**Thurston County Water Resources**

**Technical Memorandum #7**

Prepared by

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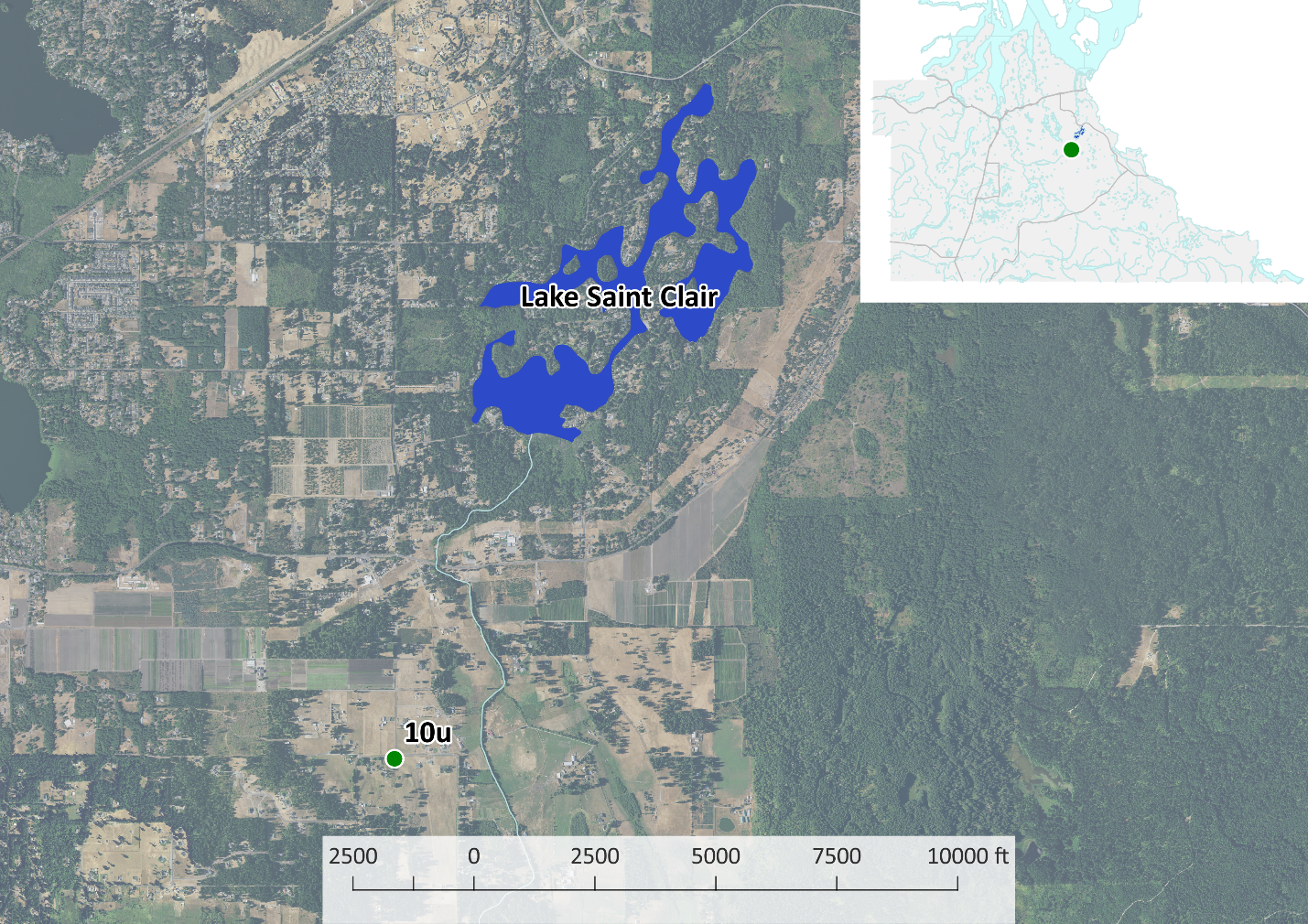
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Lake St. Clair Water Elevation  
1992-2016

