	0	0.1576	0	0.1576	0.00400
RIVER RAISIN NEAR ADRIAN, MI	0	0.2416	0	0.2416	0.00300
OTTER CREEK AT LA SALLE, MI	0	0.3205	0	0.2663	0.00310

Table 13. Annual Streamflow Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
ESCANABA RIVER NEAR ST. NICHOLAS, MI	0	0.4503	0	0.4503	-0.00570
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	0	0.4503	0	0.4503	-1.55380
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	1	0.0104	1	0.0168	-13.20190
MENOMINEE RIVER NEAR VULCAN, MI	0	0.1867	0	0.1867	-16.73390
MENOMINEE RIVER AT NIAGARA, WI	0	0.0501	0	0.0501	-41.24520
STURGEON RIVER NEAR ALSTON, MI	0	0.2931	0	0.4284	-0.07295
STURGEON RIVER NEAR SIDNAW, MI	0	0.2988	0	0.1400	-0.40560
ESCANABA RIVER AT CORNELL, MI	1	0.0117	1	0.0117	-3.97320
HURON RIVER NEAR NEW HUDSON, MI	1	0.0425	1	0.0414	0.54410
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.6653	0	0.6653	-0.65230
AU SABLE RIVER AT MIO, MI	0	0.9167	0	0.9167	0.19760
BEAR CREEK NEAR MUSKEGON, MI	0	0.8526	0	0.8526	-0.00860
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	0	0.0943	0	0.0943	-0.27140
PLATTE RIVER AT HONOR, MI	1	0.0125	1	0.0125	-1.38790
STONY CREEK NEAR ROMEO, MI	0	0.3156	0	0.1250	0.05790
STURGEON RIVER NEAR NAHMA JUNCTION, MI	1	0.0205	1	0.0205	-1.31770
FORD RIVER NEAR HYDE, MI	0	0.2922	0	0.3851	-1.05200
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	1	0.0355	1	0.0093	-1.12050
AU SABLE RIVER NEAR AU SABLE, MI	0	0.1886	0	0.1886	-7.97750
SCHWEITZER CREEK NEAR PALMER, MI	1	0.0002	1	0.0002	-0.20380
GREENWOOD RELEASE NEAR GREENWOOD, MI	1	0.0000	1	0.0000	-0.16330
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	0	0.0513	1	0.0239	-0.05870
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0.0002	1	0.0002	0.00640
EAST POND CREEK AT ROMEO, MI	1	0.0338	1	0.0338	0.11460
PAINT RIVER NEAR ALPHA, MI	0	0.1104	0	0.1104	0.87630
EAST BRANCH COON CREEK AT ARMADA, MI	1	0.0038	1	0.0038	0.11590
STONY CREEK NEAR WASHINGTON, MI	1	0.0351	1	0.0351	0.29590

Table 13. Annual Streamflow Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	0	0.2046	0	0.1510	-1.93000
WHITE RIVER NEAR WHITEHALL, MI	0	0.0790	0	0.0790	1.52990
RABBIT RIVER NEAR HOPKINS, MI	1	0.0338	1	0.0338	0.40730
TITTABAWASSEE RIVER AT MIDLAND, MI	1	0.0004	1	0.0003	10.40340
STURGEON RIVER AT WOLVERINE, MI	0	0.0997	0	0.0997	0.28100
FLINT RIVER NEAR OTISVILLE, MI	0	0.5813	0	0.2367	3.36500
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	0	0.8918	0	0.8918	0.17000
OTTER CREEK AT LA SALLE, MI	0	0.3417	1	0.0008	0.65360
MENOMINEE RIVER NEAR FLORENCE, WI	0	0.1259	0	0.1259	-2.14310
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0.0001	1	0.0000	1.43440
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	0	0.1665	0	0.1665	-1.42610
MANISTEE RIVER NEAR SHERMAN, MI	0	0.1926	0	0.1926	0.66530
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	1	0.0052	1	0.0000	0.77150
CASS RIVER AT FRANKENMUTH, MI	0	0.8816	0	0.8816	0.28340
PIGEON RIVER NEAR VANDERBILT, MI	0	0.7937	0	0.6998	0.01500
JORDAN RIVER NEAR EAST JORDAN, MI	0	0.0983	0	0.0983	-0.20490
GRAND RIVER AT JACKSON, MI	1	0.0004	1	0.0015	0.78200
RIVER ROUGE AT DETROIT, MI	1	0.0000	1	0.0000	1.09570
JUDAY CREEK NEAR SOUTH BEND, IN	0	0.9396	0	0.9396	-0.09210
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	1	0.0155	1	0.0002	0.95300
RIFLE RIVER NEAR STERLING, MI	0	0.1908	0	0.1919	0.41670
KEARSLEY CREEK NEAR DAVISON, MI	0	0.2952	0	0.2952	0.33840
BATTLE CREEK AT BATTLE CREEK, MI	1	0.0082	1	0.0082	0.98050
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.0475	1	0.0053	1.07850
LOWER RIVER ROUGE AT INKSTER, MI	1	0.0000	1	0.0000	0.93870
SHIAWASSEE RIVER AT OWOSSO, MI	0	0.0633	0	0.0531	1.63630
FLINT RIVER NEAR FLINT, MI	1	0.0003	1	0.0000	4.78390

