Fen Well Monitoring Report

Lower Minnesota River Watershed District

2013

Prepared for the Lower Minnesota River Watershed District
by Dakota County Soil and Water Conservation District

LOWER MINNESOTA RIVER WATERSHED DISTRICT

DAKOTA COUNTY SOIL AND WATER CONSERVATION DISTRICT

Contents

Introduction

The Minnesota River corridor, just upstream of the confluence with the Mississippi River, is a unique habitat consisting of calcareous fens, intersected with small trout streams (See map in Appendix 1). Flora and fauna of the fens and streams rely on groundwater input to maintain water levels and provide cool water. The abundance of dissolved minerals, particularly calcium carbonate, causes the water to be more alkaline (higher pH), a typical signature of streams and wetlands with a significant groundwater influence.

As a result of development in the area, little natural fen remains and there is concern over the quality of the fen habitat and the ability to support the wildlife that is well adapted to its unique characteristics. Groundwater pumping, infrastructure, and stormwater input have had a noticeable effect on water quality and quantity. Several assessments of this natural resource and the need for continued monitoring were done, and in 2007 the Lower Minnesota River Watershed District began working with the Dakota County Soil and Water Conservation District to conduct annual fen well monitoring. After seven years of data collection, some trends are becoming apparent.

Weather Summary

Monthly precipitation data was retrieved from the National Weather Service website for the Minneapolis/St. Paul airport weather station. Since 2006, there have been a mix of years with precipitation above (2007, 2010, 2012, 2013) and below (2006, 2008, 2009, 2011) the 30 year average, as shown in Figure 1.

In the Quarry Island and Fort Snelling fens, the well water level did not seem to change much as a result of precipitation in previous or current years. On the other hand, the Nichols wells seemed to be heavily influenced by annual precipitation. According to the “Environmental Monitoring of Nichols Fen” study conducted in 2008 by WSB & Associates, Inc., the Nichols fen has an 18-24 month response time to precipitation. Based on the data summarized here, it appears that a year with higher well level measurements is preceded by a year in which total precipitation is above average. Alternatively, years with lower well level measurements are preceded by years in which total precipitation is below average. For example, 2010 was an above average year for total rainfall, and several wells in the Nichols fen show higher levels in 2011.

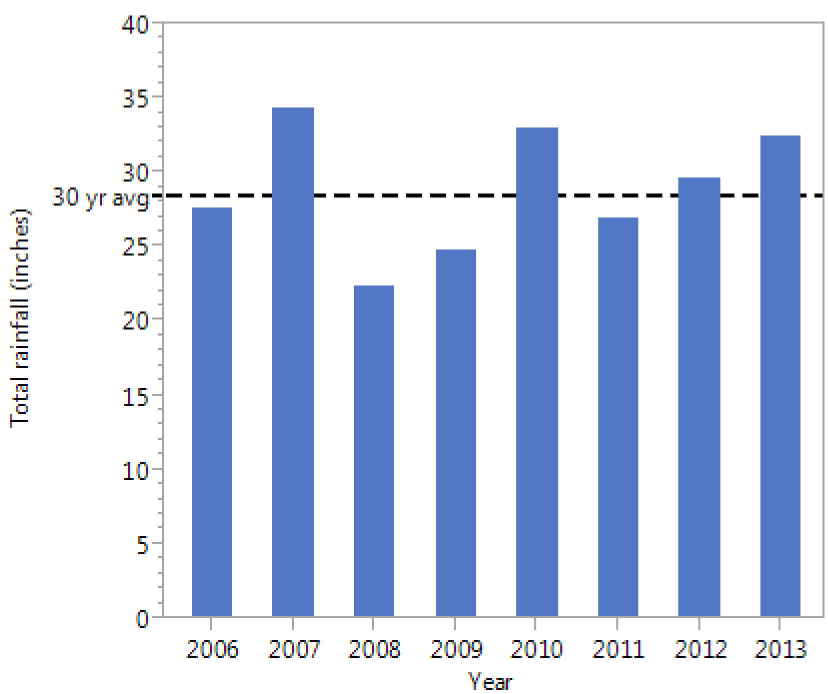


Figure 1. Total rainfall (inches) from 2006-2013 at Minneapolis/St. Paul weather station, data courtesy of National Weather Service. 30 year average (1983-2013) is shown with a black dashed line at 28.40 inches.

Methods

Fen wells were monitored on a monthly basis from March through December from 2007 through 2013. The monitoring network consists of two Quarry Island wells, 13 Fort Snelling wells, and 13 Nichols wells for a total of 28 wells.

A Solinst Water Level Meter (Model 101) was used to measure the distance from the benchmark at the top of the well casing down to the water surface. Data was later transcribed into mean sea level and reported as elevation, in feet. In cases where the water level was "flowing" or too shallow to measure, the elevation of the pipe casing was used. In cases where the water in the pipe was frozen, no level data was recorded. See figures captions and fen grouping summaries for more description.

Data are reported to the Minnesota Department of Natural Resources and can be retrieved by following this link (http://climate.umn.edu/ground_water_level/).

Interpreting Statistical Values

Kendall's tau (T) test is commonly used to evaluate monontonic trends in water quality data as a function of time. Most generally, it is a test for whether well elevations tend to increase or decrease with time. The test determines which wells are significantly trending, but does not seek to explain the cause of the trend.

The P-value is used to quantify the statistical significance of the data. It shows the likelihood that the null hypothesis is true; i.e., there is no change in well level over time. A P-value of 0.001 means there is a 0.1% probability that there is no change in well level over time. Since this probability is so small, it indicates that the pattern in the data would be highly unlikely if there was no trend (change in level over time). Thus we can reject the null hypothesis and be fairly confident that there is a change in well level over time. Generally, a P-value below 0.05 is acceptable.

The Pearson correlation coefficient (R) is used to describe the noisiness and direction of a linear relationship. If the well level is decreasing over time there will be a negative R value close to -1, if the well level is increasing over time there will be a positive R value close to 1. If there is no clear linear trend and points are scattered around the line, the R value will be close to 0.

The coefficient of determination (R^2) is a measure of how well the predicted regression line approximates the observed data points. Data that are closely associated with the line have an R^2 close to 1, while data that are very scattered around the line have an R^2 close to 0. R^2 does not indicate whether the independent variables are a cause of the changes in the dependent variable; and thus, R^2 alone cannot be used to determine if a variable is significantly trending (up or down) or not.

Fen Well Monitoring Results and Discussion

Several statistical parameters were calculated to determine if well levels were significantly increasing or decreasing with time. Linear regressions for each dataset are shown in Appendix 3.

Table 1. Water level trends over time for each fen well. Statistics are included only for those wells in which P-values were statistically significant. [1]No clear trend although the P-value is acceptable, the R and R^2 values do not indicate a strong trend and more data is needed. [2] Trends seem to be heavily influenced by precipitation.

	Well	Trend	Kendall's T, P-value	R	R^2
Quarry Island	P1-S	Decreasing	-0.5994 , <0.001	-0.7205	0.519
	P1-D	Decreasing	-0.6701 , <0.0001	-0.8602	0.740
Fort Snelling	N3	No clear trend			
	N4	No clear trend			
	N5	No clear trend			
	W1	No clear trend			
	W2	No clear trend			
	W3	No clear trend			
	W4	No clear trend[1]	0.3466 , <0.0001	0.3627	0.132
	S1-USGS	Decreasing	-0.7169 , <0.0001	0.8309	0.690
	S1	No clear trend[1]	-0.2511 , 0.0044	-0.2432	0.059
	S2-USGS	No clear trend			
	S2	No clear trend[1]	-0.1884 , 0.0272	-0.1958	0.038
	S3-USGS	No clear trend			
	S3	No clear trend			
Nichols	1LN	No clear trend			
	1LS	No clear trend			
	F3	Increasing[2]	0.3243 , 0.0005	0.5145	0.265
	F4	Increasing[2]	0.3155 , 0.0001	0.5179	0.268
	WN1-USGS	Increasing[2]	0.3125 , 0.0003	0.5031	0.253
	WN5-USGS	Increasing[2]	0.3352 , 0.0001	0.528	0.279
	WT-1	No clear trend[1]	-0.1822 , 0.0248	-0.1332	0.018
	WT-2	Increasing[2]	0.3087 , 0.0003	0.4966	0.247
	WT-3	No clear trend			
	WT-4	No clear trend			
	WT-5	No clear trend			
	F1	Increasing[2]	0.4671 , <0.0001	0.6922	0.479
	F2	Decreasing[2]	-0.4497 , <0.0001	-0.6217	0.387

Quarry Island

Water levels in the Quarry Island fen (P1-S and P1-D) appear to be significantly decreasing over time and show some annual seasonality with early fall having the lowest level measurements (Figure 2). The shallower well (P1-S) monitors water level in the peat layer while the deeper well (P1-D) monitors the layer immediately below the peat. The Quarry Island fen had originally been part of the larger Snelling Fen complex and was cut off during the highway 494 construction and watershed development. There may be little potential for restoration since the watershed is largely developed already. A longer period of record for well monitoring would increase confidence in this trend.

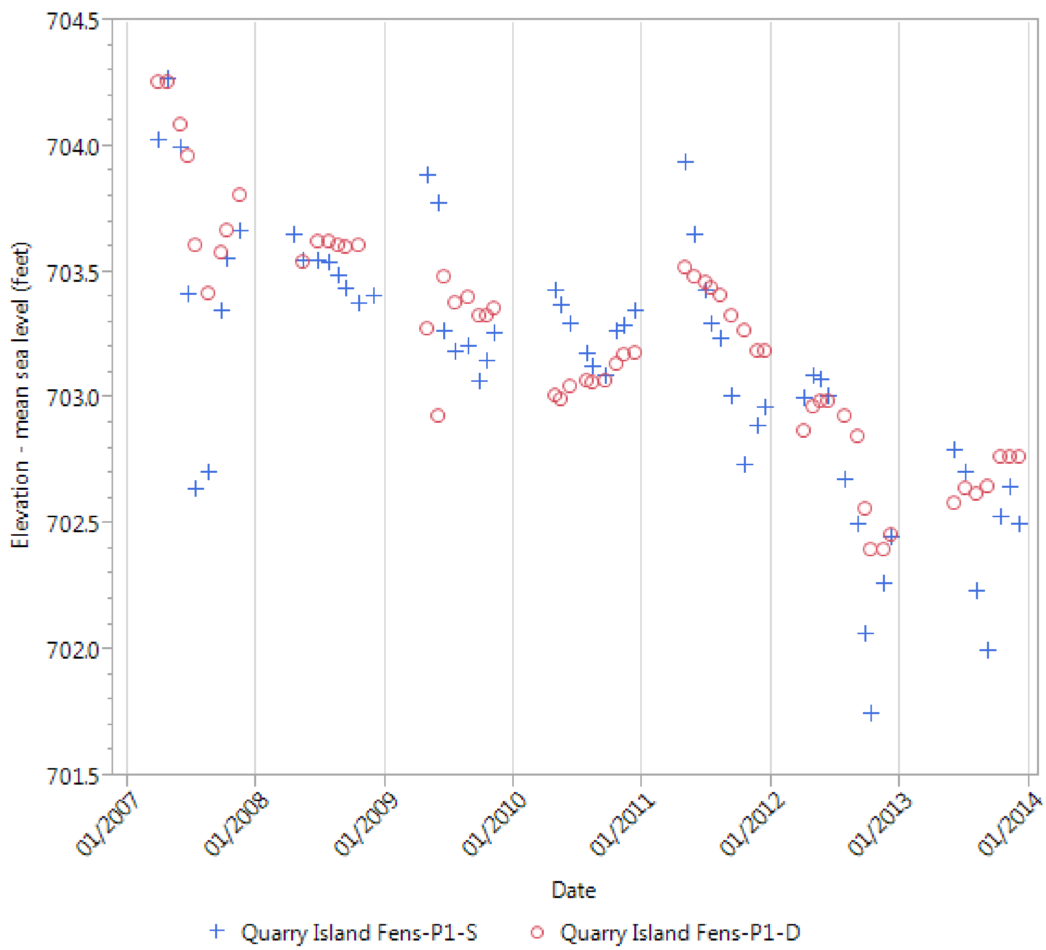


Figure 2. Water level elevation for Quarry Island Fen wells, March through December, 2007-2013.

Fort Snelling

The Fort Snelling fen is of good quality and seems to be quite stable with only one well showing a clear downward trend (S1-USGS). All the wells seem to show seasonality with levels dropping to their lowest in early fall, a pattern typical of natural water resources (Figure 2).

Continued monitoring of the Fort Snelling fen would allow for any degradation to be more quickly recognized and addressed. There is likely more historical data for the Fort Snelling fens although they are not available on the Department of Natural Resource's groundwater data access website.

