US Army Corps
of Engineers ®

Upper Susquehanna River Basin, New York
Comprehensive Flood Damage Reduction
Feasibility Study

APPENDIX C: ENGINEERING

January 2020

PREPARED BY:

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

BALTIMORE DISTRICT

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DISCLAIMER

This draft feasibility report documents findings of the Upper Susquehanna River Basin Comprehensive Flood Damage Reduction Feasibility Study conducted jointly by the U.S. Army Corps of Engineers (USACE) and New York State Department of Environmental Conservation (NYSDEC). The study was conducted from 2009 through 2019. Progress was subject to funding, which was provided unevenly in the first few years, and subsequent evolution in study scope while the study was underway. The draft feasibility report is incomplete and has not been reviewed by USACE Headquarters. The draft feasibility report details all work completed for the USRB study leading up to the conclusion of no recommendation under the study authority

This draft report includes documentation of preliminary efforts undertaken to meet the requirements of the National Environmental Policy Act (NEPA) of 1969, as amended. While information on environmental consequences and NEPA efforts is provided, NEPA compliance work remains incomplete. Coordination of the proposed projects with agencies and citizens has not occurred. This draft report was prepared intermittently over the period from 2016-2019, but is not complete. Information presented in this existing conditions section may not be the most current, depending on when it was originally prepared and when it was last revised/updated.

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CHAPTER 1 HYDROLOGY AND HYDRAULICS

1.1 SUMMARY OF HYDROLOGY AND HYDRAULICS ANALYSIS

The Upper Susquehanna River Basin (USRB) drains approximately 4,520 square miles in the south central part of New York State. This drainage area includes most of Broome, Chenango, Cortland, Otsego and Tioga Counties; parts of Delaware, Madison and Chemung Counties; and small portions of Schuyler, Tompkins, Onondaga, Oneida, Herkimer and Schoharie Counties. The USRB study identified the current risk for flooding and propose ways to minimize the impact from flood events, preliminarily determine environmental and economic impact from various levels of flooding, and suggest structural and nonstructural alternatives that could help minimize damage to life and property.

Hydrologic analysis was performed using United States Geological Survey (USGS) gage data for various locations along the Susquehanna River and its tributaries. The program HEC-SSP (Hydraulic Engineering Center – Statistical Software Package) version 2.1 was used to develop natural conditions peak flow frequency curves using the Log-Pearson Type III distribution and the Bulletin 17C EMA (Expected Moments Algorithm) methodology.

Hydrologic analysis was performed using a Hydraulic Engineering Center's River Analysis System (HEC-RAS) model. The basis of the USRB hydraulic model was the CWMS (Corps Water Management System) developed for reservoir routing of East Sydney and Whitley Point reservoirs. The USRB study HEC-RAS model expanded the CWMS HEC-RAS model to include many other FEMA models in Broome, Chenango, Cortland, Otsego and Tioga Counties; parts of Delaware, Madison and Chemung Counties; and small portions of Schuyler, Tompkins, Onondaga, Oneida, Herkimer and Schoharie Counties. In some cases, new HEC-RAS models were developed using HEC-GeoRAS where the model was not available in digital format.

1.2 HYDROLOGY

Eight USGS stream gages currently in operation in the upper stem of the Susquehanna River basin within the area covered by this study were analyzed to determine flow frequency relationships. The period of record for the stream gages was used to determine peak flow frequency relationships for the 0.2, 0.4, 1.0, 2.0, 4.0, 10, 20, and 50 percent annual chance exceedance events. Two US Army Corps of Engineers (USACE) dam projects exist in the USRB; Whitney Point Lake on the Otselic River and East Sidney Lake on Ouleout Creek. The effect of regulation of these flood control reservoirs on peak flows at the USGS gages was considered. A homogeneous data set was created by adjusting the flow data since the dams are operationally complete, Whitney Point in 1942 and East Sidney in 1950, to reflect flows that would have occurred without the reservoir regulation. This was done by using a relationship between natural (unregulated) and existing (regulated) conditions developed using historic records collected by USACE for both reservoirs. A natural conditions peak flow frequency curve for each of the USGS gages affected by regulation was produced using the Log Pearson Type III distribution and a regulated flow frequency curve was generated graphically. This produced existing (regulated) conditions peak flow frequency relationships for the USGS stream gages affected by Whitney Point and East Sidney dams. Flow change points in between the gages were derived from percentage of area contributing to the point of interest and then proportioning the appropriate gages. The gages analyzed for this study are presented in Table 1.

Table 1: Gage Information

USGS Gage Number	Gage Name	DA (mi2)	Period of Review (water years)	Discharge Affected by Regulation from
01515000	Susquehanna River Near Waverly NY	4773	1936-2015	minor
01513500	Susquehanna River at Owego NY	4216	1936, 1988-1996, 1999-2015	minor
01513831	Susquehanna River at Vestal NY	3941	1935-2016	Whitney Point (1942) and East Sidney (1950)
01503000	Susquehanna River at Conklin NY	2232	1913-2015	East Sidney (1950)
01500500	Susquehanna River at Unadilla NY	982	1935, 1936, 1938-2015	East Sidney (1950)
01512500	Chenango River Near Chenango Forks NY	1483	1913-2016	Whitney Point (1942)
01507000	Chenango River at Greene NY	593	1937-2016	n/a
01511500	Tioughnioga River at Itaska NY	730	1930-1975, 1977-2015	Whitney Point (1942)

1.3 ADJUSTING DISCHARGES AT GAGES AFFECTED BY REGULATION

There are two major Corps of Engineers dam projects that are regulated for flood risk management in the USRB study area, Whitney Point and East Sidney Lakes. East Sidney Lake is located on Ouleout Creek approximately four miles upstream from its confluence with the Susquehanna River near Unadilla, New York. It became operationally complete in June 1950. Whitney Point Lake is located on the Otselic River about 0.7 miles upstream of its confluence with the Tioughnioga River. The Tioughnioga River is a tributary to the Chenango River which flows into the Susquehanna River. The period of record for the gages downstream of these projects therefore is not homogeneous. The gages on the Susquehanna River at Unadilla and Conklin were adjusted for the regulation of East Sidney for the period of record since the project became operational in June 1950. The Vestal gage on the Susquehanna River was adjusted for regulation by East Sidney since 1950 and also Whitney Point since 1942. The gages on the Susquehanna River at Waverly and Owego were not adjusted since the drainage area controlled by the dam projects was less than 10% and would make minor differences in the observed flows. The gage on the Tioughnioga River at Itaska and the gage on the Chenango River near Chenango Forks are affected by regulation by Whitney Point since 1942. The gage on the Chenango River at Greene is upstream of the Whitney Point project and therefore not affected by its regulation. The observed discharges since 1942 were adjusted to natural (unregulated) conditions using the following methodology.

The Baltimore District (NAB) has kept records of reservoir inflow, outflow and routed net flow hydrographs for high flow events since 1993. These records were used to produce natural flows for each corresponding regulated flow for as many events that were available for each gage, ranging from 21 to 28 events. A document search produced additional historic events that had calculated natural flows with corresponding regulated flows. The combination of the NAB data and historic data was used to develop natural (unregulated) vs. existing (regulated) conditions peak flow relationship curves for the five gages affected by regulation (Vestal, Conklin, Unadilla, Chenango Forks, and Itaska). A series of curves were developed for the gages for conditions of regulation by the dam projects and were used to adjust the observed peak flows at the gages to natural flows. The curves are presented as Figures 1 through 5.

The relationship curves were used to adjust the portion of the period of record where the observed discharges were affected by regulation to produce a homogeneous natural (unregulated) conditions period of record for the five gages. The resulting discharge records are presented in Tables 2 through 6.

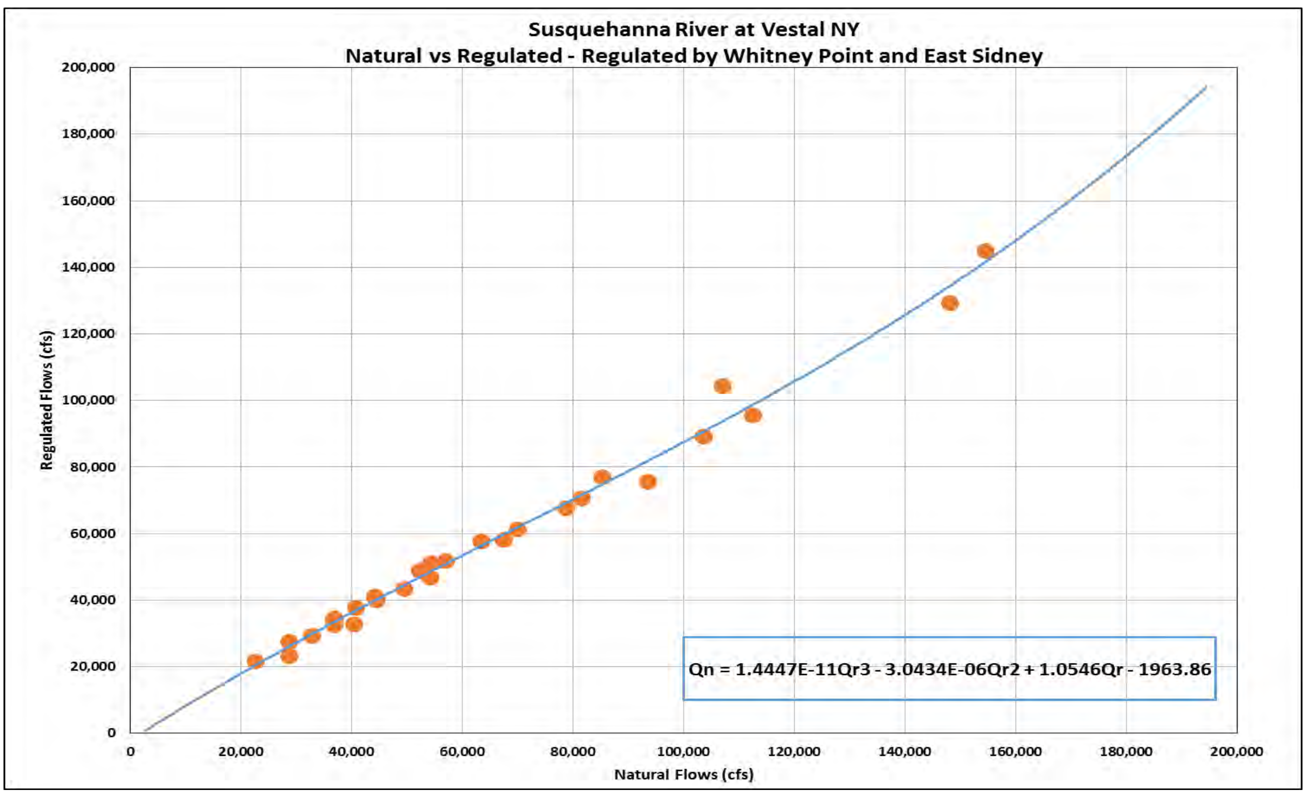


Figure 1: Susquehanna River at Vestal NY

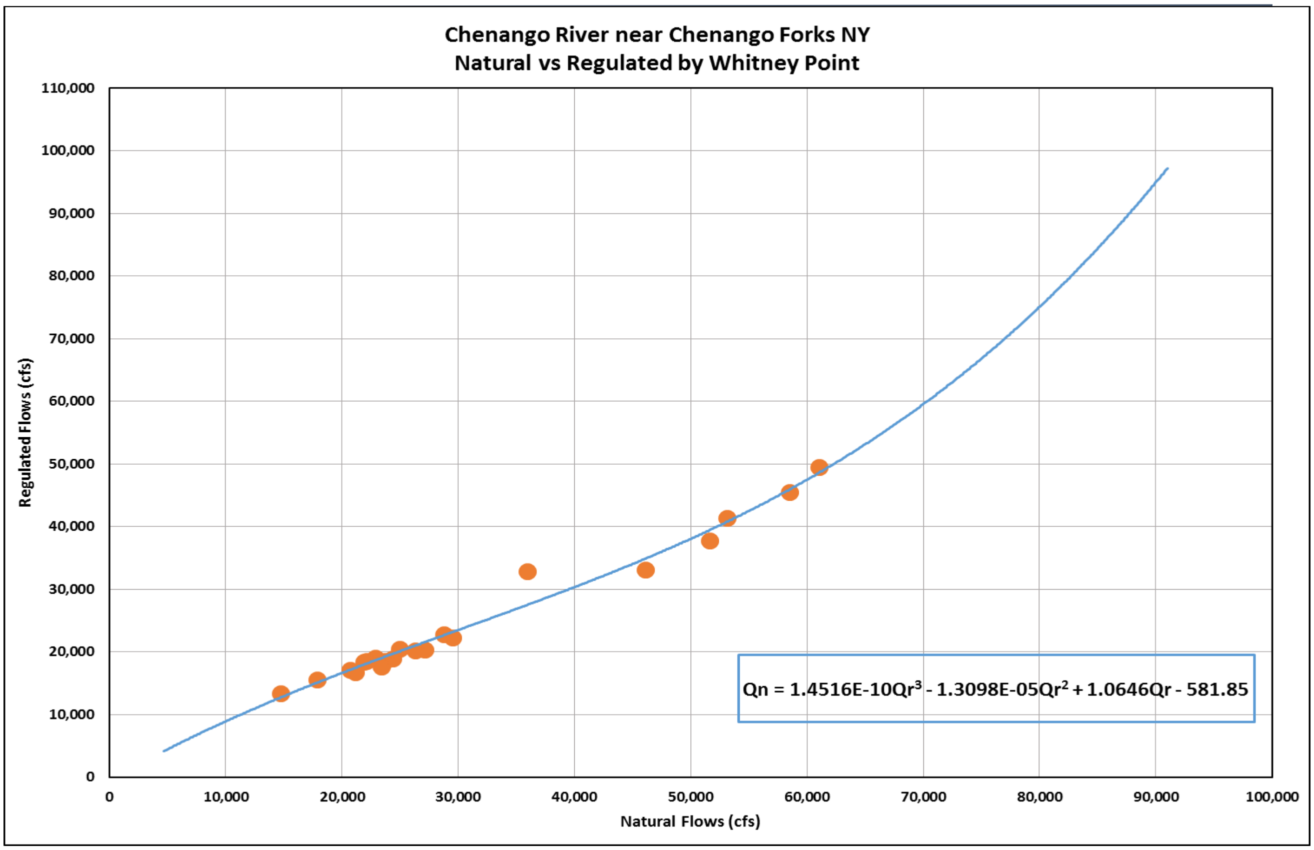


Figure 2: Chenango River near Chenango Forks NY

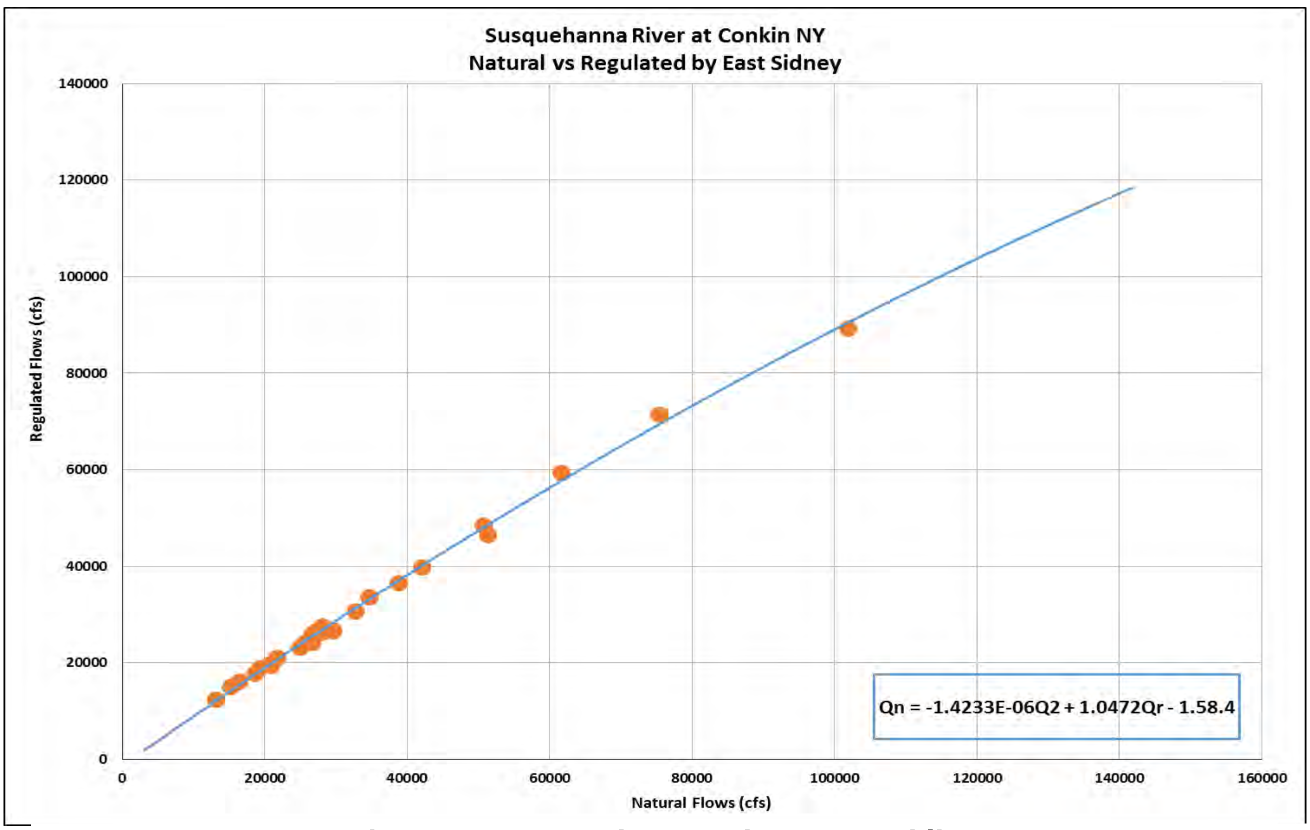


Figure 3: Susquehanna River at Conklin NY

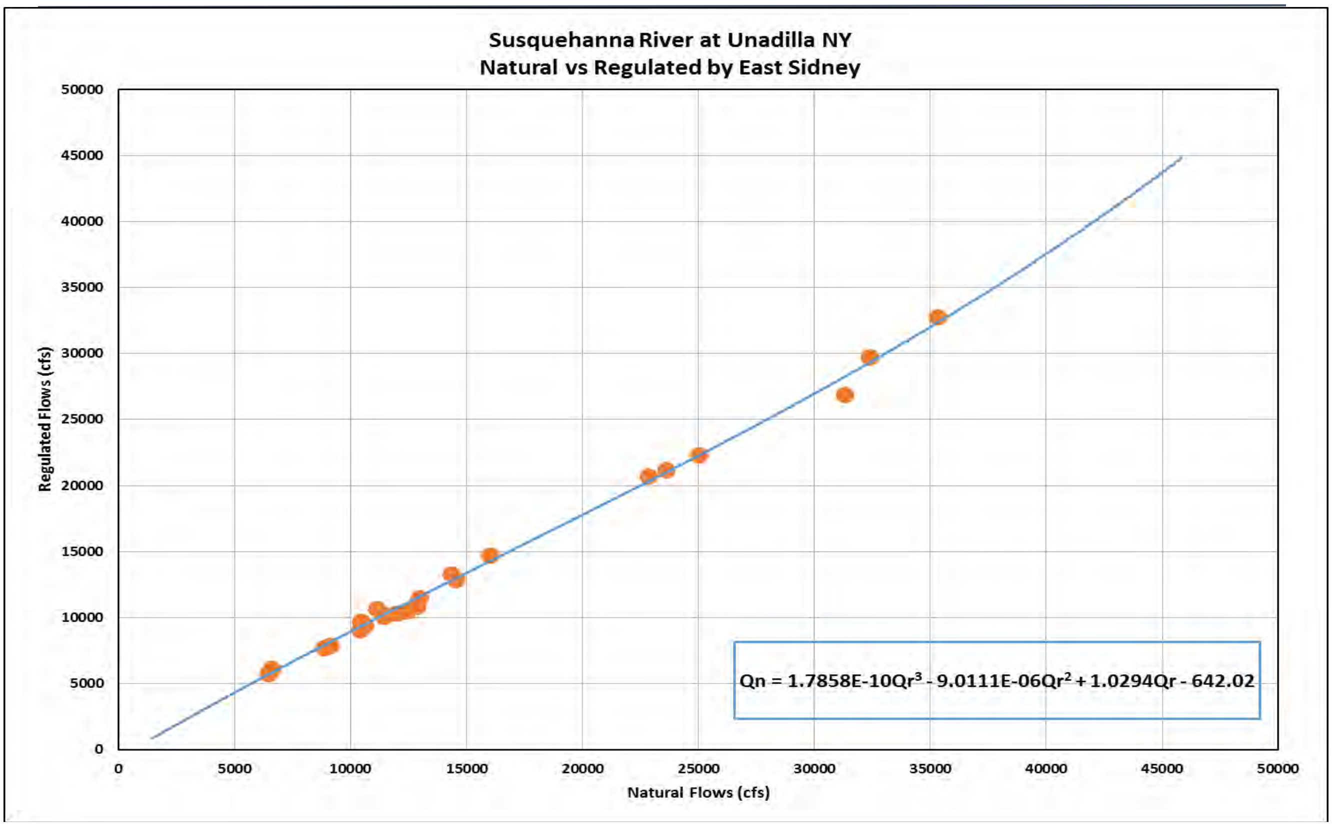


Figure 3: Susquehanna River at Unadilla NY

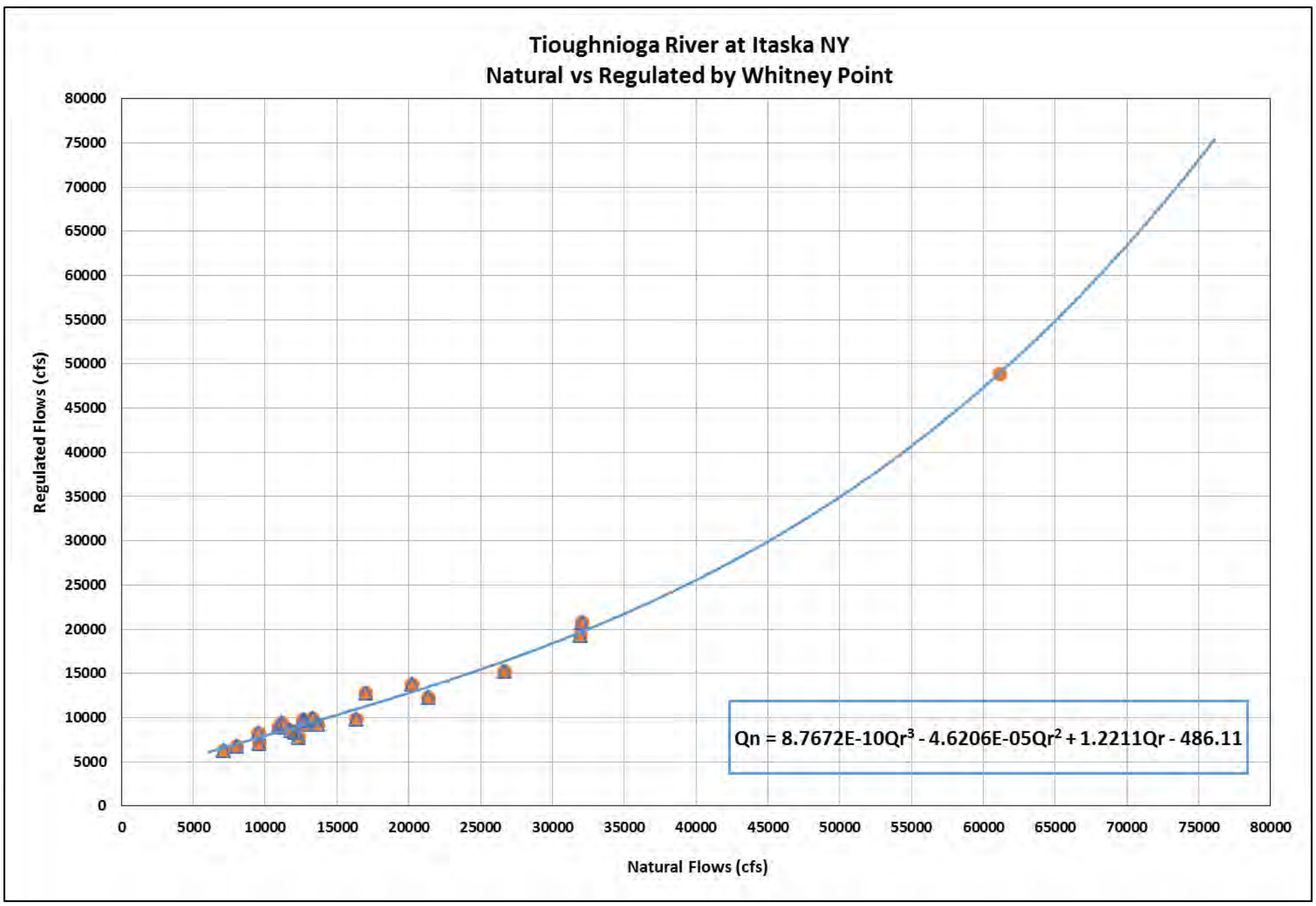


Figure 2: Tioughnioga River at Itaska NY

Table 2: Susquehanna River at Vestal NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
08Jul1935	77,000	67,800	19Feb1976	49,900	44,900
18Mar1936	107,000	93,700	14Mar1977	67,300	59,600
07Apr1937	41,300	37,400	05Apr1978	60,900	54,200
23Sep1938	47,600	42,900	06Mar1979	93,300	81,700
21Feb1939	56,200	50,300	22Mar1980	48,900	44,000
01Apr1940	85,500	75,000	21Feb1981	54,400	48,700
07Apr1941	53,400	47,900	29Oct1981	41,500	37,600
18Mar1942	48,900	43,100	16Apr1983	59,400	53,000
31Dec1942	100,500	87,500	14Dec1983	96,200	84,200
18Mar1944	60,600	52,600	13Mar1985	38,300	34,800
18Mar1945	56,500	49,300	15Mar1986	83,300	73,100
09Mar1946	61,500	53,400	27Nov1986	49,800	44,800
06Apr1947	65,700	56,900	20May1988	40,000	36,600
22Mar1948	102,400	89,300	11May1989	46,100	41,600
31Dec1948	52,300	45,800	17Feb1990	37,900	34,400
05Apr1950	66,800	57,800	24Oct1990	58,300	52,000
05Dec1950	61,200	54,500	12Mar1992	26,900	24,500
12Mar1952	51,200	46,000	11Apr1993	90,700	79,400
25Jan1953	46,300	41,800	07Apr1994	49,700	44,700
18Feb1954	45,000	40,600	09Mar1995	27,900	25,400
13Mar1955	45,800	41,300	20Jan1996	101,800	89,100
08Mar1956	72,500	64,000	02Dec1996	66,300	58,800
06Apr1957	41,300	37,400	09Jan1998	61,000	54,300
08Apr1958	72,900	64,300	25Jan1999	59,300	52,900
22Jan1959	60,300	53,700	28Feb2000	73,100	64,500
01Apr1960	76,800	67,600	10Apr2001	50,200	45,100
26Feb1961	80,600	70,800	27Mar2002	39,000	35,800
01Apr1962	66,700	59,100	23Mar2003	58,000	51,800
28Mar1963	70,800	62,600	18Sep2004	88,600	77,600
06Mar1964	90,400	79,200	03Apr2005	110,600	97,000
13Feb1965	26,700	24,300	28Jun2006	133,500	119,000
14Feb1966	40,600	36,800	17Nov2006	62,900	55,900
30Mar1967	37,700	34,200	09Mar2008	59,600	53,100
23Mar1968	48,000	43,200	09Mar2009	47,500	42,800
31Jan1969	50,000	45,000	26Jan2010	59,400	53,000
03Apr1970	49,500	44,500	08Sep2011	143,100	129,000
16Mar1971	41,200	37,300	28Jan2012	28,700	26,100
23Jun1972	56,400	50,400	13Mar2013	37,700	34,200
09Nov1972	51,700	46,400	17May2014	40,100	36,400
28Dec1973	44,200	40,000	10Apr2015	53,400	47,900
26Sep1975	69,500	61,500	26Feb2016	36,100	32,800

Table 3: Susquehanna River at Conklin NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
28Mar1913	52,000	49,100	10Feb1965	16,000	14,900
30Mar1914	47,000	44,600	06Mar1966	19,100	18,000
08Jul1915	40,500	38,600	30Mar1967	17,900	16,800
02Apr1916	42,100	40,100	23Mar1968	22,500	21,200
28Mar1917	28,700	27,400	19Nov1968	25,200	24,000
30Oct1917	29,400	28,100	03Apr1970	26,500	25,300
31Oct1918	17,900	16,800	16Mar1971	22,800	21,700
29Mar1920	35,200	33,600	23Jun1972	27,000	26,500
10Mar1921	27,100	25,900	09Nov1972	33,600	32,100
29Nov1921	39,900	38,100	28Dec1973	26,100	24,900
24Mar1923	27,300	26,100	25Feb1975	32,100	30,700
30Sep1924	44,000	41,900	19Oct1975	33,200	31,700
12Feb1925	44,900	42,700	16Mar1977	45,700	43,400
10Apr1926	30,600	29,300	19Oct1977	42,300	40,300
15Mar1927	33,600	32,100	07Mar1979	47,600	45,200
19Oct1927	43,500	41,400	22Mar1980	26,600	25,400
17Mar1929	47,000	44,600	21Feb1981	25,900	24,700
20Dec1929	18,600	17,500	27Mar1982	18,800	17,700
30Mar1931	22,800	21,700	16Apr1983	31,200	29,800
01Apr1932	29,000	27,700	14Dec1983	47,100	44,700
08Oct1932	25,000	23,800	28Sep1985	21,100	20,000
05Mar1934	25,400	24,200	15Mar1986	46,800	44,400
09Jul1935	41,900	39,900	27Nov1986	26,300	25,100
18Mar1936	61,600	59,500	20May1988	22,600	21,500
26Jan1937	24,300	23,100	07May1989	26,200	25,000
23Sep1938	34,100	32,600	17Feb1990	21,400	20,300
21Feb1939	33,100	31,600	24Oct1990	25,200	24,000
01Apr1940	51,800	49,000	12Mar1992	16,200	15,100
06Apr1941	24,900	23,700	01Apr1993	50,700	48,500
19Mar1942	28,100	26,800	07Apr1994	30,600	28,300
31Dec1942	48,600	46,100	09Mar1995	16,700	15,600
18Mar1944	30,000	28,700	19Jan1996	51,300	46,600
18Mar1945	27,500	26,300	02Dec1996	33,100	31,600
09Mar1946	32,900	31,500	10Jan1998	38,100	36,400
06Apr1947	31,000	29,600	24Jan1999	35,700	34,100
22Mar1948	60,500	56,700	28Feb2000	39,800	38,000
31Dec1948	28,400	27,100	11Apr2001	30,200	28,900
29Mar1950	34,600	33,100	27Mar2002	24,900	23,700
04Dec1950	37,800	36,100	23Mar2003	35,000	33,500
12Mar1952	25,900	24,700	18Sep2004	58,200	54,700
25Jan1953	26,600	25,400	03Apr2005	52,300	49,400
18Feb1954	30,300	29,000	28Jun2006	84,400	76,800
13Mar1955	23,600	22,500	28Mar2007	26,300	25,100
07Apr1956	41,100	39,200	09Mar2008	32,700	30,700
23Jan1957	22,500	21,400	11Mar2009	25,300	24,100
07Apr1958	40,200	38,300	25Jan2010	28,000	27,600
22Jan1959	33,800	32,300	08Sep2011	75,400	72,100
06Apr1960	46,300	44,000	28Jan2012	16,100	15,000
26Feb1961	41,000	39,100	29Jun2013	21,400	20,300
01Apr1962	37,000	35,300	17May2014	25,800	24,300
28Mar1963	39,600	37,800	10Apr2015	28,000	26,300
10Mar1964	53,200	50,200			