Table 13. Annual Streamflow Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen's
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.0309	1	0.0189	1.79280
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	0	0.1834	0	0.0689	-2.13740
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	1	0.0086	1	0.0086	1.33260
RED CEDAR RIVER AT EAST LANSING, MI	1	0.0020	1	0.0020	1.35600
RIVER ROUGE AT BIRMINGHAM, MI	1	0.0000	1	0.0000	0.30370
ST. JOSEPH RIVER AT THREE RIVERS, MI	0	0.1727	0	0.1727	23.35390
PAINT CREEK AT ROCHESTER, MI	1	0.0038	1	0.0038	0.43180
BLACK RIVER NEAR JEDDO, MI	0	0.1426	1	0.0000	1.45720
MILL CREEK NEAR DEXTER, MI	0	0.1373	1	0.0000	1.66540
RIVER ROUGE AT SOUTHFIELD, MI	1	0.0003	1	0.0000	0.81880
THORNAPPLE RIVER NEAR HASTINGS, MI	1	0.0120	1	0.0074	1.74240
PIGEON RIVER NEAR SCOTT, IN	0	0.8794	0	0.8794	0.00072
PINE RIVER NEAR RUDYARD, MI	1	0.0017	1	0.0000	-1.98350
CLINTON RIVER NEAR FRASER, MI	1	0.0081	1	0.0081	1.84170
AU TRAIN RIVER AT FOREST LAKE, MI	0	0.3434	0	0.3434	1.45130
PAW PAW RIVER AT RIVERSIDE, MI	1	0.0167	1	0.0002	1.90180
HURON RIVER AT ANN ARBOR, MI	1	0.0252	1	0.0073	2.83170
GRAND RIVER AT GRAND RAPIDS, MI	0	0.9527	0	0.9527	1.99900
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	0	0.6746	0	0.6746	-0.16400
AUGUSTA CREEK NEAR AUGUSTA, MI	0	0.7190	0	0.5843	0.03200
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	1	0.0073	1	0.0073	2.97740
RIVER RAISIN NEAR MANCHESTER, MI	0	0.5085	0	0.5085	0.51120
HURON RIVER NEAR HAMBURG, MI	1	0.0053	1	0.0053	1.39750
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	0	0.3334	0	0.3334	0.90910
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	1	0.0000	1	0.0003	3.44510
TAHQUAMENON RIVER NEAR PARADISE, MI	0	0.5678	0	0.6288	-0.99050
MUSKEGON RIVER AT EVART, MI	1	0.0027	1	0.0002	3.55410

Table 13. Annual Streamflow Analysis cont'd

	MK		MKR		
Station Location	H	P	H	P	Sen's
GRAND RIVER AT PORTLAND, MI	0	0.7780	0	0.7780	4.03120
QUAKER BROOK NEAR NASHVILLE, MI	0	0.0791	0	0.0791	0.19870
ROGUE RIVER NEAR ROCKFORD, MI	0	0.8327	0	0.8327	0.18710
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.0183	1	0.0183	1.29350
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.0649	0	0.0649	1.08500
GRAND RIVER AT LANSING, MI	1	0.0005	1	0.0005	5.32110
RIVER RAISIN NEAR ADRIAN, MI	0	0.1860	0	0.1860	3.60260
ST. JOSEPH RIVER AT ELKHART, IN	1	0.0257	1	0.0155	13.00990
KALAMAZOO RIVER AT COMSTOCK, MI	0	0.8600	0	0.7876	-0.07493
GRAND RIVER AT IONIA, MI	1	0.0012	1	0.0012	15.56600
ST. JOSEPH RIVER AT NILES, MI	1	0.0000	1	0.0000	20.18000