In Table 1, a few wells (W4, S1, and S2) had significant P-values; however, the supporting statistical parameters (R and R^2) did not indicate a strong linear relationship. A couple very low or very high measurements seemed to drive the trend.

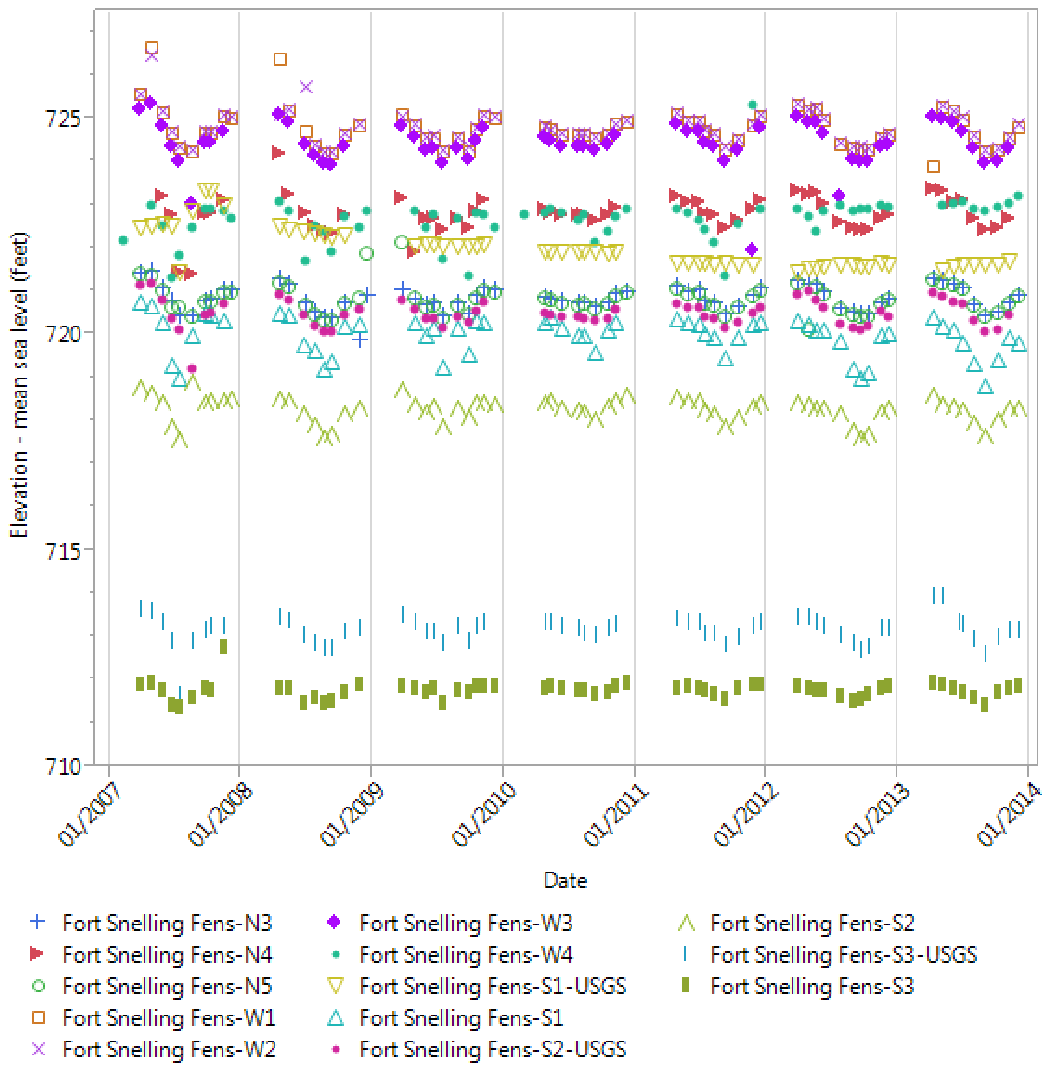


Figure 3. Water level elevation for the Fort Snelling Fen wells, March through December, 2007-2013. At well S3-USGS, when the water was overflowing, the elevation of the top of the pipe (713.97) was recorded. See individual well graphs in Appendix 3.

Nichols

Several wells show increasing trends; however, it should be noted that these trends seem to be closely tied to precipitation. Years with higher well level measurements were preceded by years which had higher than average total rainfall, and years with lower well level measurements were preceded by years which had lower than average total rainfall. This suggests a 1-2 year relationship between precipitation and groundwater elevations within the fen, similar to the conclusion made by the 2008 Nichols fen report by WSB & Associates, Inc.

Figures 4-6 summarize the results of the fen well level measurements from 2007 through 2013. Data are presented across several figures for clarity and grouping is based on proximity, not hydrologic characteristics.

Fen wells F3, F4, WN1-USGS, and WN5-USGS had well measurements in 2011 and 2013 that were higher than in other years, and likely contributed to the significant increasing trend in the data. The two years prior, 2010 and 2012, had higher than average total precipitation. Alternatively, F2 had a decreasing trend which seemed to be heavily influenced by the low values measured in 2012 (following a below average total rainfall year in 2011). Longer datasets for these wells will help to determine if there are long-term increasing or decreasing trends, and will be less heavily influenced by one to two, wet or dry years.

The WT-1 well had a significant P-value; however, the R and R^2 values were weak. Additionally, if one high value from 2007 were removed, the relationship would no longer be statistically significant. More data is needed to infer a trend for this well.

The F1 and WT-2 wells had two years (2007 and 2008) that were lower, with the following years having higher well levels. There seems to be a big step near the end of 2008 and the beginning of 2009 which is driving the significant trend and the weak R and R^2 values. When a Kendall's tau test is performed on the latest 5 years (2009-2013), there is no significant trend; however, this is a relatively short period of time and more data is needed to make a confident conclusion.

Each of the wells seems to show some annual seasonality with late summer having the lowest level measurements and early spring and summer having higher levels.

Continued monitoring would help to improve confidence in these trends and determine if there is long-term drawdown of the water table as a result of watershed impacts or if the groundwater levels in the Nichols fen are recovering and stabilizing.

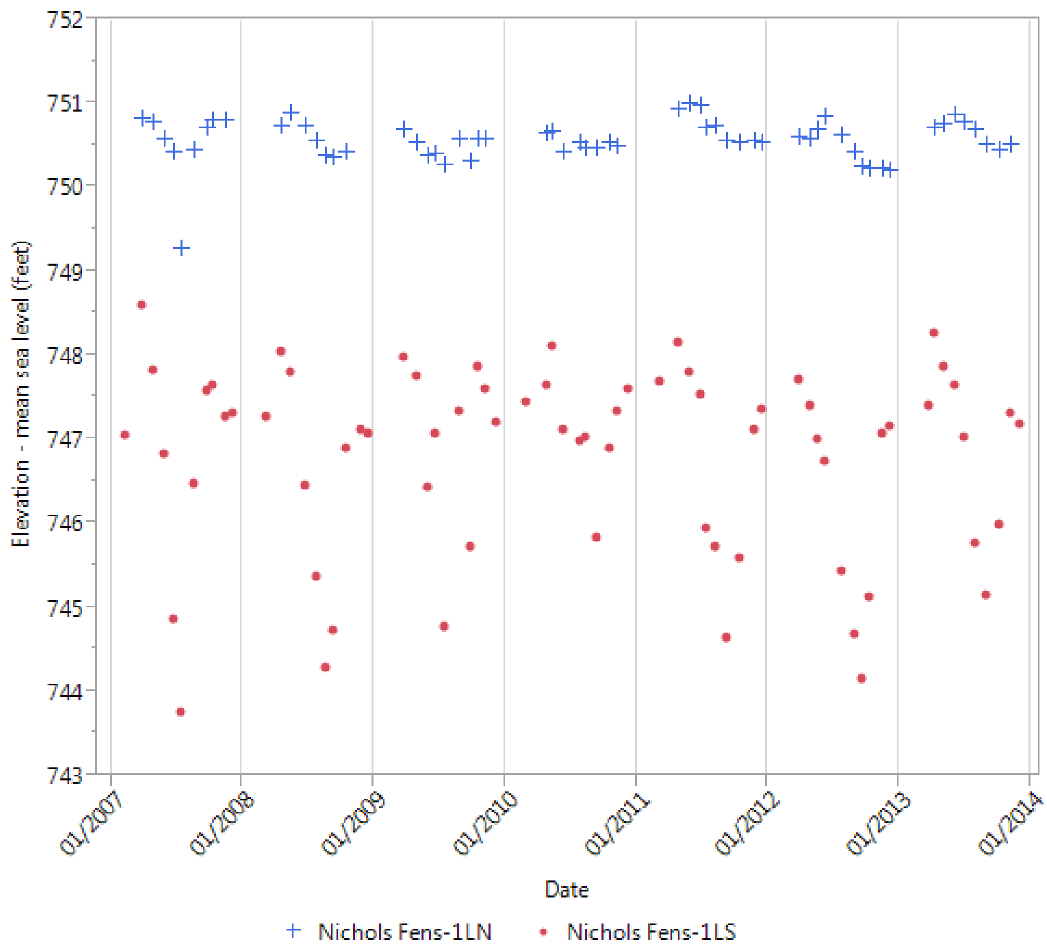


Figure 4. Water level elevation for the Nichols Fen wells (set 1 of 3), March through December, 2007-2013.

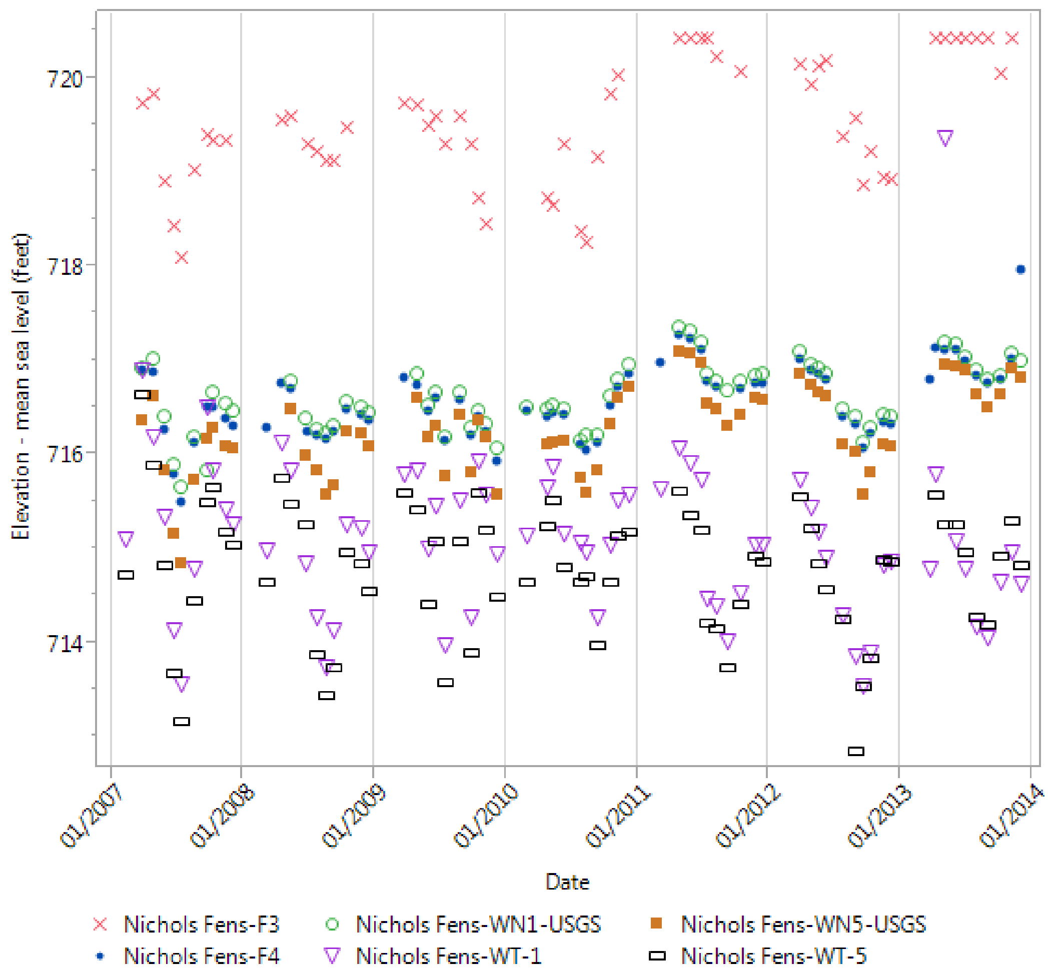


Figure 5. Water level elevation for the Nichols Fen wells (set 2 of 3), March through December, 2007-2013. At well F3 and WT-1, the water was often overflowing and the elevation of the top of the pipe (720.43 and 719.37, respectively) was recorded. See individual well graphs in Appendix 3.