Table 4: Susquehanna River at Unadilla NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
01Jul1935	29,000	26,000	19Oct1975	12,500	11,200
18Mar1936	31,300	26,900	14Mar1977	26,400	23,500
22Sep1938	21,000	18,700	18Oct1977	24,600	21,900
21Feb1939	15,600	13,900	06Mar1979	23,800	21,200
31Mar1940	20,300	18,000	22Mar1980	15,600	13,900
30Dec1940	10,300	9,200	21Feb1981	9,520	8,500
18Mar1942	16,100	14,300	29Oct1981	10,880	9,720
30Dec1942	21,500	19,100	26Apr1983	15,200	13,600
18Mar1944	14,400	12,800	14Dec1983	13,200	11,800
18Mar1945	11,500	10,300	13Mar1985	10,310	9,210
08Mar1946	13,700	12,200	16Mar1986	21,400	19,000
06Apr1947	13,600	12,100	05Apr1987	16,000	14,300
22Mar1948	19,200	17,100	02Feb1988	11,060	9,880
31Dec1948	14,500	12,900	07May1989	11,600	10,400
29Mar1950	14,400	12,800	17Feb1990	11,500	10,300
05Dec1950	13,200	11,800	11Nov1990	10,510	9,390
03Apr1952	10,570	9,440	11Mar1992	8,830	7,870
12Dec1952	13,700	12,200	31Mar1993	22,400	19,900
18Feb1954	13,100	11,700	08Apr1994	13,400	12,000
12Mar1955	12,300	11,000	09Mar1995	8,270	7,360
06Apr1956	18,000	16,000	19Jan1996	19,200	17,100
23Jan1957	10,650	9,510	10Nov1996	16,600	14,800
08Apr1958	15,900	14,200	10Jan1998	22,800	20,300
22Jan1959	19,100	17,000	25Jan1999	15,800	14,100
04Apr1960	23,600	21,200	28Feb2000	19,900	17,700
26Feb1961	15,800	14,100	10Apr2001	16,600	14,800
02Apr1962	19,400	17,200	27Mar2002	12,000	10,700
27Mar1963	18,700	16,600	22Mar2003	16,000	14,300
06Mar1964	20,500	18,200	19Sep2004	13,300	11,900
09Feb1965	6,010	5,260	03Apr2005	23,100	20,500
25Mar1966	9,090	8,100	29Jun2006	37,850	35,100
02Apr1967	8,500	7,570	28Mar2007	14,300	12,800
24Mar1968	10,650	9,610	09Mar2008	16,000	14,700
05Apr1969	8,990	8,010	10Mar2009	10,600	9,470
09Nov1969	13,900	12,400	24Mar2010	15,600	13,900
14Apr1971	10,200	9,110	08Sep2011	32,400	29,700
21Apr1972	12,700	11,300	28Jan2012	7,270	6,430
07Dec1972	12,200	10,900	14Jun2013	11,020	9,850
22Dec1973	11,800	10,500	17May2014	10,350	9,240
25Feb1975	12,100	10,800	11Apr2015	11,100	10,600

Table 5: Chenango River nearr Chenango Forks NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
27Mar1913	35,500	27,200	13Feb1965	12,000	10,600
28Mar1914	37,000	28,200	14Feb1966	17,900	15,100
25Feb1915	27,200	21,600	29Mar1967	15,600	13,400
02Apr1916	27,900	22,100	23Mar1968	19,000	15,900
28Mar1917	23,600	19,200	18Nov1968	18,700	15,700
14May1918	22,000	18,000	03Apr1970	20,800	17,200
31Oct1918	11,800	10,400	16Feb1971	25,400	20,400
27Mar1920	24,300	19,600	23Jun1972	34,000	26,200
10Mar1921	17,600	14,900	01Jan1973	18,500	15,500
12Jun1922	21,400	17,600	05Apr1974	22,900	18,700
06Apr1923	25,200	20,300	26Sep1975	35,000	26,900
30Sep1924	29,400	23,100	19Feb1976	26,000	20,800
12Feb1925	31,900	24,800	14Mar1977	39,600	30,000
10Apr1926	20,200	16,800	18Oct1977	22,000	18,000
14Mar1927	30,100	23,600	06Mar1979	51,600	39,400
19Oct1927	24,500	19,800	22Mar1980	22,500	18,400
15Mar1929	32,800	25,400	20Feb1981	26,500	21,100
08Mar1930	15,200	13,100	28Oct1981	27,200	21,600
27Mar1931	18,500	15,500	16Apr1983	20,300	16,800
13Feb1932	18,000	15,200	14Dec1983	43,400	32,800
06Oct1932	19,800	16,500	12Mar1985	18,900	15,800
05Mar1934	20,900	17,300	15Mar1986	34,500	26,500
08Jul1935	96,000	96,000	27Nov1986	25,000	20,100
18Mar1936	50,100	38,100	26Mar1988	17,500	14,800
07Apr1937	21,000	17,300	31Mar1989	17,800	15,000
24Oct1937	23,400	19,000	17Feb1990	18,900	15,800
21Feb1939	25,000	20,100	24Oct1990	30,800	24,000
09Apr1940	37,000	28,200	27Mar1992	14,300	12,400
07Apr1941	29,000	22,800	11Apr1993	44,300	33,500
17Mar1942	26,300	21,000	17Apr1994	23,000	18,700
30Dec1942	53,400	41,000	08Mar1995	12,800	11,200
17Mar1944	31,300	24,400	20Jan1996	46,100	33,700
22Mar1945	28,100	22,200	02Dec1996	31,500	24,500
09Mar1946	22,000	18,000	09Jan1998	28,100	22,200
07Apr1947	28,500	22,500	25Jan1999	24,200	19,600
22Mar1948	42,600	32,200	28Feb2000	33,900	26,100
30Dec1948	21,700	17,800	10Apr2001	27,400	21,700
05Apr1950	39,700	30,100	06Jun2002	17,500	15,500
31Mar1951	24,700	19,900	22Mar2003	24,400	19,700
11Mar1952	21,400	17,600	18Sep2004	24,300	19,600
11Dec1952	21,500	17,700	03Apr2005	58,500	45,400
17Feb1954	17,100	14,500	28Jun2006	53,100	41,500
12Mar1955	26,900	21,400	17Nov2006	32,200	25,000
05Apr1956	41,500	31,400	09Mar2008	24,400	19,100
23Jan1957	18,700	15,700	09Mar2009	21,900	18,500
07Apr1958	28,400	22,400	25Jan2010	25,000	20,600
22Jan1959	24,900	20,000	08Sep2011	61,000	49,500
01Apr1960	40,100	30,400	27Jan2012	16,400	14,000
26Feb1961	45,000	34,000	09Aug2013	29,200	22,900
01Apr1962	23,700	19,200	30Mar2014	20,200	16,800
28Mar1963	32,200	25,000	09Apr2015	22,900	19,200
06Mar1964	51,600	37,800	25Feb2016	18,400	15,500

Table 6: Tioughnioga River at Itaska NY

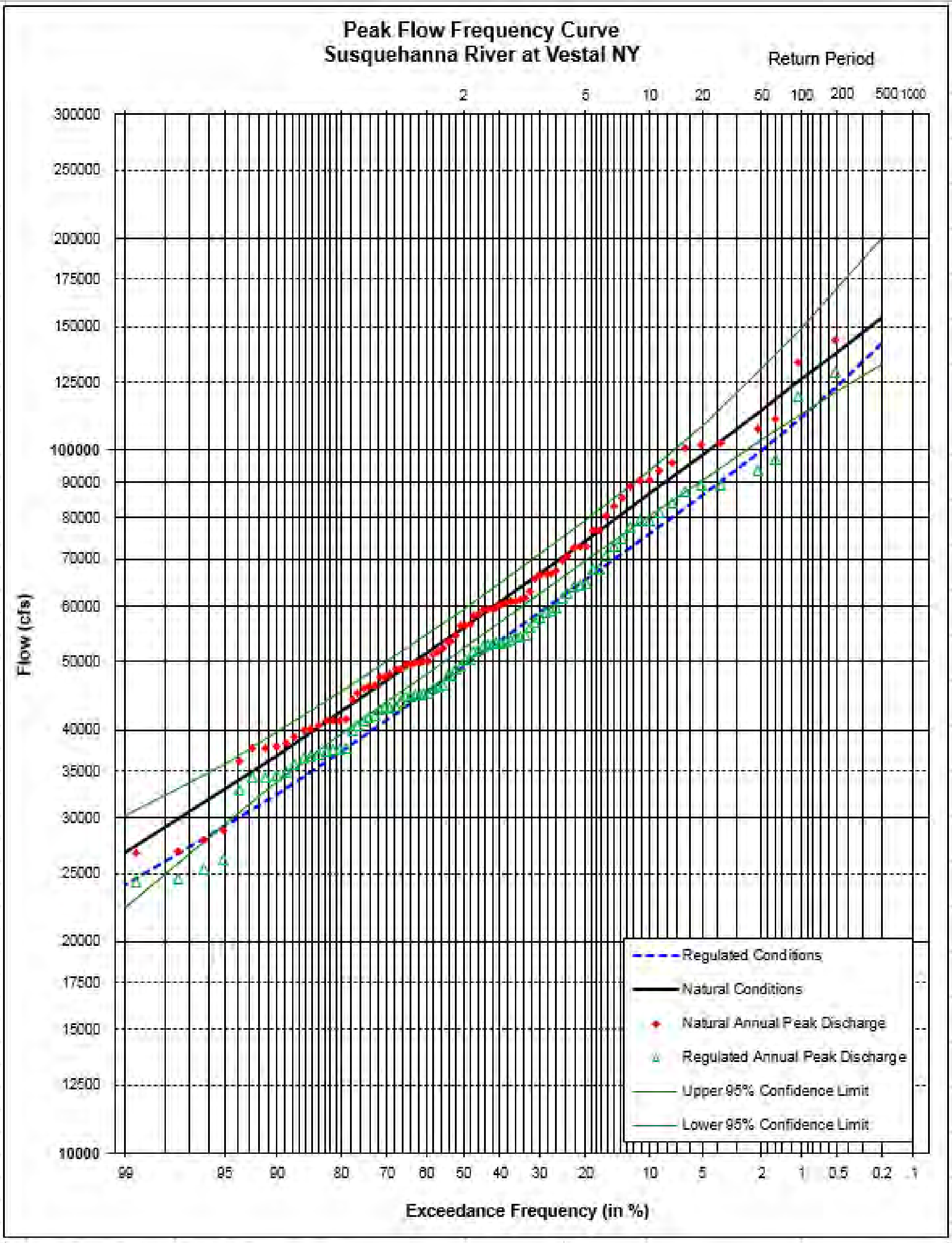
Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
08Mar1930	9,250	7,500	25Nov1972	17,800	11,600
27Mar1931	11,000	8,500	05Apr1974	15,500	10,600
13Feb1932	11,000	8,500	26Sep1975	24,900	14,800
06Oct1932	10,000	8,000	13Mar1977	23,600	14,100
01Apr1934	12,500	9,300	01Apr1978	12,750	9,390
08Jul1935	61,100	48,900	06Mar1979	28,400	17,000
18Mar1936	28,700	17,200	22Mar1980	12,960	9,490
07Apr1937	14,300	10,100	20Feb1981	13,320	9,650
24Oct1937	15,900	10,800	28Oct1981	25,500	15,100
20Feb1939	15,300	10,500	30Apr1983	9,480	7,680
09Apr1940	21,200	13,000	15Feb1984	24,400	14,500
07Apr1941	19,100	12,100	15Mar1985	9,200	7,520
17Mar1942	19,900	12,400	15Mar1986	17,200	11,300
30Dec1942	29,800	18,100	26Nov1986	14,400	10,100
17Mar1944	20,000	12,500	26Mar1988	9,430	7,660
22Mar1945	21,700	13,200	12May1989	9,140	7,480
07Mar1946	12,800	9,400	17Feb1990	8,840	7,300
06Apr1947	19,000	12,000	24Oct1990	21,300	13,000
20Mar1948	22,900	13,800	27Mar1992	8,750	7,250
06Jan1949	8,170	6,880	11Apr1993	24,200	14,400
05Apr1950	22,700	13,700	16Apr1994	12,480	9,260
31Mar1951	14,600	10,200	08Mar1995	12,300	9,170
11Mar1952	10,200	8,100	19Jan1996	32,800	20,800
11Dec1952	11,300	8,680	02Dec1996	15,900	10,800
17Feb1954	9,980	7,970	08Jan1998	15,600	10,600
11Mar1955	19,300	12,200	24Jan1999	9,560	7,730
05Apr1956	26,600	15,800	28Feb2000	17,400	11,400
06Apr1957	7,390	6,370	10Apr2001	15,600	10,600
07Apr1958	15,700	10,700	16Jun2002	9,170	7,500
02Apr1959	13,400	9,700	05Apr2003	11,000	8,520
01Apr1960	24,500	14,600	11Dec2003	11,100	8,570
26Feb1961	36,200	22,600	03Apr2005	31,200	19,300
31Mar1962	11,220	8,640	28Jun2006	21,400	12,400
27Mar1963	16,500	11,000	16Nov2006	15,300	10,500
05Mar1964	29,100	17,500	06Feb2008	12,600	9,670
13Feb1965	7,680	6,560	09Mar2009	12,170	9,110
25Apr1966	8,150	6,870	25Jan2010	12,700	9,650
29Mar1967	9,500	7,700	08Sep2011	26,600	15,400
23Mar1968	9,910	7,930	27Jan2012	8,930	7,360
19Nov1968	11,560	8,810	09Aug2013	20,200	13,800
06Feb1970	14,030	9,970	30Mar2014	12,470	9,260
16Feb1971	23,800	14,200	09Apr2015	13,300	9,990
23Jun1972	17,600	11,500			

1.4 DEVELOPMENT OF PEAK FLOW FREQUENCY CURVES FOR GAGES AFFECTED BY REGULATION

The program HEC-SSP (Hydraulic Engineering Center – Statistical Software Package) version 2.1 was used to develop natural conditions peak flow frequency curves using the Log-Pearson Type III distribution and the Bulletin 17C EMA methodology. Station skews were used for all the gages since no studies of regional skew have been performed for gages in New York. Perception thresholds were used to extend the period of record using the historical information presented by USGS in the gage records. The USGS gage records state that at the Vestal and Conklin gages the March 1936 event was the largest since 1865, and for the Unadilla gage the March 1936 event was the largest since 1902. At the Chenango gage, the USGS records state that the July 1935 event was the largest since 1865 and at the Itaska gage it was the largest since 1902.

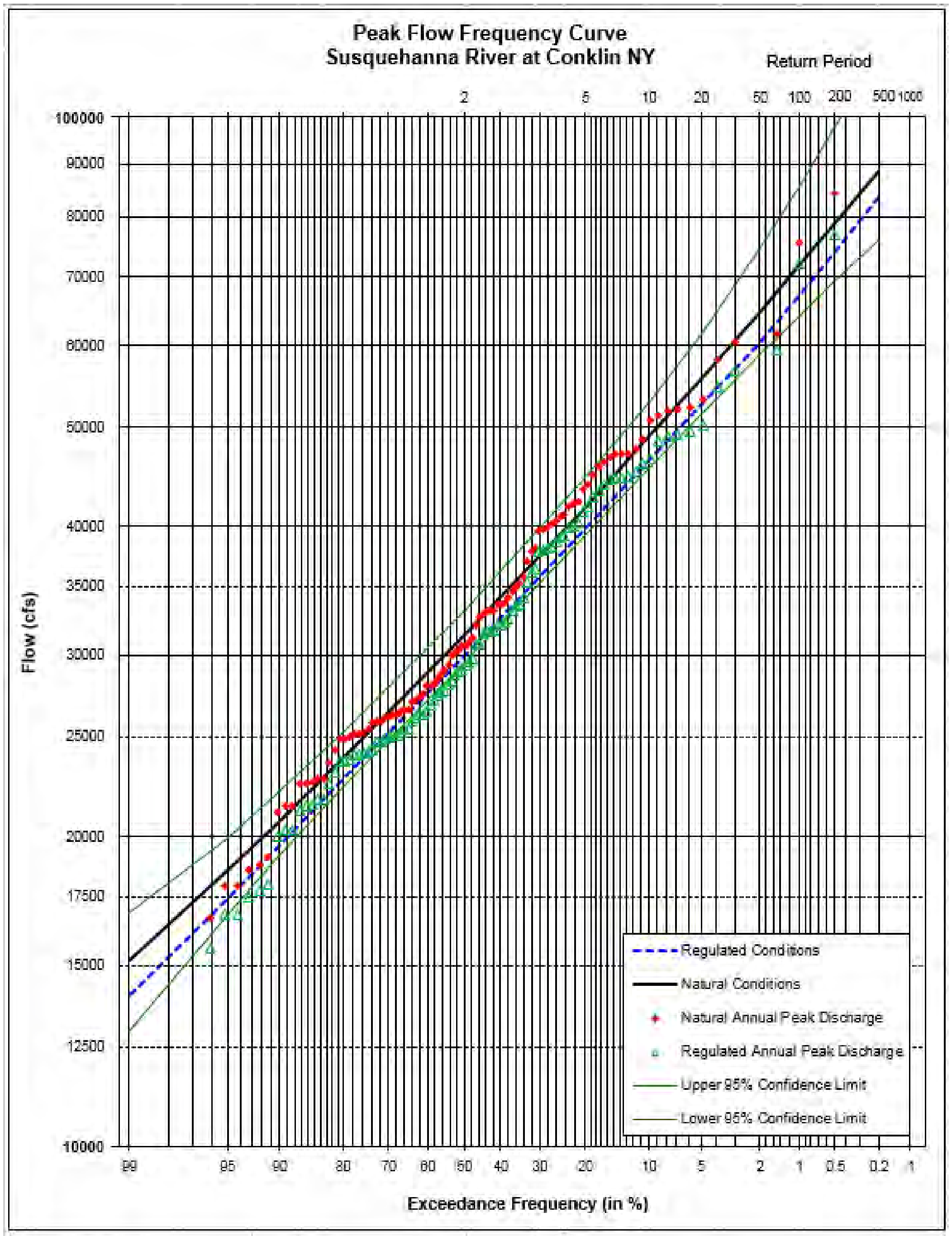
This data was used to set the perception thresholds in HEC-SSP and extend the period of record of the gages.

The regulated (existing conditions) peak flow frequency curves were developed using a graphical fit through regulated peak flow points, using the natural conditions curve and the regulation effects on the gages as a guide in plotting the curves. The resulting natural and existing conditions peak flow frequency curves are presented in Figures 6 through 10



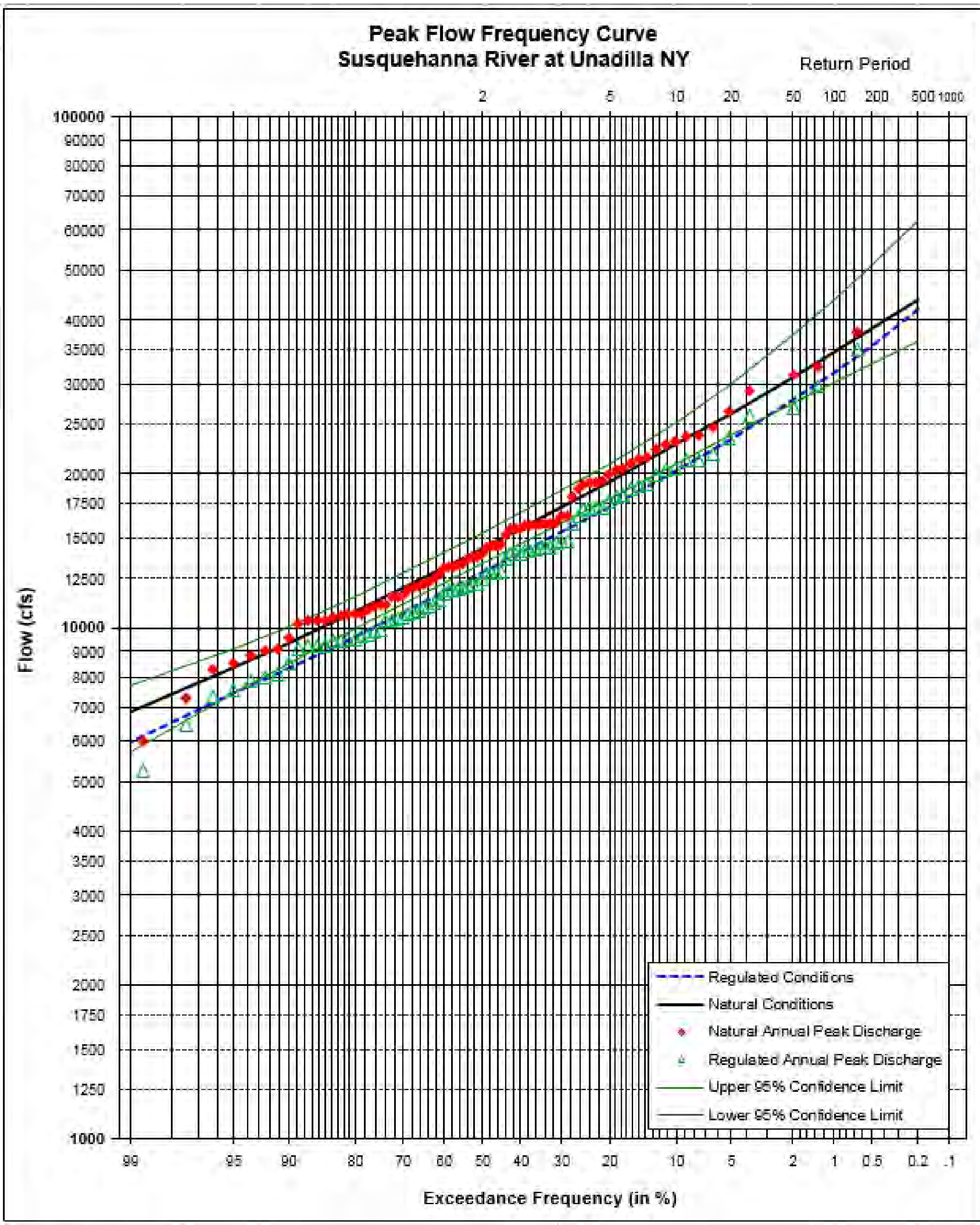
Natural Flow Frequency Statistics				
Log Transform of Flow, cfs		Number of Events		Susquehanna River at Vestal NY
Mean	4.75	Historic Events	0	USGS Gage 01513500
Standard Dev	0.145	High Outliers	0	Drainage Area = 3941 sq mi
Station Skew	0.127	Low Outliers	0	Period of Record 1935-2016
Regional Skew	n/a	Zero or Missing	70	Historic POR to 1865
Weighted Skew	n/a	Systematic Events	82	Apr 2017
Adopted Skew	0.127	Historic Period	152	

Figure 4: Susquehanna River at Vestal NY



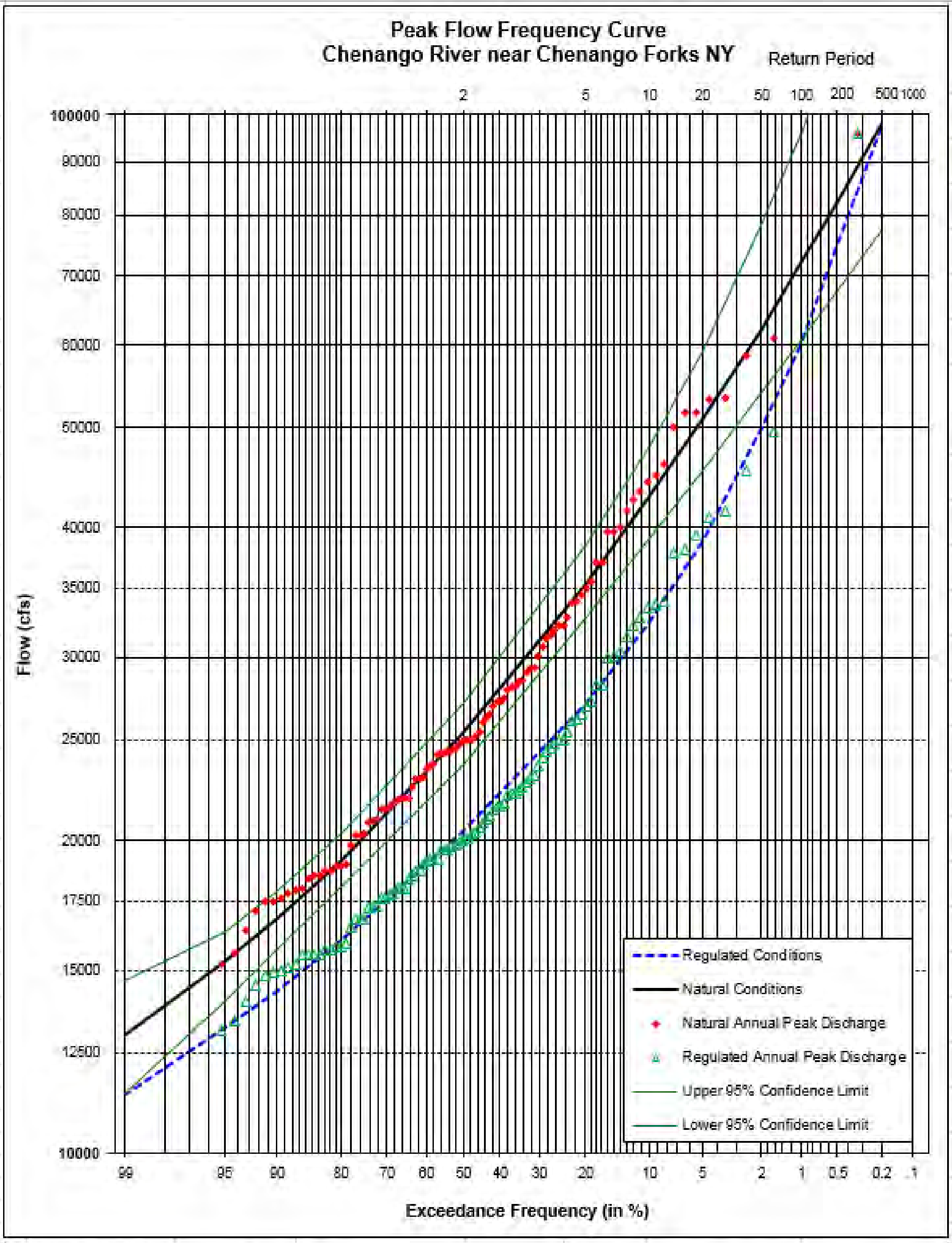
Frequency Statistics				
Log Transform of Flow, cfs		Number of Events		Susquehanna River at Conklin NY
Mean	4.5	Historic Events	0	USGS Gage 01503000
Standard Dev	0.145	High Outliers	0	Drainage Area = 2232 sq mi
Station Skew	0.167	Low Outliers	0	Period of Record 1913-2015
Regional Skew	n/a	Zero or Missing	48	Historic POR to 1865
Weighted Skew	n/a	Systematic Events	103	Mar 2017
Adopted Skew	0.167	Historic Period	151	

Figure 5: Susquehanna River at Conklin NY



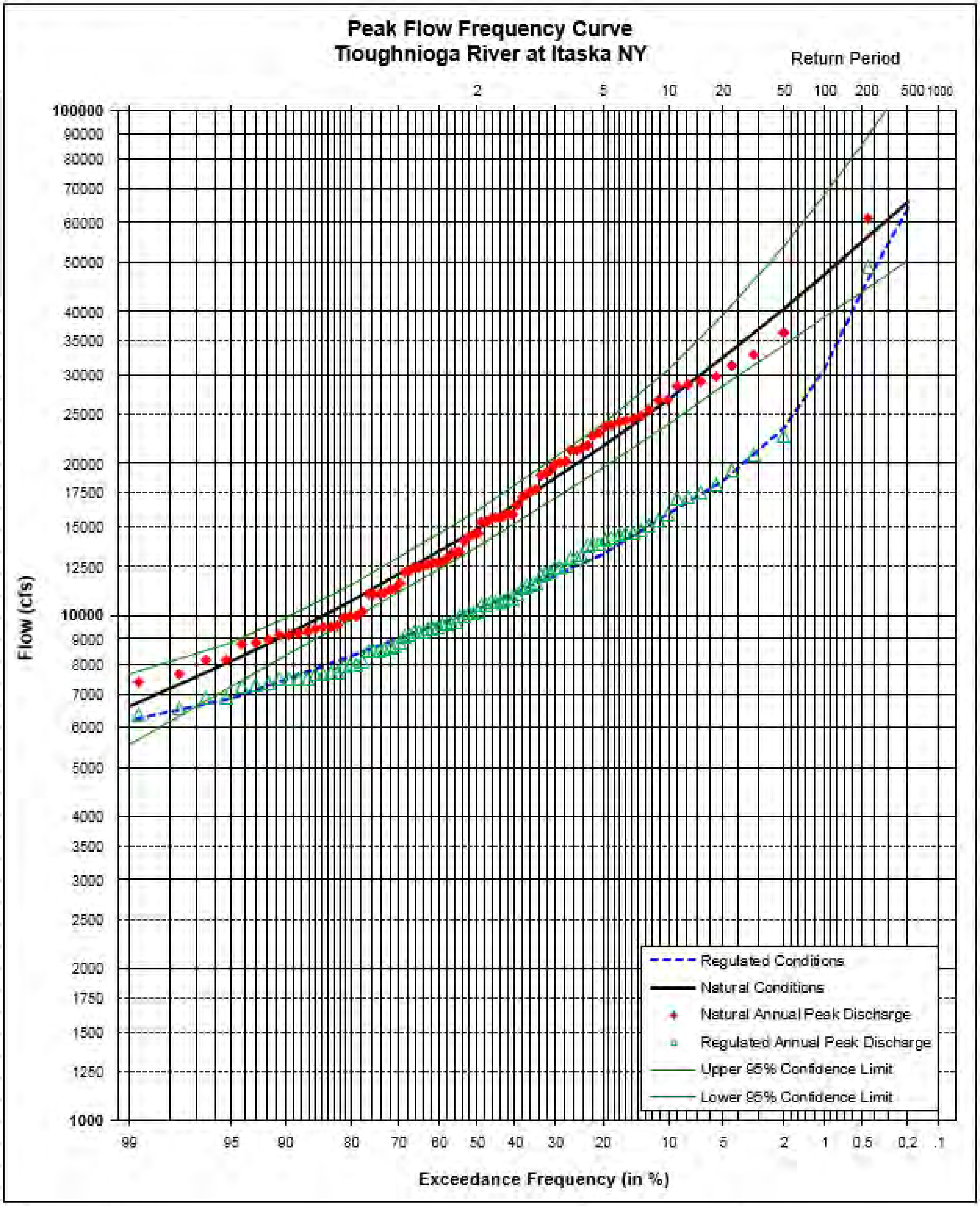
Frequency Statistics		Number of Events		
Log Transform of Flow, cfs				Susquehanna River at Unadilla NY
Mean	4.161	Historic Events	0	USGS Gage 01500500
Standard Dev	0.152	High Outliers		Drainage Area = 982 sq mi
Station Skew	0.236	Low Outliers	0	Period of Record 1935, 1936, 1938-2015
Regional Skew		Zero or Missing	34	Historic POR to 1902
Weighted Skew		Systematic Events	80	Apr 2017
Adopted Skew	0.236	Historic Period	114	

Figure 6: Susquehanna River at Unadilla NY



Frequency Statistics				
Log Transform of Flow, cfs		Number of Events		Chenango River near Chenango Forks NY
Mean	4.419	Historic Events	0	USGS Gage 01512500
Standard Dev	0.16	High Outliers	0	Drainage Area = 1483 sq mi
Station Skew	0.563	Low Outliers	0	Period of Record 1913-2016
Regional Skew	n/a	Zero or Missing	48	Historic POR to 1865
Weighted Skew	n/a	Systematic Events	104	Apr 2017
Adopted Skew	0.563	Historic Period	152	

Figure 7: Chenango River at Chenango Forks NY



Frequency Statistics		Number of Events		
Log Transform of Flow, cfs				Tioughnioga River at Itaska NY
Mean	4.185	Historic Events	0	USGS Gage 01511500
Standard Dev	0.184	High Outliers		Drainage Area = 730 sq mi
Station Skew	0.467	Low Outliers	0	Period of Record 1930-1975, 1977-2015
Regional Skew		Zero or Missing	29	Historic POR to 1902
Weighted Skew		Systematic Events	85	Apr 2017
Adopted Skew	0.467	Historic Period	114	

Figure 8: Tioughnioga River at Itaska NY

1.5 DEVELOPMENT OF PEAK FLOW FREQUENCY CURVES FOR GAGES NOT AFFECTED BY REGULATION

The gages at the Susquehanna River near Waverly and Susquehanna River at Owego have minor effects due to regulation and therefore did not require adjustment to the discharge period of record. The gage at Chenango River at Greene is not affected by upstream regulation. The period of record for these gages are presented in Tables 7 through 9.