Table 14. Annual Precipitation Analysis

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
STURGEON RIVER NEAR SIDNAW, MI	0	0.0501	0	0.1251	-0.00490
STURGEON RIVER NEAR ALSTON, MI	1	0.0054	1	0.0001	-0.00610
AU TRAIN RIVER AT FOREST LAKE, MI	0	0.5366	0	0.5366	0.00780
TAHQUAMENON RIVER NEAR PARADISE, MI	1	0.0000	1	0.0000	0.01170
MANISTIQUE RIVER NEAR MANISTIQUE, MI	0	0.1119	1	0.0299	-0.00370
STURGEON RIVER NEAR NAHMA JUNCTION, MI	0	0.8794	0	0.8794	0.00045
MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	0	0.6847	0	0.5429	-0.00120
GREENWOOD RELEASE NEAR GREENWOOD, MI	0	1.0000	0	1.0000	0.00013
MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	0	0.0655	0	0.0655	-0.01660
SCHWEITZER CREEK NEAR PALMER, MI	0	0.4124	0	0.4124	-0.00240
ESCANABA RIVER NEAR ST. NICHOLAS, MI	1	0.0201	1	0.0201	-0.02360
ESCANABA RIVER AT CORNELL, MI	0	0.7322	0	0.6987	0.00100
FORD RIVER NEAR HYDE, MI	0	0.9945	0	0.9945	0.00003
BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	0	0.7905	0	0.8332	0.00062
PAINT RIVER NEAR ALPHA, MI	0	0.7577	0	0.7577	0.00079
MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	0	0.2497	0	0.2497	0.00250
MENOMINEE RIVER NEAR FLORENCE, WI	0	0.0848	0	0.0848	0.00200
MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	0	0.0514	1	0.0000	0.00230
MENOMINEE RIVER AT NIAGARA, WI	0	0.4841	0	0.4841	-0.00880
MENOMINEE RIVER NEAR VULCAN, MI	0	0.3156	0	0.3156	-0.00960
MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	0	0.5276	0	0.5276	0.00140
ST. JOSEPH RIVER AT THREE RIVERS, MI	0	0.0690	0	0.0690	0.03970
ST. JOSEPH RIVER AT MOTTVILLE, MI	1	0.0002	1	0.0002	0.00640
PIGEON RIVER NEAR SCOTT, IN	0	0.8794	0	0.8794	0.00072
ST. JOSEPH RIVER AT ELKHART, IN	1	0.0034	1	0.0034	0.00720
JUDAY CREEK NEAR SOUTH BEND, IN	0	0.4047	0	0.4047	0.02650
ST. JOSEPH RIVER AT NILES, MI	1	0.0303	1	0.0303	0.00430

Table 14. Annual Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
KALAMAZOO RIVER AT COMSTOCK, MI	0	0.3780	0	0.3780	-0.01060
WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	1	0.0000	1	0.0000	0.01580
GRAND RIVER AT PORTLAND, MI	0	0.1278	0	0.1278	0.01390
WANADOGA CREEK NEAR BATTLE CREEK, MI	0	0.2604	0	0.2604	0.02350
ROGUE RIVER NEAR ROCKFORD, MI	0	0.9159	0	0.9159	0.00150
GRAND RIVER AT GRAND RAPIDS, MI	0	0.3531	0	0.3531	0.00900
AUGUSTA CREEK NEAR AUGUSTA, MI	1	0.0031	1	0.0031	0.01050
EAST BRANCH PINE RIVER NEAR TUSTIN, MI	0	0.1237	0	0.1237	0.02840
PLATTE RIVER AT HONOR, MI	0	0.0744	0	0.0744	0.02750
JORDAN RIVER NEAR EAST JORDAN, MI	0	0.8833	0	0.8833	0.00041
MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	0	0.0819	0	0.0819	0.00590
GRAND RIVER AT JACKSON, MI	0	0.6020	0	0.5828	0.00089
PINE RIVER NEAR RUDYARD, MI	0	0.5975	0	0.3155	0.00190
SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	0	0.9741	0	0.9741	-0.00086
AU SABLE RIVER NEAR AU SABLE, MI	0	0.0702	0	0.0702	0.01610
MAPLE RIVER AT MAPLE RAPIDS, MI	1	0.0144	1	0.0173	0.00530
SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	0	1.0000	0	1.0000	-0.00001
QUAKER BROOK NEAR NASHVILLE, MI	0	0.3923	0	0.3923	0.01660
FLINT RIVER NEAR OTISVILLE, MI	0	0.1119	0	0.1119	0.02480
ST. JOSEPH RIVER AT BURLINGTON, MI	1	0.0003	1	0.0003	0.01490
DOWAGIAC RIVER AT SUMNERVILLE, MI	1	0.0086	1	0.0183	0.01030
PAW PAW RIVER AT RIVERSIDE, MI	0	0.2093	0	0.2093	0.00390
BEAR CREEK NEAR MUSKEGON, MI	0	0.3044	1	0.0246	-0.00370
BATTLE CREEK AT BATTLE CREEK, MI	0	0.5122	0	0.3821	0.00120
KALAMAZOO RIVER NEAR BATTLE CREEK, MI	0	0.7934	0	0.8170	0.00060
MANISTEE RIVER NEAR SHERMAN, MI	0	0.0713	0	0.0713	0.00260
RABBIT RIVER NEAR HOPKINS, MI	1	0.0044	1	0.0044	0.01050