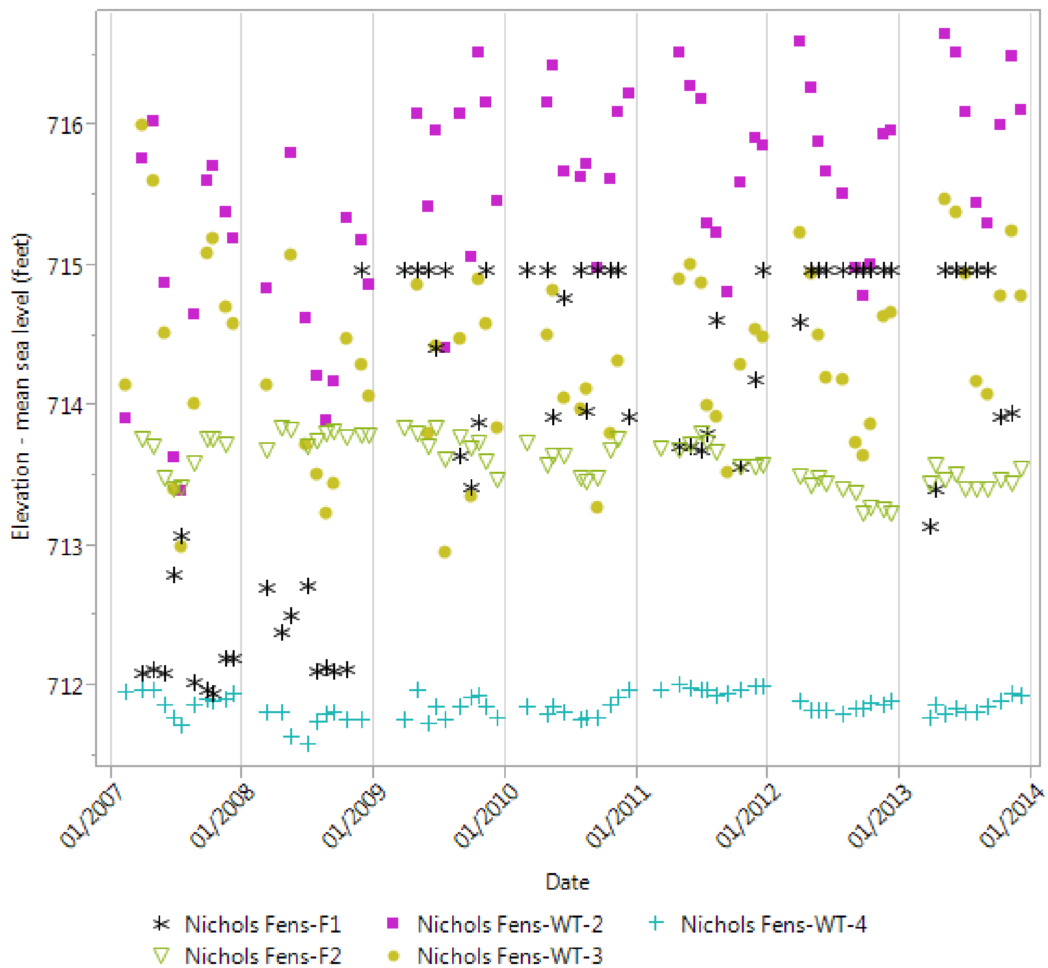


Figure 6. Water level elevation for the Nichols Fen wells (set 3 of 3), March through December, 2007-2013. At well F1, the water was often overflowing and the elevation of the top of the pipe (714.97) was recorded. See individual well graphs in Appendix 3.

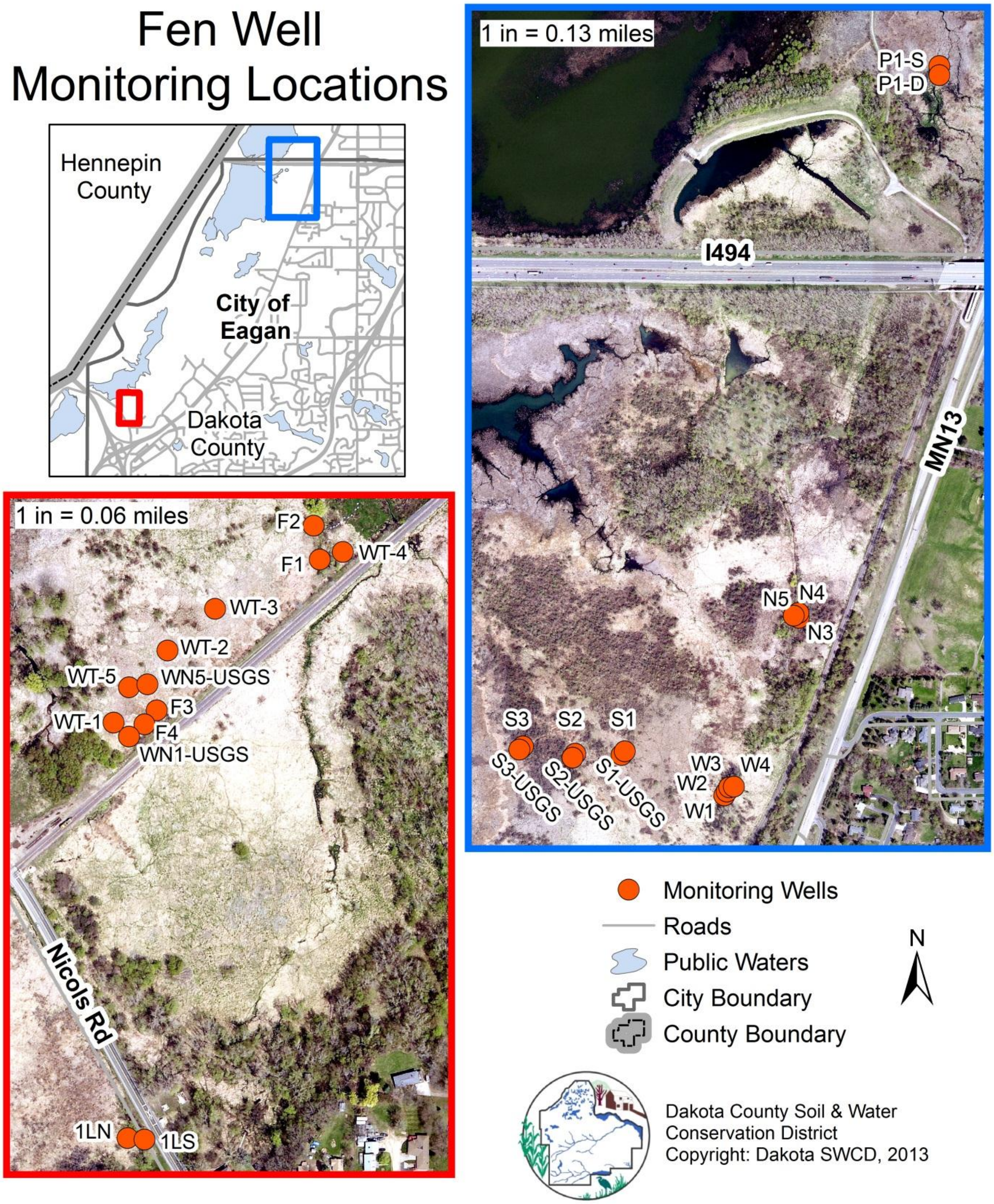
Conclusion

Based on the data presented in this report, it appears as though groundwater levels in the Quarry Island fen are decreasing while the levels in the Nichols fen may be recovering and the Fort Snelling fen is stable.

For some of the fen wells, water levels fluctuate seasonally as well as annually based on current and past weather patterns. Above average precipitation years seem to be followed by higher well level measurements during subsequent years. The opposite is also true when total annual precipitation is below average.

After seven years of collecting well level measurements, there is sufficient data to begin applying statistics to determine if there are increasing or decreasing trends. Longer datasets are needed to confirm degradation or stability of fens (such as for the Quarry Island fen and Fort Snelling fen, respectively), and also to determine if the Nichols Fen is recovering or if the apparent increasing trend at many of the wells is just an artifact of the recent wetter than average years. Seasonal changes in temperature, precipitation, flow, etc. can have an influence on fen well water levels, especially over short periods of time. Continued monitoring, to build a long-term dataset, would help to further define and build confidence in these initial trends.

Appendix 1: Map of Fen Well Monitoring Locations



This drawing is neither a legally recorded map nor a survey and is not intended to be used as one. This drawing is a compilation of records, information and data located in various City, County, and State Offices and other sources, affecting the area shown, and is to be used for reference purposes only. Dakota County SWCD is not responsible for any innaccuracies herein contained. If discrepencies are found please contact the Dakota County Soil & Water Conservation District at 651.480.7777.