Table 7: Susquehanna River near Waverly NY

Date	Observed Peak (cfs)	Date	Observed Peak (cfs)
18Mar1936	128,000	19Feb1976	60,100
08Apr1937	47,500	14Mar1977	70,300
23Sep1938	54,900	18Oct1977	70,300
21Feb1939	72,800	06Mar1979	107,000
01Apr1940	106,000	22Mar1980	56,900
06Apr1941	68,500	21Feb1981	59,200
10Mar1942	53,500	29Oct1981	51,500
31Dec1942	112,000	16Apr1983	67,300
18Mar1944	58,600	14Dec1983	110,000
22Mar1945	60,400	13Mar1985	40,100
28May1946	84,700	15Mar1986	93,800
06Apr1947	74,200	27Nov1986	64,300
22Mar1948	109,000	20May1988	47,100
31Dec1948	51,300	12May1989	52,000
29Mar1950	75,400	17Feb1990	40,800
05Dec1950	59,300	24Oct1990	72,200
12Mar1952	55,800	28Mar1992	38,600
12Dec1952	46,800	11Apr1993	93,600
18Feb1954	43,900	25Mar1994	55,000
02Mar1955	50,000	09Mar1995	30,300
08Mar1956	83,700	20Jan1996	102,000
07Apr1957	48,100	02Dec1996	75,300
08Apr1958	83,500	09Jan1998	67,500
23Jan1959	66,600	25Jan1999	60,500
01Apr1960	89,500	28Feb2000	76,000
26Feb1961	88,400	11Apr2001	55,300
01Apr1962	69,500	27Mar2002	45,900
27Mar1963	73,200	23Mar2003	61,700
06Mar1964	94,400	18Sep2004	89,400
10Feb1965	29,200	03Apr2005	105,000
14Feb1966	48,000	29Jun2006	128,000
30Mar1967	42,600	17Nov2006	72,600
24Mar1968	57,100	09Mar2008	63,900
19Nov1968	48,200	10Mar2009	53,400
03Apr1970	58,000	26Jan2010	69,100
16Mar1971	46,900	08Sep2011	167,000
23Jun1972	121,000	28Jan2012	30,100
09Nov1972	59,500	02Jul2013	42,300
28Dec1973	49,800	30Mar2014	47,400
27Sep1975	111,000	10Apr2015	58,400

Table 8: Susquehanna River at Owego NY

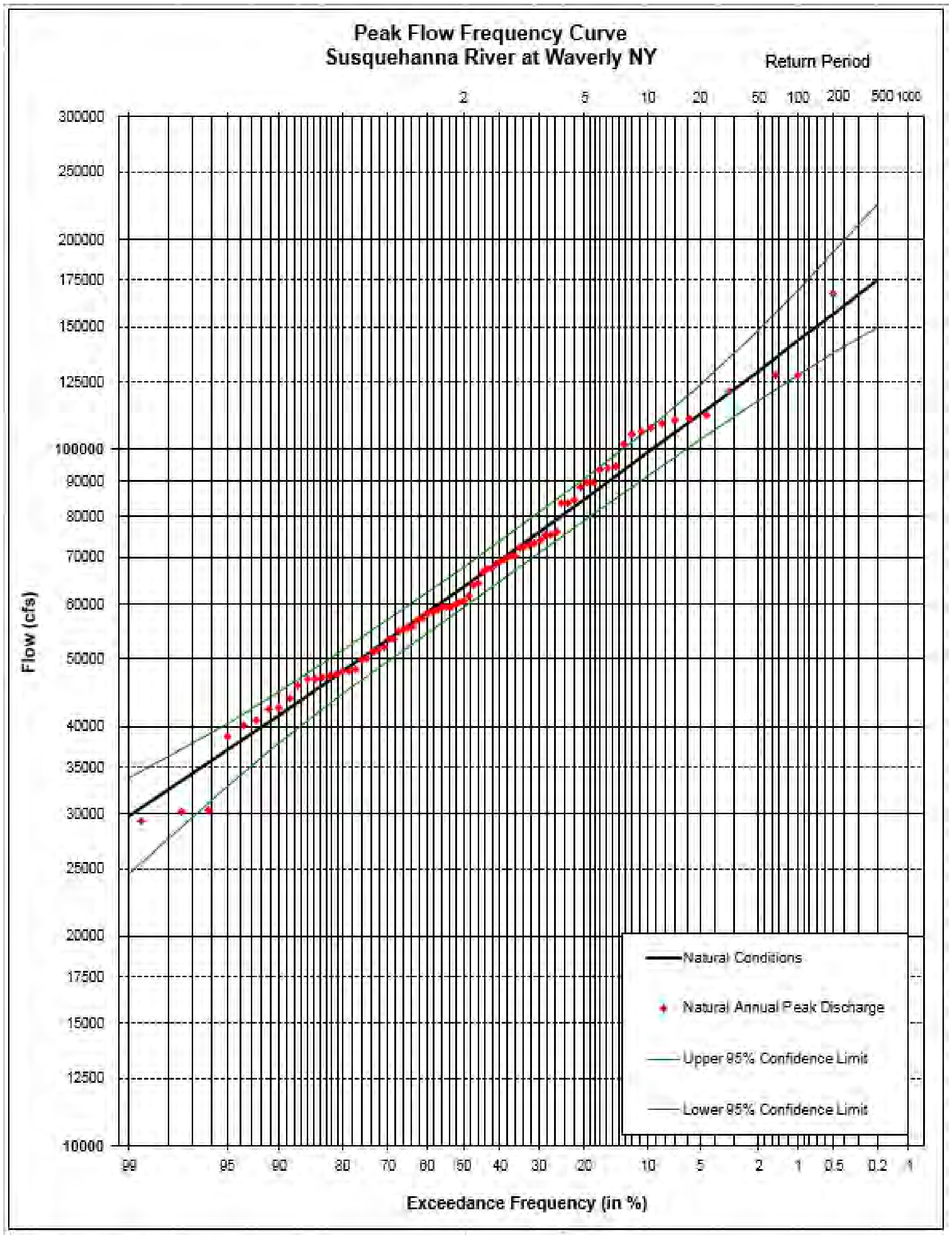
Date	Observed Peak (cfs)
18Mar1936	107,000
20May1988	39,200
11May1989	41,800
17Feb1990	36,600
24Oct1990	55,700
28Mar1992	30,700
11Apr1993	76,300
07Apr1994	46,300
09Mar1995	27,800
20Jan1996	81,400
25Jan1999	54,500
28Feb2000	66,200
11Apr2001	47,100
27Mar2002	41,300
23Mar2003	59,500
18Sep2004	89,800
03Apr2005	106,000
29Jun2006	127,000
17Nov2006	64,600
09Mar2008	59,900
09Mar2009	49,400
26Jan2010	60,500
08Sep2011	159,000
28Jan2012	26,000
02Jul2013	39,200
30Mar2014	43,000
10Apr2015	54,500

HEC-SSP was used to develop the existing conditions peak flow frequency curves using the Bulletin 17C EMA methodology. Station skews were used for all the gages since no studies of regional skew have been performed for gages in New York. Perception thresholds were used to extend the period of record using the historical information presented by USGS in the gage records. The USGS gage records state that at Waverly the March 1936 event was the largest since 1865. This historic data for Waverly along with the historical data at the Conklin, Vestal and Unadilla gages was used to make comparisons of flows records and set perception thresholds at the Owego gage. At the Greene gage, the USGS records state that the March 1936 event was the largest since 1902. This data was used to set the perception thresholds in HEC-SSP and extend the period of record of the gages.

Table 9: Chenango River at Greene NY

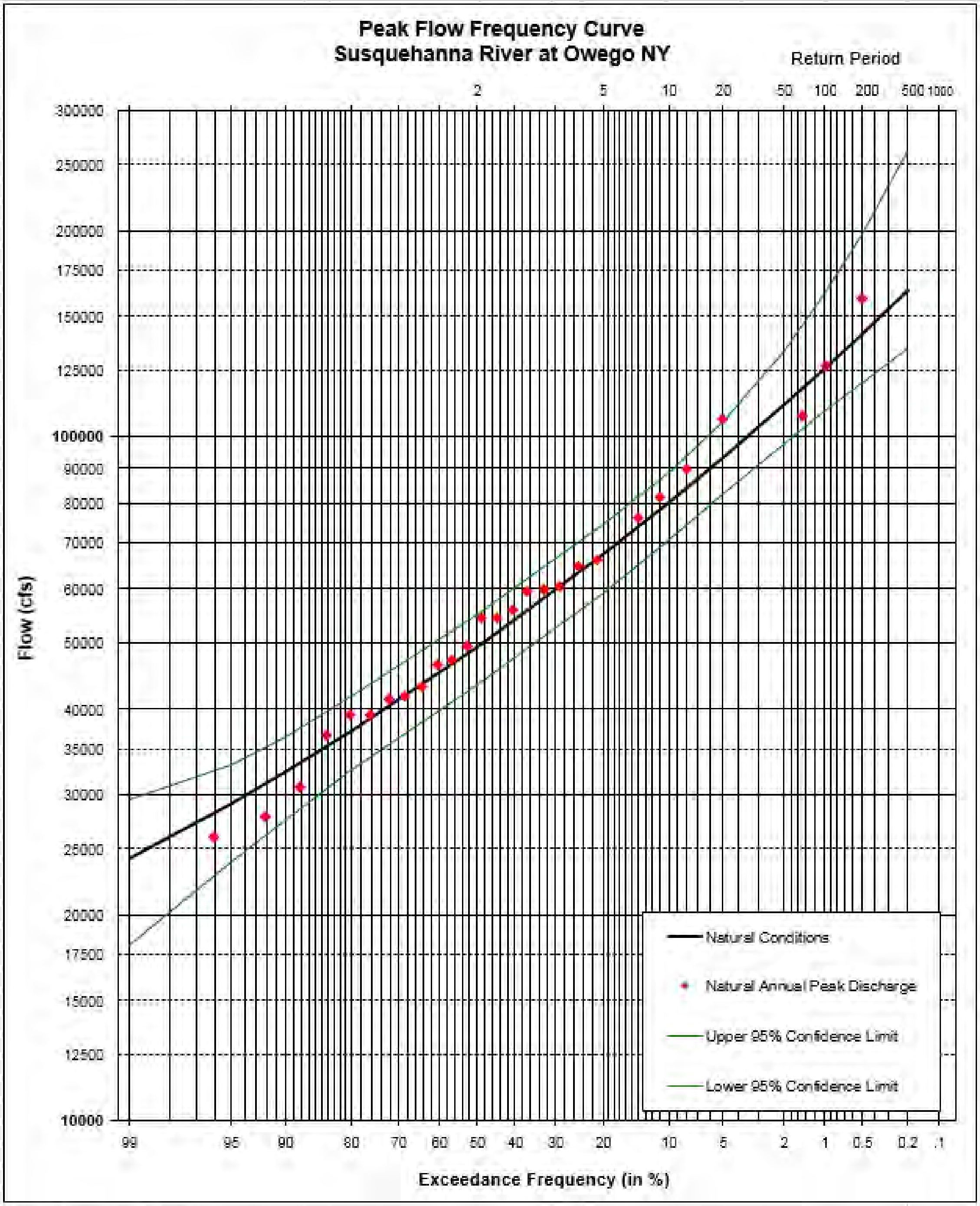
Date	Observed Peak (cfs)	Date	Observed Peak (cfs)
07Apr1937	6,900	14Mar1977	13,900
24Oct1937	6,690	27Jan1978	12,300
21Feb1939	9,650	06Mar1979	17,900
09Apr1940	12,700	22Mar1980	8,040
07Apr1941	9,020	22Feb1981	6,460
18Mar1942	9,020	01Apr1982	5,480
31Dec1942	18,900	02May1983	8,240
17Mar1944	11,000	14Dec1983	14,500
18Mar1945	8,700	12Mar1985	6,810
09Mar1946	8,080	15Mar1986	13,000
07Apr1947	8,570	27Nov1986	8,700
22Mar1948	13,200	26Mar1988	6,220
31Dec1948	6,340	11May1989	6,740
05Apr1950	11,800	17Feb1990	7,280
04Dec1950	7,540	24Oct1990	8,760
12Mar1952	7,380	01Jun1992	4,230
25Jan1953	7,580	11Apr1993	14,200
18Feb1954	6,670	17Apr1994	8,520
12Mar1955	8,180	08Mar1995	4,230
06Apr1956	13,300	20Jan1996	14,700
23Jan1957	7,380	02Dec1996	11,600
07Apr1958	9,860	09Jan1998	9,320
22Jan1959	11,800	25Jan1999	11,700
01Apr1960	12,900	28Feb2000	12,000
26Feb1961	14,700	10Apr2001	10,600
01Apr1962	10,200	06Jun2002	6,580
27Mar1963	11,600	22Mar2003	9,780
06Mar1964	16,800	18Sep2004	8,520
10Feb1965	3,500	03Apr2005	20,800
14Feb1966	8,040	28Jun2006	27,100
30Mar1967	4,910	17Nov2006	13,800
24Mar1968	6,620	09Mar2008	9,030
19Nov1968	6,670	09Mar2009	7,390
03Apr1970	8,860	26Jan2010	7,870
28Feb1971	6,200	08Sep2011	26,900
23Jun1972	12,000	27Jan2012	4,740
01Jan1973	7,190	03Jul2013	8,920
27Dec1973	12,800	12Jan2014	9,240
25Feb1975	10,000	10Apr2015	8,320
23Feb1976	7,740	25Feb2016	5,310

The resulting existing conditions peak flow frequency curves are presented in Figures 11 through 13.



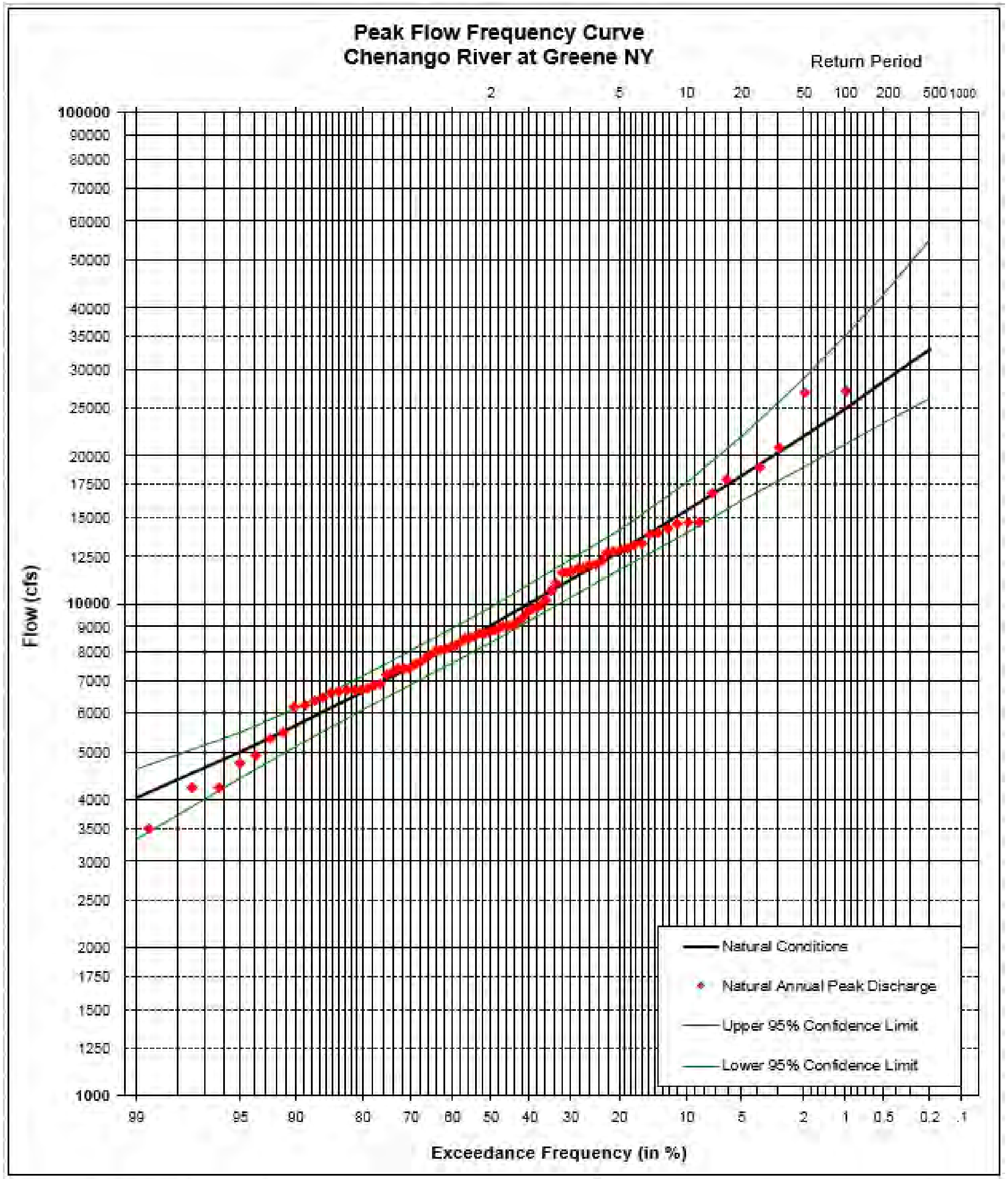
Flow Frequency Statistics				
Log Transform of Flow, cfs		Number of Events		Susquehanna River near Waverly NY
Mean	4.805	Historic Events	0	USGS Gage 01515000
Standard Dev	0.146	High Outliers	0	Drainage Area = 4773 sq mi
Station Skew	0.088	Low Outliers	0	Period of Record 1936-2015
Regional Skew	n/a	Zero or Missing	71	Historic POR to 1865
Weighted Skew	n/a	Systematic Events	80	Apr 2017
Adopted Skew	0.088	Historic Period	151	

Figure 9: Susquehanna River at Waverly NY



Flow Frequency Statistics				
Log Transform of Flow, cfs		Number of Events		Susquehanna River at Owego NY
Mean	4.701	Historic Events	1	USGS Gage 01513831
Standard Dev	0.154	High Outliers	0	Drainage Area = 4216 sq mi
Station Skew	0.362	Low Outliers	0	Period of Record 1936, 1988-2015
Regional Skew	n/a	Zero or Missing	124	Historic POR to 1865
Weighted Skew	n/a	Systematic Events	26	Apr 2017
Adopted Skew	0.362	Historic Period	151	

Figure 10: Susquehanna River at Owego NY



Frequency Statistics					
Log Transform of Flow, cfs		Number of Events			Chenango River at Greene NY
Mean	3.965	Historic Events	0		USGS Gage 01507000
Standard Dev	0.170	High Outliers			Drainage Area = 593 sq mi
Station Skew	0.296	Low Outliers	0		Period of Record 1937-2016
Regional Skew		Zero or Missing	2		Historic POR to 1935
Weighted Skew		Systematic Events	80		Apr 2017
Adopted Skew	0.296	Historic Period	82		

Figure 11: Chenango River at Greene NY

Table 9A Peak Discharge for Susquehanna River and Tributaries

Peak Discharges for USRB Hydraulic Model										
River	Reach	RS	2 Yr	5 Yr	10 Yr	20 Yr	50 Yr	100 Yr	200 Yr	500 Yr
Cayuta Creek	Cayuta Creek	17100	3,230	4,990	6,290	8,060	9,540	11,000	12,500	14,700
Chemung	Chemung	65809	33,451	44,549	51,913	58,960	68,165	75,213	82,313	91,886
Chemung	Chemung	49888	34,077	45,383	52,884	60,064	69,440	76,620	83,853	93,605
Chenango	Chenango	391742	25,000	31,000	37,000	43,000	55,000	66,000	84,000	110,000
Chenango	Chenango	117900		12,800	15,400	18,200	22,000	25,000	28,300	32,900
Chenango	Lower Reach	71596	22,133	29,905	35,666	42,055	52,268	61,066	75,207	90,028
Chenango	Lower Reach	53000	20,897	27,727	33,146	39,599	51,124	61,535	76,847	99,812
Chenango	Lower Reach	25483	21,803	28,869	34,503	41,237	53,352	64,331	80,209	104,931
Chenango	Lower Reach	513	21,803	28,869	34,503	41,237	53,352	64,331	80,209	104,931
Little Choconut	Lower Reach	6219	212	282	327	371	431	479	532	609
Nanticoke Creek	Nanticoke Creek	36599	1,420	1,891	2,192	2,486	2,891	3,215	3,568	4,082
Otselic	Whitney Point	3900	3,318	4,029	4,977	5,925	7,347	9,717	13,983	20,145
OuleoutCk	BelowEastSidney	25130	1,344	1,806	2,131	2,457	2,929	3,318	3,748	4,410
PierceCk	Binghamton	1974	110	146	171	196	233	264	301	356
Susquehanna	Upper	784743	1,050	2,592	4,763	7,414	10,011	11,339	12,810	15,071
Susquehanna	Upper	775048	1,411	3,483	6,400	9,962	13,452	15,236	17,213	20,250
Susquehanna	Upper	756669	1,966	4,853	8,916	13,879	18,742	21,228	23,982	28,215
Susquehanna	Upper	746482	2,166	5,347	9,823	15,290	20,648	23,386	26,420	31,083
Susquehanna	Upper	717956	2,366	5,840	10,729	16,701	22,553	25,544	28,858	33,951
Susquehanna	Upper	715275	2,366	5,840	10,729	16,701	22,553	25,544	28,858	33,951
Susquehanna	Upper	697960	2,470	6,098	11,203	17,439	23,549	26,672	30,132	35,450
Susquehanna	Upper	676494	2,470	6,098	11,203	17,439	23,549	26,672	30,132	35,450
SusquehannaRv	UnadillaOuleout	643655	12,800	17,200	20,300	23,400	27,900	31,600	35,700	42,000
SusquehannaRv	PierceUnadilla	603890	21,009	28,096	32,920	37,638	44,059	49,441	55,253	63,738
SusquehannaRv	PierceUnadilla	580234	21,458	28,697	33,624	38,443	45,001	50,498	56,435	65,101
SusquehannaRv	PierceUnadilla	443044	24,537	32,814	38,448	43,958	51,458	57,743	64,532	74,441
SusquehannaRv	PierceUnadilla	305078	29,900	39,800	46,300	52,500	60,300	67,000	74,000	83,500
SusquehannaRv	ChenangoPierce	261782	30,541	40,647	47,274	53,591	61,514	68,327	75,435	85,055
SusquehannaRv	Chen-Choco	252935	48,515	64,621	74,902	84,980	98,791	109,854	121,896	139,443
SusquehannaRv	Choco-Nanticoke	232859	48,853	65,070	75,420	85,569	99,489	110,631	122,764	140,457
SusquehannaRv	Nanticoke-Cayuta	198847	51,283	68,308	79,175	89,829	104,428	116,122	128,851	147,399

River	Reach	RS	2 Yr	5 Yr	10 Yr	20 Yr	50 Yr	100 Yr	200 Yr	500 Yr
SusquehannaRv	Cayuta-Chemung	31634	65,518	87,254	101,676	115,480	133,508	147,312	161,219	179,967
SusquehannaRv	Lower Reach	6383	100,327	133,612	155,696	176,834	204,440	225,578	246,874	275,584
Tioughnioga	Upper Reach	67800	6,166	7,903	9,519	11,075	14,069	18,499	26,461	38,195
Tioughnioga	Lower Reach	52239	9,741	12,483	15,037	17,495	22,224	29,222	41,800	60,335
Tioughnioga	Lower Reach	37800	10,300	13,200	15,900	18,500	23,500	30,900	44,200	63,800
UnadillaRv	BelowRockdale	28993	6,772	9,100	10,740	12,380	14,761	16,718	18,887	22,220
BlueCreek	BlueCreek	1553	300	500	688	820	1,040	1,200	1,450	1,610
DryCreek	DryCreek	13276.27	500	650	815	950	1,250	1,450	1,800	1,940
OtterCreek	OtterCreek	19853.69	700	1,000	1,300	1,600	1,950	2,240	2,600	2,950
Tioughnioga	West Branch	38117	1,900	2,670	3,180	3,840	4,320	4,820	5,300	5,920
Tioughnioga	Upper	527872	6,166	7,903	9,519	11,075	14,069	18,499	26,461	38,195

Final peak discharge used for HEC-RAS modeling is shown in table 9A above.

1.6 DEVELOPMENT OF FLOW DISTRIBUTION LOCATIONS

In developing the flow distribution locations it became evident that the short period of record at the Owego gage was causing some discrepancies. The solution was not to use the gage information when determining the flow distributions for the peak flow frequency events. Because of the short period of record and given that three of the largest events have occurred since the gage was installed in 1988, large uncertainties especially in the higher frequency events such as the 10, 20 and 50% events made estimating these events problematic.

1.7 HYDRAULIC MODEL

The original basis of the USRB hydraulic model was the CWMS developed for reservoir routing of East Sydney and Whitley Point reservoirs. The USRB study HEC-RAS model expanded the CWMS to include many other FEMA models to capture the sponsor's area of interest described in following section. In some cases, new HEC-RAS models were developed using HEC-GeoRAS where model was not available in digital format.

For the CWMS study, approximately 220 miles of streams were modeled including the main stem Upper Susquehanna River, all tributaries downstream of both East Sidney Dam and Whitney Point Dam, and other major tributaries, as needed. As part of the CWMS modeling, the HEC-RAS model was extended from the Susquehanna – Chemung River confluence to Whitney Point Dam. This segment included portions of the Susquehanna River, Chemung River, Cayuta Creek, Nanticoke Creek, Little Choconut Creek, Chenango River, Tioughnioga River, and Otselic River. Another segment extended from the Susquehanna – Chenango River confluence to East Sidney Dam. This segment included portions of the Susquehanna River, Pierce Creek, Unadilla River, and Ouleout Creek.

As part of the USRB study, the HEC-RAS model was extended for the Susquehanna River up to Oneonta, New York. The HEC-RAS model was also extended along the Tioughnioga River and its tributaries within Cortland County. HEC-RAS model updates were based on FEMA's latest models. New HEC-RAS model was developed and added using the latest LIDAR data obtained from State of New York where FEMA models were not available in digital format. Manning's roughness coefficients were obtained from FEMA studies for the extended model.

Here is the listing of updated reaches for the USRB HEC-RAS model:

- **Upper Susquehanna River** extended from Cross Sections 676494 through 784743
- **Chenango River** extended from Cross-Sections 117900 through 391742
- **Tioughnioga River** extended upstream of Cross Section 67800
- **West Branch Tioughnioga River** – From it confluence with Tioughnioga River to 38120 feet upstream
- **Tioughnioga River** - extended from Cross Sections 68270 through 527872
- **Otter creek** - From its confluence with West Branch Tioughnioga River to a point located approximately 51 feet upstream of State Route 13
- **Dry Creek No. 1** - From its confluence with West Branch Tioughnioga River to a point located approximately 306 feet upstream of Kinney Gulf Road
- **Blue creek** - From its confluence with Dry Creek No. 1 to a point located approximately 200 feet upstream of Kinney Gulf Road

The original CWMS model was an unsteady flow model where the USRB HEC-RAS model was updated as a steady state model as per the USRB Project Management Plan. The original model included lateral structures and storage areas which are appropriate for an unsteady state model, but while updating the model as a steady state model, the lateral structures and storage area were removed from the model as the model became unstable for flow optimization under those conditions. Lateral structures and storage areas were modeled as part of the extended cross sections. Cross-sections were extended based on the latest LIDAR topography to fully capture the extent of flood prone area. Because LIDAR is not adequate for the channel area, original channel portion was retained for channel area of each cross sections as appropriate.

The USRB HEC-RAS model was updated to reflect top of levee survey data. Levee card in the model used latest top of the levee information.

One HEC-RAS model was prepared stitching all reaches for the USRB HEC-RAS model. As built bridge and culvert data obtained from New York department of Transportation and also was surveyed by the USACE planning team for some bridges/culverts.

A summary of HEC-RAS model results are presented in the following section under Attachment 1

1.7.1 COINCIDENT PEAKS MODELING

For starting conditions on tributaries, FEMA guidance requires the use of normal depth unless a coincident peak situation is assumed, or the tributary flow depths are higher than the corresponding mainstream events. The USACE methodology for coincident peak analysis is a more accurate approach for starting boundary condition for a tributary in a steady state model.

Coincident peak analysis was performed for the Chenango River for its confluence at the Susquehanna River using USACE software HEC-SSP program. Summary of coincident peak analysis for Chenango River is displayed under Attachment 2. For the Chenango River HEC-RAS modeling, a separate geometry file was created in the project file that only contains the Chenango River reaches and used the rating curve as the downstream boundary condition where a separate smaller model was run to determine WSEL for Chenango River.