Table 14. Annual Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
RED CEDAR RIVER AT EAST LANSING, MI	0	0.3248	0	0.3248	0.00190
GRAND RIVER AT LANSING, MI	0	0.1307	0	0.1307	0.00300
GRAND RIVER AT IONIA, MI	1	0.0289	1	0.0001	0.00730
THORNAPPLE RIVER NEAR HASTINGS, MI	0	0.5427	0	0.5427	0.00160
PIGEON RIVER NEAR VANDERBILT, MI	0	0.1513	0	0.1513	0.00290
MUSKEGON RIVER AT EVART, MI	1	0.0023	1	0.0006	0.00590
WHITE RIVER NEAR WHITEHALL, MI	0	0.3004	0	0.3004	-0.00320
PERE MARQUETTE RIVER AT SCOTTVILLE, MI	0	0.8973	0	0.9082	0.00031
RIFLE RIVER NEAR STERLING, MI	1	0.0037	1	0.0064	0.00440
SHIAWASSEE RIVER AT OWOSSO, MI	1	0.0081	1	0.0081	0.00510
STURGEON RIVER AT WOLVERINE, MI	1	0.0207	1	0.0207	0.00370
AU SABLE RIVER AT MIO, MI	0	0.4639	0	0.4639	0.00160
KEARSLEY CREEK NEAR DAVISON, MI	0	0.1866	0	0.1171	0.00380
FLINT RIVER NEAR FLINT, MI	1	0.0278	1	0.0000	0.00510
CASS RIVER AT FRANKENMUTH, MI	0	0.2038	0	0.0624	0.00280
SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	0	0.2643	0	0.2643	0.01260
CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	1	0.0278	1	0.0021	0.00380
TITTABAWASSEE RIVER AT MIDLAND, MI	0	0.1169	1	0.0031	0.00260
BLACK RIVER NEAR JEDDO, MI	0	0.1235	0	0.1235	0.00330
PAINT CREEK AT ROCHESTER, MI	1	0.0217	1	0.0062	0.00710
STONY CREEK NEAR ROMEO, MI	0	0.9396	0	0.8966	-0.00027
STONY CREEK NEAR WASHINGTON, MI	0	0.4535	0	0.4535	0.00320
CLINTON RIVER NEAR FRASER, MI	0	0.6808	0	0.6808	0.00093
EAST POND CREEK AT ROMEO, MI	0	0.5434	0	0.5434	0.00330
EAST BRANCH COON CREEK AT ARMADA, MI	0	0.0840	0	0.0701	0.00600
NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	0	0.1319	0	0.1319	0.00360
RIVER ROUGE AT BIRMINGHAM, MI	1	0.0151	1	0.0151	0.00610

Table 14. Annual Precipitation Analysis cont'd

	MK		MKR		
Station Location	**H**	**P**	**H**	**P**	**Sen's**
RIVER ROUGE AT SOUTHFIELD, MI	1	0.0201	1	0.0201	0.00710
RIVER ROUGE AT DETROIT, MI	1	0.0119	1	0.0119	0.00420
MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	0	0.6168	0	0.6620	0.00600
LOWER RIVER ROUGE AT INKSTER, MI	0	0.0752	1	0.0269	0.00450
HURON RIVER NEAR NEW HUDSON, MI	0	0.2021	1	0.0005	-0.00490
HURON RIVER NEAR HAMBURG, MI	1	0.0000	1	0.0000	0.01070
MILL CREEK NEAR DEXTER, MI	0	0.0957	0	0.0957	0.03580
HURON RIVER AT ANN ARBOR, MI	1	0.0000	1	0.0000	0.01020
RIVER RAISIN NEAR MANCHESTER, MI	0	0.0939	0	0.0939	0.01100
RIVER RAISIN NEAR ADRIAN, MI	1	0.0473	1	0.0473	0.01890
OTTER CREEK AT LA SALLE, MI	0	0.1696	0	0.1696	0.01710

Table 15. USGS Streamflow Station Coordinates

Station ID	Station Location	Latitude	Longitude
04184500	BEAN CREEK AT POWERS, OH	41°39'34"	84°14'57"
04101000	ST. JOSEPH RIVER AT ELKHART, IN	41°41'30"	85°58'30"
04095300	TRAIL CREEK AT MICHIGAN CITY, IN	41°43'00"	86°51'35"
04095380	TRAIL CREEK AT MICHIGAN CITY HARBOR, IN	41°43'22"	86°54'15"
04101370	JUDAY CREEK NEAR SOUTH BEND, IN	41°43'43"	86°15'46"
04099750	PIGEON RIVER NEAR SCOTT, IN	41°44'56"	85°34'35"
04099000	ST. JOSEPH RIVER AT MOTTVILLE, MI	41°48'03"	85°45'22"
04101500	ST. JOSEPH RIVER AT NILES, MI	41°48'45"	86°15'35"
04176000	RIVER RAISIN NEAR ADRIAN, MI	41°54'17"	83°58'51"
04101800	DOWAGIAC RIVER AT SUMNERVILLE, MI	41°54'48"	86°12'47"
04097500	ST. JOSEPH RIVER AT THREE RIVERS, MI	41°56'25"	85°37'58"
04176500	RIVER RAISIN NEAR MONROE, MI	41°57'38"	83°31'52"
04096405	ST. JOSEPH RIVER AT BURLINGTON, MI	42°06'11"	85°04'48"
04175600	RIVER RAISIN NEAR MANCHESTER, MI	42°10'05"	84°04'34"
04102500	PAW PAW RIVER AT RIVERSIDE, MI	42°11'11"	86°22'08"
04174518	MALLETTS CREEK AT ANN ARBOR, MI	42°14'33"	83°42'37"
04106400	WEST FORK PORTAGE CREEK AT KALAMAZOO, MI	42°14'40"	85°36'52"
04103500	KALAMAZOO RIVER AT MARSHALL, MI	42°15'53"	84°57'50"
04168580	ECORSE RIVER AT DEARBORN HEIGHTS, MI	42°16'10"	83°17'23"
04109000	GRAND RIVER AT JACKSON, MI	42°17'01"	84°24'32"
04106000	KALAMAZOO RIVER AT COMSTOCK, MI	42°17'08"	85°30'50"
04174500	HURON RIVER AT ANN ARBOR, MI	42°17'13"	83°44'02"
04173500	MILL CREEK NEAR DEXTER, MI	42°18'01"	83°53'54"
04168000	LOWER RIVER ROUGE AT INKSTER, MI	42°18'02"	83°18'01"
04105500	KALAMAZOO RIVER NEAR BATTLE CREEK, MI	42°19'26"	85°11'51"
04105000	BATTLE CREEK AT BATTLE CREEK, MI	42°19'53"	85°09'13"
04167000	MIDDLE RIVER ROUGE NEAR GARDEN CITY, MI	42°20'53"	83°18'42"
04105700	AUGUSTA CREEK NEAR AUGUSTA, MI	42°21'12"	85°21'14"