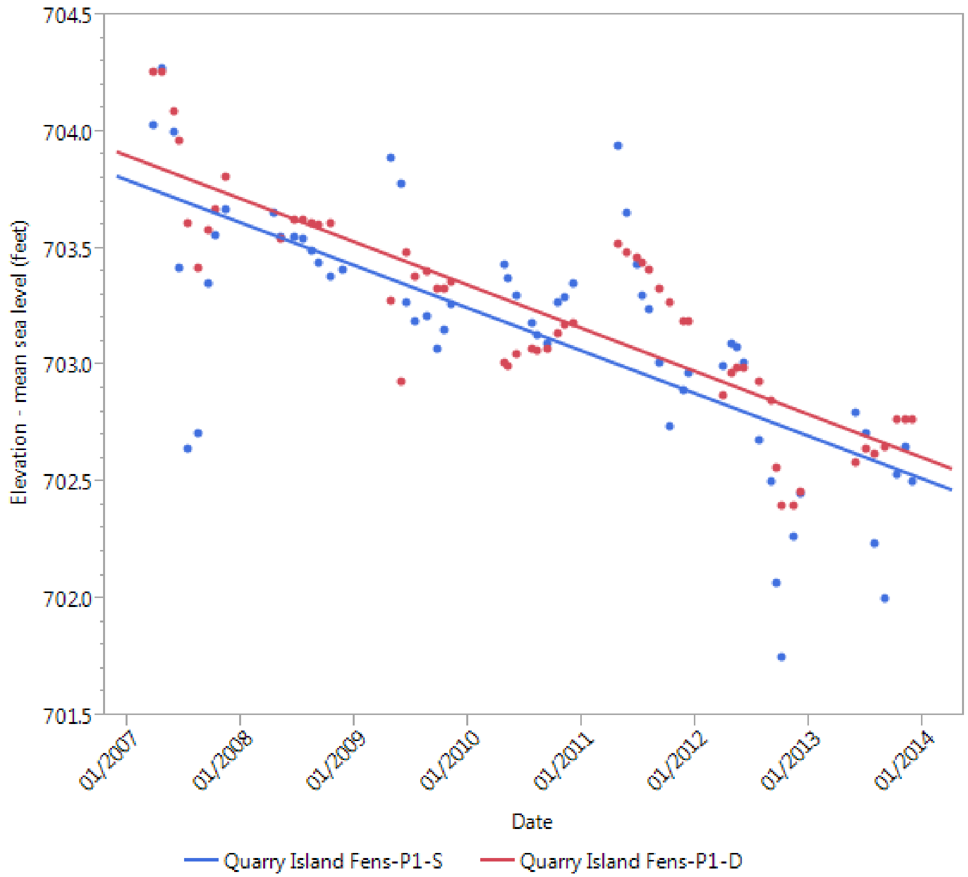
Appendix 2: Well Metadata

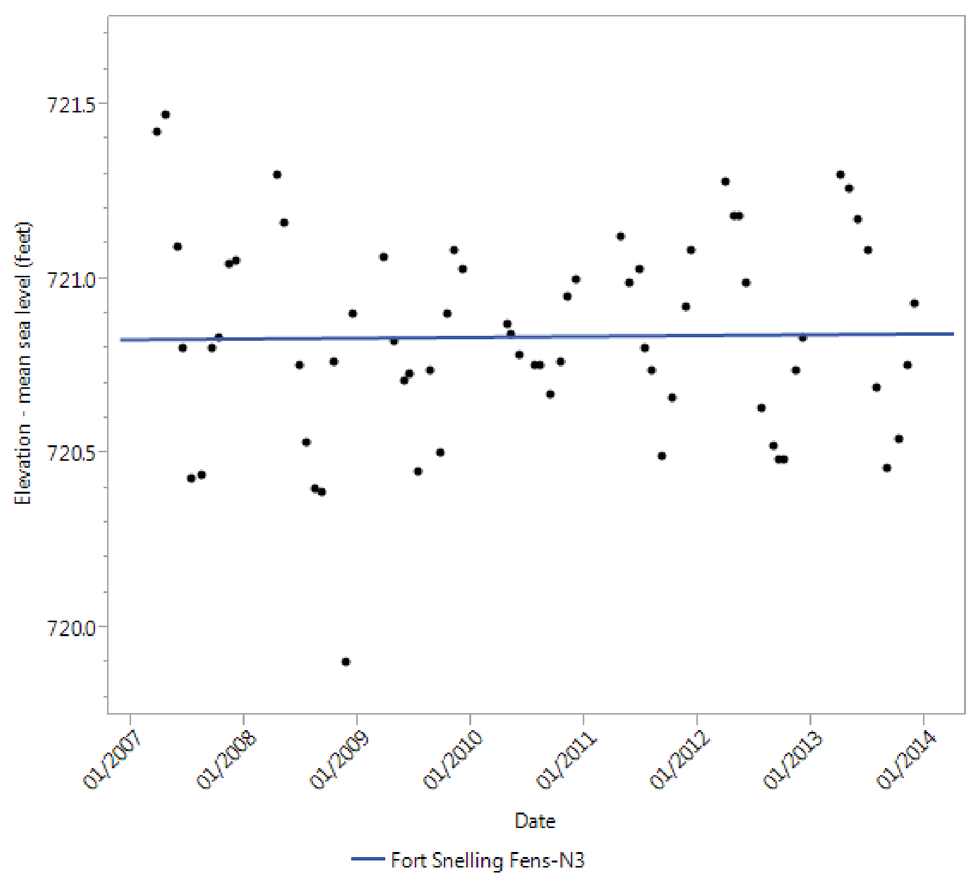
Approximate depth, coordinates, and mean sea-level elevation for each well (data courtesy of Minnesota Department of Natural Resources).

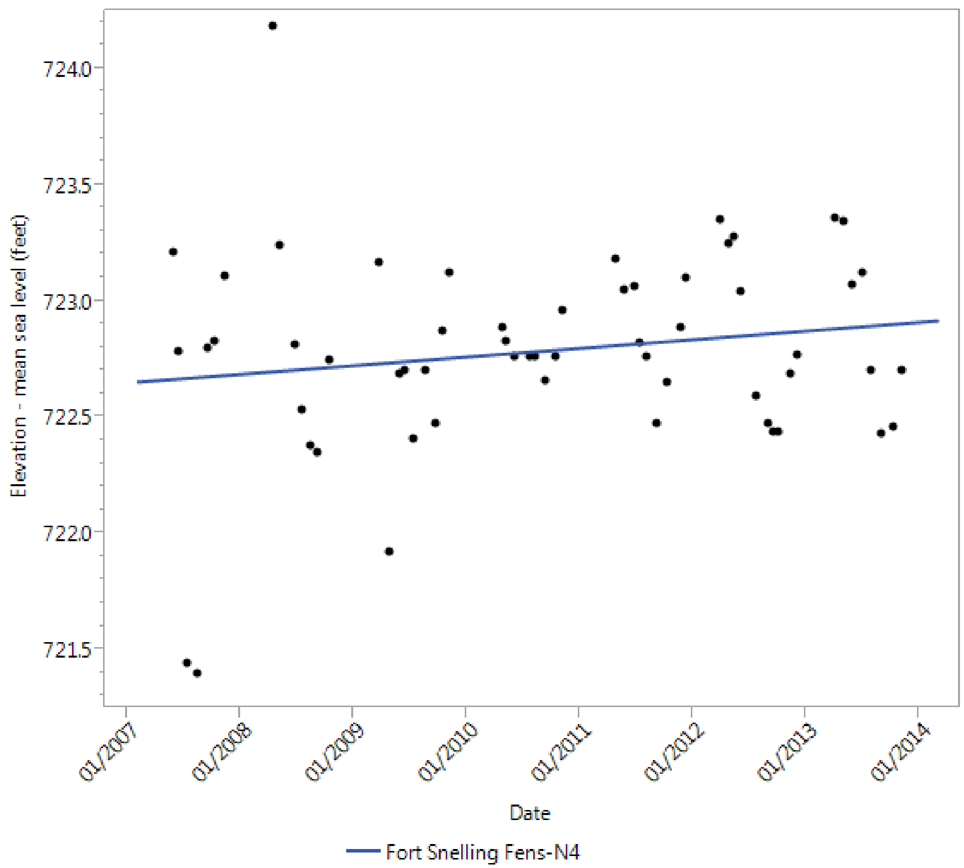
Well	Approximate depth (feet)	Northing (UTM)	Easting (UTM)	Elevation (feet)
P1-S	4	243025.4	535925.6	707.29
P1-D	8	243024.2	535925	706.98
N3	45.21	240030.6	535345.7	723.87
N4	75.34	240030.5	535349.3	724.27
N5	21.69	240035.5	535347.4	724.06
W1	77.00	239330.3	535121.9	728.45
W2	50.12	239325.1	535119.2	728.47
W3	21.83	239330.7	535130.5	726.87
W4	12.00	239333.3	535130.2	727.6
S1-USGS	20.67	239503.2	534796.5	723.44
S1	5.35	239502.7	534796.6	723.83
S2-USGS	27.00	239519.2	534506.9	722.35
S2	5.25	239518.1	534507	721.13
S3-USGS	21.68	239547.5	534222.3	713.97
S3	21.68	239548.3	534222.9	715.06
1LN	29	226915.8	525306.8	751.59
1LS	8	226913.4	525308.8	751.43
F3	75	228058.8	525367.6	720.43
F4	21	228055.9	525364.7	720.36
WN1-USGS	19.82	228054.3	525357.3	719.51
WN5-USGS	16.08	228125.3	525293.5	717.92
WT-1	9	228054.7	525356	719.37
WT-2	9	228222.7	525372.2	719.88
WT-3	8	228330.4	525514.2	721.27
WT-4	6	228457.4	525783.2	713.58
WT-5	7	228126	525293	720.69
F1	N/A	228466.4	525785	714.96
F2	15	228454.9	525794.3	714.68

Appendix 3: Linear Regressions for Each Well Dataset

Linear regressions are included for each of the wells. In cases where wells were overflowing, the top of the pipe elevation was recorded and is shown with a black dashed line. In cases where the water in the well was frozen, no water level measurement was recorded.






724.0
723.5
723.0
722.5
722.0
721.5
Elevation - mean sea level (feet)
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01/2008
01/2009
01/2010
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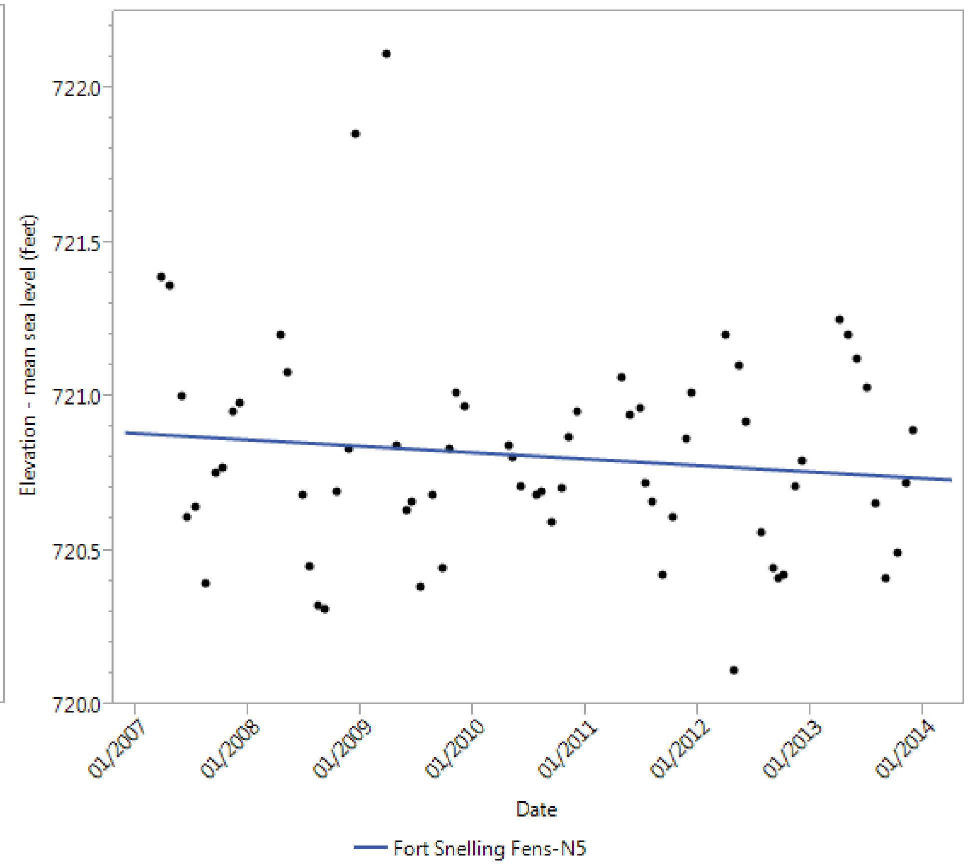
01/2013
01/2014
Date
Fort Snelling Fens-N4


722.0
721.5
721.0
720.5
720.0
Elevation - mean sea level (feet)
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01/2009
01/2010
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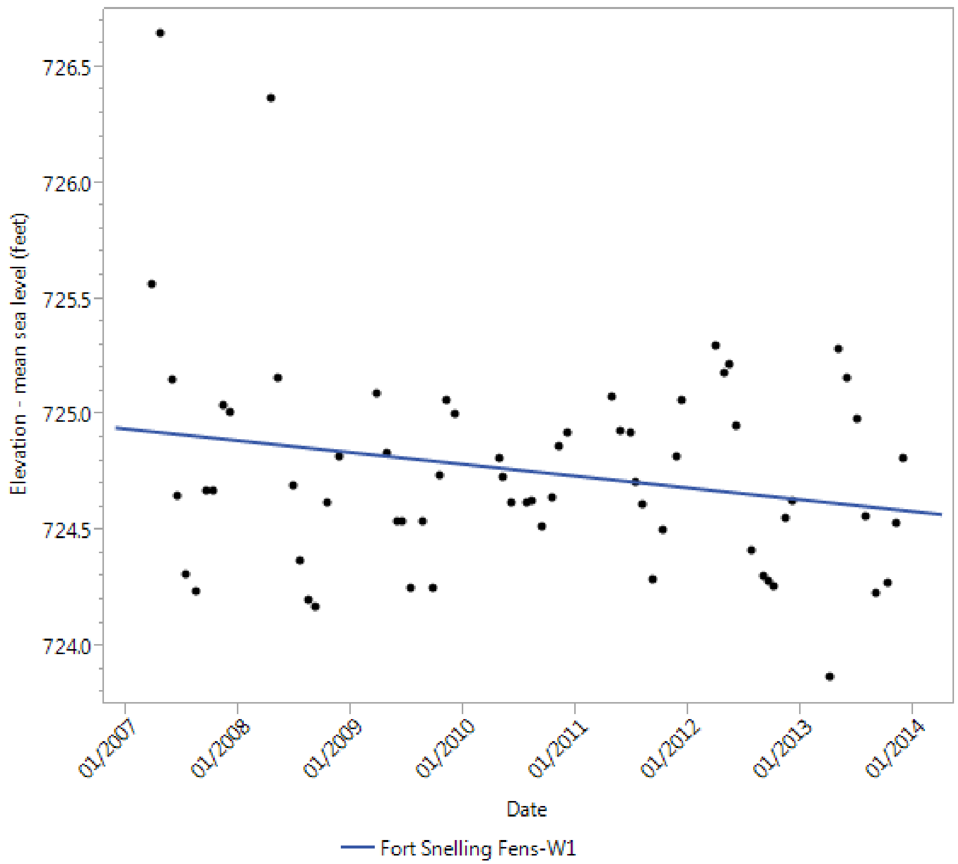
Date
Fort Snelling Fens-N5