# Goal

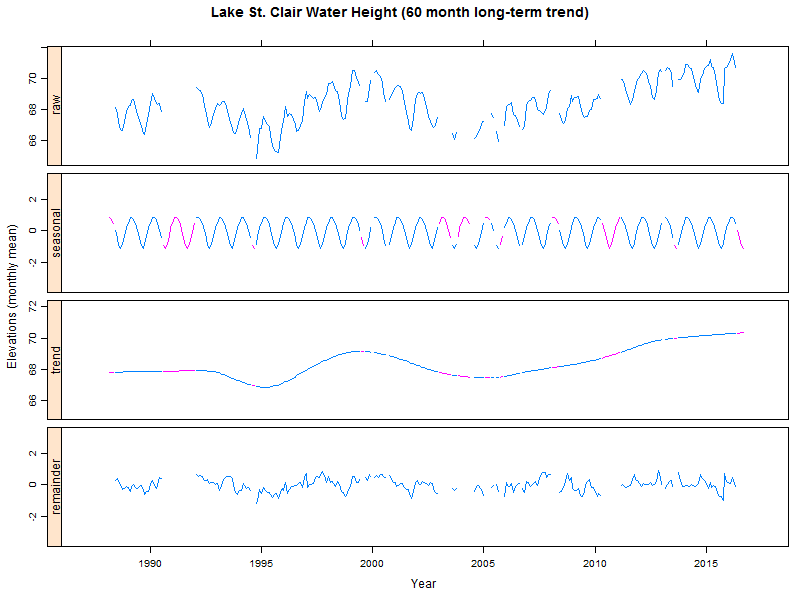
Improve the understanding of the water elevation at Lake St. Clair, both independent of and with respect to precipitation.

# Results



Lake St. Clair water elevation displays a clear annual cycle, rising during the wet season and lowering during the dry season by about 2 feet over the course of the year. It is also strongly effected by long-term trends that account for at least as much of the variation in elevation as the seasonal variation. These long term trends have varied going back to 1992, but since at least 2005 the overall trend has been an increase in water level of about 3 feet.