1.7.2 CALIBRATION OF HEC-RAS MODEL

The original CWMS model was calibrated for the Susquehanna River, Chenango River, Tioughnioga River and Chemung Rivers. To better fit the USGS observed data and rating curve, several changes were made: For low flow rates, the below-water channel shape was slightly modified to have a flatter bottom section and steeper banks using FEMA Flood Insurance Study data and for the medium and high flow rates, Manning's "n" values and ineffective flow area placements were modified. For the updated HEC-RAS model, no adjustments to the roughness coefficient or channel bottom were made.

The CWMS HEC-RAS-computed WSEL matched within ±0.5 to ±1 foot of the USGS and NAB rating curves for most of the flow rates with a few exceptions, especially at low flow rates in the Lisle and Itaska gages and at mid-range flow rates for the Owego and Vestal gages. The updated HEC-RAS model continue to perform with same accuracy. No adjustment was necessary for the calibration. The calibrated results at each USGS gaging station are shown in Figure 14 through Figure 20 below.

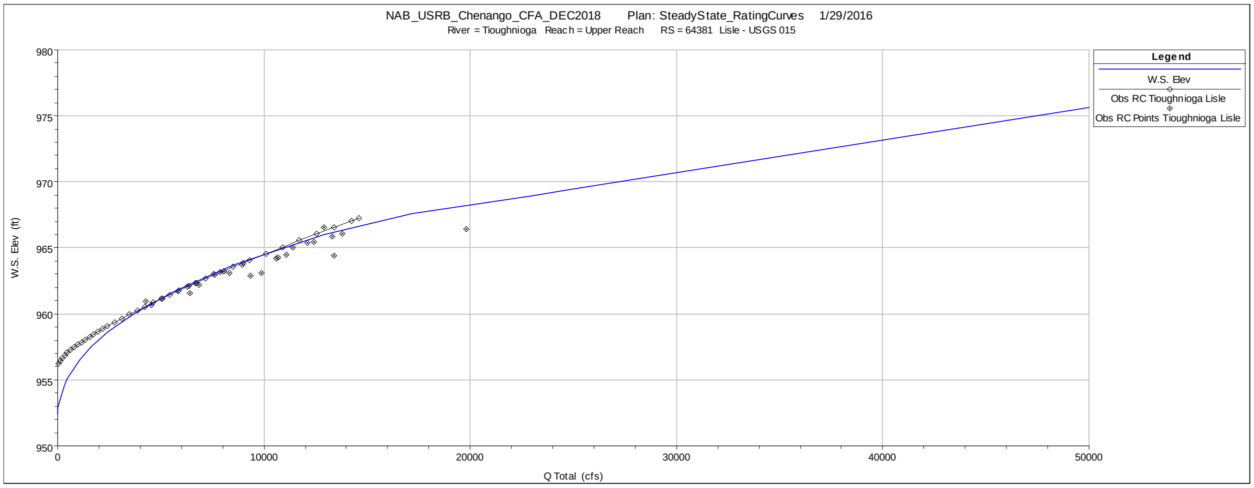


Figure 14: USGS 01509520 – Tioughnioga River at Lisle, NY

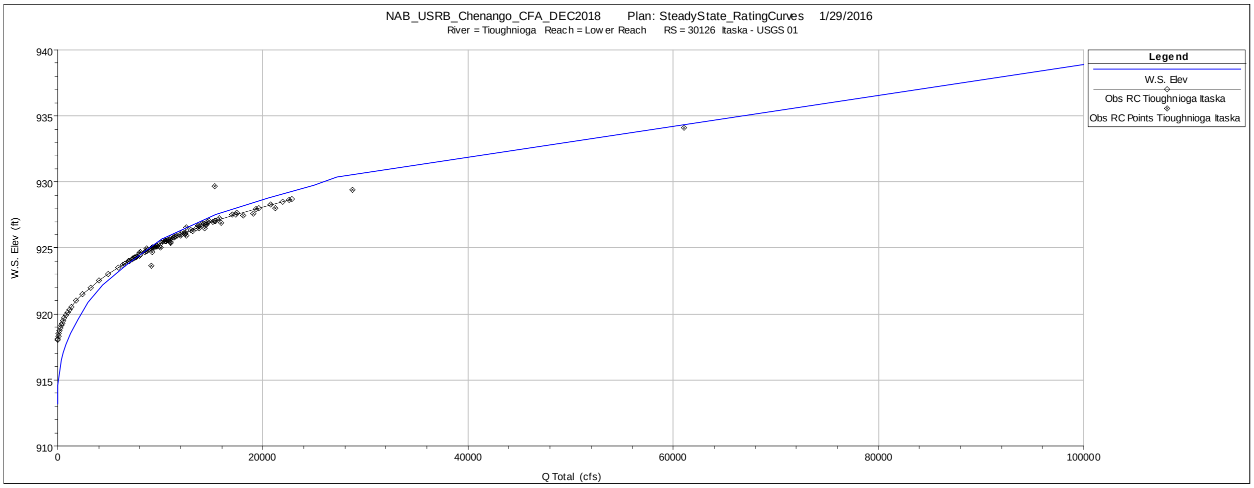


Figure 15: USGS 01511500 – Tioughnioga River at Itaska, NY

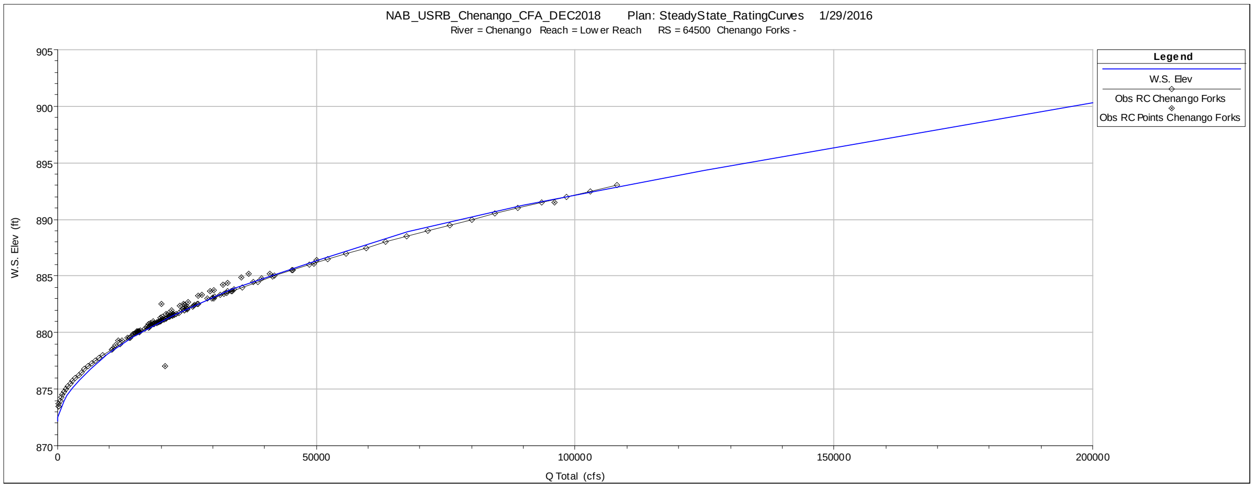


Figure 16: USGS 01512500 – Chenango River at Chenango Forks, NY

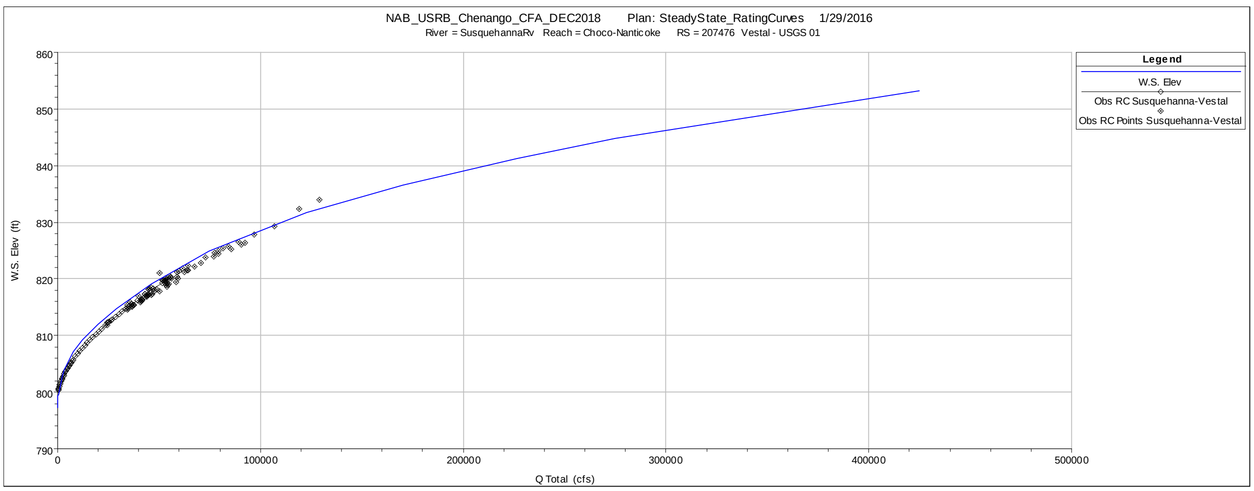


Figure 17: USGS 01513500 – Susquehanna River at Vestal, NY

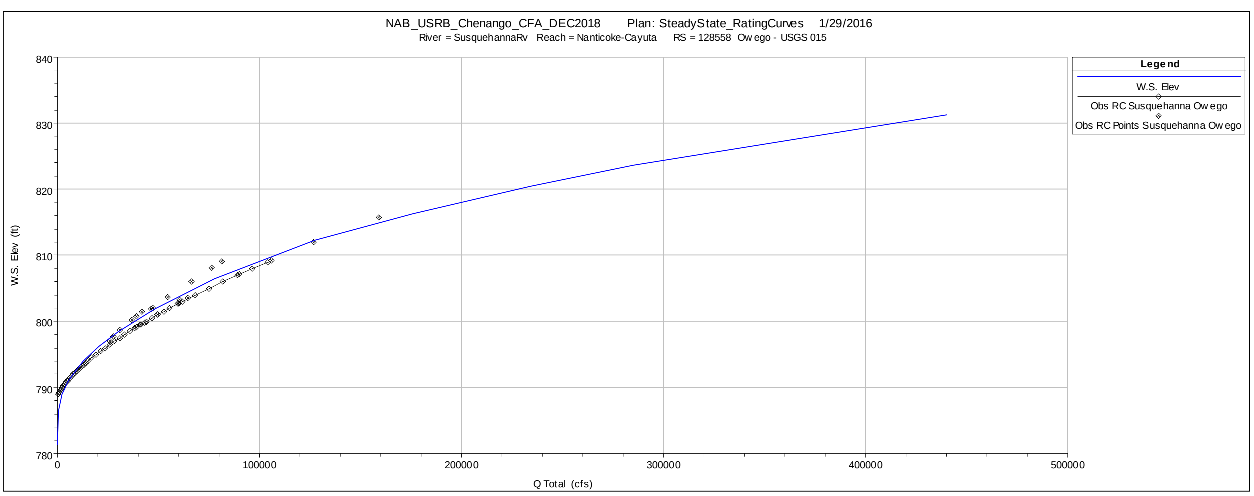


Figure 18: USGS 01513831 – Susquehanna River at Owego, NY

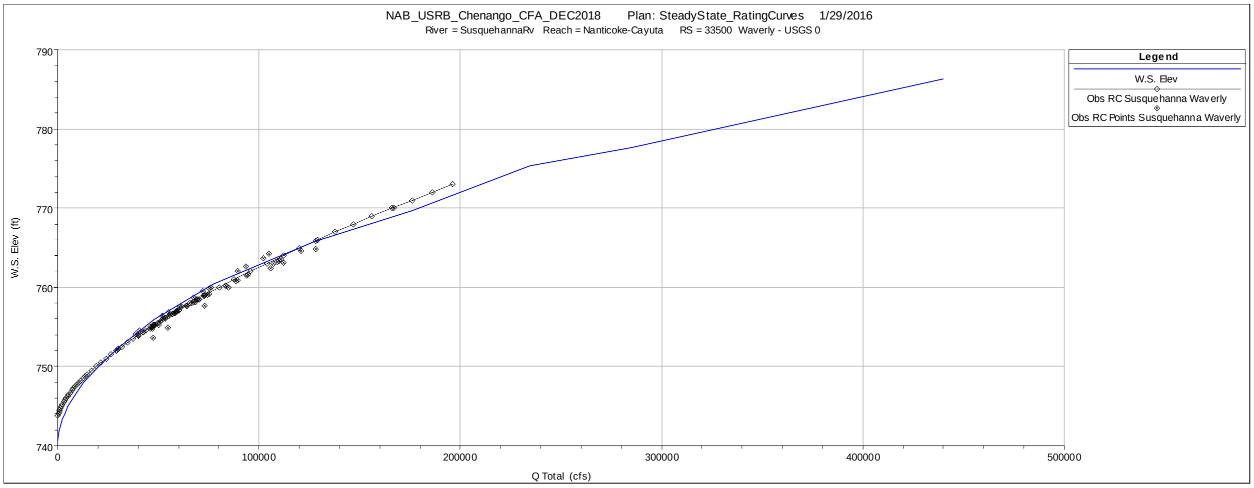


Figure 19: USGS 01515000 – Susquehanna River at Waverly, NY

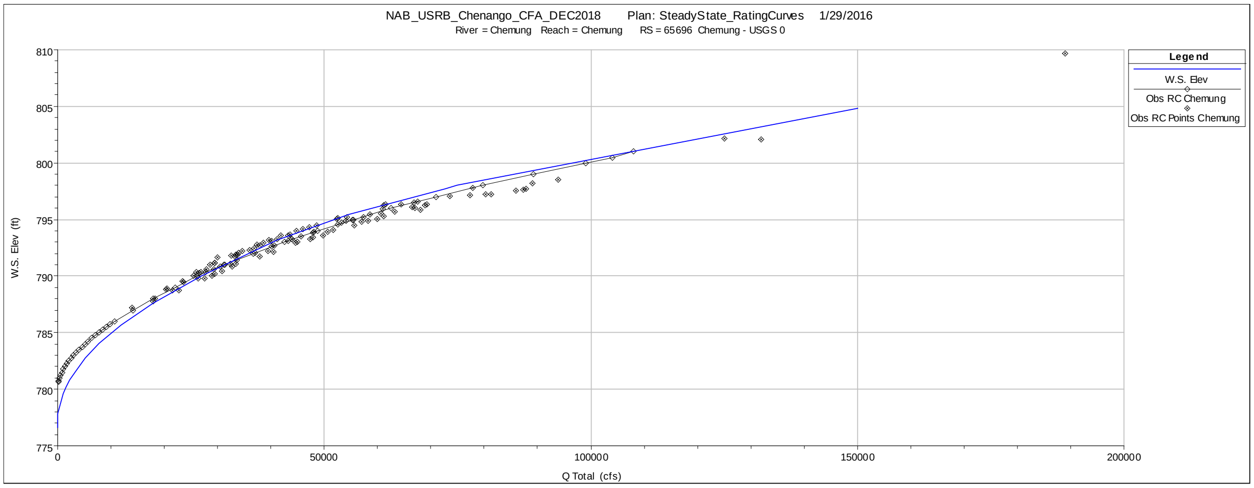


Figure 20: USGS 01531000 – Chemung River at Chemung, NY

1.7.3 LIMITATIONS OF THE HEC-RAS MODEL

While USACE used the best available information to create a comprehensive model there are several things to consider when using a model like for predictive and study purposes. First, this is a steady state model which comes with some inherent shortcomings especially at or near river confluences because of coincident peak flows. For starting conditions on tributaries, FEMA guidance requires the use of normal depth unless a coincident peak situation is assumed, or the tributary flow depths are higher than the corresponding mainstream events. We used a more detailed approach to perform a coincident stage frequency analysis of main stem (Susquehanna River) water surface elevations to tributary (Chenango River) water surface elevations to see if there is any correlation. This method will more accurately capture tributary flooding near the confluence and would differ from FEMA's modeling results. Besides the coincident stage frequency analysis, we also updated hydrology based on latest gage record analysis. Our hydrologic analysis resulted in slightly different peak discharges when compared against FEMA's peak discharges for the same flood frequency events.

These differences in peak discharges will be another reason for the USRB HEC-RAS model results not matching with that of FEMA's Flood Insurance Studies.

If the USRB HEC-RAS model is to be used to submit to FEMA for levee accreditation, the model portion for the area of interest should be "saved out" to create a separate model. Second, if someone wanted to improve upon this model, USACE would recommend that the entire model be converted to an unsteady state model as this would allow for more accurate WSEL's in "real" time as hydrographs could be used. Through the use of GIS, one could add in the natural storage areas to account for attenuated waters along the rivers and tributaries. Taking the model a step further, one could take the HEC-HMS model from the CWMS study and expand on that to utilize rain gages throughout the basin to create more events based rainfalls that could then be entered into the HEC-RAS model.

1.8 SYSTEM STATUS FOR EXISTING LEVEES & FLOODWALLS

Table 10 compares the Existing conditions FRM projects that include levees/floodwalls. If the FRM Line of Protection is overtopped, the system descriptor is “Flooded”, if the water does not overtop the Line of Protection, the descriptor is “Dry”.

“-” number indicates amount of overtopping, approximate maximum. So negative is bad.
“+” number indicated amount of minimum Freeboard remaining, or good

Table 10: Existing Flood Risk Management Project Status

System	1% Annual Exceedance Probability Flood	0.2% Annual Exceedance Probability Flood
Binghamton	**Flooded** Range -2.1 ft to +4.2 ft	**Flooded** Range -5.1 ft to -0.7 ft
Endicott	Dry, +4.3 ft	Dry, -0.4 ft
Johnson City	**Dry, not enough freeboard** Range -0.5 ft to 2.8 ft	**Flooded** Range -0.8 ft to -3.1 ft
Vestal	Dry, +3.0 ft	**Flooded**, Range -1.1 to 1.6 ft
Lisle	Dry, +4.7 ft	Dry, +1.6 ft to 7.5 ft
Whitney Point Vil.	Dry, +3.3 ft	**Flooded**, -3.6 ft
Nichols	Dry, +4.9 ft	Dry, +2 ft to 9.9 ft

CHAPTER 2 FUTURE WITHOUT PROJECT CONDITIONS

The future without project (FWOP) condition is a forecast of conditions anticipated if no action is taken, starting from the base year to the end of the period of analysis, normally 50 years for USACE Civil works projects. The future without project forms the baseline from which “alternative plans are formulated and impacts are assessed” (ER1105-2-100, 2000). Considerations during this period of analysis include evaluating changes in hydrology (i.e. precipitation, streamflow, and future storm conditions), population, land use/land cover, and socioeconomic conditions in the future that may affect formulation or potential impacts from flood risk management projects. This section summarized FWOP considerations for hydrology based on existing literature and analysis conducted for the USRB. Considerations for other factors is included in Appendix B Economics.

2.1 CLIMATE CHANGE CONSIDERATIONS IN USRB

The USACE projects, programs, missions, and operations have generally proven to be resilient enough against natural variability over their operating life spans. However, recent scientific evidence shows that in some places and for some impacts relevant to USACE operations, climate change is shifting the climatological baseline about which natural climate variability occurs, and may be changing the range of that variability as well. Engineering Construction Bulletin (ECB) No. 2016-25 (USACE 2016) updated in 2018 (ECB 2018-14) provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaption policy. The ECB guidance requires a qualitative analysis for all hydrologic studies to support the planning and engineering decisions. The ECB has the goal of identifying whether there is a trend in flows and the positive or negative direction of any detected trend. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant climatic and hydrologic variables. The flow chart of the USACE climate change assessments from ECB No. 2016-25 and ECB 2018-14 is shown in Figure 21 below.

The USRB feasibility study examines whether any modifications to the existing flood management system in the basin would result in additional flood damage reduction and increased public safety. Recent events such as the heavy rains associated with Hurricane Irene (August 27-29, 2011) shows vulnerabilities to extreme flood events in the region. These heavy rains are part of a broader pattern of wet weather preceding the storm (rainfall totals for August and September exceeded 25 inches across much of the Northeast) that left the region predisposed to extreme flooding from Irene. Any flow regime changes due to climate change in the Susquehanna River Basin will impact the level protection afforded by the existing or future flood management projects.

In addition to the required qualitative analysis using USACE tools, the historic unregulated stream flow trends were analyzed. Eight USGS stream gages currently in operation in the upper reach of the Susquehanna River basin within the area covered by this study were analyzed to determine flow frequency relationships and their future trends based on historic records. The USGS period of record for the stream gages was used to determine the peak flow frequency relationships for the 0.2, 0.4, 1.0, 2.0, 4.0, 10, 20, and 50 percent chance exceedance events.

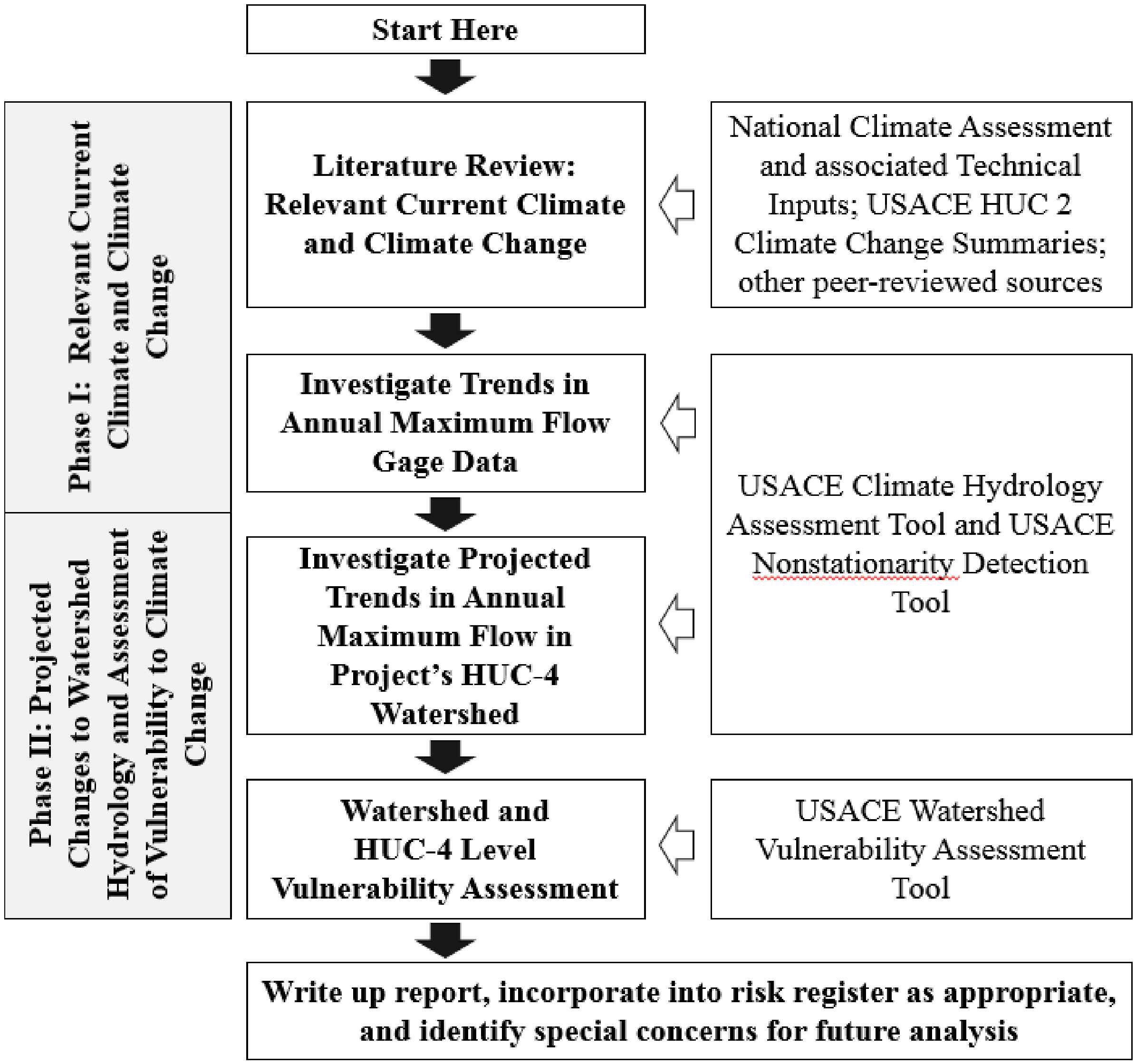


Figure 21: Flow Chart of the USACE Climate Change Assessments

There are two USACE reservoirs in the USRB - Whitney Point Lake and East Sidney Lake that regulate flows for portions of the basin. The Whitney Point reservoir is located on the Otselic River in Broome County, New York, and controls a drainage area of 255 square miles. It is primarily operated for flood management, but is also used for recreation and upland wildlife management. This dam provides flood damage reduction for the valley along the lower Tioughnioga River, the lower Chenango River, and the Susquehanna River downstream of Binghamton. The project was completed in 1942. East Sidney Dam is located on Ouleout Creek in Delaware County, New York and controls a drainage area of 102 square miles. The reservoir was operationally complete in April 1950. Recreational facilities were available starting in May 1965.

The effect of regulation of these flood control reservoirs on peak flows at the USGS gages was considered. A homogenous data set was created by adjusting the flow data since the dams were operationally complete, Whitney Point in 1942 and East Sidney in 1950, to reflect flows that would have occurred without the reservoir regulation. This was done by using a relationship between natural (unregulated) and existing (regulated) conditions developed using historic records collected by USACE for both reservoirs. A natural conditions peak flow frequency curve for each of the USGS gages affected by regulation was produced using the Log Pearson Type III distribution and a regulated flow frequency curve was generated graphically. This produced an existing (regulated) conditions peak flow frequency relationships for the USGS stream gages affected by Whitney Point and East Sidney. For the peak flow trend analysis, unregulated flow was computed and utilized. Because this study may lead to additional Flood Risk Management Projects, future trends in peak discharge will have impact on project design and their performance during their life cycle.

2.2 LITERATURE REVIEW

The National Climate Assessment - The Global Change Research Act of 1990 mandates that the U.S. Global Change Research Program (USGCRP) deliver a report to Congress and the President every four years on climate change and its impact on the United States. The Fourth National Climate Assessment (NCA4) fulfills that mandate in two volumes. Volume I, the *Climate Science Special Report (CSSR)* describes foundational science behind climate change. Volume II focuses on the human welfare, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics, with particular attention paid to observed and projected risks, impacts, consideration of risk reduction, and implications under different mitigation alternatives. The NCA4 report helps inform decision-makers, utility and natural resource managers, public health officials, emergency planners, and other stakeholders by providing a thorough examination of the effects of climate change on the United States.

According to the NCA4 report on Region 2, The Chesapeake Bay watershed is experiencing stronger and more frequent storms, an increase in heavy precipitation events, increasing bay water temperatures, and a rise in sea level. These trends vary throughout the watershed and over time but are expected to continue over the next century under all scenarios considered.

A synthesis of peer-reviewed climate change literature for the Mid-Atlantic region HUC 0205 (USACE, 2015c), based on the identification and detection of climate trends in recent historical record, indicates the following trends observed over the past century: increases in the annual temperature in the Mid-Atlantic Region (particularly over the past 40 years), with an increase in the number of extreme heat days and a decrease in the number of extreme cold days; and increased precipitation and occurrence of extreme storm events. Despite the increased precipitation in the region, evidence is inconclusive of significant increases in base stream flow over the same period. This is potentially attributed to seasonal differences in the timing of the changes in precipitation versus streamflow.

Predictions by general circulation models indicate consensus that regional air temperatures will increase sharply upward over the next century. There is less consensus on precipitation and streamflow, although most studies project an increase in both and particularly during extreme storm events. There is moderate consensus that peak flows will increase in the region through the 21st century, although low flows are projected to decrease (USACE, 2015c).

Precipitation volume and intensity has increased in the mid-Atlantic region of the Chesapeake watershed over the last century and these trends are projected to continue to the end of the 21st century (NOAA, 2013; Najjar et al., 2010). Simulations for the Chesapeake Bay watershed through the year 2100 predict increased precipitation amounts in winter and spring, as well as increased intensities of precipitation, Nor'easters (though their frequency may decrease), and tropical storms. By 2030, annual mean precipitation may increase by up to 4 percent, with increases of up to 15 percent by 2095 (Najjar et al., 2010).

It is expected that increased air temperatures and frequencies of drought, particularly in the summer months, will result in increased stream water temperatures, potentially affecting dissolved oxygen levels. Higher average and extreme temperatures combined with an increased annual rainfall in the region may lead to higher peak flows as well as more frequent low flows (USACE, 2015c).

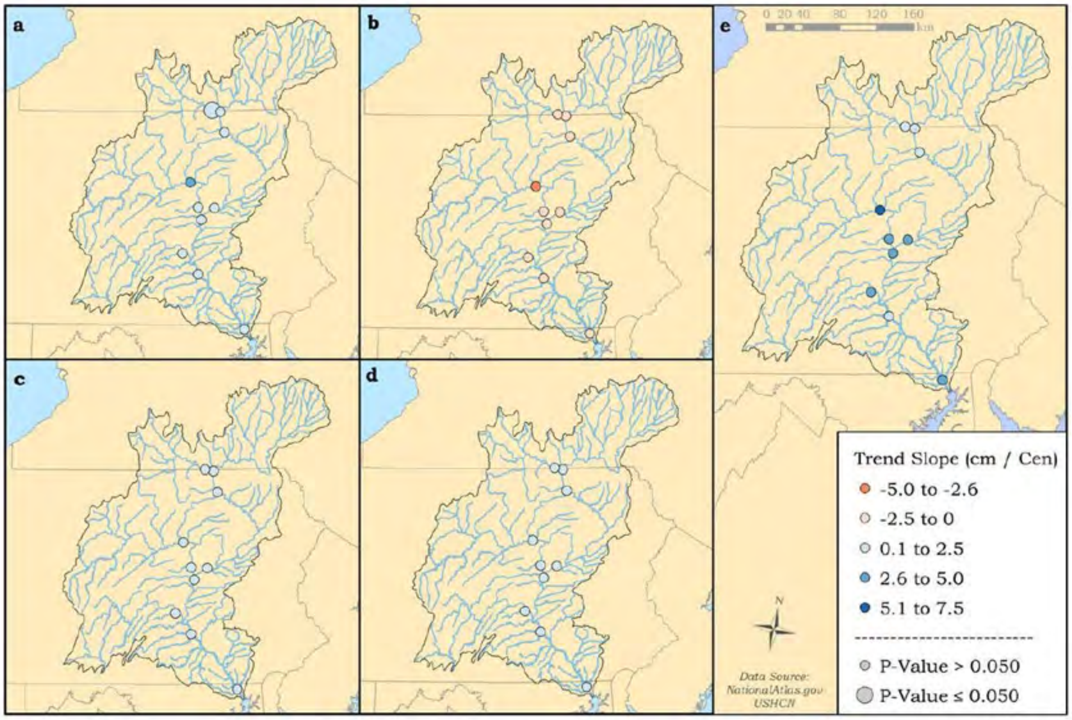


Figure 22: Changes in stream flow for the a) winter, b) spring, c) summer, d) fall and e) Water year from 1932 to 2008 (Source: USACE, 2015c)

2.2.1 FIRST ORDER STATISTICAL ANALYSIS OF TRENDS IN OBSERVED & PROJECTED

The Climate Hydrology Assessment tool (CHAT) [USACE, 2016a] allows users to access data concerning past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. The qualitative analysis required by this ECB includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. A first-order statistical analysis of the potential impacts to particular hydrologic elements of the study can be very useful in considering FWOP and the potential direction of climate change.