726.5
726.0
725.5
725.0
724.5
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Elevation - mean sea level (feet)
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01/2012
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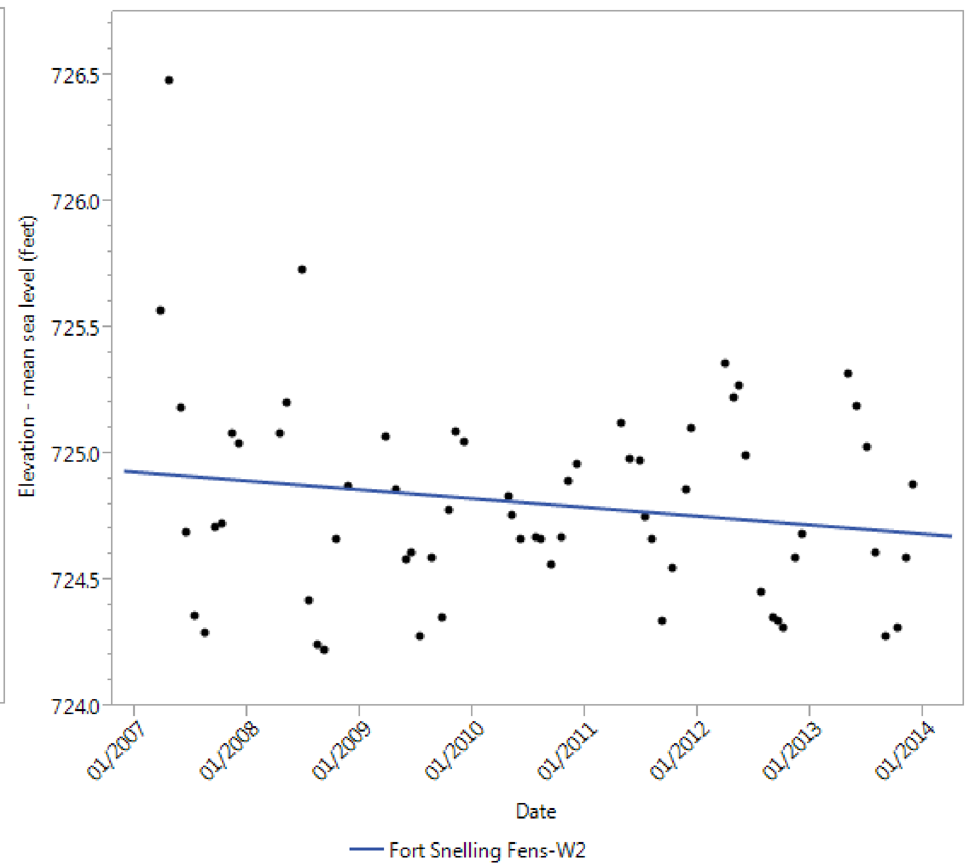
Date
Fort Snelling Fens-W1



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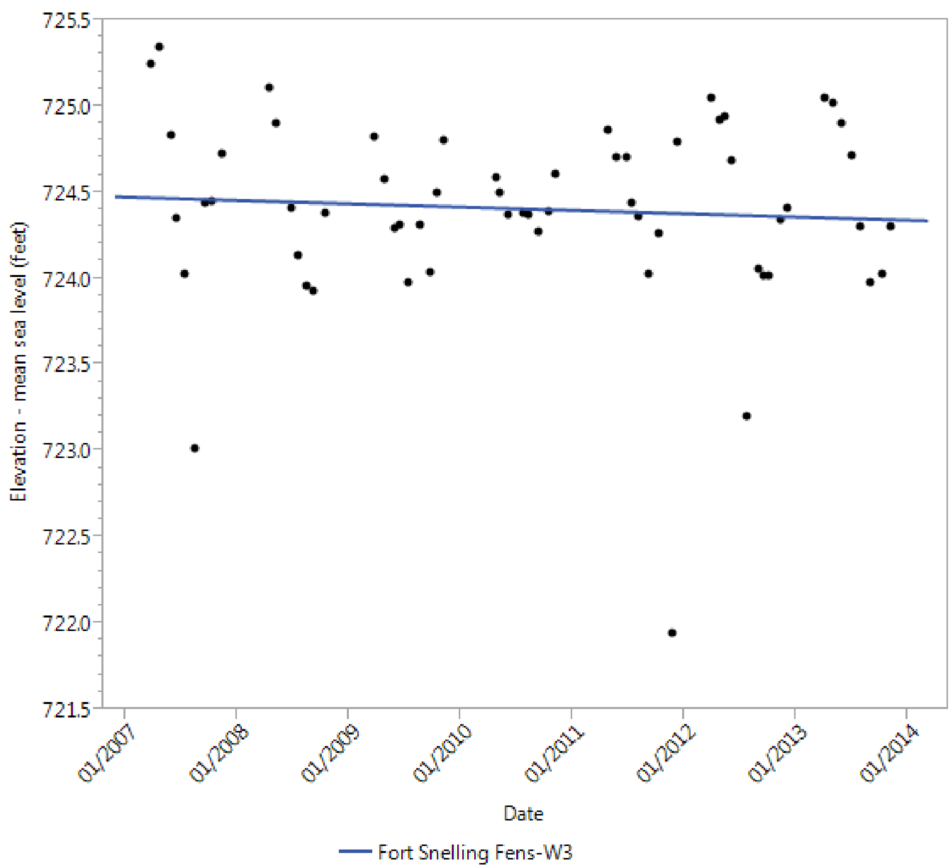
Date
Fort Snelling Fens-W2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723.5
723.0
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721.5
Elevation - mean sea level (feet)
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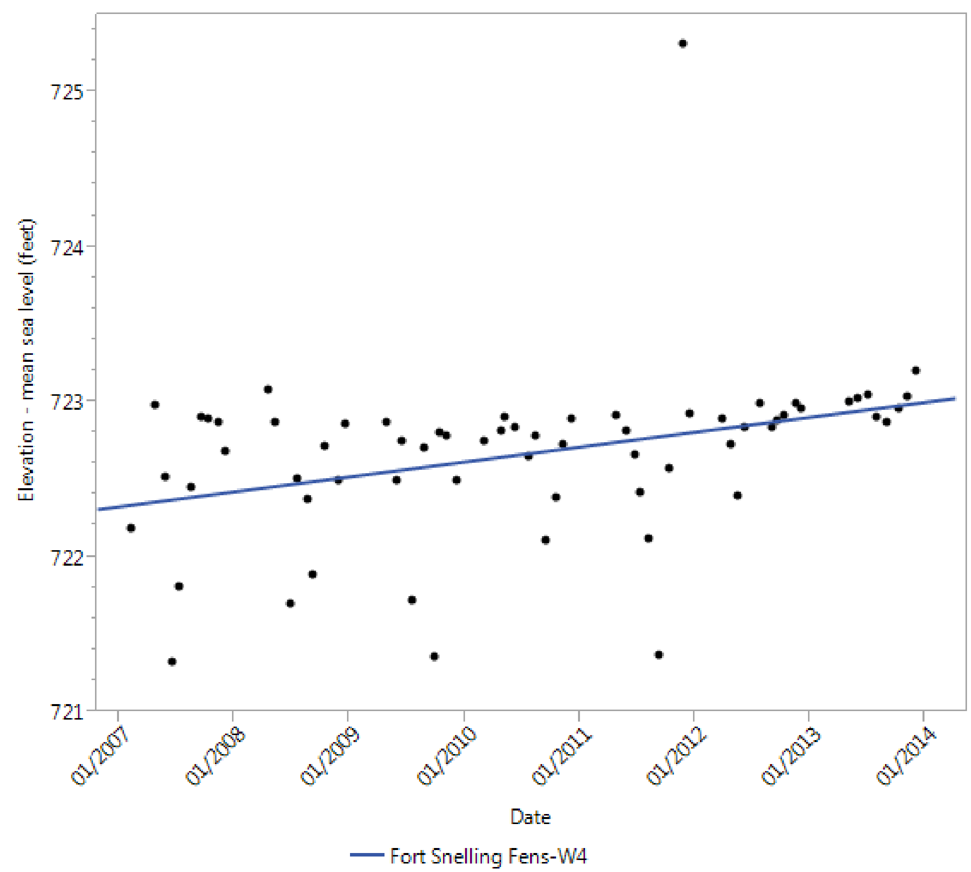
Date
Fort Snelling Fens-W3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724
723
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Elevation - mean sea level (feet)
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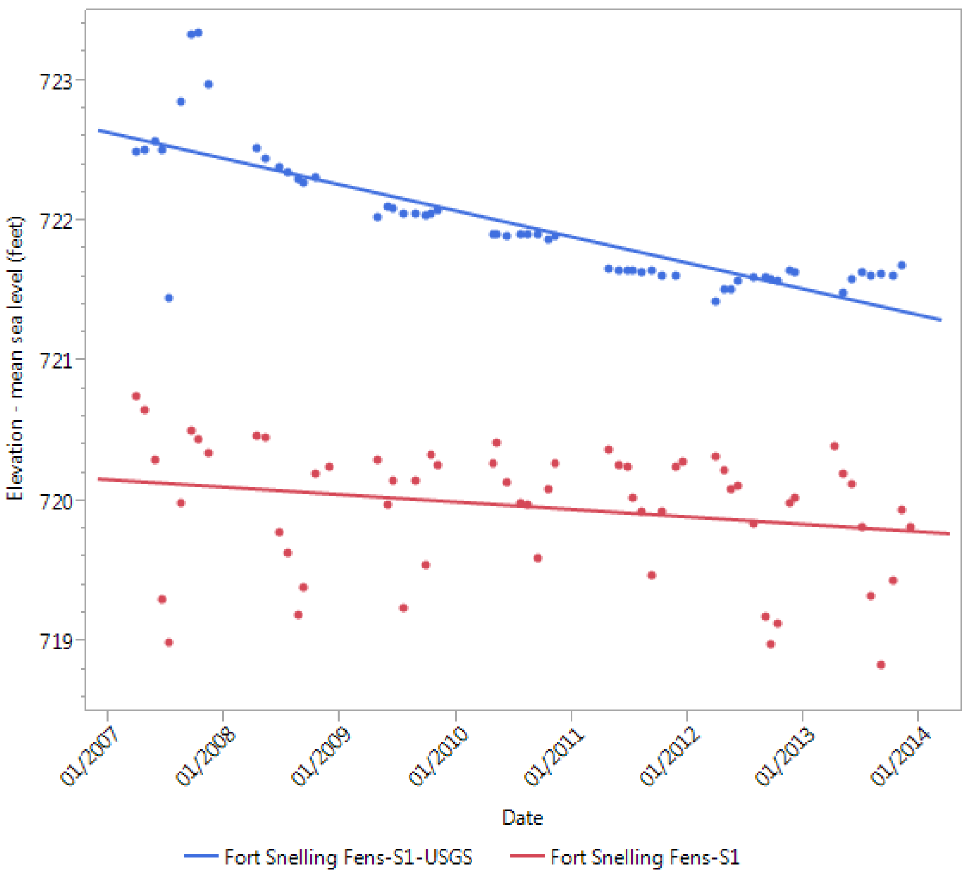
Date
Fort Snelling Fens-W4



Elevation - mean sea level (feet)
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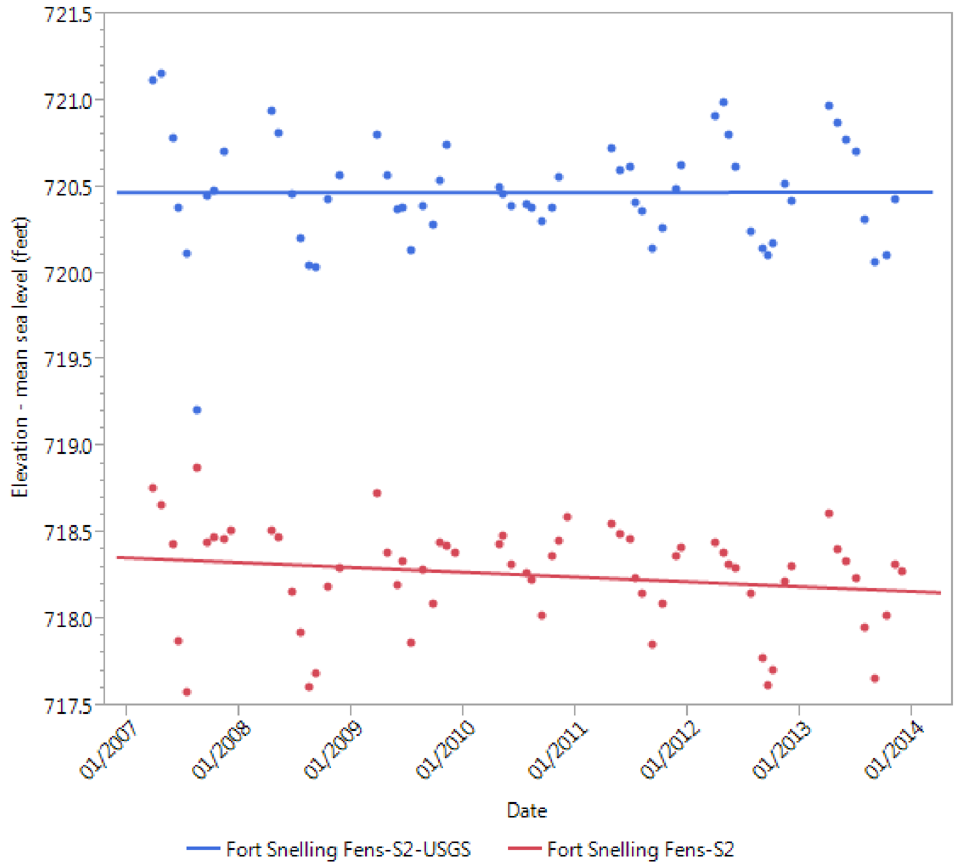
Fort Snelling Fens-S1-USGS
Fort Snelling Fens-S1