Figure 1: Water Elevation Decomposition

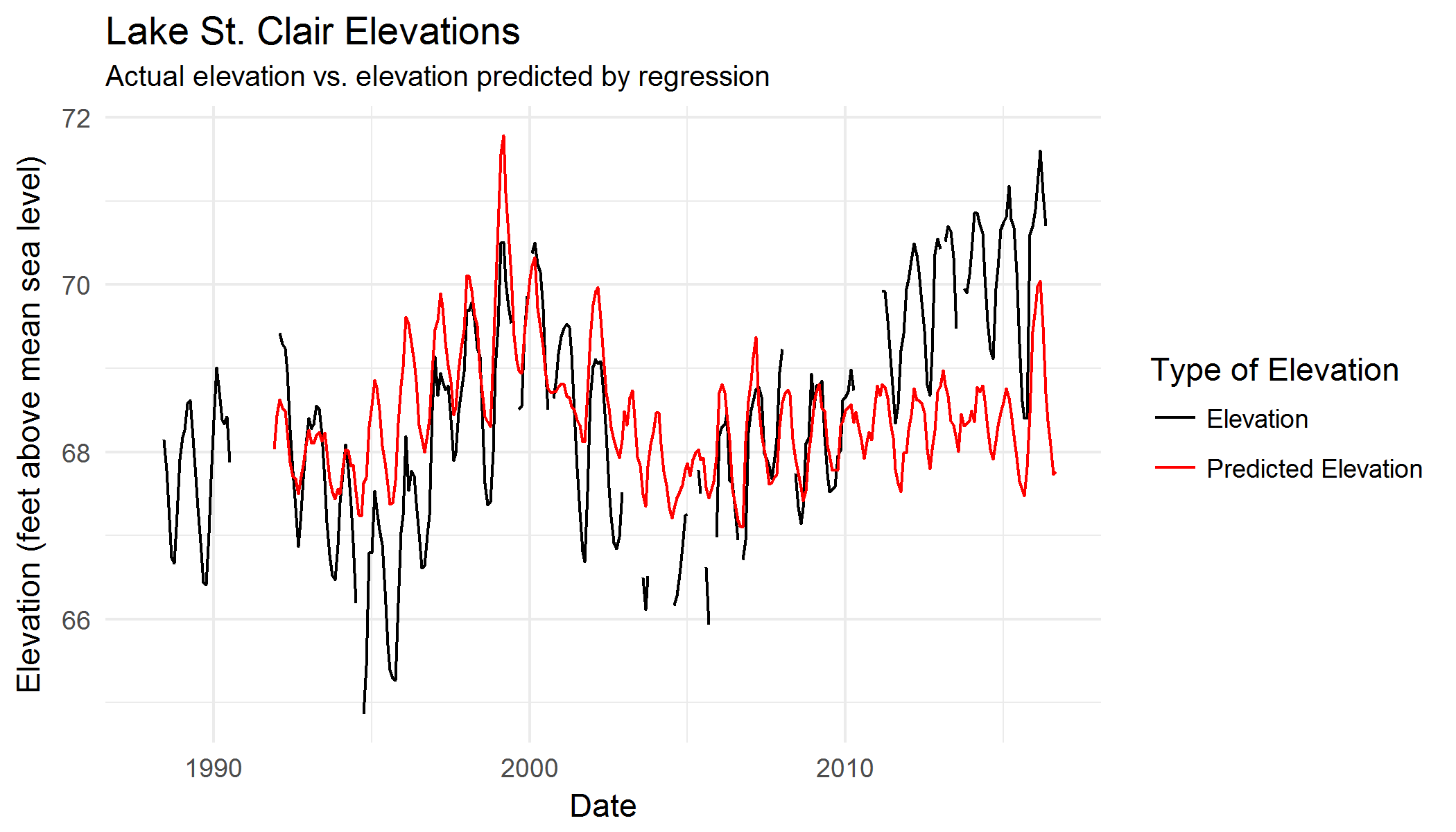


Note that in Figure 1, missing data in the “seasonal” and “trend” series are in pink; those values are estimated, whereas values in blue are derived directly from the data.

Water elevations in Lake St. Clair also follow precipitation patterns. It is possible to predict lake elevations by calculating the cumulative precipitation of the preceding 5 months, and the preceding 4 years.

The relationship between Lake St. Clair and precipitation has changed over time, with a significant break occurring in mid-2004. Before 2004 the seasonal precipitation fluctuation (represented by the 5 month cumulative precipitation) drives the elevation, with the long-term trend (represented by the 4 year cumulative precipitation) making less of an impact; after 2004, the long-term precipitation trend is more important.

Figure 2: Water Elevation Correlation with Precipitation



When all of the data are included in a single series, as with Figure 2, precipitation can explain at most about 30% of the variation in lake elevations. When split in two, with separate analyses for pre-2004 and post-2004 data, precipitation can explain closer to 70% of the variation.

# Methods

## Software

This analysis was conducted in R 3.3.1 (RStudio 1.0.44, plus packages dplyr, ggplot2, lubridate, readr, stlplus, zoo); QGIS 2.14; Excel 2013; and Notepad++ 7.1.

## Data

Daily precipitation data were acquired from NOAA for the Olympia Airport site. Daily precipitation data for the Eaton monitoring site from 2004-2016 were available in the Thurston County monitoring archive. Data from the PEA1 monitoring site (the same site as Eaton, also known as 10u) from 1992-2000 were also available from Thurston County archives, following Thurston County Water Resources Technical Memorandum #6.

Elevation data for Lake St. Clair were also obtained from Thurston County monitoring archives. Daily values from 2008-2016 were available; from 1988-2008, monthly minima and maxima were available, with some breaks in the data.

## Analysis

This exploratory analysis included:

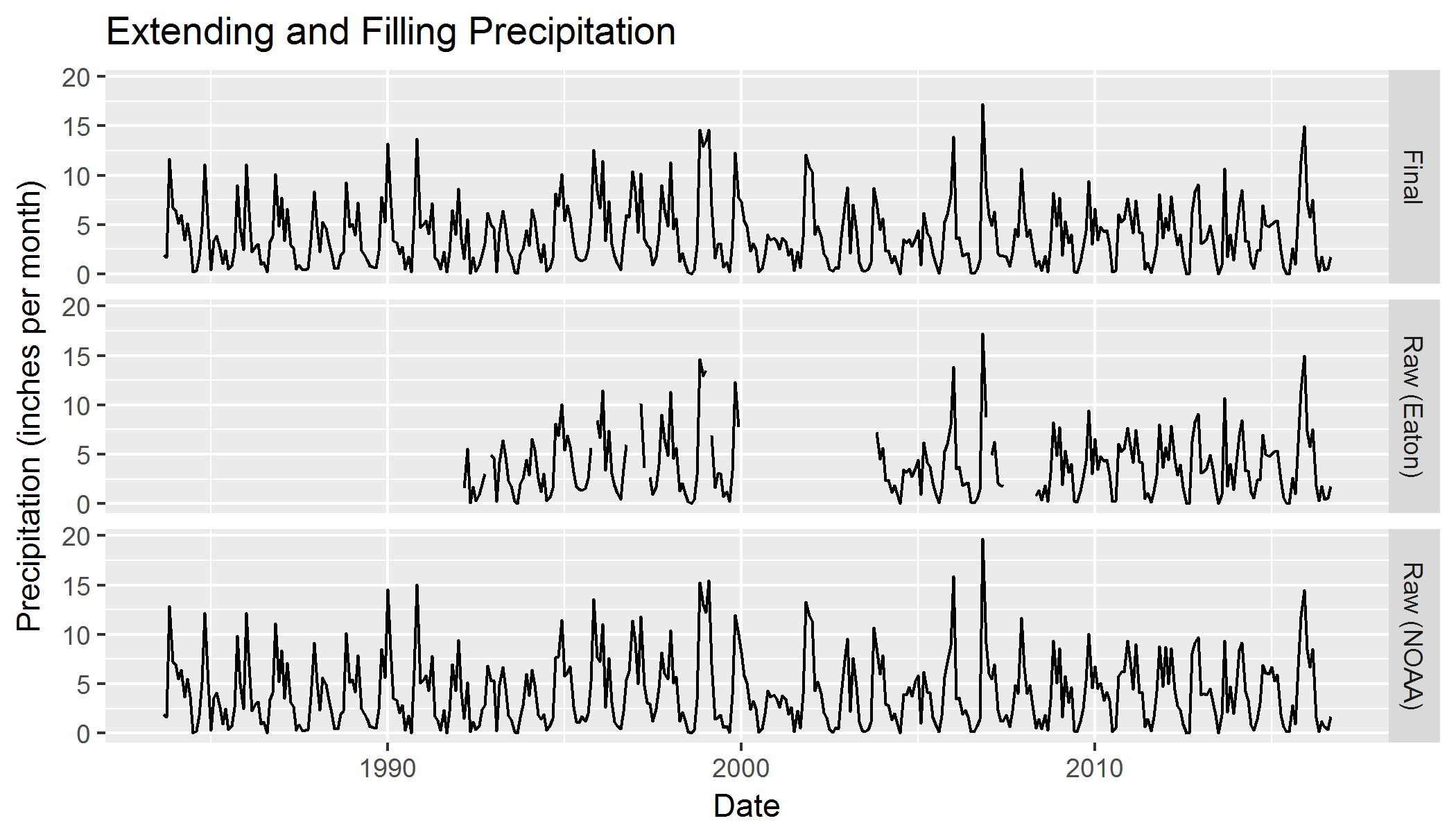
* Extending and filling the 10u precipitation record.
* Decomposing the rainfall and lake elevation records.
* Calculating rainfall intensity.
* Comparing precipitation records (raw, cumulative, and intensity) to lake elevation records.

## Extending and Filling Precipitation

The most complete daily precipitation record in Thurston County is the NOAA gaging station at the Olympia Airport. Since 1992 Thurston County has operated the Eaton (also 10u or PEA1) precipitation station in the Eaton Creek/Lake St. Clair watershed. The Eaton station does not have a complete record over the Lake St. Clair elevation record, but because it is in the Lake St. Clair watershed it better represents precipitation in areas that drain to the lake.

The 10u daily precipitation record was extended by establishing a relationship with the NOAA daily precipitation using linear regression. Original measured values from Eaton were retained, while missing values (including gaps in the dataset, precipitation values prior to 1992, and data dropped because they were flagged as poor quality) were filled with the values predicted by the relationship with the NOAA gage.