The following figures were developed using the Online CHAT. These graphs show an increasing trend in the average annual maximum monthly peak discharge for the overall Susquehanna River Basin (HUC 0205). The P value for the trend line is less than 0.05, indicating the trend is statistically significant.

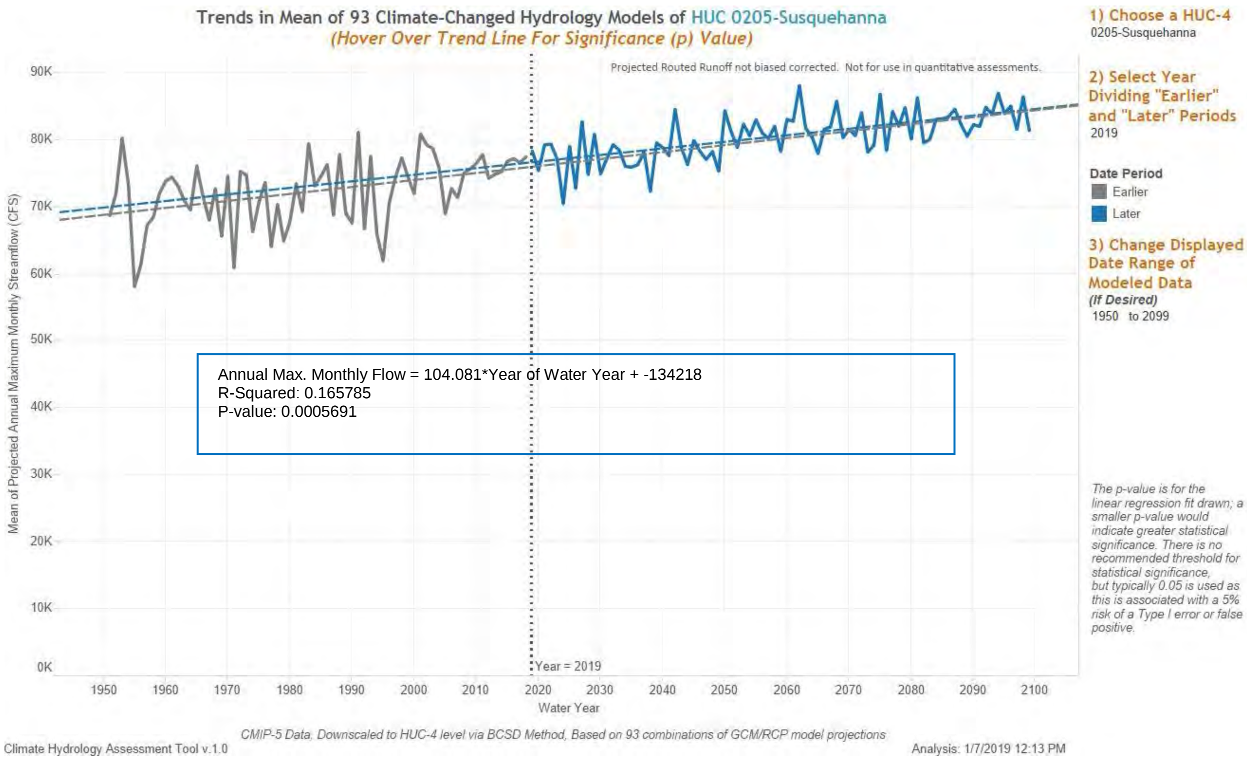


Figure 23: CHAT Projected Climate Change Hydrology Models of Monthly Streamflow in the Susquehanna River Basin (HUC0205)

The following figure shows projected annual Maximum monthly stream flows. It follows the same trend line with a P value less than 0.05. However, the uncertainty with climate changed hydrology is high and not currently, readily quantifiable. The above trend line cannot be used for quantifying the potential changes due to climate change.

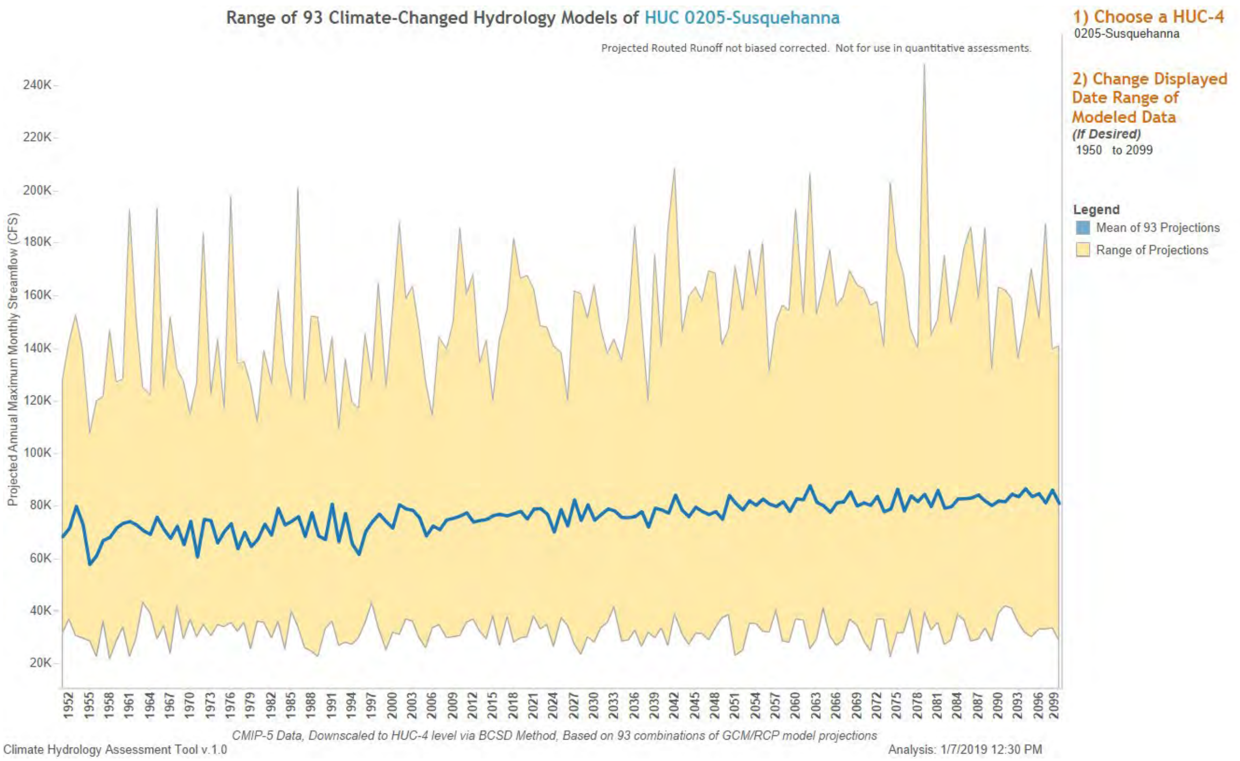


Figure 24: CHAT Projected Climate Change Hydrology Model of Monthly Streamflows with Range in the Susquehanna River Basin (HUC0205)

In addition to the overall watershed assessments, we also reviewed specific gage data along the Susquehanna, Chenango and Tioughnioga rivers. The peak stream flow is an important parameter which affects flood risk management projects. The following gages along with length of record were reviewed for Annual Peak Instantaneous Stream flow using The CHAT:

- Gage 1500000 Ouleout Creek At East Sidney NY, 1941-2018
- Gage 1500500 Susquehanna River At Unadilla NY, 1938-2018
- Gage 1502632 Susquehanna River At Bainbridge NY, 1988-2018
- Gage 1502731 Susquehanna River At Windsor NY, 1988-2018
- Gage 1503000 Susquehanna River At Conklin NY, 1913-2018
- Gage 1505000 Chenango River At Sherburne NY, 1938-2018
- Gage 1507000 Chenango River At Greene NY, 1937-2018
- Gage 1509000 Tioughnioga River At Cortland NY, 1939-2018
- Gage 1511500 Tioughnioga River At Itaska NY, 1929-2018
- Gage 1512500 Chenango River Near Chenango Forks NY, 1913-2018
- Gage 1513500 Susquehanna River At Vestal NY, 1935-2018
- Gage 1513831 Susquehanna River At Owego NY, 1936-2014* gap in data
- Gage 1515000 Susquehanna River Near Waverly NY, 1936-2018

Details of these gage record and their trends are shown in Attachment 3. The following stream gages show an increase in peak discharge over time,

- Gage 1502731 Susquehanna River at Windsor NY, 1988-2014
- Gage 1502632 Susquehanna River At Bainbridge NY, 1988-2018
- Gage 1505000 Chenango River At Sherburne NY, 1938-2018
- Gage 1507000 Chenango River At Greene NY, 1937-2018

Two of the Susquehanna River gages have relatively short periods of record with four of the largest events occurring since the gages has been active (1996, 2004, 2006 and 2011). These larger events within relatively short period of time has a significant impact on the trend line for these gages. In addition, two Chenango River gages with longer periods of record show a positive trend. It should be noted that all 4 gages have p-value greater than 0.05 therefore there is no statistical significance for these trends.

In addition to the CHAT analysis, we also reviewed the following gages near Binghamton independently outside of CHAT tool.

- Gage 1513500 Susquehanna River at Vestal NY, 8-JUL-1935 through 26-FEB-2016
- Gage 1503000 Susquehanna River at Conklin NY, 28-MAR-2013 through 10-APR-2015
- Gage 1512500 Chenango River near Chenango Forks NY, 27-MAR-2013 through 25-FEB-2016
- Gage 1511500 Tioughnioga River at Itaska NY, 8-MAR-1930 through 9-APR-2015

Simple regression analysis was performed with excel, and these stream gages indicate both negative and positive trends within the USRB. With this analyses, the effect of regulation of these flood control reservoirs on peak flows at the USGS gages was considered. A homogenous data set was created by adjusting the flow data since the dams were operationally complete, Whitney Point in 1942 and East Sidney in 1950, to reflect flows that would have occurred without the reservoir regulation. This was done by using a relationship between natural (unregulated) and existing (regulated) conditions developed using historic records collected by the USACE for both reservoirs. The summary of findings are included in Table 11.

Table 11: Regression Analysis Results for Selected Stream Gages in USRB

Gage Locations	Trend	Projected Change in 50 years	R^2
Gage 1513500 Susquehanna River at Vestal NY	Negative	-1.70%	0.0005
Gage 1503000 Susquehanna River at Conklin NY	Negative	-1.40%	0.0005
Gage 1512500 Chenango River near Chenango Forks NY	Positive	1.30%	0.0004
Gage 1511500 Tioughnioga River at Itaska NY	Negative	-15%	0.0176

R^2 value for these trend lines are too low to explain much of the variance in these gage records thus trend may be associated with changes in land use and land cover or other factors that may be affecting the stream record. Details of these analysis are shown in Attachment 3.

2.2.2 NON-STATIONARITY DETECTION TOOL

The USACE Nonstationarity Detection (NSD) Tool (USACE, 2016b) enables the user to apply a series of statistical tests to assess the stationarity of annual instantaneous peak streamflow data series at any United States Geological Survey (USGS) streamflow gage site with more than 30 years of annual instantaneous peak streamflow records through Water Year 2014. The tool helps practitioners in identifying continuous periods of statistically homogenous (stationary) annual instantaneous peak streamflow datasets that can be adopted for further hydrologic analysis. The tool also allows users to conduct monotonic trend analyses on the identified subsets of stationary flow records.

The NSD Tool for the USRB Project in New York detected several nonstationarities starting around the mid 1960's. Nonstationarities indicate that past conditions may not represent future conditions. The nonstationarities that occurred for the available gages were investigated and it was determined that they occurred at a time that coincided with either the construction of a reservoir, or factors within the region. Here is the summary results of NSD tool findings:

- Gage 1500000 Ouleout Creek At East Sidney NY, 1941-2014
    - Nonstationarity detected in the 1940's which can be attributed to the filling of the newly constructed Whitney Point Dam completed in 1942.
    - Also strong nonstationarity detected in the mid-1990s. Most likely caused by regulation during large event.
    - Monotonic trend analysis shows no significant trend exists.
- Gage 1503000 Susquehanna River At Conklin NY, 1913-2014
    - Nonstationarity detected 1960s, however it is not clear what caused it.
    - Monotonic trend analysis shows no significant trend exists.
- Gage 1505000 Chenango River At Sherburne NY, 1938-2014
    - No strong nonstationarity detected.
    - Monotonic trend analysis shows no significant trend exists.
- Gage 1507000 Chenango River At Greene NY, 1937-2014
    - No strong nonstationarity detected.
    - Monotonic trend analysis shows no significant trend exists.
- Gage 1509000 Tioughnioga River At Cortland NY, 1939-2014
    - No strong nonstationarity detected.
    - Monotonic trend analysis shows no significant trend exists.
- Gage 1512500 Chenango River Near Chenango Forks NY, 1913-2014
    - Nonstationarity detected around the 1960s, however it is not clear what caused it.
    - Monotonic trend analysis shows no significant trend exists.
- Gage 1513500 Susquehanna River At Vestal NY, 1935-2014

- Nonstationarity detected in the 1960s, however it is not clear what caused it.
- Monotonic trend analysis shows no significant trend exists.

2.2.3 CLIMATE CHANGE VULNERABILITY ASSESSMENT AT THE WATERSHED-SCALE

The USACE Watershed Climate Vulnerability Assessment (VA) Tool facilitates a screening level, comparative assessment of the vulnerability of a given HUC 04 watershed to the impacts of climate change relative to a maximum of 202 HUC04 watersheds within the continental United States (CONUS). The HUC04 watershed used in the Vulnerability Assessment analysis is the Susquehanna River watershed (HUC 0205). The tool can be used to assess the vulnerability of a specific USACE business line, such as Flood Risk Reduction, Ecosystem Restoration, and Navigation, to projected climate change impacts. Assessments using this tool identify and characterize specific climate threats and sensitivities or vulnerabilities, at least in a relative sense, across regions and business lines.

The Watershed Vulnerability tool uses the Weighted Order Weighted Average (WOWA) method to represent a composite index of how vulnerable (vulnerability score) a given HUC04 watershed is to climate change specific to a given business line by using a set of specific indicator variables which relate to a particular business line. The HUC04 watersheds with the top 20% of WOWA scores are flagged as vulnerable. All vulnerability assessment analyses were performed using the National Standard Settings (USACE, 2016b).

Indicators considered within the WOWA score for Flood Risk Reduction include: the acres of urban area within the floodplain, the coefficient of variation in cumulative annual flow, runoff elasticity (ratio of streamflow runoff to precipitation), and two indicators of flood magnification (indicator of how much high flows are projected to change overtime). Additional information about each of these indicator variables and how they are used to determine a WOWA score is described in the Vulnerability Assessment User Manual (USACE, 2016b).

The USACE Climate Vulnerability Assessment Tool makes an assessment for two 30-year epochs centered at 2050 and 2085 to judge future risk due to climate change. These two epochs are selected to be consistent with many other national and international analyses related to climate. The Vulnerability tool assesses climate change vulnerability for a given business line using climate changed hydrology based on a combination of projected climate outputs from the General Circulation Models (GCM) and representative concentration pathway (RCPs) of greenhouse gas emissions resulting in 100 traces per watershed per time period. The top 50% of the traces are called “wet” and the bottom 50% of traces are called “dry.” Meteorological data projected by the GCMs is translated into runoff using the Variable Infiltration Capacity (VIC) macroscale hydrologic model. The VIC model applied to generate the results used by the Vulnerability Assessment Tool was developed by the U.S. Bureau of Reclamation and is configured to model unregulated basin conditions.

Based on the USACE Screening-Level Climate Change Vulnerability Assessment Tool (USACE, HUC4 level), the Susquehanna River watershed (HUC 0205) is not in the top 20 percent of vulnerability ratings, but is still expected to experience changes related to climate change, as identified above.

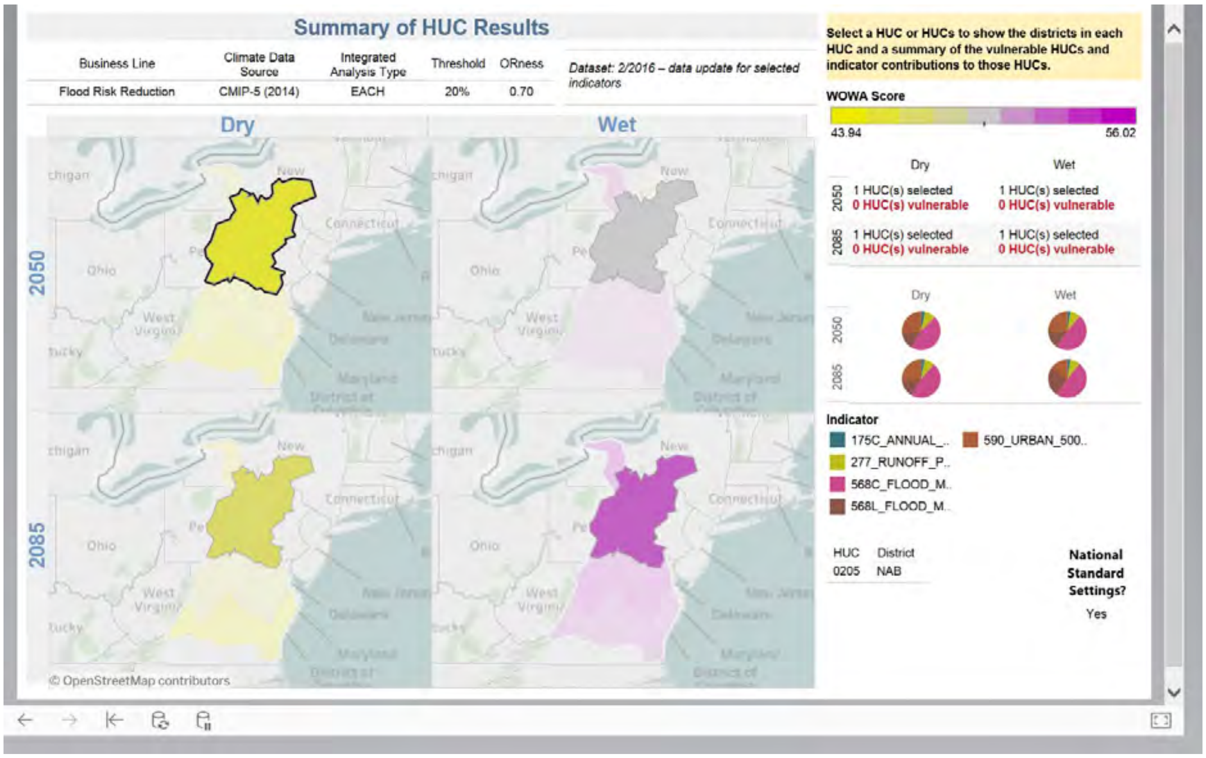


Figure 25: Climate Vulnerability Tool Results for Susquehanna River Basin

There is a great deal of uncertainty with the climate change hydrology given by the vulnerability assessment tool. Each of the inputs to the vulnerability assessment tool has uncertainty associated with it. The vulnerability tool relies on projected, climate change hydrology. The uncertainty associated with projected hydrologic data includes error in temporal downscaling, errors in spatial downscaling, errors in the hydrologic modeling, errors associated with emissions scenarios, and errors associated with GCMs. Beyond the uncertainties associated with the inputs to the vulnerability assessment tool, the analysis also contains substantial uncertainty inherent in the exact level of risk aversion selected (ORness factor) and the importance weights applied. Some users may elect to use a higher level of risk aversion while others may not. The results of these tools are only for qualitative assessments and not for quantitative assessments due to all of these uncertainties.

Because the USRB study is intended for flood hazard mitigation, the Flood Risk Reduction business line was analyzed for this watershed. Although not in the top 20%, some vulnerability still exists within the Susquehanna River watershed for future climate changes. The results of the assessment show that the USRB could become more vulnerable over the period 2050 to 2085, under both relatively drier and wetter conditions, with greater vulnerability resulting from wetter conditions. The primary factors associated with vulnerability in this analysis were the percent of urban area within the 500-yr floodplain (per FEMA) and the flood magnification factor determined based on Vogel et al. (2011).

2.3 CONCLUSIONS

Based on the literature review, regression analysis, climate hydrology assessment, nonstationarity analysis, and vulnerability assessment it appears that climate change is a factor in the USRB and is likely to persist in the future. Climate change affects many variables; therefore, the extent of the impact from climate change is difficult to quantify. Determining the impact of climate change on flood risk management projects is hard because of the complex interactions between hydro-climatic variables and watershed characteristics. Portions of this assessment indicate that flood risk has increased and may continue to increase in the future, however, other information presented in this assessment indicates that there is a great deal of uncertainty associated with determining how the basin's hydrology will respond to climate change.

The increase in observed temperature is the strongest evidence that climate change is evident in the basin. The literature review indicates that precipitation increased over the observed period of record and is projected to increase in the future as a result of climate change. For New York USGS Gage (1513500), the four highest ranking flooding events occurred along Susquehanna River at Vestal within last 22 years. For New York USGS Gage (1503000), the top 2 flooding events occurred along Susquehanna River at Conklin within the last 12 years. More extreme events have occurred in recent years and the climate hydrology assessment tool predicts increases in projected annual maximum monthly flows during the next century.

The interaction between streamflow, precipitation, and temperature illustrates that there is some uncertainty with predicting future flood flows. While precipitation increased during the observed record and may continue to increase in the future, increases in temperature and evapotranspiration may potentially outweigh watershed runoff which could reduce flood risk. The effects from increases in temperature also have the ability to alter flood risk in the basin. Results from the vulnerability assessment tool do not indicate that Flood Risk Reduction in the USRB is highly vulnerable to the effects of climate change and variability relative to other watersheds in the United States.

The nonstationarity tool detected a strong change point in the1940's at the USGS gage at East Sidney, New York, which coincides with the construction of the Whitney Point Dam. Also strong nonstationarity was detected in the mid1990s for the same USGS gage, most likely caused by regulation during large events. In addition, nonstationarity was detected in the 1960s for USGS gages at Conklin, Chenango Forks and Vestal, New York, however it is not clear what caused them.

The nonstationarity detected in the 1960s and 1990s and cannot be attributed to a specific driver based on this analysis. In addition to anthropogenic climate change, land use change, land cover change, changes in drainage patterns, changes in channel geomorphology, and natural fluctuations in climate can all contribute to nonstationarity within a flow record. For example, the USRB has undergone significant land use changes due to reforestation over the past century which may affect nonstationarity of flows in the basin.

Methods of quantitatively accounting for climate change impacts or long-term persistent climate trends in an engineering analysis are not currently outlined in USACE guidance; however, NYSDEC and local government may wish to take on this responsibility based on the information provided. It is recommended that the USACE project team and local water resources agencies seek cost effective opportunities to build resiliency into flood risk reduction projects to account for added uncertainty in future flood risk characterization due to climate change and other land use related impacts on the basin's hydrology. While five of the largest events have occurred since the 1990's, much uncertainty remains when examining the peak flow frequency under the future scenarios. Current evidence does not support any specific increase of peak flows due to climate change. Therefore, FWOP peak discharge for USRB study would remain same as existing condition peak discharge.

CHAPTER 3 STRUCTURAL ENGINEERING

3.1 STRUCTURAL ENGINEERING NARRATIVE FOR CONCEPTUAL DESIGNS

The structural support effort for the Binghamton conceptual design began with a site visit performed in July 2018 by the civil, geotechnical, and structural engineers from NAB. The observations made and discussions which took place during the site visit, along with research into the as-built drawings and available topographical and mapping data, served as the basis for the concept plan developed by the civil engineer. After the development of this overall plan, the primary objective of structural support for the conceptual design was to design floodwall sections for each segment along the line of protection where a floodwall was designated, and provide input into the subsequent cost estimate.

At many locations in the three systems (Northeast, Northwest, and South) within the project area, there is an existing floodwall in place which offers an insufficient level of protection. In these areas, the wall/levee profiles and existing as-built drawings were used to determine the appropriate approach for raising the level of protection, whether it be raising an existing structure or replacing in-kind at the new design elevation. In some cases, the reaches designated in the civil plan were further sub-divided for the purposes of the structural design and estimate, as varying ground elevations dictated different structural approaches or wall heights.

The determination whether to raise the existing wall or replace in-kind was based on the height of the required raising compared to the height of the existing wall, assuming that the wall was visually observed to be in sound condition during the site visit. In sections where the raising height is only one or two feet, or where the existing wall is particularly high, for example, the determination was made that the existing foundation and structure is sufficient to handle the increased loads associated with raising the wall. A summary of the assumed approach for each reach within the three systems is shown in the attached table.

A typical raising will consist of roughening the concrete surface at the top of the wall, drilling vertical holes in 2 longitudinal rows into the top of the wall at approximately 24 inch spacing for new epoxy-grouted rebar, and pouring a new reinforced cast-in-place concrete wall section on top of the existing wall, matching the existing wall thickness.

In sections where the wall will be replaced in-kind, the new floodwall height was determined based on the required design elevation, the ground elevation from the wall profiles, and the minimum required frost depth for the region. The wall thickness and foundation dimensions are based on engineering experience and on concept-level calculations based on typical riverine flood load cases. The foundation width is conservatively assumed to be the same as the vertical stem wall height above the foundation. The stem wall thickness and foundation thickness vary between 1.5 and 2.5 feet as the height of the wall increases. Quantities for excavation and formwork for casting concrete are based on the floodwall dimensions established by these parameters. Additionally, a reinforcing ratio of 0.003 was assumed in all floodwall sections in order to estimate the quantity of steel reinforcing.

In the majority of cases where an existing wall is being replaced, there appears to be sufficient real estate to construct the new wall on the land side of the existing line of protection and demolish the existing wall once the new wall is completed. For the purposes of the concept design and cost estimate, this was the assumed approach. Further development of the design will require verification of this approach, subject to real estate constraints and customer preference. If it is ultimately required or preferred to replace the existing walls within the same footprint, additional effort will be required and cost incurred to provide temporary flood protection during demolition and subsequent construction of the new wall.

In locations where an existing closure in the floodwall will have to be raised, a similar analysis to that utilized for the walls themselves was performed in order to determine whether raising or replacement in-kind of the closure structure is the recommended approach. In the majority of cases where an existing stoplog closure is present, the determination was made that providing additional stoplogs to the new design height is sufficient, along with replacement of the intermediate vertical supports. In new sections of floodwall, or where raising the existing closure is not feasible, either a new stoplog closure (for shorter closures or where limited real estate controls) or a new roller gate closure is included in the estimate. During design, a more detailed analysis of the immediate area around each closure and customer feedback on the cost and manpower requirements for the different closure types will dictate the type of closure selected.

Table 12: Northeast Binghamton Alternative 2-1 Recommended Approach

Northeast Binghamton (Susquehanna)		
Station	**Recommended approach**	**Wall height above grade**
Sta 0+00 to 10+00	New wall	10 ft.
Sta 10+00 to 21+00	Raising	-
Sta 29+50 to 44+00	New wall	10 ft.
Sta 68+00 to 76+00	New wall	17 ft.
Sta 76+00 to 83+50	New wall	14 ft.
Sta 83+50 to 91+00	New wall	8 ft.
Sta 91+00 to 107+00	New wall	17 ft.
Sta 107+00 to 113+00	New wall	15 ft.
Sta 113+00 to 117+00	New wall	5 ft.
Northeast Binghamton (Chenango)		
Station	**Recommended approach**	**Wall height above grade**
Sta 200+00 to 208+00	New wall	7 ft.
Sta 208+00 to 215+00	Raising	-
Sta 215+00 to 219+00	New wall	8 ft.
Sta 219+00 to 221+00	Raising	-
Sta 221+00 to 237+00	Raising	-
Sta 237+00 to 257+00	New wall	3 ft.

Table 13: South Binghamton Alternative 2-1 Recommended Approach

Station	Recommended approach	Wall height above grade
Sta. 45+50 to 50+00	New wall	7 ft.
Sta 50+00 to 59+00	New wall	10 ft.
Sta 59+00 to 62+00	New wall	12 ft.
Sta 62+00 to 64+00	New wall	9 ft.
Sta 64+00 to 66+00	New wall	7 ft.
Sta 66+00 to 68+00	New wall	5 ft.
Sta 80+00 to 84+30	Raising	-
Sta 84+30 to 85+50	New wall	13 ft.
Sta 85+50 to 87+50	New wall	10 ft.

Table 14: Northwest Binghamton Alternative 2-1 Recommended Approach

Station	Recommended approach	Wall height above grade
Sta. 00+00 to 04+00	New wall	12 ft.
Sta. 04+00 to 10+00	New wall	6 ft.
Sta. 10+00 to 15+00	New wall	10 ft.
Sta. 15+00 to 17+00	New wall	5 ft.
Sta. 29+50 to 40+00	Raising	-

CHAPTER 4 MECHANICAL ENGINEERING

NOTES: Pump information based upon an e-mailed spreadsheet received from the sponsor in 19 November 2018. No interior pumping activity is included. Previous names of pump stations can be found in the Binghamton O&M manual.

Binghamton Northeast Section
Pennsylvania Avenue pump station (Susquehanna & Water Streets, 206+10). Pump station contains 2 pumps at 15,000 gallons per minute (gpm) each-150 horse power (HP) nameplate and 2 pumps at 6,500 gpm each-85 HP nameplate.

Thompkins Street (Brandywine, Frederick, & Bevier). Pump station contains 2 pumps at 15,000 gpm each-125 HP nameplate.

Upper Court Street. Pump station contains 2 pumps at 12,000 gpm each. Motor size not indicated.

Port Dickinson-King Street. Pump station contains 1 pump at 660 gpm. Motor size 7.5 HP nameplate.

Binghamton South System
Jackson Street (Webster Street, 97+30). Pump station contains 2 pumps at 10,000 gpm each- 100 HP nameplate.

Binghamton Northwest Section
South McDonald Avenue (East Clinton Street). Pump station contains 2 pumps at 3,100 gpm each-75 HP nameplate.

Trout Brook (McDonald Avenue). Pump station contains 2 pumps at 21,000 gpm each-150 HP nameplate.

Utilities
Reviewing some of the photos it is clear that some of the levee raisings will require pole line relocations. It is not clear if there is sufficient space on the street side of the levee to allow relocation in accordance with the requirements of the electrical utility.

In addition there may be natural gas lines in the vicinity of some of the levees. Gas lines penetrating a levee or a levee toe may have to be relocated because of increased soil pressure. The gas utility will have to be involved to provide mapping and to determine what relocations are necessary. Street boxes providing access for valves will not be buried which means they would have to be extended vertically upward to the new surface.