Table 15. USGS Streamflow Station Coordinates cont'd

Station ID	Station Location	Latitude	Longitude
04102700	SOUTH BRANCH BLACK RIVER NEAR BANGOR, MI	42°21'15"	86°11'15"
04166500	RIVER ROUGE AT DETROIT, MI	42°22'23"	83°15'17"
04104945	WANADOGA CREEK NEAR BATTLE CREEK, MI	42°23'47"	85°07'54"
04166100	RIVER ROUGE AT SOUTHFIELD, MI	42°26'51"	83°17'51"
04172000	HURON RIVER NEAR HAMBURG, MI	42°27'55"	83°48'00"
04170500	HURON RIVER NEAR NEW HUDSON, MI	42°30'46"	83°40'35"
04111000	GRAND RIVER NEAR EATON RAPIDS, MI	42°32'05"	84°37'23"
04166000	RIVER ROUGE AT BIRMINGHAM, MI	42°32'45"	83°13'25"
04117000	QUAKER BROOK NEAR NASHVILLE, MI	42°33'57"	85°05'37"
04164000	CLINTON RIVER NEAR FRASER, MI	42°34'40"	82°57'06"
04161820	CLINTON RIVER AT STERLING HEIGHTS, MI	42°36'52"	83°01'36"
04117500	THORNAPPLE RIVER NEAR HASTINGS, MI	42°36'57"	85°14'11"
04164500	NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	42°37'45"	82°53'20"
04161000	CLINTON RIVER AT AUBURN HILLS, MI	42°38'00"	83°13'28"
04108600	RABBIT RIVER NEAR HOPKINS, MI	42°38'32"	85°43'19"
04108660	KALAMAZOO RIVER NEAR NEW RICHMOND, MI	42°39'03"	86°06'24"
04161540	PAINT CREEK AT ROCHESTER, MI	42°41'18"	83°08'35"
04161800	STONY CREEK NEAR WASHINGTON, MI	42°42'55"	83°05'31"
04112500	RED CEDAR RIVER AT EAST LANSING, MI	42°43'38"	84°28'41"
04113000	GRAND RIVER AT LANSING, MI	42°45'02"	84°33'19"
04108800	MACATAWA RIVER AT STATE ROAD NEAR ZEELAND, MI	42°46'45"	86°01'06"
04161580	STONY CREEK NEAR ROMEO, MI	42°48'03"	83°05'25"
04118000	THORNAPPLE RIVER NEAR CALEDONIA, MI	42°48'40"	85°29'00"
04164100	EAST POND CREEK AT ROMEO, MI	42°49'21"	83°01'13"
04114498	LOOKING GLASS RIVER NEAR EAGLE, MI	42°49'41"	84°45'34"
04164300	EAST BRANCH COON CREEK AT ARMADA, MI	42°50'45"	82°53'06"
04114000	GRAND RIVER AT PORTLAND, MI	42°51'23"	84°54'44"
04119000	GRAND RIVER AT GRAND RAPIDS, MI	42°57'52"	85°40'35"