Elevation - mean sea level (feet)
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01/2007
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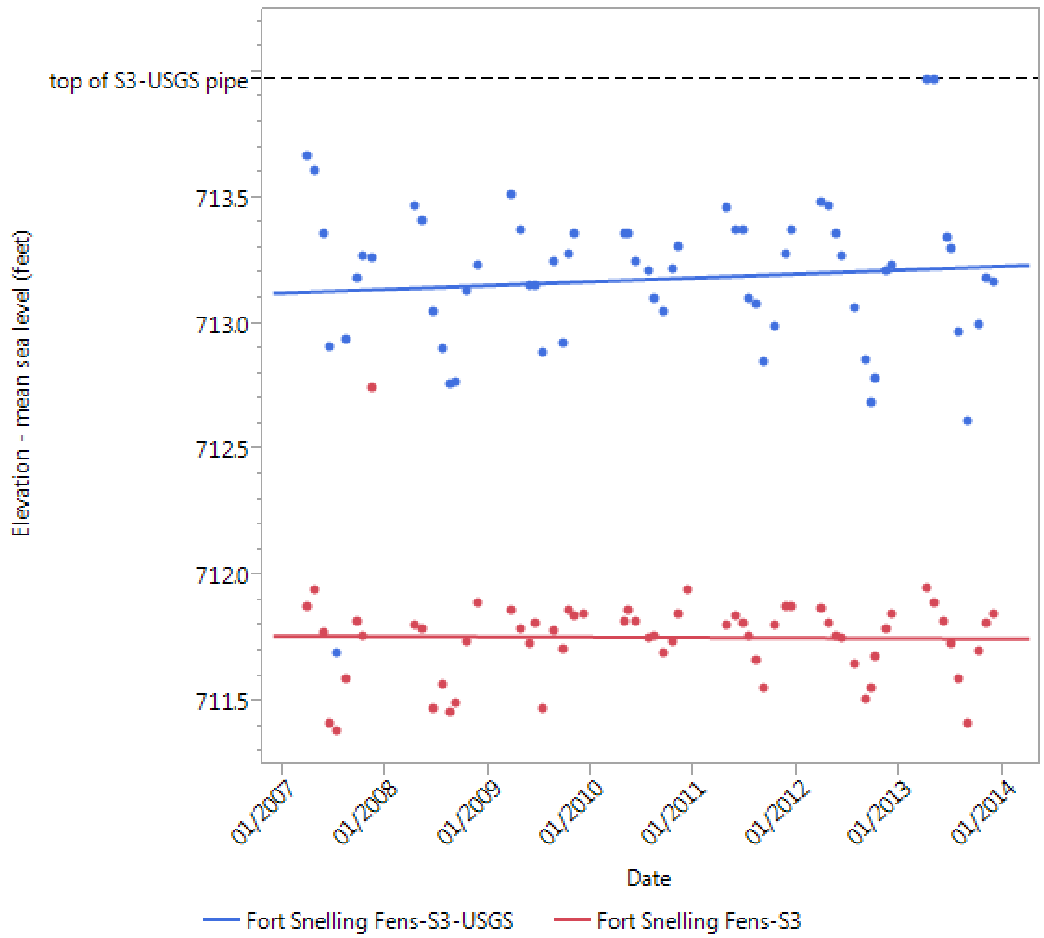
Date
Fort Snelling Fens-S2-USGS
Fort Snelling Fens-S2


top of S3-USGS pipe
713.5
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Elevation - mean sea level (feet)
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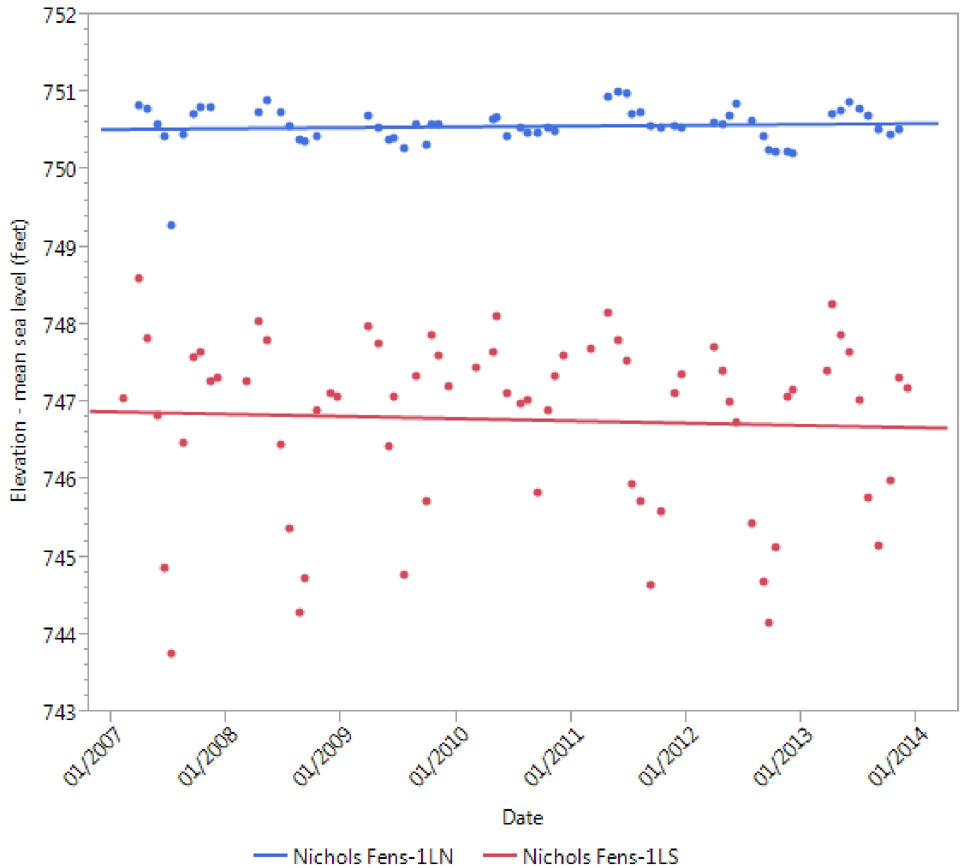
Fort Snelling Fens-S3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747
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745
744
743
Elevation - mean sea level (feet)
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01/2011
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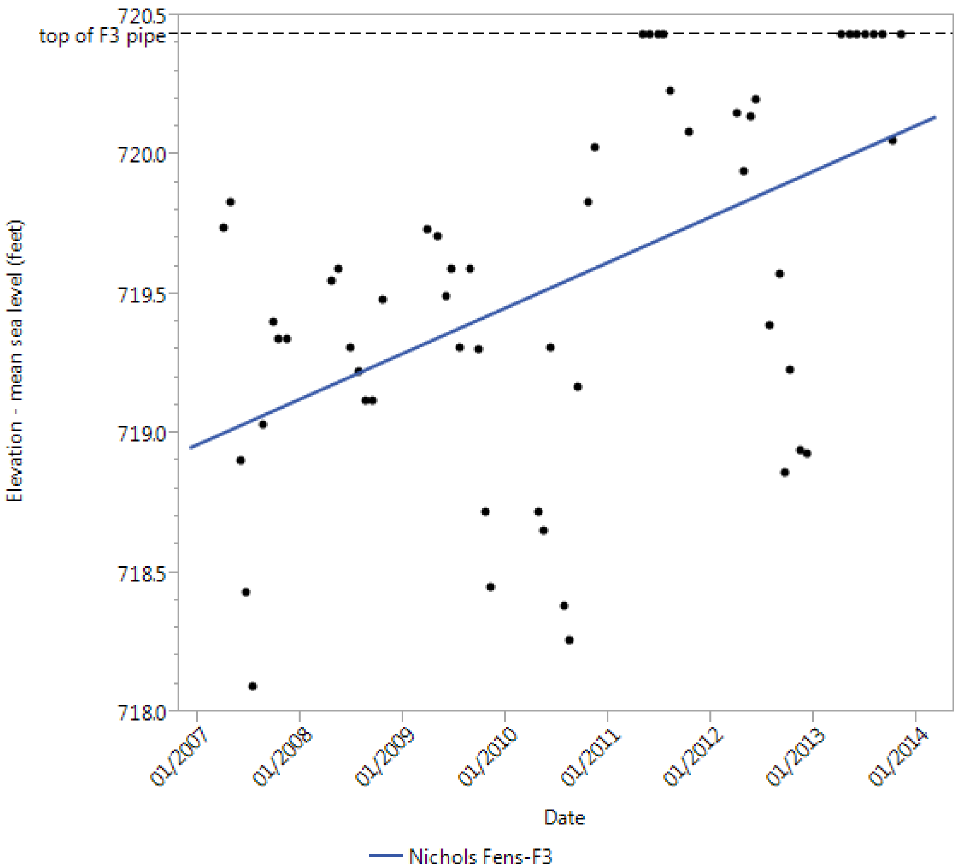
01/2014
Date
Nichols Fens-1LN
Nichols Fens-1LS


720.5
top of F3 pipe
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Elevation - mean sea level (feet)
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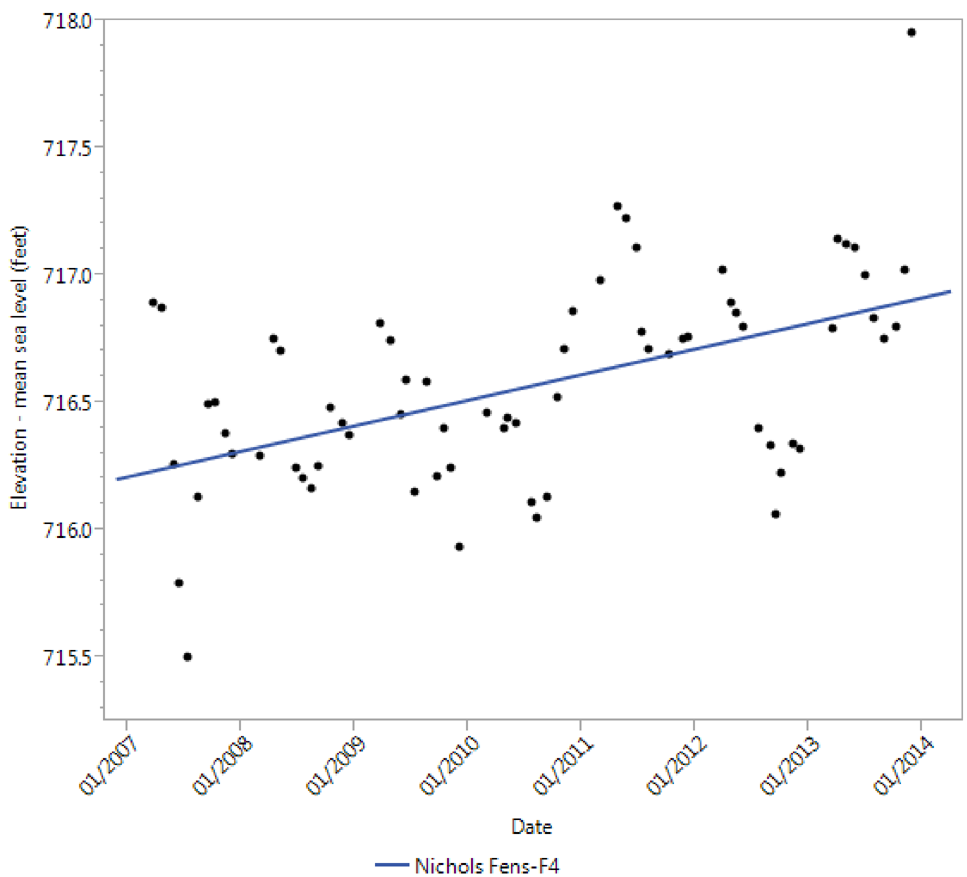
Nichols Fens-F3