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CHAPTER 5 CIVIL ENGINEERING

Introduction

The Civil Engineering Section investigated the feasibility of modifying the existing Binghamton flood risk management to provide protection for the 100-year storm event. This investigation was limited to a conceptual analysis.

The Binghamton project consists of three hydraulically connected systems known as Northeast, South, and Northwest Binghamton. In total, the existing project consists of approximately 19,000 linear feet of levees and 14,000 linear feet of floodwalls.

Surveys and Mapping

The Pittsburgh District field surveyed the centerline of the levees and the top of the floodwalls at the following projects: Binghamton, Endicott-Johnson City-Vestal, Greene, Lisle, Nichols, Oxford, and Whitney Point Village. Horizontal control was based on New York State Plane, Central Zone. Vertical control was based on NAVD88. This survey was used to identify which levees and floodwalls would need to be raised.

NAB Planning Division provided additional mapping consisting of LIDAR contours for the Binghamton project. These contours were imported into Autocad Civil3D to create an approximate terrain surface. This mapping was only used to depict contours and assist in developing estimated construction quantities.

Study Baseline

Baselines were established in AutoCAD Civil 3D, running along the approximate centerline of the levees and floodwalls. These were developed for the purpose of creating profiles and cross-sections.

Top of Levee/Floodwall Profiles

The H&H Engineer provided a spreadsheet showing the 100-year water surface elevation plus freeboard at every HEC-RAS section.

Site Visit

On July 23 and July 24, 2018, a site visit was scheduled to view all of the levees and floodwalls while making conceptual design decisions on how to raise or re-build them. New levee/floodwall tie-in locations were also investigated.

Concept Drawings

Plan view drawings for all three systems were developed at a scale of 1”= 50’. These drawings show the study baselines, contours, and aerial imagery.

AutoCAD Civil 3D profiles of all the levees and floodwalls were created using both the LIDAR data and the field survey data. The H&H section provided the top of levee/floodwall profile. Using this data, a 3D polyline representing the top of levee/wall was created and superimposed onto the levee and floodwall profiles. This profile was used to identify which levees and floodwalls would need to be raised. Areas where no levees or floodwalls exist, but new ones are needed, were also identified.

Conceptual cross-sections were developed for the purpose of estimating construction quantities for the levee raisings.

Estimated Construction Quantites
Based on the concept drawings, construction quantities for the levee raisings were developed (included in Attachment 6).

5.1 NORTHEAST BINGHAMTON, SUSQUEHANNA RIVER

Stationing begins with 0+00 at North Shore Bridge and proceeds eastward.

Existing floodwall sta. 0+00 to 5+00 Susquehanna, estimate raising 3' to 4':
Raising the wall at the confluence of the Susquehanna and Chenango may require a closure structure at the Memorial Bridge on North Shore Drive, shown below.

It may be possible to avoid a closure if the floodwall is extended parallel to the bridge where it can tie into the bridge abutment like it does on the north side of the bridge. Would need a survey of the bridge deck to verify that it is high enough.

The small pedestrian closure just east of the bridge will need to be raised.

According to NYSDEC, North Shore Drive will likely be re-built and located further inland, allowing for a levee alternative.

A closure will be needed at the Washington Street pedestrian bridge. It may make sense to remove the jog in the floodwall at the Washington Street pedestrian bridge. This will require changing the bike path and sidewalk locations to minimize closure structures.

Existing floodwall sta.5+00 to 10+00 Susquehanna, estimated raising 3’ to 4’:

There is some room to build a new wall on the riverside of the existing wall, but there will be hydraulic impacts. Locating it landward would require shifting North Shore Drive. According to NYSDEC, North Shore Drive will likely be re-built and located further inland, allowing for a levee alternative.

Existing floodwall sta. 10+00 to 21+00 Susquehanna, estimate raising 1’ to 2’:

There is some room to build a new wall on the riverside of the existing wall, but there will be hydraulic impacts. Locating it landward would require shifting North Shore Drive.

According to NYSDEC, North Shore Drive will likely be re-built and located further inland, allowing for a levee alternative.

There is adequate clearance beneath the State Street/Vestal Pkwy Bridge for raising the wall:

Existing levee sta. 21+00 to 29+50 Susquehanna, estimate raising 2.5’ to 3

Should be able to expand levee a bit riverward, but not much room landward.

Closure at Exchange Street, Susquehanna River, will need to be raised:

Existing floodwall sta. 29+50 to 41+50 Susquehanna, estimate raising 3’ to 3.5’:

If a new wall is needed, there is room to locate it riverward from 29+50 to 36+00.

According to NYSDEC, North Shore Drive will likely be re-built and located further inland, allowing for a levee alternative.

From sta. 36+00 Susquehanna onward, there is room to locate a new wall landward of the existing wall:

It looks like the wall will need to be extended to sta. 44+00 to tie into high ground. According to NYSDEC, North Shore Drive will likely be re-built and located further inland, allowing for a levee alternative.

Sta. 44+00 to 65+00 Susquehanna, no existing levees or floodwalls:

The 100 year water surface elevation is estimated to be 849.5 to 850. No levees are needed.

A low closure will be needed at Tompkins Street, Susquehanna River. The wall will need to be extended across Tompkins Street to tie into high ground at 65+00.

The pump station at 68+00 may need to be modified, and the surrounding wall raised (estimated 3.5'):

Existing floodwall sta.68+00 to 83+50 Susquehanna, estimated raising 3.5 ’:

Sta. 83+50 to 117+00 Susquehanna, no existing levees or floodwalls:

The 100-year water surface elevation is estimated at 851 to 852. The development north of Court street sits at elevation 845. Although the crest of the adjacent railroad embankment is around elevation 855, it may not be capable of acting as a levee, and the crest is probably not high enough to provide enough freeboard/superiority. For conceptual design, it is assumed that a new floodwall/levee is required from 83+50 to 117+00. A closure structure will be needed at the railroad spur near sta. 114+00.

Existing levee sta. 117+00 to 124+50 Susquehanna, estimate raising 2.5':

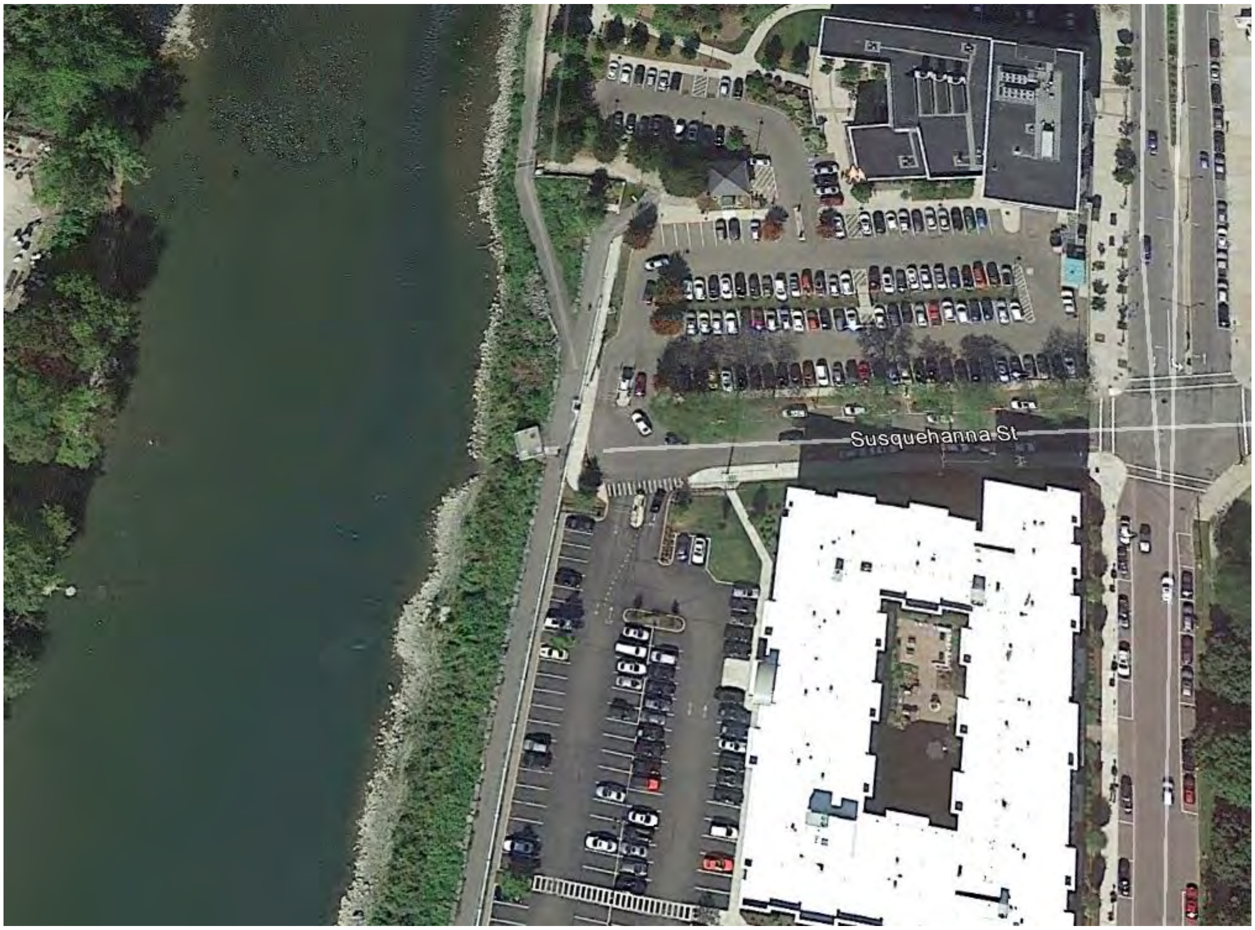
To raise the levee, it would have to be expanded to the west side due to the adjacent concrete channel. Closures at the railroad and at Court Street will need to be raised. The levee north of Court Street would need to be extended northward to tie into high ground.

5.2 NORTHEAST BINGHAMTON, CHENANGO RIVER

Stationing begins with 200+00 at the Memorial Bridge on North Shore Drive and proceeds northward. The wall currently ties into Memorial Bridge. Raising it may require a closure. A survey will be needed to see if bridge deck is high enough.

Existing floodwall sta. 200+00 Chenango (North Shore Drive) to 221+00 (Court Street), estimate raising 2.5’ to 3.5’:

Pump station sta. 206+00 Chenango may need to be modified. Estimated wall raising 2.5’ to 3.5’:



There is a paved walking path on the riverside of the wall, and parking lots with paved paths on the landside.

Based on the LIDAR data, a closure may not be needed at the Court Street Bridge, Chenango River. Should survey to verify.

Existing floodwall sta. 221+00 Chenango (Court St) to 237+00 (Clinton St), estimated raising 2.5’ to 4’:

A paved pedestrian path runs along the landside of the wall.

A closure structure will be needed at Clinton Street, Chenango:

The wall show above is not a floodwall. It is part of the bridge railing. The floodwall ties into high ground just to the left of the picture.

Existing floodwall sta. 237+00 Chenango (Clinton St) to 257+00, estimated raising 2.5' to 3.5':

Will need to extend the wall to the new closure at Clinton Street.

Not sure if the wall can be raised without affecting the overhead railroad bridge at 242+00. Should do a detailed survey of the bridge abutment and low steel, and obtain close-up photos. Consider tying it into the vertical face of the bridge abutment rather than passing beneath it.

Not much room to work between 243+00 and 248+00 Chenango.

Existing levee sta. 257+00 to 265+00 Chenango, no raising:

Existing levee sta. 265+00 to 296+00 Chenango, estimated raising 0.5’ to 2’:

The riverside slope has large flat riprap from 273+00 to 296+00. The crest is paved from 257+00 to 281+00. When raising the levee, there is room to expand the footprint on the riverside. The landside will likely require real estate.
The levee will need to be extended at 296+00 to tie into high ground.

Sta. 296+00 to 338+00 Chenango, no levee or floodwall exists. The 100-year water surface elevation is estimated at el. 852 to 853. Levees are not needed.

Existing levee sta. 338+00 to sta. 367+00 Chenango, estimated raising negligible.

If areas need some raising, there is room to expand the levee on either side.

Existing pump station sta. 354+00. Estimated levee raising negligible:

Sta. 367+00 to 393+00 Chenango, no levee exists. The estimated 100-year water surface elevation is 352. No levee is needed for the most part. One house on Mill Street near sta. 378+00 may be affected.

Existing levee sta. 393+00 to 402+50 Chenango, no raising needed:

There is a sandbag closure at Chenango Street.

The original levee extended east of Route 7 to tie into high ground. It may have been neglected over the years since Route 7 was constructed. If the levee is raised, the tie out should be investigated.

Estimated Construction Quantities

Based on the concept drawings, construction quantities for the levee raisings were developed (included in Attachment 6).

5.3 NORTHWEST BINGHAMTON

Stationing begins with 0+00 approximately 900-feet south of the railroad bridge, and proceeds north.

The existing floodwall starts at the north side of the railroad bridge abutment. Raising the wall by 3.5-feet means that the railroad abutment/embankment will no longer act as high ground. Therefore the floodwall will have to be extended south in order to tie into high ground

Station 0+50 to 10+00: No wall exists. A new wall will be needed. A closure structure will be needed across Clinton St.

Existing pumping station, sta. 5+00:

The existing wall begins at the railroad bridge abutment, sta. 10+00. Estimated raising 3.5-feet:

Raising the wall by 3.5-feet would probably prohibit putting the wall below the girder. Will need to investigate how to tie the raised wall into the railroad abutment/embankment so as to provide a continuous line of protection through the abutment/embankment. Recommend doing a detailed survey of the abutment.

Existing floodwall sta.10+00 to 17+00 at McDonald Avenue, estimated raising 3.5':

Most of this floodwall is not part of the federal project. It was constructed by the City of Binghamton.

Existing levee sta.17+00 to 29+50, estimated raising 1' to 2':

Riverside has concrete revetment. There appears to be room for raising the levee on the landside. Utility poles may have to be relocated.

Existing pump station sta.17+00, estimated floodwall raising, 1' to 2':

Existing floodwall sta. 29+50 to 40+00, estimated raising 1.5':

According to NYSDEC, the floodwall between 31+00 and 35+50 lies along property where a building has been recently demolished and the land is owned by the city. NYSDEC would like to look at a levee alternative in this area. It appears that a levee would fit, but the landside slope would need to be 2.5:1, and the riverside slope would need to be 2:1 to minimize obstruction of the channel. It is assumed that a riprap revetment is required.

Existing floodwall sta. 29+50 to 40+00, estimated raising 1.5’

The north end of the USACE floodwall ties into a taller concrete highway wall, which appears to tie into high ground. Should survey top of the wall to verify that it is high enough, and investigate whether this wall can function as a floodwall.

Concrete highway wall:

5.4 SOUTH BINGHAMTON

Stationing begins with 9+00 at the western end of the levee and proceeds east

Existing levee sta. 9+50 to 25+00, estimated raising up to 1.5':

The existing levee ties into the high point of the Vestal Parkway embankment. Based on LIDAR data, the proposed raising at the parkway is approximately 1'. Putting a closure structure across a highway is undesirable. One alternative may be to raise the parkway with an asphalt overlay. A survey of the highway crest should be done to verify the amount of raising needed.

Existing levee sta. 25+00 to 45+50, estimated raising less than 0.5’ if any:

May only need to raise a small portion of the levee where it ties into a floodwall at sta. 45+50.

Existing pump station, sta. 43+00. Estimated levee raising negligible:

Existing floodwall sta. 45+50 to 50+00 (Washington St), estimated raising 2’ to 3’

Notice how the levee was designed with more freeboard than the floodwall.

The wall crosses Park Creek at sta. 46+00. This should be investigated for potential flooding caused by backwater:

The closure at Washington Street will need to be raised:

Existing floodwall sta. 50+00 (Washington St) to sta.59+00 (Vestal Pkwy), estimated raising 3’ to 4’:

If a new wall is needed, there is room on both sides of the existing wall.

There is adequate clearance to raise the wall beneath Vestal Pkwy.

At the request of NYSDEC, a levee alternative was briefly explored. It appears that a levee with 2.5:1 side slopes will fit, however the landside toe will likely encroach upon the sidewalk along Conklin Avenue.

Existing floodwall sta. 59+00 (Vestal Pkwy) to 66+00 (Exchange St), estimated raising 3.5' to 4':

There is room on both sides of existing wall. Will need to extend raised wall to tie into high ground around sta. 68+00. No closure needed at Exchange St.
At the request of NYSDEC, a levee alternative was briefly explored. It appears that a levee with 2.5: 1 side slopes will fit, however the landside toe will encroach upon the sidewalk along Conklin Avenue.

Sta. 66+00 (Exchange St) to 80+00, no levee or floodwall exists. Estimated 100-year water surface elevation is 849. No levee is needed. Diner appears to be above the floodplain.

Existing wall sta. 80+00 to sta. 84+30 (Crowley's building), no levee or floodwall exists:

The existing brick wall is not a floodwall. The 100-year water surface elevation is 849. It appears that the Crowley building may have a low opening at the NE corner that is below that elevation. Investigate flood proofing of the building, or extend floodwall around the building. For the purpose of this study, the latter was chosen.

Existing floodwall sta. 84+30 to 87+50, estimated raising 3.5’ to 4’

The old floodwall (foreground in the picture) begins at a concrete headwall for a drainage pipe. The adjacent wall that connects to the Crowley building is not a floodwall.

Raising the floodwall will require a tie-out into high ground near the Crowley building.

Existing levee sta. 87+50 to 115+00 (Tompkins St), estimated raising 1.5' to 2':

Existing pump station, sta. 97+00, estimated raising 1.5' to 2':

A closure will be required at Tompkins Street:

Existing levee sta. 116+00 to 138+00, estimated raising 2' to 3':

This levee ties into Homer Street which acts as a levee. Raising the levee would require raising Homer Street by 3.5' to 4', but that would cause problems with driveways, and would leave some properties unprotected. To avoid raising Homer Street, a levee/floodwall could be run along the west side of Pierce Creek, likely requiring real estate.

Homer Street levee:

5.5 BINGHAMTON FRM PROJECT RAISING CONCEPT DESIGNS

ALTERNATIVE 2-A: BINGHAMTON FRM PROJECT LEVEE AND FLOODWALL RAISING

The following figures summarize the locations and estimated heights for raising the levees and floodwalls in the Binghamton FRM project in Alternative 2-A.

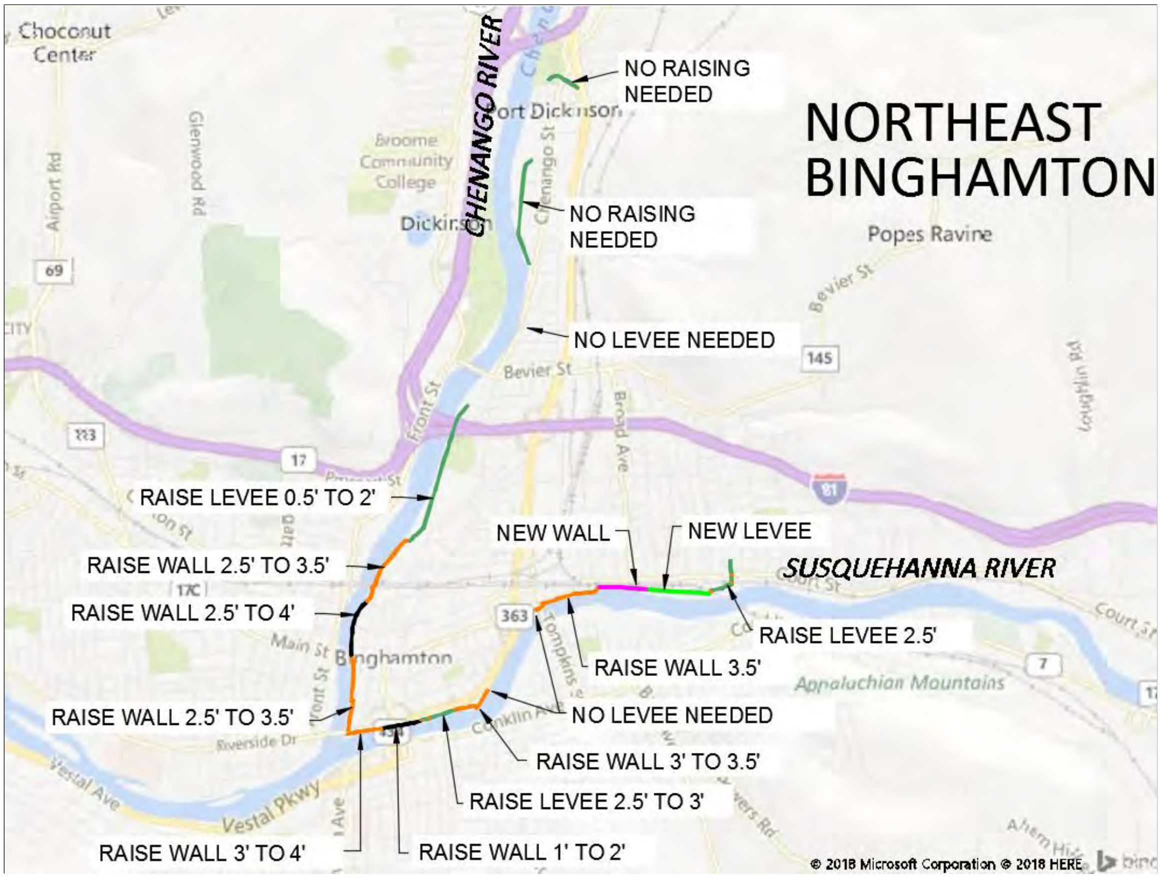


Figure 26: Northeast Binghamton Proposed Raising Concept Design

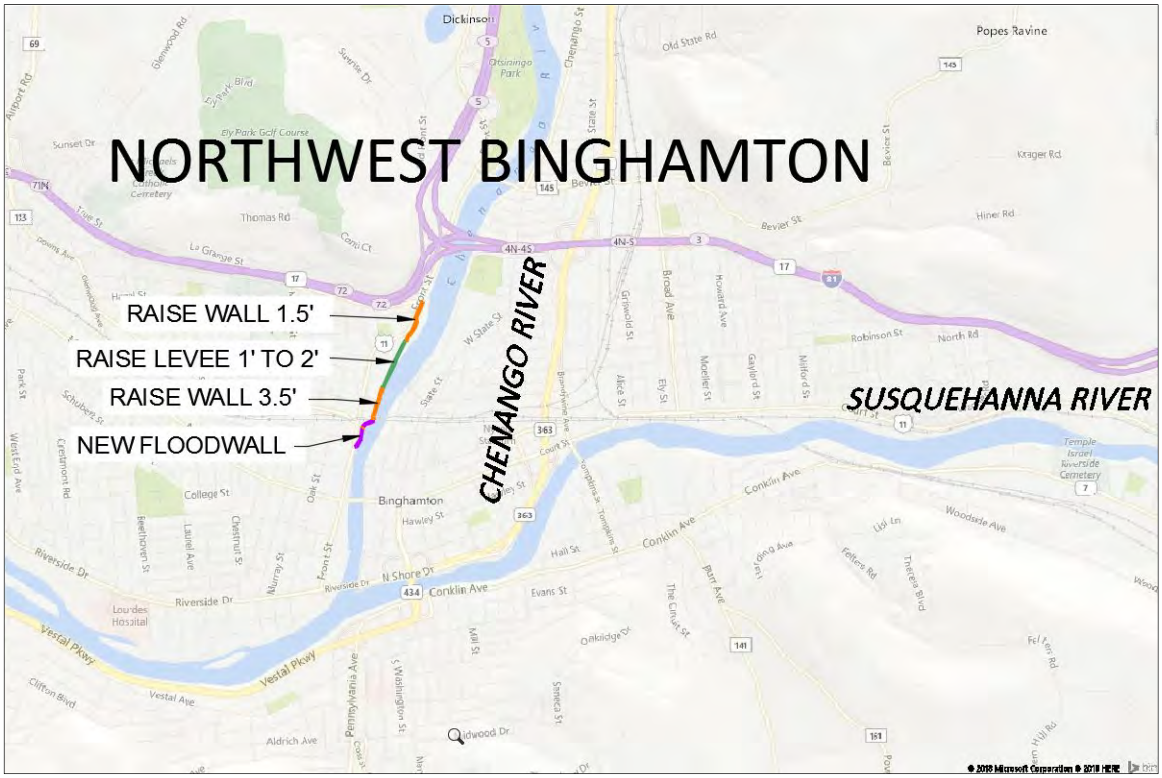


Figure 27: Northwest Binghamton Proposed Raising Concept Design

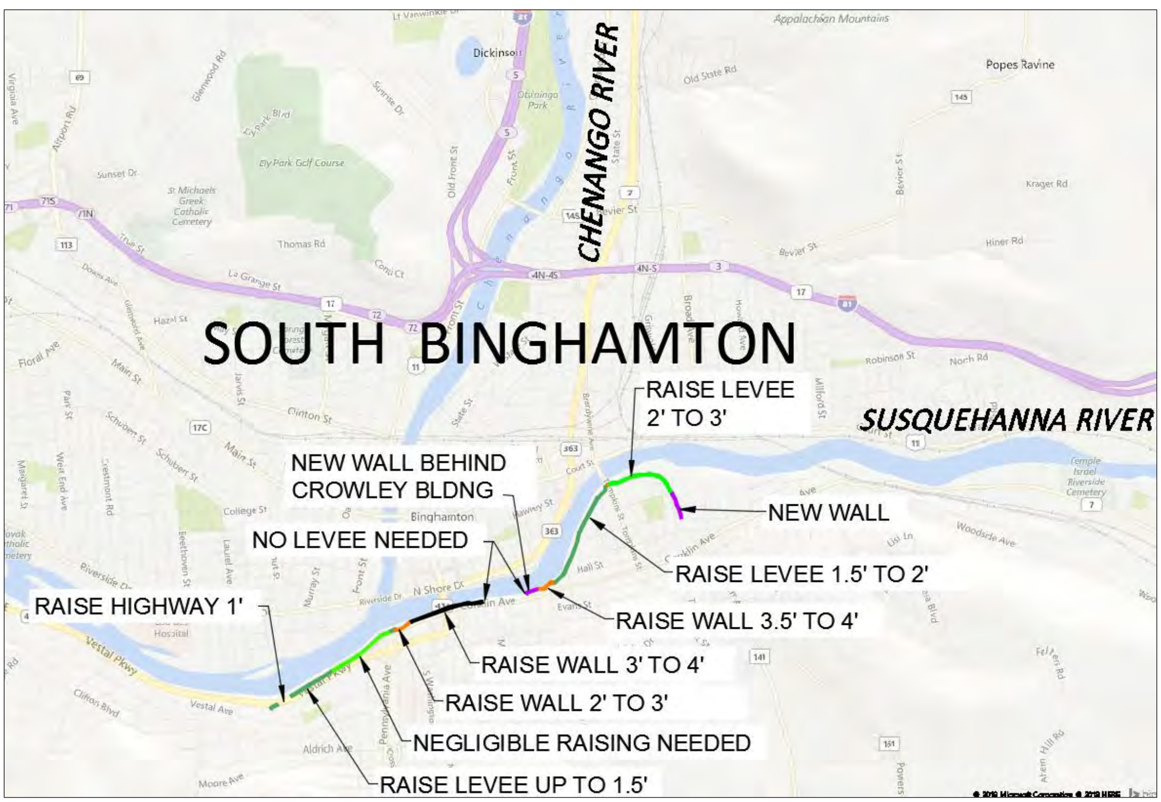


Figure 28: South Binghamton Proposed Raising Concept Design

ALTERNATIVE 2-B: BINGHAMTON FRM PROJECT LEVEE AND FLOODWALL RAISING, WITH REPLACEMENT OF FLOODWALLS WITH LEVEES AT SELECT LOCATIONS

USACE and NYSDEC engineers discussed the possibility of replacing floodwalls with levees at some locations, under the assumption that costs would be substantially reduced by that design change. Concept designs were updated in Alternative 2-B to include levee and floodwall raising and replacement of some floodwalls with levees in each of the systems.