Table 15. USGS Streamflow Station Coordinates cont'd

Station ID	Station Location	Latitude	Longitude
04116000	GRAND RIVER AT IONIA, MI	42°58'19"	85°04'09"
04148440	THREAD CREEK NEAR FLINT, MI	42°58'20"	83°38'09"
04148300	SWARTZ CREEK AT FLINT, MI	42°59'16"	83°43'57"
04144500	SHIAWASSEE RIVER AT OWOSSO, MI	43°00'54"	84°10'48"
04148140	KEARSLEY CREEK NEAR DAVISON, MI	43°02'01"	83°34'53"
04148500	FLINT RIVER NEAR FLINT, MI	43°02'20"	83°46'18"
04116500	FLAT RIVER AT SMYRNA, MI	43°03'10"	85°15'53"
04159900	MILL CREEK NEAR AVOCA, MI	43°03'16"	82°44'05"
04118500	ROGUE RIVER NEAR ROCKFORD, MI	43°04'56"	85°35'27"
04115000	MAPLE RIVER AT MAPLE RAPIDS, MI	43°06'35"	84°41'35"
04147500	FLINT RIVER NEAR OTISVILLE, MI	43°06'40"	83°31'10"
04159492	BLACK RIVER NEAR JEDDO, MI	43°09'09"	82°37'27"
04146063	SOUTH BRANCH FLINT RIVER NEAR COLUMBIAVILLE,MI	43°09'34"	83°21'03"
04122100	BEAR CREEK NEAR MUSKEGON, MI	43°17'19"	86°13'22"
04151500	CASS RIVER AT FRANKENMUTH, MI	43°19'40"	83°44'53"
04157000	SAGINAW RIVER AT SAGINAW, MI	43°24'46"	83°57'47"
04121944	LITTLE MUSKEGON RIVER NEAR OAK GROVE, MI	43°25'51"	85°35'44"
04121970	MUSKEGON RIVER NEAR CROTON, MI	43°26'05"	85°39'55"
04150800	CASS RIVER AT WAHJAMEGA, MI	43°27'02"	83°26'29"
04122200	WHITE RIVER NEAR WHITEHALL, MI	43°27'51"	86°13'57"
04155500	PINE RIVER NEAR MIDLAND, MI	43°33'52"	84°22'09"
04156000	TITTABAWASSEE RIVER AT MIDLAND, MI	43°35'43"	84°14'08"
04154000	CHIPPEWA RIVER NEAR MOUNT PLEASANT, MI	43°37'34"	84°42'28"
04157065	SAGINAW RIVER AT WEADOCK ROAD AT ESSEXVILLE, MI	43°37'41"	83°50'12"
04152238	SOUTH BRANCH TOBACCO RIVER NEAR BEAVERTON, MI	43°52'01"	84°32'43"
04121500	MUSKEGON RIVER AT EVART, MI	43°53'57"	85°15'19"
04122500	PERE MARQUETTE RIVER AT SCOTTVILLE, MI	43°56'42"	86°16'43"
04142000	RIFLE RIVER NEAR STERLING, MI	44°04'21"	84°01'12"

Table 15. USGS Streamflow Station Coordinates cont'd

Station ID	Station Location	Latitude	Longitude
04124500	EAST BRANCH PINE RIVER NEAR TUSTIN, MI	44°06'09"	85°31'02"
04125460	PINE RIVER AT HIGH SCHOOL BRIDGE NR HOXEYVILLE, MI	44°11'36"	85°46'11"
04125550	MANISTEE RIVER NEAR WELLSTON, MI	44°15'34"	85°56'30"
04124200	MANISTEE RIVER NEAR MESICK, MI	44°21'47"	85°49'15"
442409084274001	LAKE ST HELEN AT ST HELEN, MI	44°22'27"	84°25'17"
442805084411001	HIGGINS LAKE NEAR ROSCOMMON, MI	44°25'35"	84°40'55"
04124000	MANISTEE RIVER NEAR SHERMAN, MI	44°26'11"	85°41'55"
04137500	AU SABLE RIVER NEAR AU SABLE, MI	44°26'11"	83°26'02"
04137005	AU SABLE RIVER NEAR CURTISVILLE, MI	44°33'39"	83°48'10"
04136900	AU SABLE RIVER NEAR MC KINLEY, MI	44°36'46"	83°50'16"
04135700	SOUTH BRANCH AU SABLE RIVER NEAR LUZERNE, MI	44°36'53"	84°27'20"
04126970	BOARDMAN R ABOVE BROWN BRIDGE ROAD NR MAYFIELD, MI	44°39'24"	85°26'12"
04136500	AU SABLE RIVER AT MIO, MI	44°39'36"	84°07'52"
04126740	PLATTE RIVER AT HONOR, MI	44°40'05"	86°02'05"
04136000	AU SABLE RIVER NEAR RED OAK, MI	44°40'37"	84°17'33"
450415085153501	INTERMEDIATE LAKE AT CENTRAL LAKE, MI	45°04'15"	85°15'35"
04127800	JORDAN RIVER NEAR EAST JORDAN, MI	45°06'09"	85°05'53"
04133501	THUNDER BAY RIVER AT HERRON ROAD NEAR BOLTON, MI	45°07'27"	83°38'08"
04069416	PESHTIGO RIVER AT PORTERFIELD, WI	45°08'36"	87°48'02"
04128990	PIGEON RIVER NEAR VANDERBILT, MI	45°09'22"	84°28'03"
04127997	STURGEON RIVER AT WOLVERINE, MI	45°16'28"	84°36'00"
04067500	MENOMINEE RIVER NEAR MC ALLISTER, WI	45°19'33"	87°39'48"
04066800	MENOMINEE RIVER AT KOSS, MI	45°23'14"	87°42'07"
04066030	MENOMINEE RIVER AT WHITE RAPIDS DAM NEAR BANAT, MI	45°28'55"	87°48'08"
04066003	MENOMINEE RIVER BELOW PEMENE CREEK NR PEMBINE, WI	45°34'46"	87°47'13"
04065722	MENOMINEE RIVER NEAR VULCAN, MI	45°44'12"	87°51'48"
04059500	FORD RIVER NEAR HYDE, MI	45°45'18"	87°12'07"
04065106	MENOMINEE RIVER AT NIAGARA, WI	45°46'04"	87°58'50"