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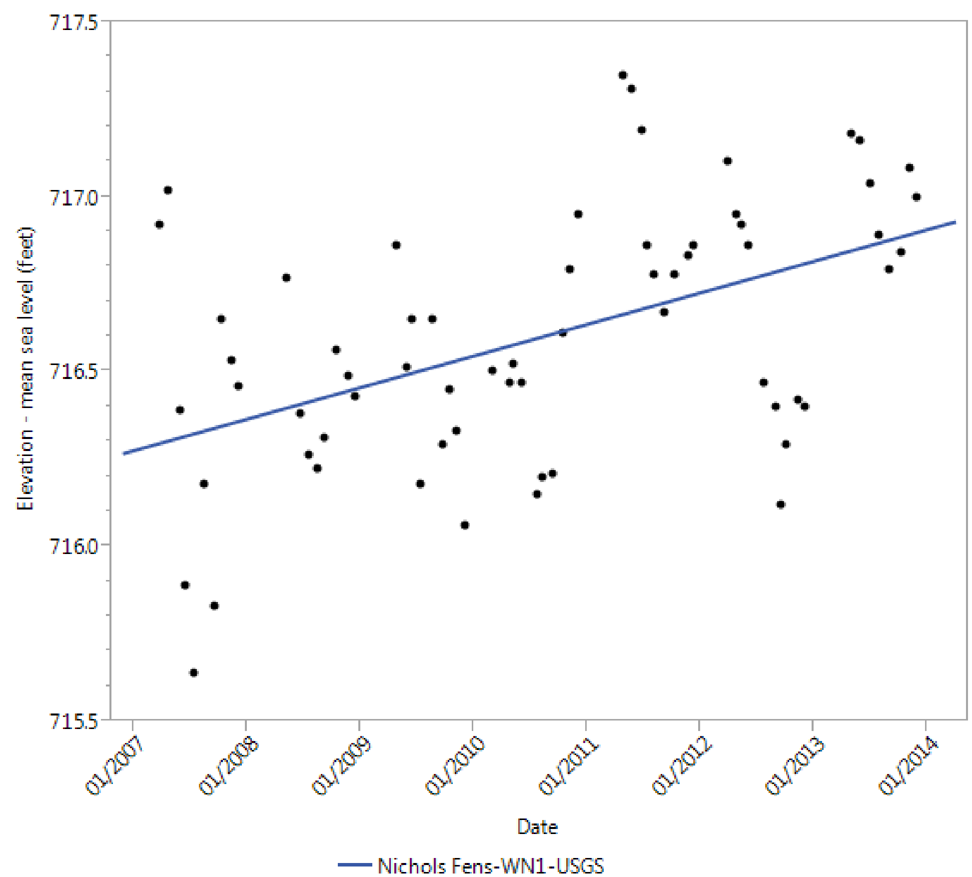
Date
Nichols Fens-F4



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Elevation - mean sea level (feet)
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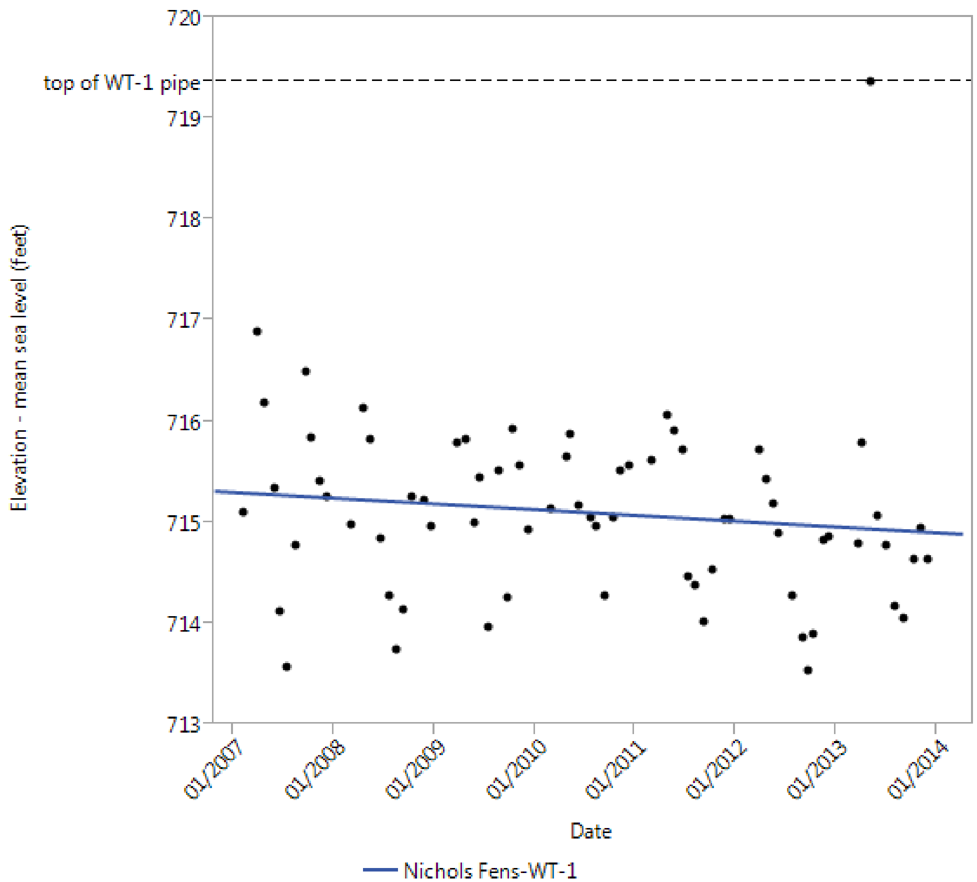
Date
Nichols Fens-WN1-USGS



720
top of WT-1 pipe
719
718
717
716
715
714
713
Elevation - mean sea level (feet)
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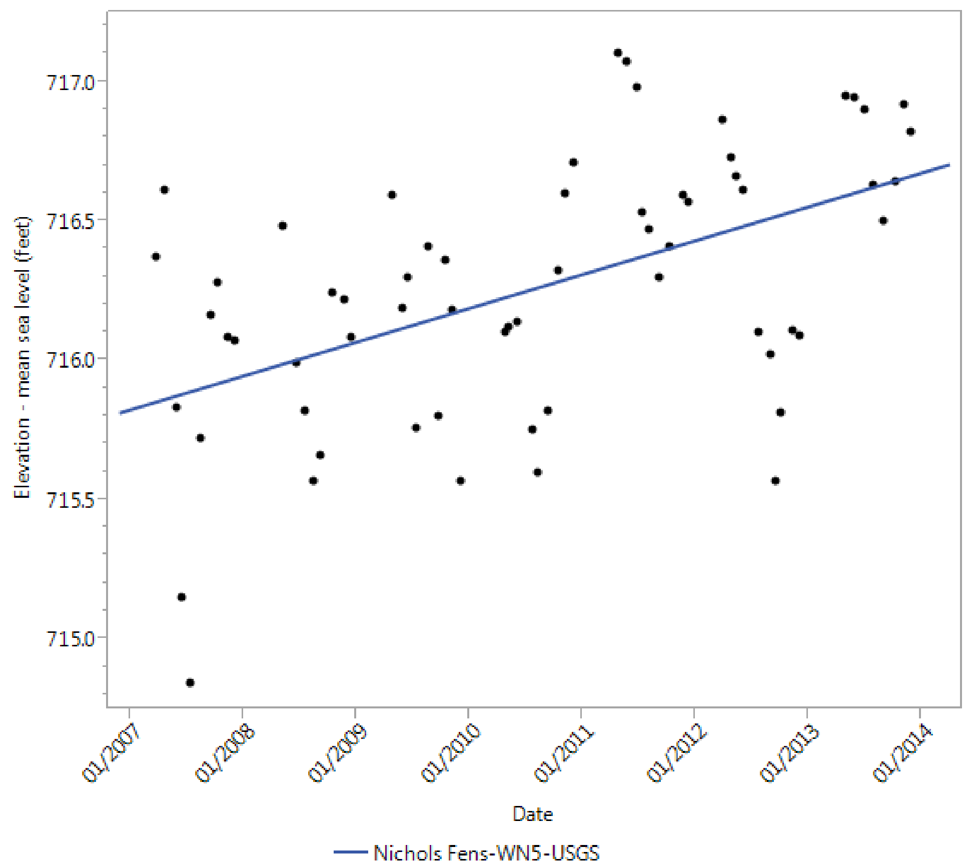
01/2014
Date
Nichols Fens-WT-1