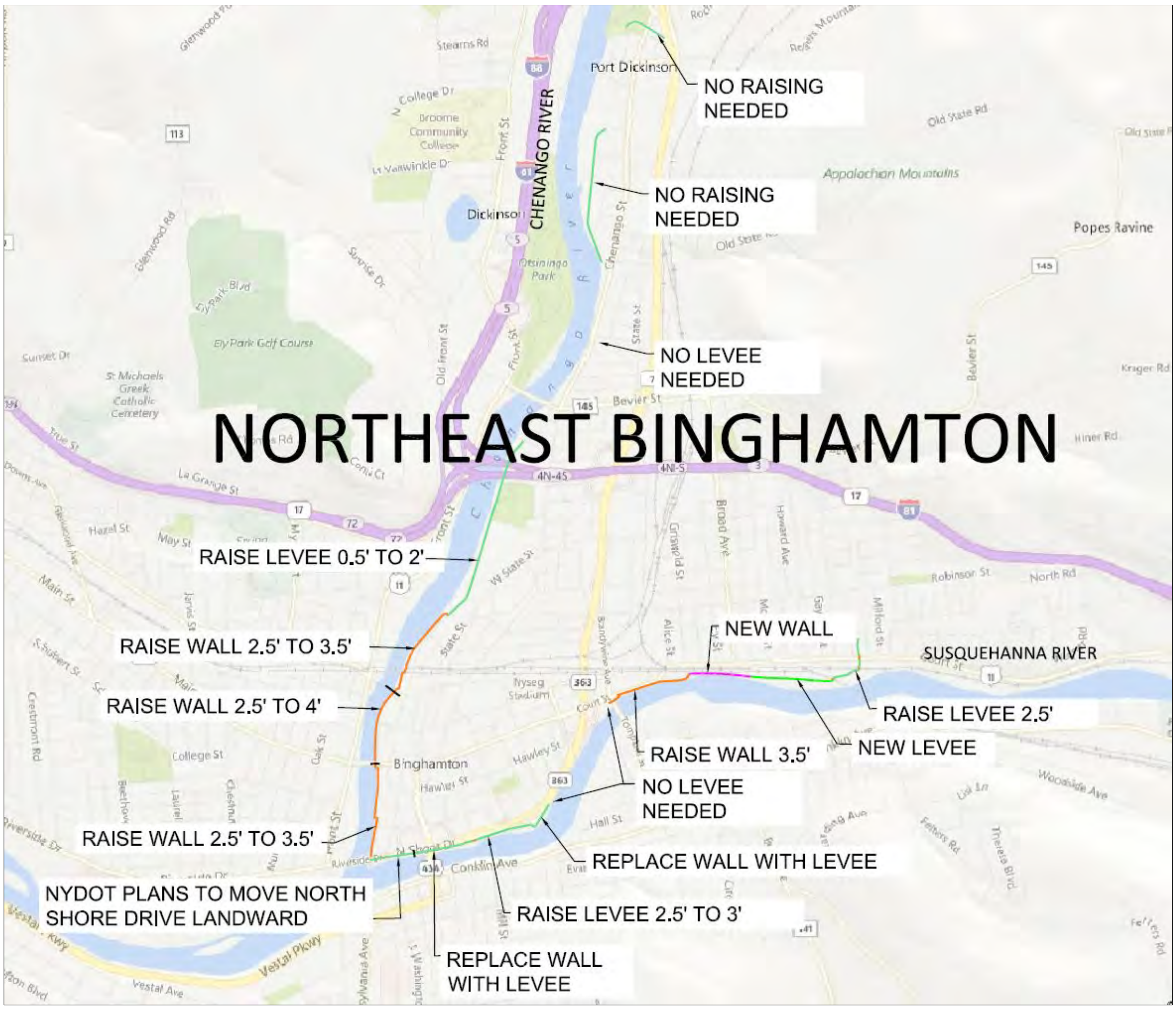


Figure 29: Northeast Binghamton Concept Designs for Levee System Raisings

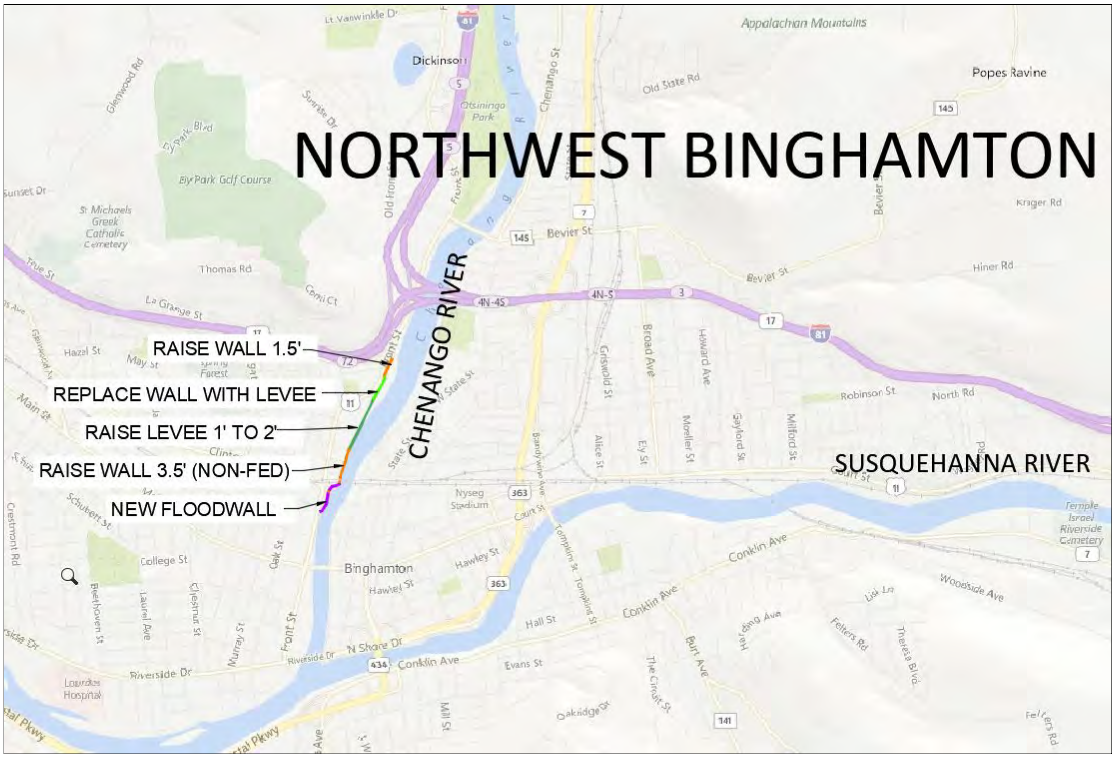


Figure 30: Northwest Binghamton Concept Designs for Levee System Raising

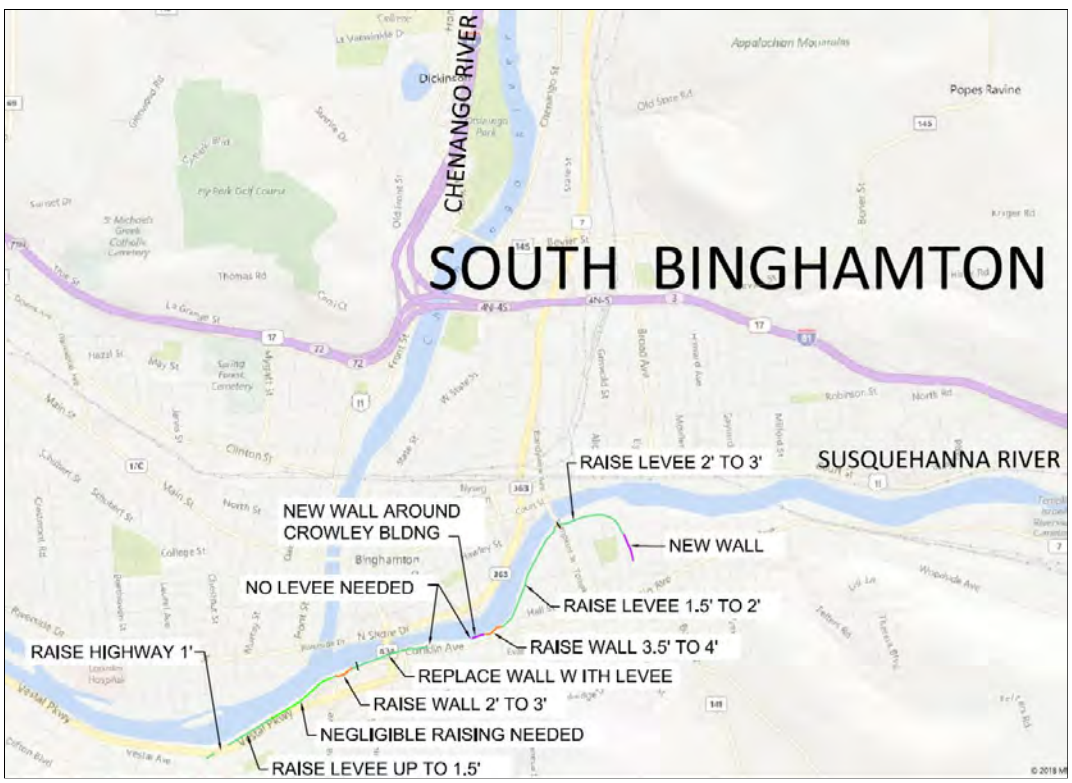


Figure 31: South Binghamton Concept Designs for Levee System Raising

CHAPTER 6 COST ENGINEERING

The Concept Alternatives for the USRB Project includes the following civil works feature accounts:

- Account 01. Land and Damages. Real estate survey has not been done and is estimated by 1% of the total of all construction costs including account 05, 11, 13, and 15, as a placeholder in the Total Project Cost Summary (TPCS) Excel file. The 1% is based on estimator's best judgment. It is not included in the M-CACES Second Generation (MII) estimate file.

- Account 02. Relocations. There is no utility survey and relocation, and it is estimated by 5% of the total of all other construction costs including account 11, 13, and 15, as a placeholder in the TPCS Excel file. The 5% is based on estimator's best judgment. It is not included in the MII estimate file.

- Account 11. Levees and Floodwalls. The proposed project alignment for Northeast, Northwest, and South of Binghamton include walls and levee constructions for multiple areas. As far as flood wall construction goes, new T-wall with shallow foundation were used. In some areas, existing T-wall were raised a few feet. Preliminary length and quantities of the concrete walls were provided by Baltimore District structural engineer. Preliminary length and quantities of the levees were provided by Baltimore District civil engineer. Preliminary quantity take-offs for the wall and levee were conservatively estimated based on a conceptual design of the proposed lengths for wall and levee. In cases of a levee or a floodwall being near a body of water, water diversion such as cofferdams and sandbags were added to the MII estimate. Street intersections in busy parts of town where project alignment is crossing may need traffic control, which is estimated by assuming that new traffic signals, vehicle barriers, and flagmen may be needed. All costs in connection with construction work for floodwalls and levees were estimated in MII using MII software, Cost Book Library 2016, latest local Davis Bacon wage rates and fuel prices.

<u>NOTE:</u> Account 13 was initially used for cost estimating of pump stations, but since the pump stations are locally operated and maintained and not part of the authorized project, it was not deemed necessary for cost estimating after the fact.

- Account 13. Pumping Plant. The NAO preliminary estimate for a pump station in Freemanson, Norfolk VA with two 48" pumps (45,000 gpm) at 3rd quarter, 2014 price level was used to parametrically estimate pump stations for some of the areas in the project alignment. The size of concrete sump chamber, sluice gates, pipes, electrical, and other appropriate items are adjusted to accommodate the new number of pumps. Since large cost items such as the pumps themselves were obtained through quotes, no escalation on material was used on the pump to bring it to present value. Since cost items were repriced using 2016 Cost Book, latest Davis Bacon wage rates, and latest fuel prices, the price level for labor and equipment costs of this account is considered at Quarter 1 2019. Therefore only escalation on material is needed to bring material costs from Quarter 1 2016 to Quarter 1 2019. Civil Works Construction Cost Index System (CWCCIS) Escalation Calculation dated 31 Mar 2018 for account 13 was used.

- Account 15. Floodway Control - Diversion Structures. In some areas, the project alignment requires street roller closure gates or stop logs. Roller gate closure structures were also parametrically estimated by size adjustment and historical cost from the MII bid box estimate for Plot and Green Ridge Contract 1 by Baltimore District. The stop log closures were parametrically estimated by size adjustment and historical cost from the Belle Haven Flood Damage Reduction Study (in VA), escalated to Quarter 1 2019. The costs for the roller gates are escalated by using escalation factors from CWCCIS Escalation Calculation dated 31 Mar 2018 for account 13 to bring historical costs to date.

6.1 CONSTRUCTION COST ESTIMATE METHODS

The following methodology is used in the preparation of the concept cost estimates for different alternatives for the USRB study:

a. The estimate is in accordance with the guidance contained in ER 1110-2-1302, Civil Works Cost Engineering.

b. The estimate is presented in Civil Works Work Breakdown Structure.

c. The price level for the estimate is in 1st Quarter of FY2019.

d. Construction costs developed by Estimating and Specifications Section, Engineering Division, Baltimore District are based on a concept design developed by NAB Engineering team. Unit costs are developed using the M-CACES Second Generation (MII) software containing the 2016 English Cost Book Library which was used as a starting point. Historical cost data from similar projects are used for parametric estimate, and vendor quotes were used for non-Cost Book data. The estimate is documented with notes to explain the assumed construction methods, crews, productivity, and other specific information. The intent is to provide or convey a “fair and reasonable” estimate that which depicts the local market conditions.

e. Labor costs are based on the National Labor Library which is updated with latest Davis Bacon wage rates for Binghamton, New York.

f. Bid competition: No contracting plan is done at this point. Bidding competition may be unrestricted since the overall work is typical to the area and the large size of the project will likely draw multiple national level large size contractors to bid on the project. The estimate is however conservatively assumed that most work will be subcontracted. The risk assessment due to competition is reflected accordingly in the Abbreviated Risk Analysis.

g. Contract Acquisition Strategy: Acquisition strategy is not yet determined at this point. However Prime Contractor is conservatively assumed to perform minimal earth work and will sub-contract out all remaining work.

h. Labor Shortages: It is assumed that there will be a normal labor market in this area.

i. Materials: Most material costs are from the Cost Book Library. Vendor quotes were used for non-Cost Book items such as Aqua Barrier and Portadam rent costs. Assumptions include:
    1. Rent materials will be part of the construction contract. No government furnished materials are assumed. Quoted delivery charge is used for hauling cost.
    2. Materials will be rented from local nearest available sources.
    3. Hauling: most hauling will be done by trucks. For trucking, it is assumed that the average speed is 30 mph factoring traffic hours in often congested major routes.

j. Equipment: Rates used are based from the latest USACE EP-1110-1-8, Region II. Adjustments are made for fuel and facility capital cost of money (FCCM). Judicious use of owned verses rental rates was considered based on typical contractor usage and local equipment availability. Full FCCM/Cost of Money rate is latest available; MII program takes EP recommended discount, no other adjustments have been made to the FCCM.

k. Fuels (gasoline, on and off-road diesel) were based on local market averages for on-road and off-road fuels in Binghamton, NY. Since fuels fluctuate irrationally, an average was used.

l. Major crew and productivity rates were developed and studied by senior USACE estimators familiar with the type of work. Most of the work is typical to the USACE. The crews and productivities were checked by local NAB estimators, discussions with contractors and comparisons with historical cost data. Major crews include concrete work, hauling, earthwork, and planting.

m. Most crew work hours are assumed to be 8 hours. 5 days/week which is typical to the area. It is anticipated that no overtime is required for reasons such as time of year restriction because there are none.

n. Mobilization and demobilization: Contractor mobilization and demobilization are based on the assumption that most of the contractors will take about one 8 hours a day to mobilize and one 8 hour a day to demobilize. Mobilization and demobilization cost is also estimated from 1% to 5% of total construction costs depending the size of work.

o. Field Office Overhead: Typically civil works project has field office overhead ranging from 9% to 11%. Since this project is a larger than the norm, 13% was used for Job Office Overhead. Overhead assumptions may include: Superintendent, office manager, pickups, periodic travel, costs, communications, temporary offices (contractor and government), office furniture, office supplies, computers and software, as-built drawings and minor designs, tool trailers, staging setup, camp and kitchen maintenance and utilities, utility service, toilets, safety equipment, security and fencing, small hand and power tools, project signs, traffic control, surveys, temp fuel tank station, generators, compressors, lighting, and minor miscellaneous.

p. Home Office Overhead (HOOH): Since project could be treated as multiple small segments, typical percentage was used (5% to 7%) for HOOH. The rates are based upon estimating and negotiating experience, and consultation with local construction representatives.

q. Profit: Since the Construction Cost Estimate is currently in a budgetary phase, profit is included at 10% for Prime Contractor. However, because general expectation is that there may be some competition, 9% profit on subcontracted work was considered.

r. Sales Tax: Only State sales tax was applied. No local sales tax was included in the estimate.

s. Bond: Bond is calculated using Bond Table in MII for the Prime contractor.

t. Contingency: Contingency is based the outcome of the Abbreviated Risk Analysis for the Alternatives.

u. Escalation: No escalation to midpoint of construction according to tentative construction start dates is included in the MII estimate and non-MII estimates (placeholders calculated by % of construction cost for account 01 and 02). Escalation will only be included in the TPCS to avoid duplicates.

v. HTRW: Hazardous, Toxic, and Radioactive Waste (HTRW) materials (in soil or in demolitions or in anywhere) were not considered in the MII estimate.

ATTACHMENT 1: SUMMARY HEC-RAS MODEL RESULTS

-RESULTS FORTHCOMING-

ATTACHMENT 2: HEC-SSP COINCIDENT PEAK ANALYSIS

-RESULTS FORTHCOMING-

ATTACHMENT 3: CLIMATE HYDROLOGY ASSESSMENT TOOL ANALYSIS

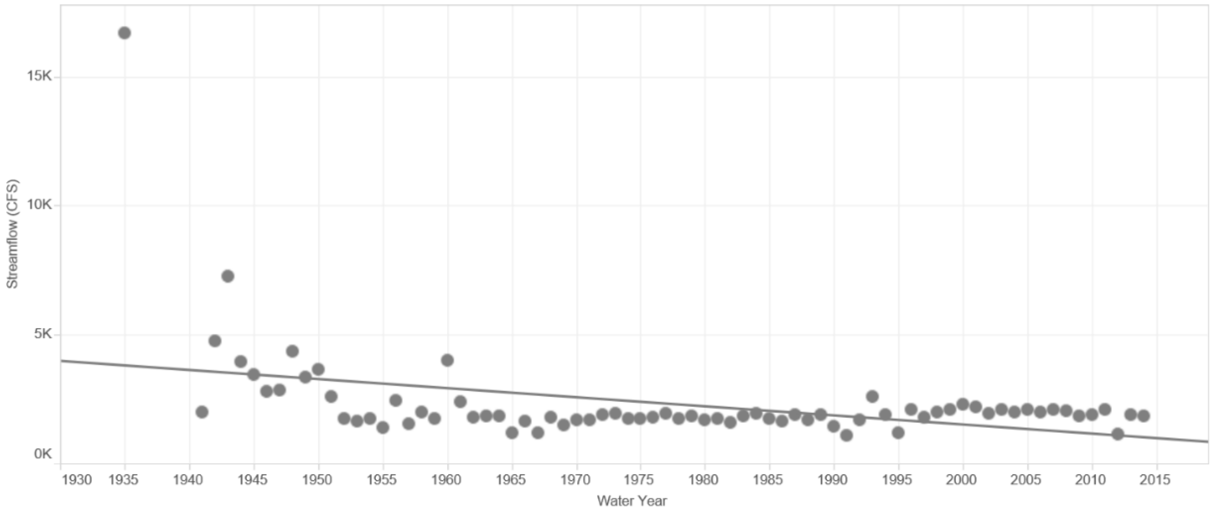
MIDATLANTIC REGION

The Climate Hydrology Assessment tool allows users to access data concerning past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. The qualitative analysis required by this ECB includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. A first-order statistical analysis of the potential impacts to particular hydrologic elements of the study can be very useful in considering FWOP and the potential direction of climate change.

The figures in the following pages of this attachment were developed using the USACE Climate Hydrology Assessment tool. Trend is detected in observed annual peak instantaneous streamflow for various USGS gages. Here Susquehanna HUC-4 watershed and USGS gauges using the pick list or the map. Hovering over the trend line provides the equation for the line and also an indication of statistical significance

Annual Peak Instantaneous Streamflow, OULEOUT CREEK AT EAST SIDNEY NY Selected

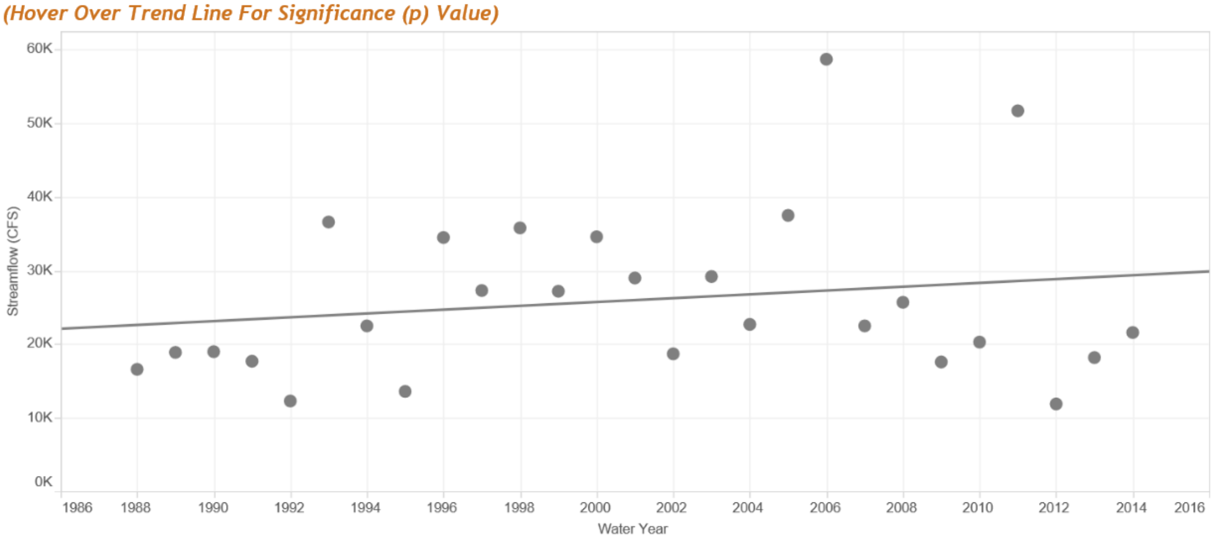
(Hover Over Trend Line For Significance (p) Value)



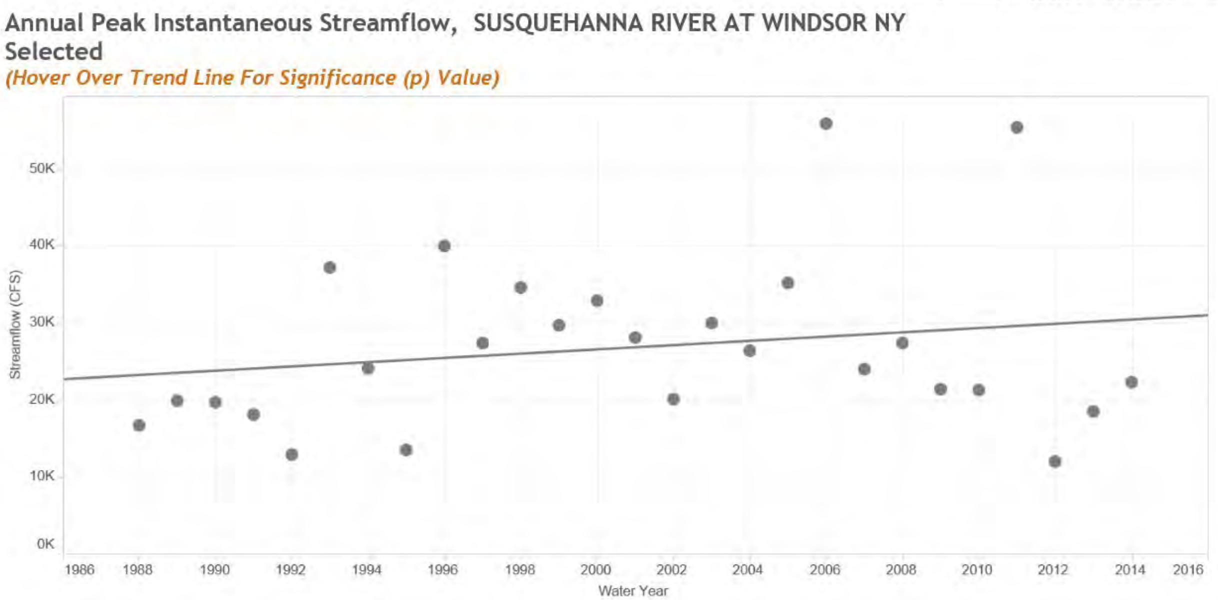
Value = -35.2091*Water Year + 71936.9
R-Squared: 0.16182
P-value: 0.0003467

Annual Peak Instantaneous Streamflow, SUSQUEHANNA RIVER AT BAINBRIDGE NY Selected

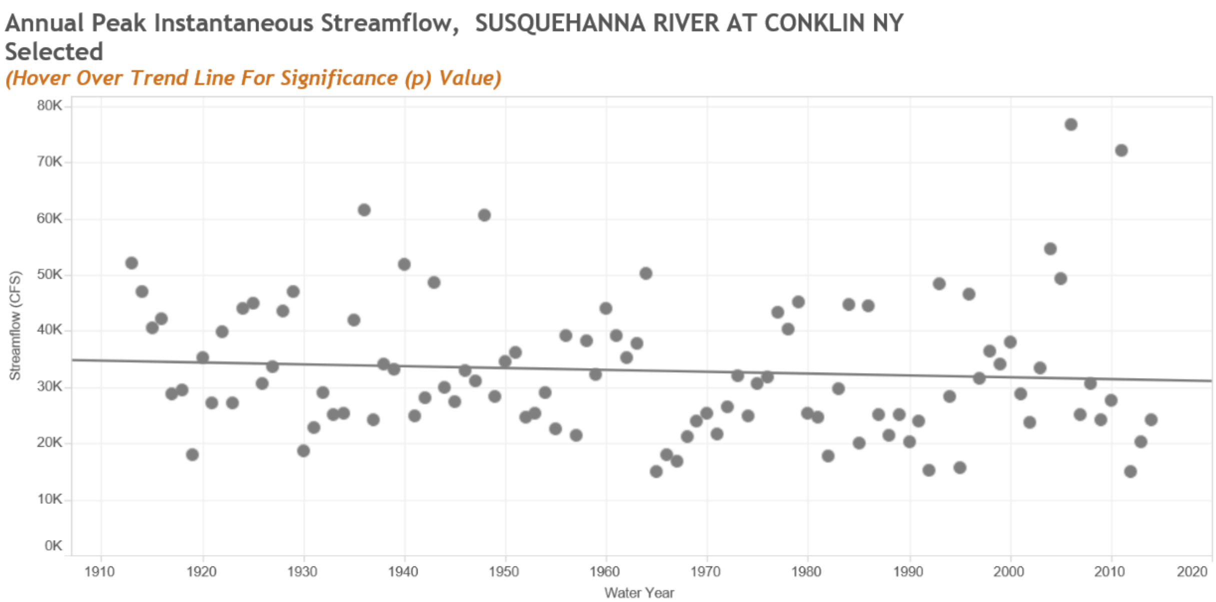
(Hover Over Trend Line For Significance (p) Value)



Value = 259.402*Water Year + -493067
R-Squared: 0.0333197
P-value: 0.362139



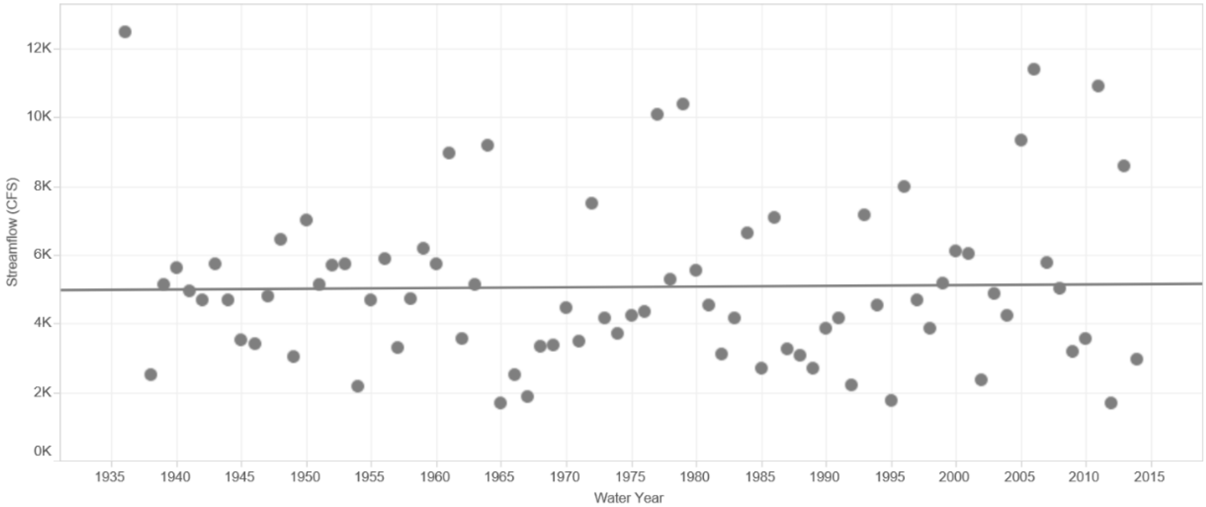
Value = 276.862*Water Year + -527160
R-Squared: 0.0391096
P-value: 0.322768



Value = -32.8751*Water Year + 97489.5
R-Squared: 0.0065354
P-value: 0.41925

Annual Peak Instantaneous Streamflow, CHENANGO RIVER AT SHERBURNE NY Selected

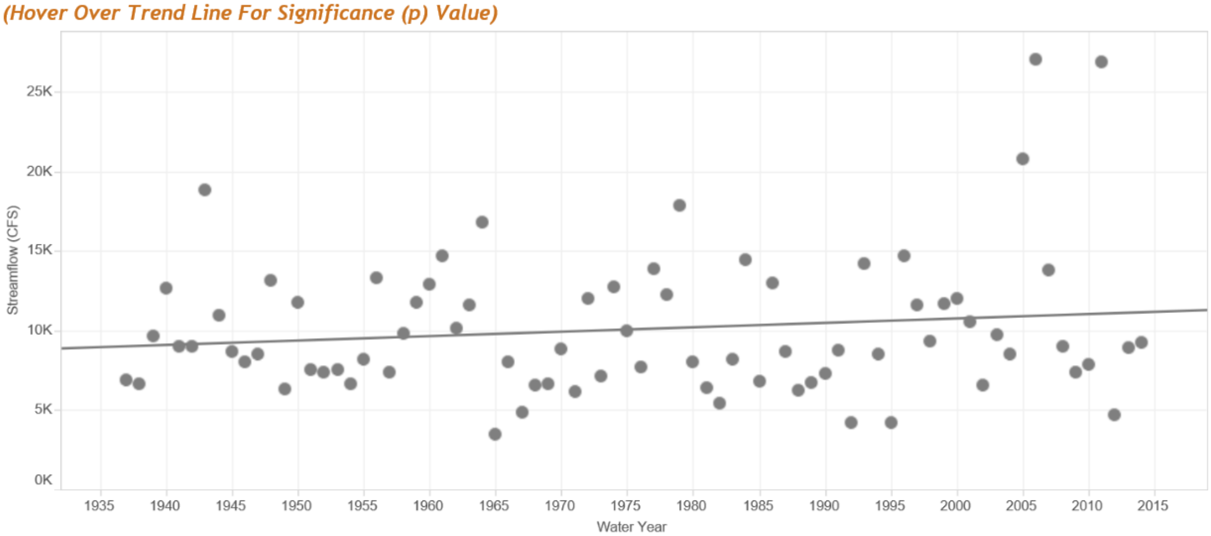
(Hover Over Trend Line For Significance (p) Value)



Value = 2.07971*Water Year + 954.627
R-Squared: 0.0003973
P-value: 0.862487

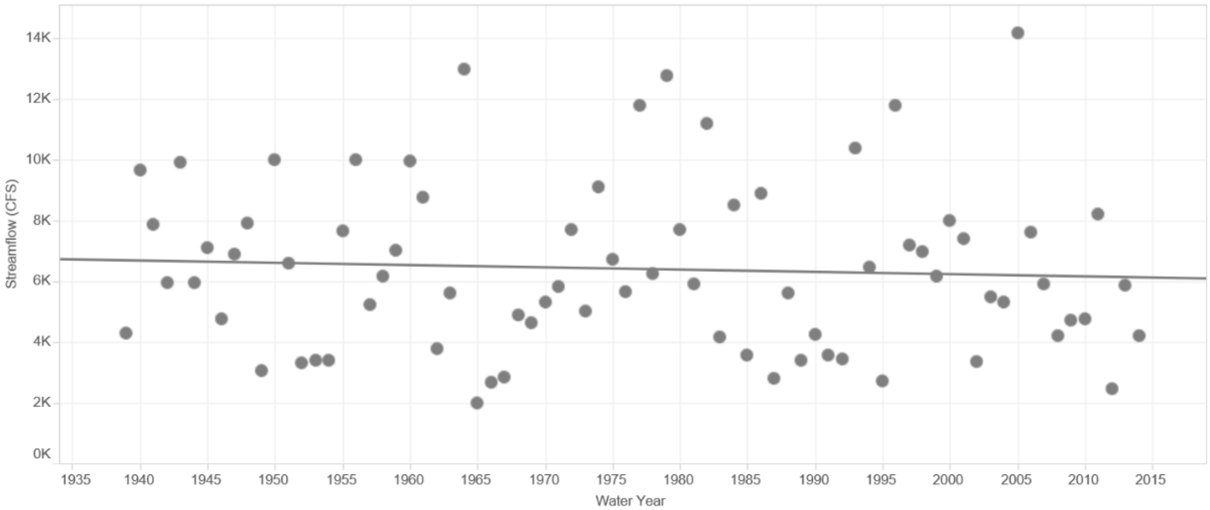
Annual Peak Instantaneous Streamflow, CHENANGO RIVER AT GREENE NY Selected