Table 15. USGS Streamflow Station Coordinates cont'd

Station ID	Station Location	Latitude	Longitude
04064500	PINE RIVER BELOW PINE R POWERPLANT NR FLORENCE, WI	45°50'14"	88°13'31"
04063500	MENOMINEE RIVER AT TWIN FALLS NEAR IRON MT, MI	45°52'17"	88°04'12"
04059000	ESCANABA RIVER AT CORNELL, MI	45°54'31"	87°12'49"
04057510	STURGEON RIVER NEAR NAHMA JUNCTION, MI	45°56'35	86°42'20"
04063000	MENOMINEE RIVER NEAR FLORENCE, WI	45°57'05"	88°11'21"
04060993	BRULE RIVER AT US HIGHWAY 2 NEAR FLORENCE, WI	45°57'39"	88°18'57"
04058940	ESCANABA RIVER NEAR ST. NICHOLAS, MI	45°58'45"	87°16'13"
04062000	PAINT RIVER NEAR ALPHA, MI	46°00'40"	88°15'30"
04056500	MANISTIQUE RIVER NEAR MANISTIQUE, MI	46°01'50"	86°09'40"
04060500	IRON RIVER AT CASPIAN, MI	46°03'31"	88°37'38"
04062500	MICHIGAMME RIVER NEAR CRYSTAL FALLS, MI	46°06'50"	88°12'57"
04127918	PINE RIVER NEAR RUDYARD, MI	46°11'09"	84°35'52"
04037500	CISCO BRANCH ONTONAGON R AT CISCO LAKE OUTLET, MI	46°15'12"	89°27'05"
04058100	MIDDLE BRANCH ESCANABA RIVER NR PRINCETON, MI	46°19'02"	87°30'07"
04044724	AU TRAIN RIVER AT FOREST LAKE, MI	46°20'27"	86°51'00"
04033000	MIDDLE BRANCH ONTONAGON RIVER NEAR PAULDING, MI	46°21'25"	89°04'35"
04033500	BOND FALLS CANAL NEAR PAULDING, MI	46°23'57"	89°08'47"
04058200	SCHWEITZER CREEK NEAR PALMER, MI	46°24'40"	87°37'27"
04057814	GREENWOOD RELEASE NEAR GREENWOOD, MI	46°26'22"	87°47'52"
04057812	GREENWOOD AFTERBAY NEAR GREENWOOD, MI	46°26'32"	87°48'02"
04057800	MIDDLE BRANCH ESCANABA RIVER AT HUMBOLDT, MI	46°29'57"	87°53'11"
04031000	BLACK RIVER NEAR BESSEMER, MI	46°30'41"	90°04'28"
04045500	TAHQUAMENON RIVER NEAR PARADISE, MI	46°34'30"	85°16'10"
04040500	STURGEON RIVER NEAR SIDNAW, MI	46°35'03"	88°34'33"
04036000	WEST BRANCH ONTONAGON RIVER NEAR BERGLAND, MI	46°35'15"	89°32'30"
04043275	YELLOW DOG RIVER NEAR BIG BAY, MI	46°42'49"	87°50'26"
04040000	ONTONAGON RIVER NEAR ROCKLAND, MI	46°43'15"	89°12'25"
04041500	STURGEON RIVER NEAR ALSTON, MI	46°43'35"	88°39'43"

Table 15. USGS Streamflow Station Coordinates cont'd

Station ID	Station Location	Latitude	Longitude
04043140	GOMANCHE CREEK AT INDIAN ROAD NEAR L'ANSE, MI	46°45'04"	88°21'42"
04043238	SALMON TROUT RIVER NEAR BIG BAY, MI	46°46'56"	87°52'39"
04043244	EAST BRANCH SALMON TROUT RIVER NEAR DODGE CITY, MI	46°47'09"	87°51'08"
04043150	SILVER RIVER NEAR L'ANSE, MI	46°48'15"	88°19'01"
04043050	TRAP ROCK RIVER NEAR LAKE LINDEN, MI	47°12'43"	88°23'07"
04001000	WASHINGTON CREEK AT WINDIGO, MI	47°55'17"	89°08'45"
04176605	OTTER CREEK AT LA SALLE, MI	41°52'01"	83°27'13"

BIBLIOGRAPHY

BIBLIOGRAPHY

"Inland Lakes and Streams". Michigan Department of Environmental Quality. http://www.michigan.gov/deq/0,4561,7-135-3313_3681---,00.html

Adeloye, A.J., Montaseri, M., 2002. Preliminary streamflow data analyses prior to water resources planning study. Hydrologic Science Journal 47(5), 679-692.