Figure 3: Eaton (10u) Precipitation

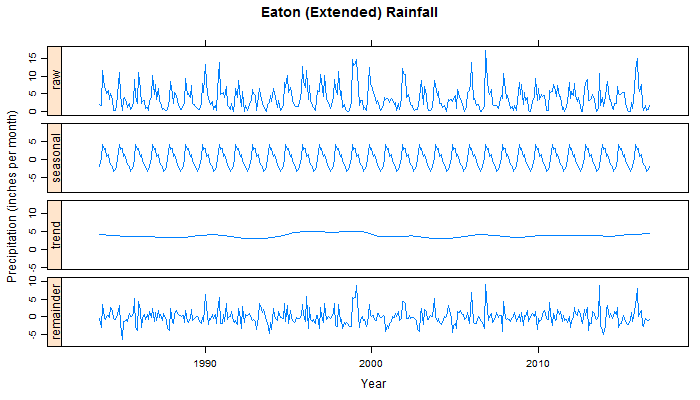


Monthly precipitation values were calculated by summing the daily filled and extended precipitation record.

## Decomposing Trends

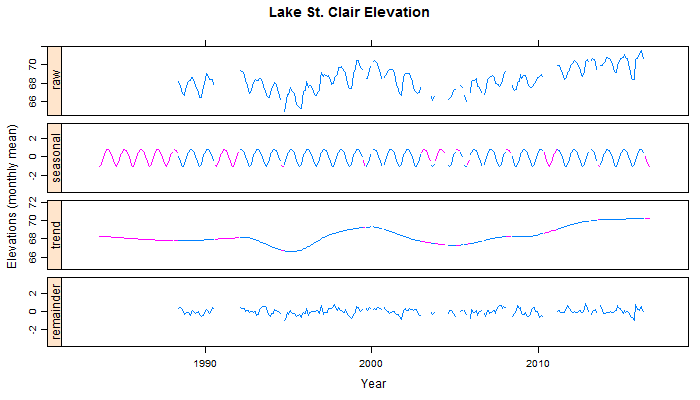
Both rainfall and lake elevations vary over time with the season, and in response to longer-term trends. It is possible to “decompose” a time series into seasonal, trend, and remainder components that, when added together, recreate the original series. This process of decomposition is called STL, or Seasonal and Trend Decomposition using Loess (Cleveland, Cleveland, McRae, & Terpenning, 1990).

Figure 4: Precipitation Decomposition



Rainfall has an obvious seasonal pattern, rising and falling over the course of a year. The long-term trend, in this case calculated over a 3.5 year (42 month) window, is important, but explains very little of the variation in the data (note that the y axes on all four graphs are set to the same scale); we’ll return to long-term trends later. Much of the “raw” precipitation is explained by the remainder, meaning that seasonal and long-term trends have limited ability to explain precipitation variation over time. This is an expected result – climate is fairly consistent, but weather is unpredictable.

Figure 5: Lake St. Clair Water Elevation Decomposition



In this graph, blue indicates values calculated directly from the data, while pink/purple indicates values that were extrapolated based on neighboring values. Note that while the seasonal and trend graphs are extended and gap-filled, no attempt was made to estimate a remainder.

As with the precipitation decomposition, a yearly cycle is clearly evident in the seasonal water elevation trend. Unlike the precipitation decomposition, the long-term trend (again calculated over a 3.5 year window) explains a great deal of the variation. The remainder is relatively small, suggesting that seasonal and long-term effects at the primary influences on lake elevations.

Ultimately precipitation drives lake elevations. The annual variation component is shared between the lake elevation data and precipitation data. The co-variation is probably mostly causal (increased rainfall drives up lake elevations), but could include correlation with a third factor (summer weather both increases evaporation/evapotranspiration and reduces precipitation).

It is difficult to see from Figures 4 and 5 whether there’s a strong relationship between the long term precipitation and water elevation trends.

Figure 6: Long-term Trends

# Conclusions and Recommendations

# Works Cited

Cleveland, R. B., Cleveland, W. S., McRae, J. E., & Terpenning, I. (1990). STL: A Seasonal-Trend Decomposition Procedure Based on Loess. *Journal of Official Statistics*, 3-33.