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Elevation - mean sea level (feet)
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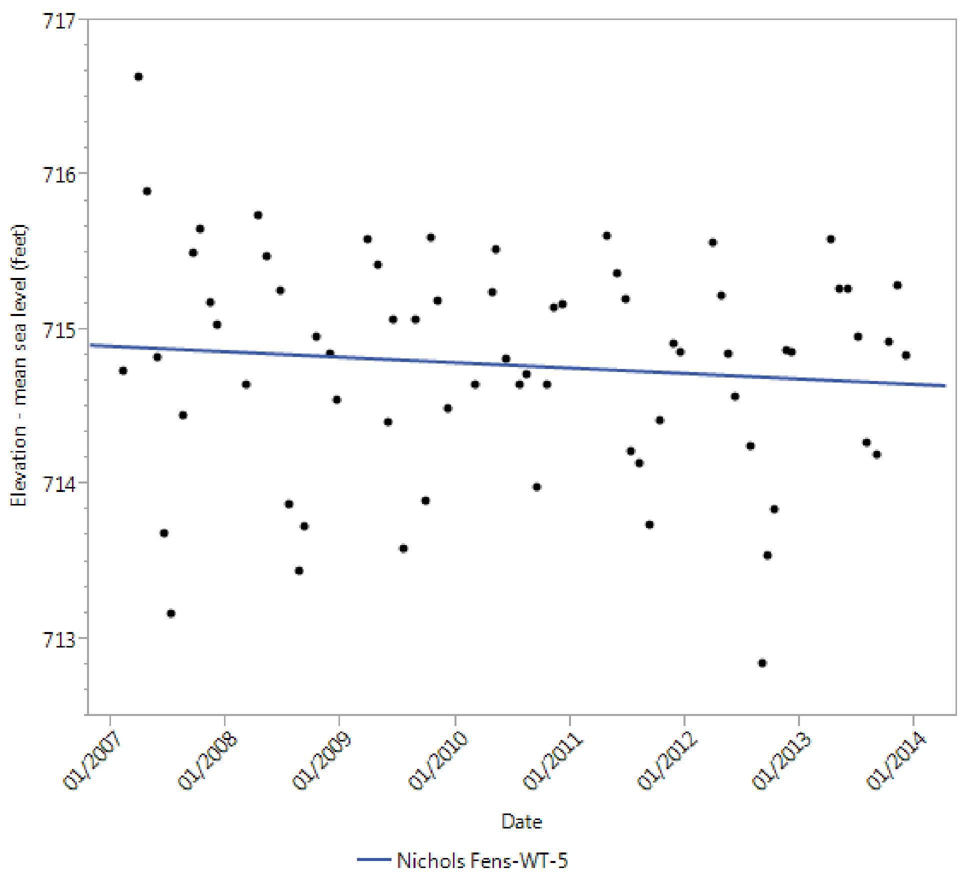
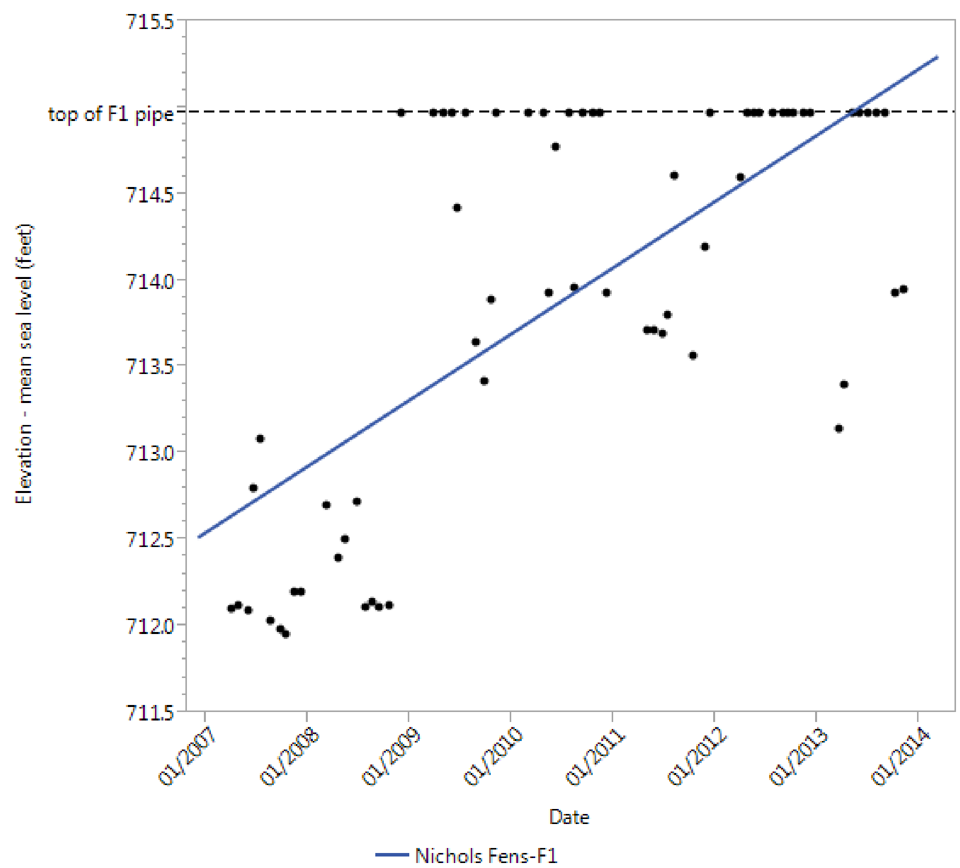
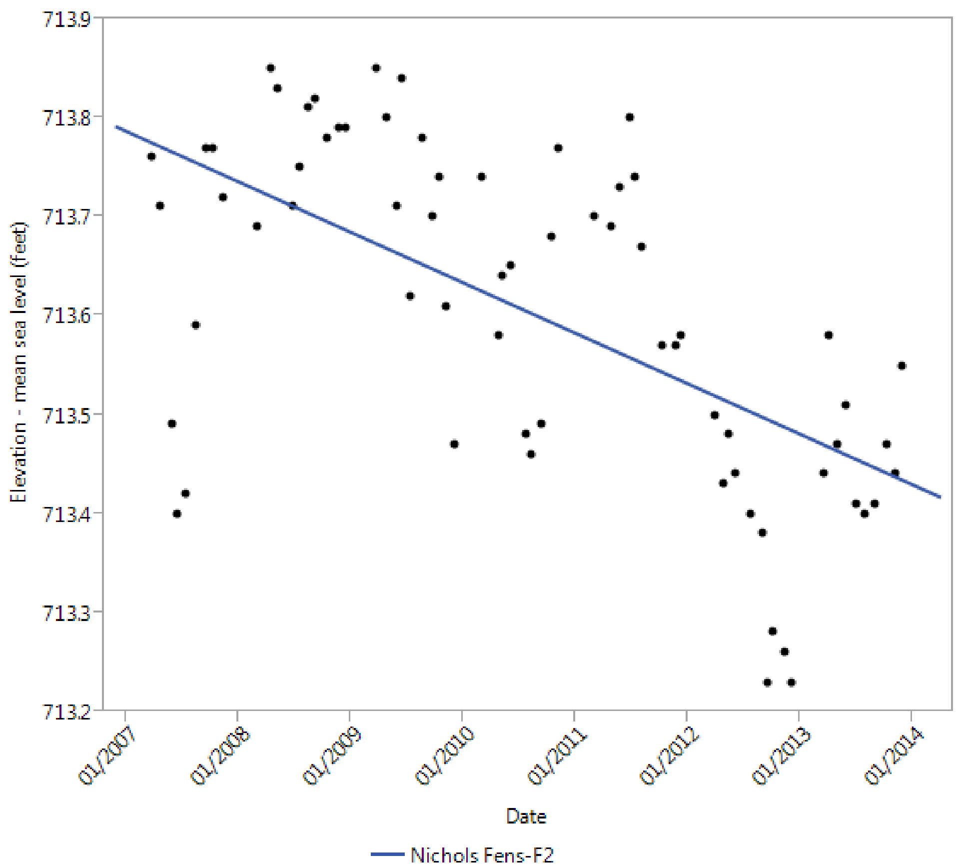
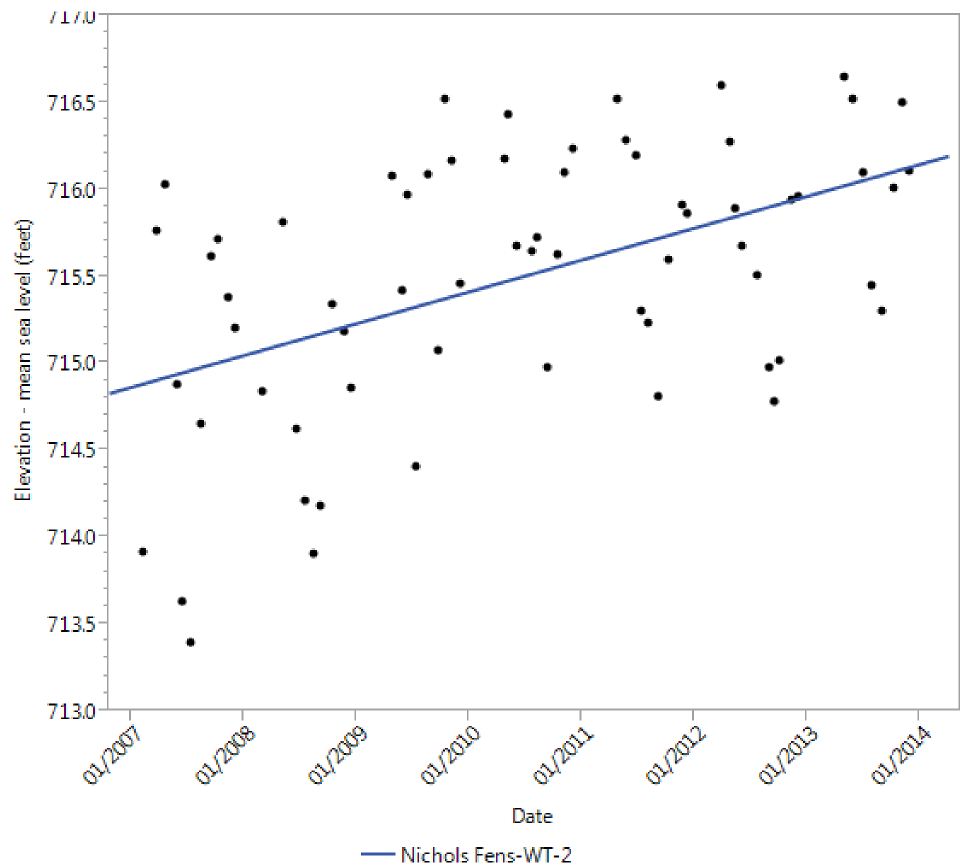
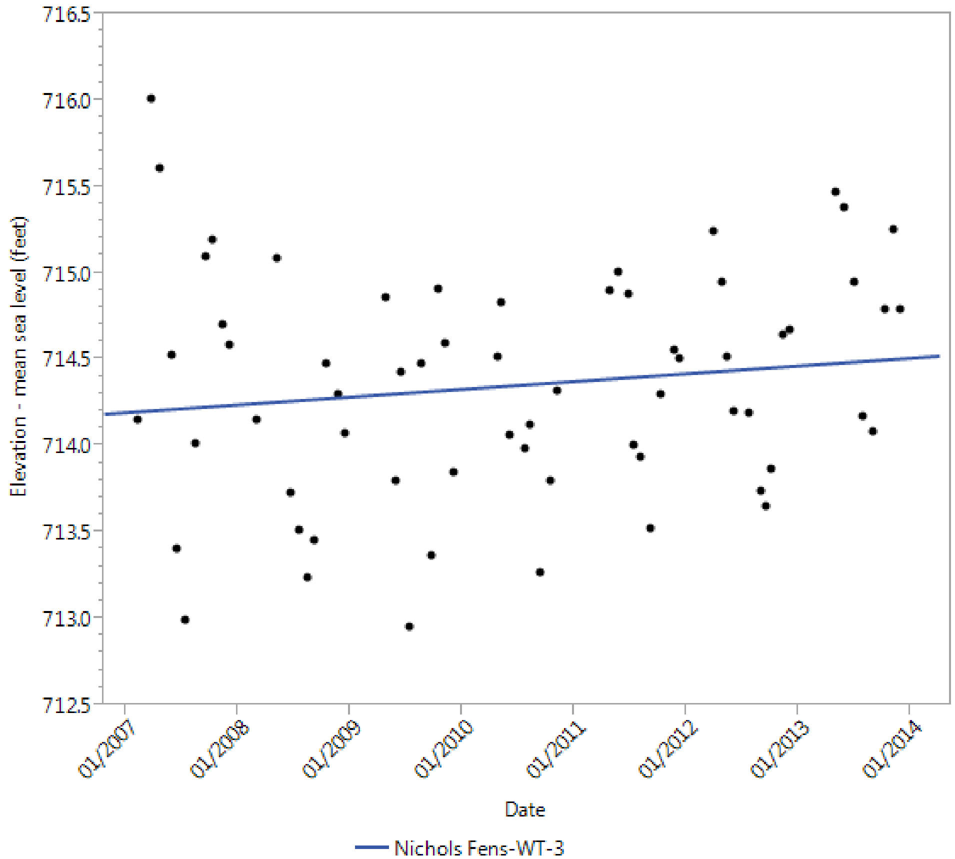
01/2014
Date
Nichols Fens-WN5-USGS

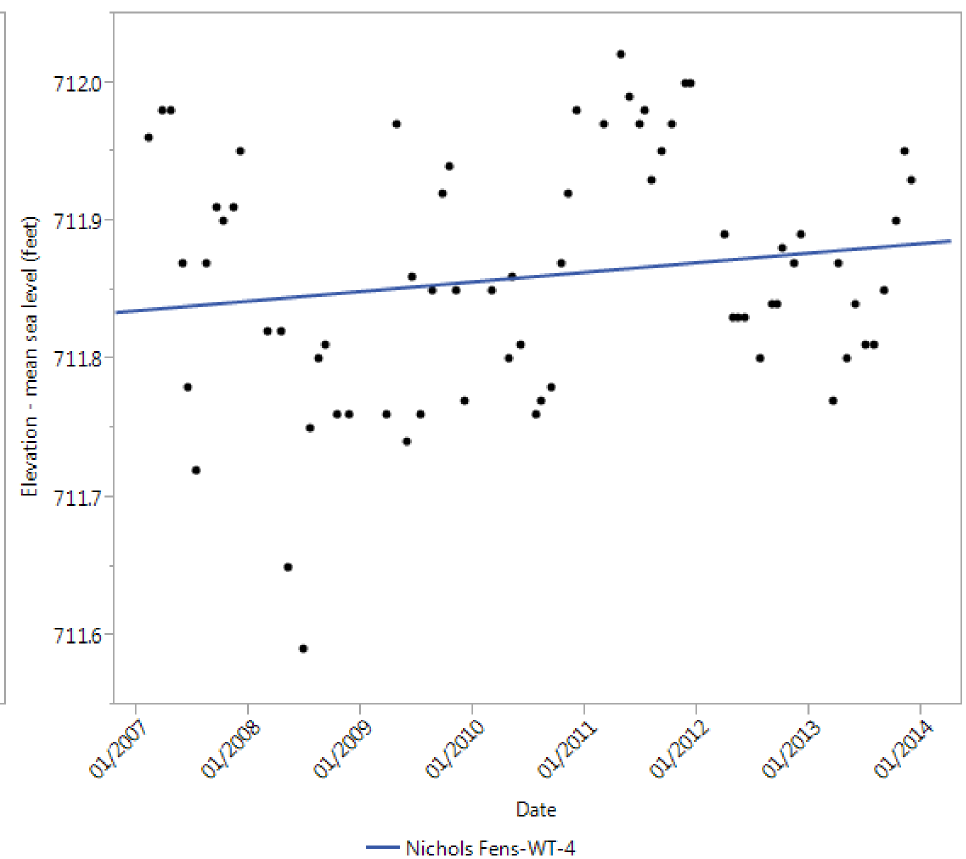

717
716
715
714
713
Elevation - mean sea level (feet)
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
Date
Nichols Fens-WT-5


715.5
top of F1 pipe
714.5
714.0
713.5
713.0
712.5
712.0
711.5
Elevation - mean sea level (feet)
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
Date
Nichols Fens-F1


713.9
713.8
713.7
713.6
713.5
713.4
713.3
713.2
Elevation - mean sea level (feet)
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
Date
Nichols Fens-F2


717.0
716.5
716.0
715.5
715.0
714.5
714.0
713.5
713.0
Elevation - mean sea level (feet)
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
Date
Nichols Fens-WT-2


716.5
716.0
715.5
715.0
714.5
714.0
713.5
713.0
712.5
Elevation - mean sea level (feet)
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
Date
Nichols Fens-WT-3


712.0
711.9
711.8
711.7
711.6
Elevation - mean sea level (feet)
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
Date
Nichols Fens-WT-4