Birsan, M-V., Molnar, P., Burlando P., Pfaundler M., 2005. Streamflow trends in Switzerland. Journal of Hydrology 313 (4).

Barua, S., Muttil, N., Ng, A., Perera, B., 2012. Rainfall trend and its implications for water resource management with in the Yarra River catchment, Australia. Wiley Online Library. 1-12.

Kalayci, S., Kahya, E., 2006. Assessment of streamflow variability modes in Turkey: 1964-1994. Journal of Hydrology 324. 163-177.

Wilson, D., Hisdale, H., Lawerence, D., 2010. Has streamflow changed in the Nordic countries? – Recent trends and comparisons to hydrological projections. Journal of Hydrology 394. 334-346.

Kumar S., Merwade V., Kam J., Thurner K., 2009. Streamflow trends in Indiana: Effects of long term persistence, precipitation and subsurface drains. Journal of Hydrology 171 178.

Machwal, D., Jha, M.K., 2012. Hydrologic Time Series Analysis: Theory and Practice. Springer, Dordrecht, The Netherlands. 303.

Hamed, K.H., Rao, 1998. A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology 204. 182-196.

Haslett, J., Raftery, A.E., 1989. Space-time modeling with long-memory dependence: Assessing Irelands' wind power resource. Applied Statistics, Vol. 38, No. 1. 1-50

Hirsch R.M., Slack J.R., 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research, Vol. 20, No. 6. 727-732.

Chen, H.-L., Rao, A.R., 2002. Testing Hydrologic time series for stationarity. J. Hydrologic Engineering ASCE, 7(2). 129-136

Dazhi M., Cherkauer K., 2009. Impacts of land-use change on hydrologic responses in the Great Lakes region. Journal of Hydrology. 71-72, 80-82.

Douglass, E.M., Vogel, R.M., and Kroll, C.N., 2000. Trends in floods and low flows in the United States: impact of spatial correlation. Journal of Hydrology 240. 90 – 105.

Johnston C., Shmagin B., 2008. Regionalization, seasonality and trends of streamflow in the US Great Lakes Basin. Journal of Hydrology, 77-86.

Shahin, M., Van Oorschot, H.J.L., De Lange, S.J., 1993. Statistical Analysis in Water Resources Engineering. A.A. Balkema, Rotterdam, The Netherlands. 394.

Yue, S., Wang C.Y., 2002. Applicability of pre-whitening to eliminate the influence of serial correlation on the Mann-Kendall test. Water Resources Research, Vol. 38, No. 6, doi:10.1029/WR000861.

Yue, S., Wang C.Y., 2002. The influence of serial correlation on the Mann-Whitney test for detection a shift in median. Advance Water Resources, 25(3), 325-333.

Zhang, Y.-K., Schilling, K.E., 2006 Increasing streamflow and baseflow in the Mississippi River since the 1940's: Effect of land use change. Journal of Hydrology, 418-420.

The Mathworks Inc., Matick, Ma, Version 7.12.0.635

Systat Software Inc. San Jose, CA. SYSTAT-13 (2012).

Paquette, C. Statistical Analysis of Trends in the Red River Over a 45 Year Period. Department of Statistics. University of Manitoba. 8-9, 12-26.

Seidou, O., Ouarda, T.B.M.J, 2007. Recursion-based multiple change point detection in multiple linear regression and application to river streamflow. Water Resources Research, 43 W07404, doi:10.1029/2006WR005021.

Kang, S., Lin, H., 2007. Wavelet analysis of hydrological and water quality signals in an agricultural watershed. Journal of Hydrology, Vol. 338, No. 3-4. 1-14.

Labat, D., 2005. Recent Advances in wavelet analyses: Part 1: A review of concepts. Journal of Hydrology, Vol. 314, No. 1-4. 275-288.

Labat, D., 2010. Cross-Wavelet analyses of annual continental freshwater discharge and selected climate indices. Journal of Hydrology, Vol. 385, No. 1-4. 269-278.

Capodaglio, A.G., and Moisello, U. 1990. Simple stochastic model for annual flows. Journal of Water Resource Planning and Management, ASCE, 220-232.

Sednek, S.P., and Zorn, T.G., 2001. Au Sable River Assessment. Michigan Department of Natural Resources Fisheries Division. Fisheries Special Report 26. 14-15.

Kendall, M.G., 1955. Rank Correlation Methods. Griffin, London.

Mann H.B., 1945. Nonparametric tests against trend. Econometrica. 13, 145-259.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's Tau, Journal of the American Statistical Association 39: 1379–1389

Climate Change in the Great Lakes Region. 2012. Great Lakes Integrated Sciences and Assessments Center.