(Hover Over Trend Line For Significance (p) Value)



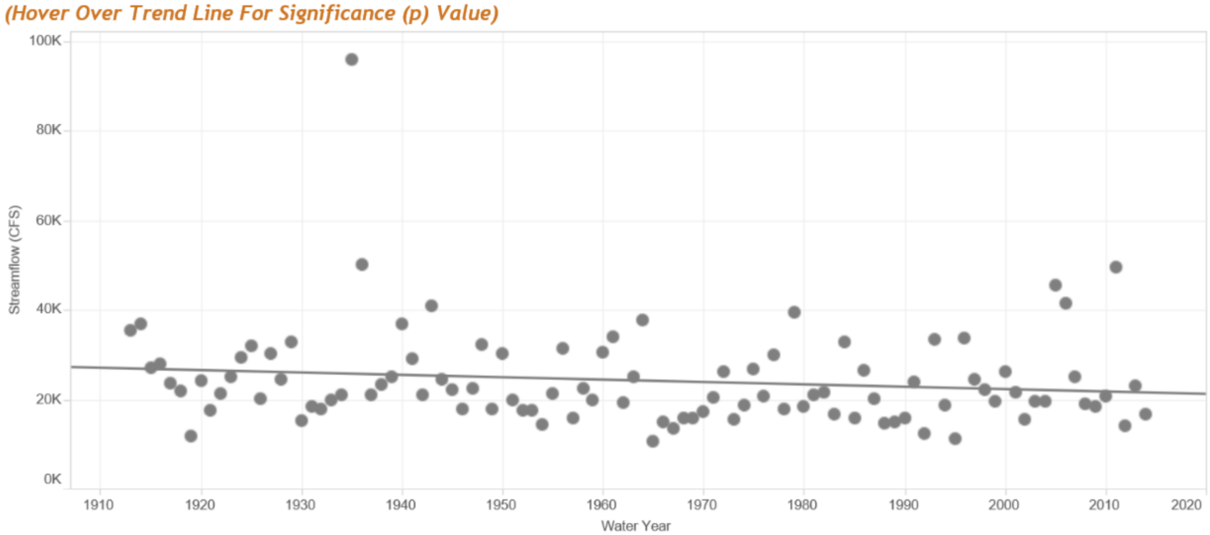
Value = 27.7567*Water Year + -44742.4
R-Squared: 0.0203943
P-value: 0.21229

Annual Peak Instantaneous Streamflow, TIOUGHNIOGA RIVER AT CORTLAND NY
Selected
(Hover Over Trend Line For Significance (p) Value)

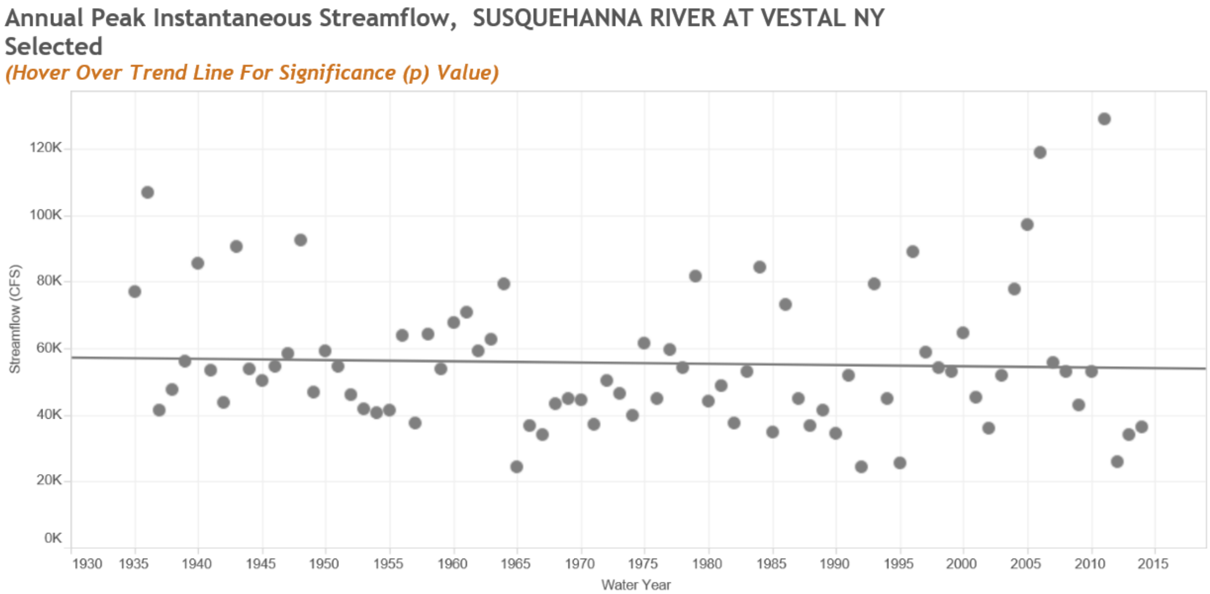


Value = -7.45934*Water Year + 21159.7
R-Squared: 0.0035652
P-value: 0.608398

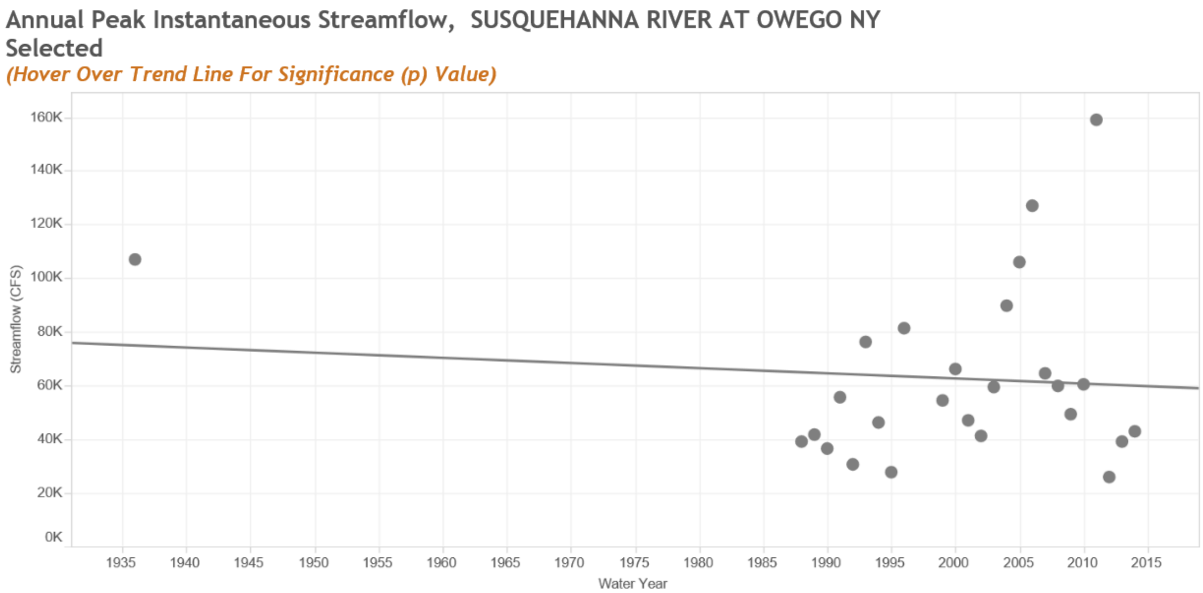
Annual Peak Instantaneous Streamflow, CHENANGO RIVER NEAR CHENANGO FORKS NY
Selected
(Hover Over Trend Line For Significance (p) Value)



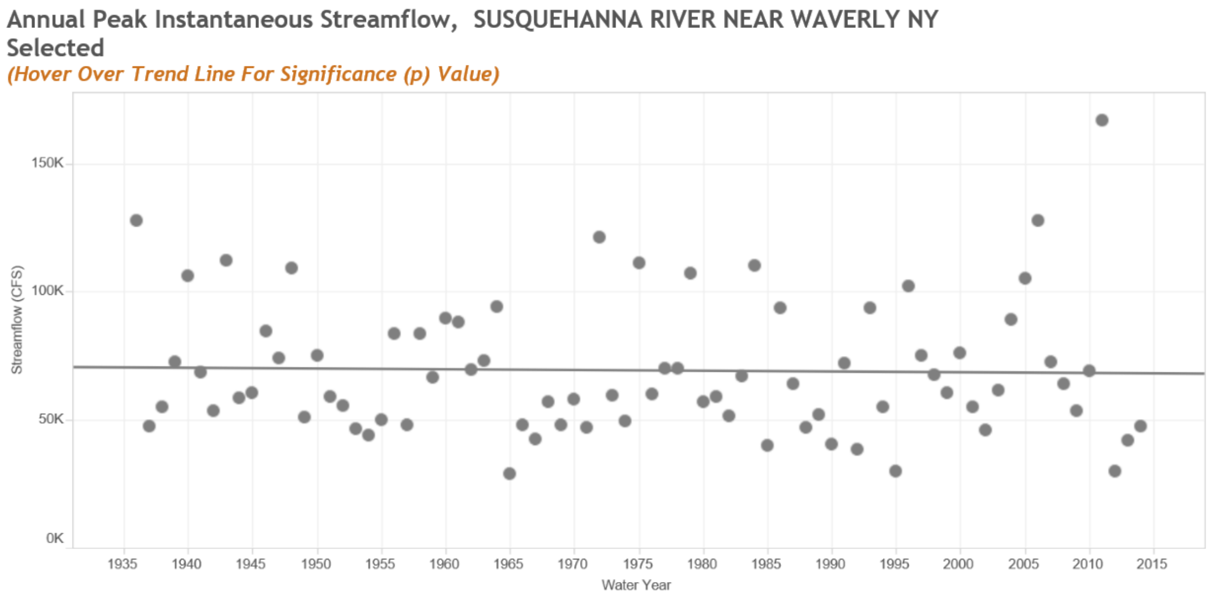
Value = -53.0034*Water Year + 128295
R-Squared: 0.0208021
P-value: 0.148102



Value = -37.2925*Water Year + 129139
R-Squared: 0.001745
P-value: 0.712938



Value = -191.957*Water Year + 446593
R-Squared: 0.0080856
P-value: 0.662227



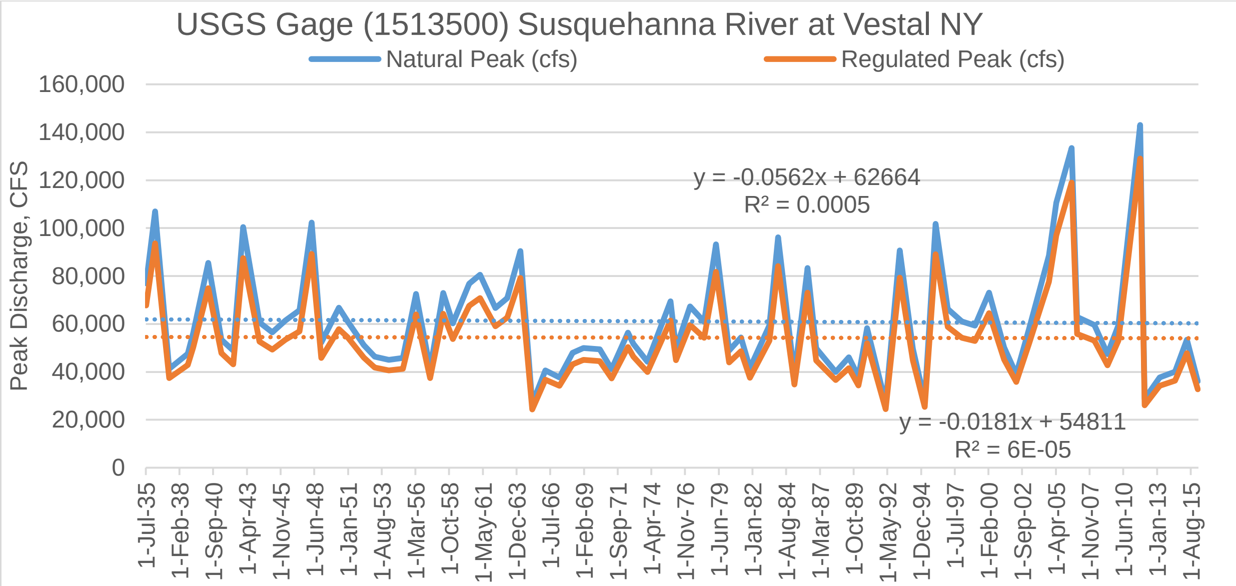
Value = -28.8827*Water Year + 126329
R-Squared: 0.0006495
P-value: 0.823574

ATTACHMENT 4: REGRESSION ANALYSIS OF USGS STREAM GAGES IN USRB

Simple regression analysis was performed for four USGS gages near Binghamton, New York and details of these analysis is presented in this attachment.

USGS Gage (1513500) Susquehanna River at Vestal NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
8-Jul-35	77,000	67,800	1-Apr-62	66,700	59,100	11-May-89	46,100	41,600
18-Mar-36	107,000	93,700	28-Mar-63	70,800	62,600	17-Feb-90	37,900	34,400
7-Apr-37	41,300	37,400	6-Mar-64	90,400	79,200	24-Oct-90	58,300	52,000
23-Sep-38	47,600	42,900	13-Feb-65	26,700	24,300	12-Mar-92	26,900	24,500
21-Feb-39	56,200	50,300	14-Feb-66	40,600	36,800	11-Apr-93	90,700	79,400
1-Apr-40	85,500	75,000	30-Mar-67	37,700	34,200	7-Apr-94	49,700	44,700
7-Apr-41	53,400	47,900	23-Mar-68	48,000	43,200	9-Mar-95	27,900	25,400
18-Mar-42	48,900	43,100	31-Jan-69	50,000	45,000	20-Jan-96	101,800	89,100
31-Dec-42	100,500	87,500	3-Apr-70	49,500	44,500	2-Dec-96	66,300	58,800
18-Mar-44	60,600	52,600	16-Mar-71	41,200	37,300	9-Jan-98	61,000	54,300
18-Mar-45	56,500	49,300	23-Jun-72	56,400	50,400	25-Jan-99	59,300	52,900
9-Mar-46	61,500	53,400	9-Nov-72	51,700	46,400	28-Feb-00	73,100	64,500
6-Apr-47	65,700	56,900	28-Dec-73	44,200	40,000	10-Apr-01	50,200	45,100
22-Mar-48	102,400	89,300	26-Sep-75	69,500	61,500	27-Mar-02	39,000	35,800
31-Dec-48	52,300	45,800	19-Feb-76	49,900	44,900	23-Mar-03	58,000	51,800
5-Apr-50	66,800	57,800	14-Mar-77	67,300	59,600	18-Sep-04	88,600	77,600
5-Dec-50	61,200	54,500	5-Apr-78	60,900	54,200	3-Apr-05	110,600	97,000
12-Mar-52	51,200	46,000	6-Mar-79	93,300	81,700	28-Jun-06	133,500	119,000
25-Jan-53	46,300	41,800	22-Mar-80	48,900	44,000	17-Nov-06	62,900	55,900
18-Feb-54	45,000	40,600	21-Feb-81	54,400	48,700	9-Mar-08	59,600	53,100
13-Mar-55	45,800	41,300	29-Oct-81	41,500	37,600	9-Mar-09	47,500	42,800
8-Mar-56	72,500	64,000	16-Apr-83	59,400	53,000	26-Jan-10	59,400	53,000
6-Apr-57	41,300	37,400	14-Dec-83	96,200	84,200	8-Sep-11	143,100	129,000
8-Apr-58	72,900	64,300	13-Mar-85	38,300	34,800	28-Jan-12	28,700	26,100
22-Jan-59	60,300	53,700	15-Mar-86	83,300	73,100	13-Mar-13	37,700	34,200
1-Apr-60	76,800	67,600	27-Nov-86	49,800	44,800	17-May-14	40,100	36,400
26-Feb-61	80,600	70,800	20-May-88	40,000	36,600	10-Apr-15	53,400	47,900
						26-Feb-16	36,100	32,800

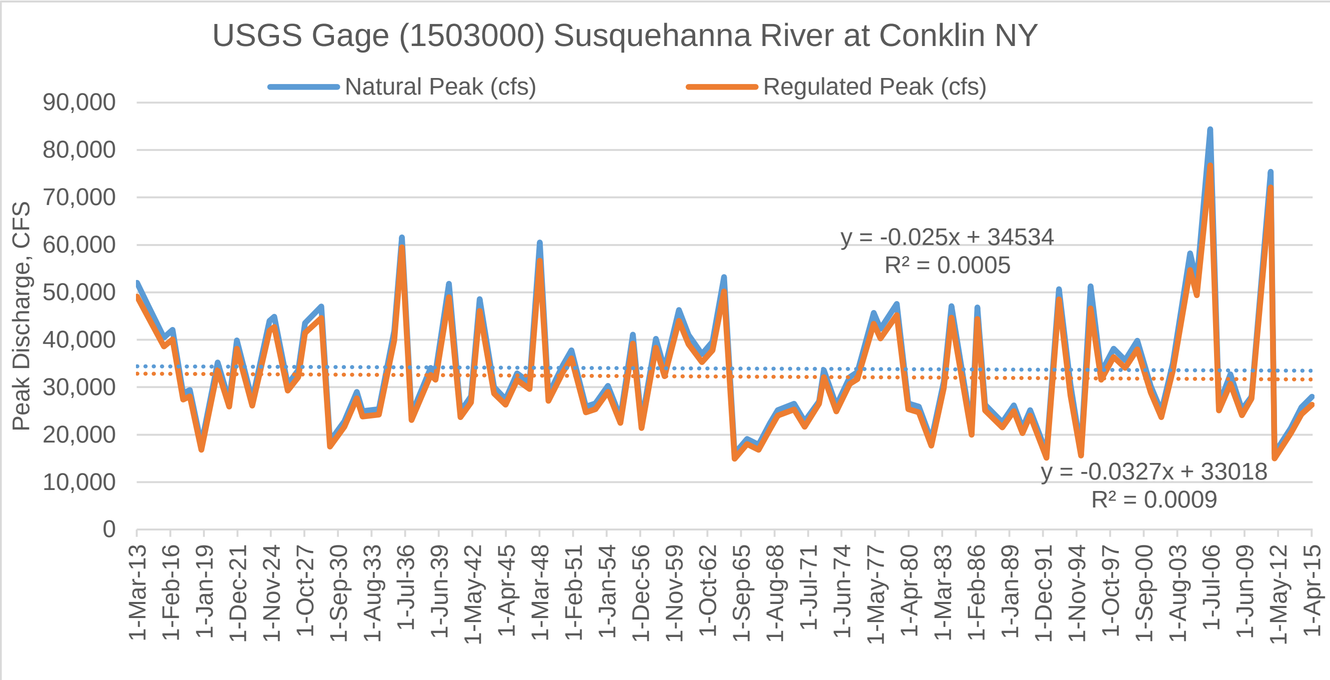


Using above regression equation for peak flow changes, projected flow change is negative for 50-year project life cycle and is shown in the table below.

Date	Natural Peak Flow (cfs)	Regulated Peak Flow (cfs)
1/1/2025	60,098	53,985
1/1/2075	59,072	53,654
Change	-1.7%	-0.6%

USGS Gage (1503000) Susquehanna River at Conklin NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
28-Mar-13	52,000	49,100	6-Apr-47	31,000	29,600	21-Feb-81	25,900	24,700
30-Mar-14	47,000	44,600	22-Mar-48	60,500	56,700	27-Mar-82	18,800	17,700
8-Jul-15	40,500	38,600	31-Dec-48	28,400	27,100	16-Apr-83	31,200	29,800
2-Apr-16	42,100	40,100	29-Mar-50	34,600	33,100	14-Dec-83	47,100	44,700
28-Mar-17	28,700	27,400	4-Dec-50	37,800	36,100	28-Sep-85	21,100	20,000
30-Oct-17	29,400	28,100	12-Mar-52	25,900	24,700	15-Mar-86	46,800	44,400
31-Oct-18	17,900	16,800	25-Jan-53	26,600	25,400	27-Nov-86	26,300	25,100
29-Mar-20	35,200	33,600	18-Feb-54	30,300	29,000	20-May-88	22,600	21,500
10-Mar-21	27,100	25,900	13-Mar-55	23,600	22,500	7-May-89	26,200	25,000
29-Nov-21	39,900	38,100	7-Apr-56	41,100	39,200	17-Feb-90	21,400	20,300
24-Mar-23	27,300	26,100	23-Jan-57	22,500	21,400	24-Oct-90	25,200	24,000
30-Sep-24	44,000	41,900	7-Apr-58	40,200	38,300	12-Mar-92	16,200	15,100
12-Feb-25	44,900	42,700	22-Jan-59	33,800	32,300	1-Apr-93	50,700	48,500
10-Apr-26	30,600	29,300	6-Apr-60	46,300	44,000	7-Apr-94	30,600	28,300
15-Mar-27	33,600	32,100	26-Feb-61	41,000	39,100	9-Mar-95	16,700	15,600
19-Oct-27	43,500	41,400	1-Apr-62	37,000	35,300	19-Jan-96	51,300	46,600
17-Mar-29	47,000	44,600	28-Mar-63	39,600	37,800	2-Dec-96	33,100	31,600
20-Dec-29	18,600	17,500	10-Mar-64	53,200	50,200	10-Jan-98	38,100	36,400
30-Mar-31	22,800	21,700	10-Feb-65	16,000	14,900	24-Jan-99	35,700	34,100
1-Apr-32	29,000	27,700	6-Mar-66	19,100	18,000	28-Feb-00	39,800	38,000
8-Oct-32	25,000	23,800	30-Mar-67	17,900	16,800	11-Apr-01	30,200	28,900
5-Mar-34	25,400	24,200	23-Mar-68	22,500	21,200	27-Mar-02	24,900	23,700
9-Jul-35	41,900	39,900	19-Nov-68	25,200	24,000	23-Mar-03	35,000	33,500
18-Mar-36	61,600	59,500	3-Apr-70	26,500	25,300	18-Sep-04	58,200	54,700
26-Jan-37	24,300	23,100	16-Mar-71	22,800	21,700	3-Apr-05	52,300	49,400
23-Sep-38	34,100	32,600	23-Jun-72	27,000	26,500	28-Jun-06	84,400	76,800
21-Feb-39	33,100	31,600	9-Nov-72	33,600	32,100	28-Mar-07	26,300	25,100
1-Apr-40	51,800	49,000	28-Dec-73	26,100	24,900	9-Mar-08	32,700	30,700
6-Apr-41	24,900	23,700	25-Feb-75	32,100	30,700	11-Mar-09	25,300	24,100
19-Mar-42	28,100	26,800	19-Oct-75	33,200	31,700	25-Jan-10	28,000	27,600
31-Dec-42	48,600	46,100	16-Mar-77	45,700	43,400	8-Sep-11	75,400	72,100
18-Mar-44	30,000	28,700	19-Oct-77	42,300	40,300	28-Jan-12	16,100	15,000
18-Mar-45	27,500	26,300	7-Mar-79	47,600	45,200	29-Jun-13	21,400	20,300
9-Mar-46	32,900	31,500	22-Mar-80	26,600	25,400	17-May-14	25,800	24,300

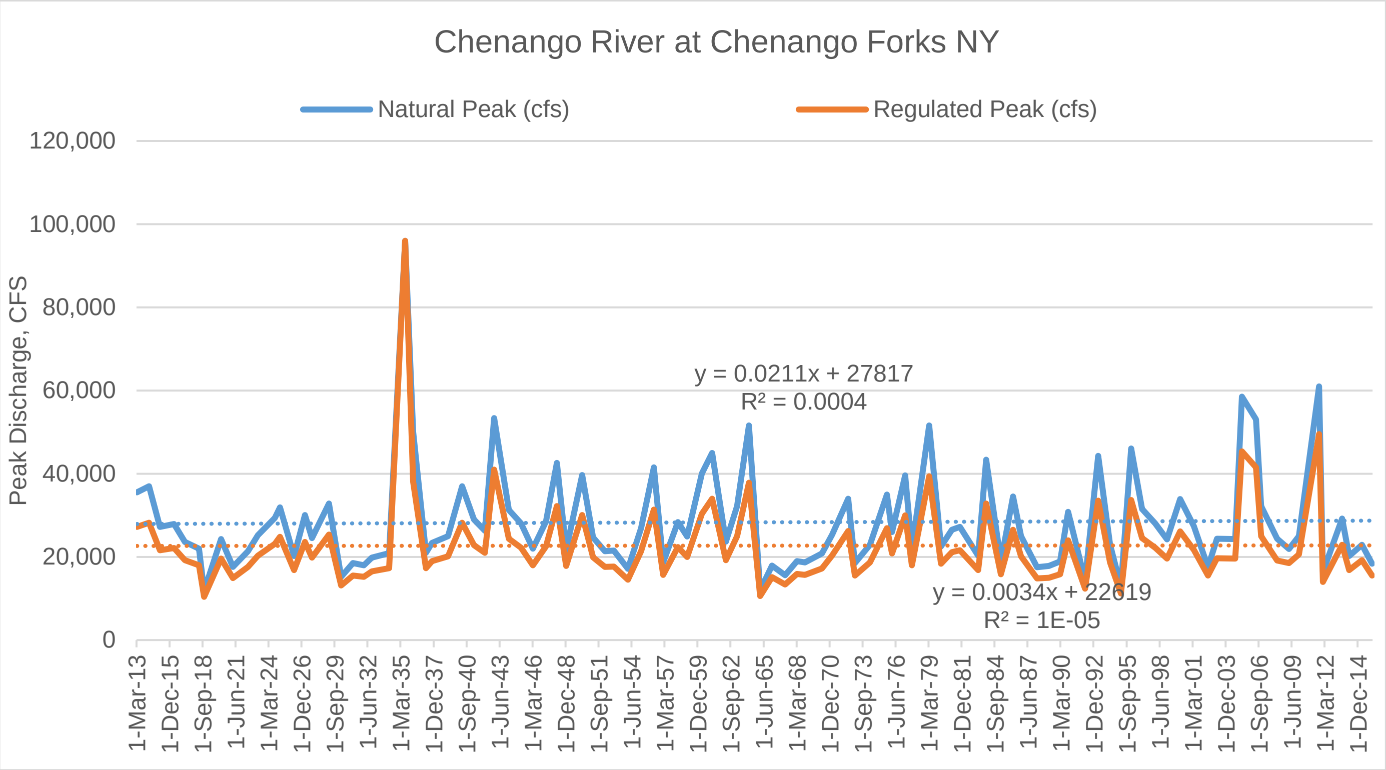


Using above regression equation for peak flow changes, projected flow change is negative for 50-year project life cycle and is shown in the table below.

Date	Natural Peak Flow (cfs)	Regulated Peak Flow (cfs)
1/1/2025	33,393	31,525
1/1/2075	32,936	30,928
Change	-1.4%	-1.9%

USGS Gage (1512500) Chenango River at Chenango Forks NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
27-Mar-13	35,500	27,200	7-Apr-47	28,500	22,500	20-Feb-81	26,500	21,100
28-Mar-14	37,000	28,200	22-Mar-48	42,600	32,200	28-Oct-81	27,200	21,600
25-Feb-15	27,200	21,600	30-Dec-48	21,700	17,800	16-Apr-83	20,300	16,800
2-Apr-16	27,900	22,100	5-Apr-50	39,700	30,100	14-Dec-83	43,400	32,800
28-Mar-17	23,600	19,200	31-Mar-51	24,700	19,900	12-Mar-85	18,900	15,800
14-May-18	22,000	18,000	11-Mar-52	21,400	17,600	15-Mar-86	34,500	26,500
31-Oct-18	11,800	10,400	11-Dec-52	21,500	17,700	27-Nov-86	25,000	20,100
27-Mar-20	24,300	19,600	17-Feb-54	17,100	14,500	26-Mar-88	17,500	14,800
10-Mar-21	17,600	14,900	12-Mar-55	26,900	21,400	31-Mar-89	17,800	15,000
12-Jun-22	21,400	17,600	5-Apr-56	41,500	31,400	17-Feb-90	18,900	15,800
6-Apr-23	25,200	20,300	23-Jan-57	18,700	15,700	24-Oct-90	30,800	24,000
30-Sep-24	29,400	23,100	7-Apr-58	28,400	22,400	27-Mar-92	14,300	12,400
12-Feb-25	31,900	24,800	22-Jan-59	24,900	20,000	11-Apr-93	44,300	33,500
10-Apr-26	20,200	16,800	1-Apr-60	40,100	30,400	17-Apr-94	23,000	18,700
14-Mar-27	30,100	23,600	26-Feb-61	45,000	34,000	8-Mar-95	12,800	11,200
19-Oct-27	24,500	19,800	1-Apr-62	23,700	19,200	20-Jan-96	46,100	33,700
15-Mar-29	32,800	25,400	28-Mar-63	32,200	25,000	2-Dec-96	31,500	24,500
8-Mar-30	15,200	13,100	6-Mar-64	51,600	37,800	9-Jan-98	28,100	22,200
27-Mar-31	18,500	15,500	13-Feb-65	12,000	10,600	25-Jan-99	24,200	19,600
13-Feb-32	18,000	15,200	14-Feb-66	17,900	15,100	28-Feb-00	33,900	26,100
6-Oct-32	19,800	16,500	29-Mar-67	15,600	13,400	10-Apr-01	27,400	21,700
5-Mar-34	20,900	17,300	23-Mar-68	19,000	15,900	6-Jun-02	17,500	15,500
8-Jul-35	96,000	96,000	18-Nov-68	18,700	15,700	22-Mar-03	24,400	19,700
18-Mar-36	50,100	38,100	3-Apr-70	20,800	17,200	18-Sep-04	24,300	19,600
7-Apr-37	21,000	17,300	16-Feb-71	25,400	20,400	3-Apr-05	58,500	45,400
24-Oct-37	23,400	19,000	23-Jun-72	34,000	26,200	28-Jun-06	53,100	41,500
21-Feb-39	25,000	20,100	1-Jan-73	18,500	15,500	17-Nov-06	32,200	25,000
9-Apr-40	37,000	28,200	5-Apr-74	22,900	18,700	9-Mar-08	24,400	19,100
7-Apr-41	29,000	22,800	26-Sep-75	35,000	26,900	9-Mar-09	21,900	18,500
17-Mar-42	26,300	21,000	19-Feb-76	26,000	20,800	25-Jan-10	25,000	20,600
30-Dec-42	53,400	41,000	14-Mar-77	39,600	30,000	8-Sep-11	61,000	49,500
17-Mar-44	31,300	24,400	18-Oct-77	22,000	18,000	27-Jan-12	16,400	14,000
22-Mar-45	28,100	22,200	6-Mar-79	51,600	39,400	9-Aug-13	29,200	22,900
9-Mar-46	22,000	18,000	22-Mar-80	22,500	18,400	30-Mar-14	20,200	16,800

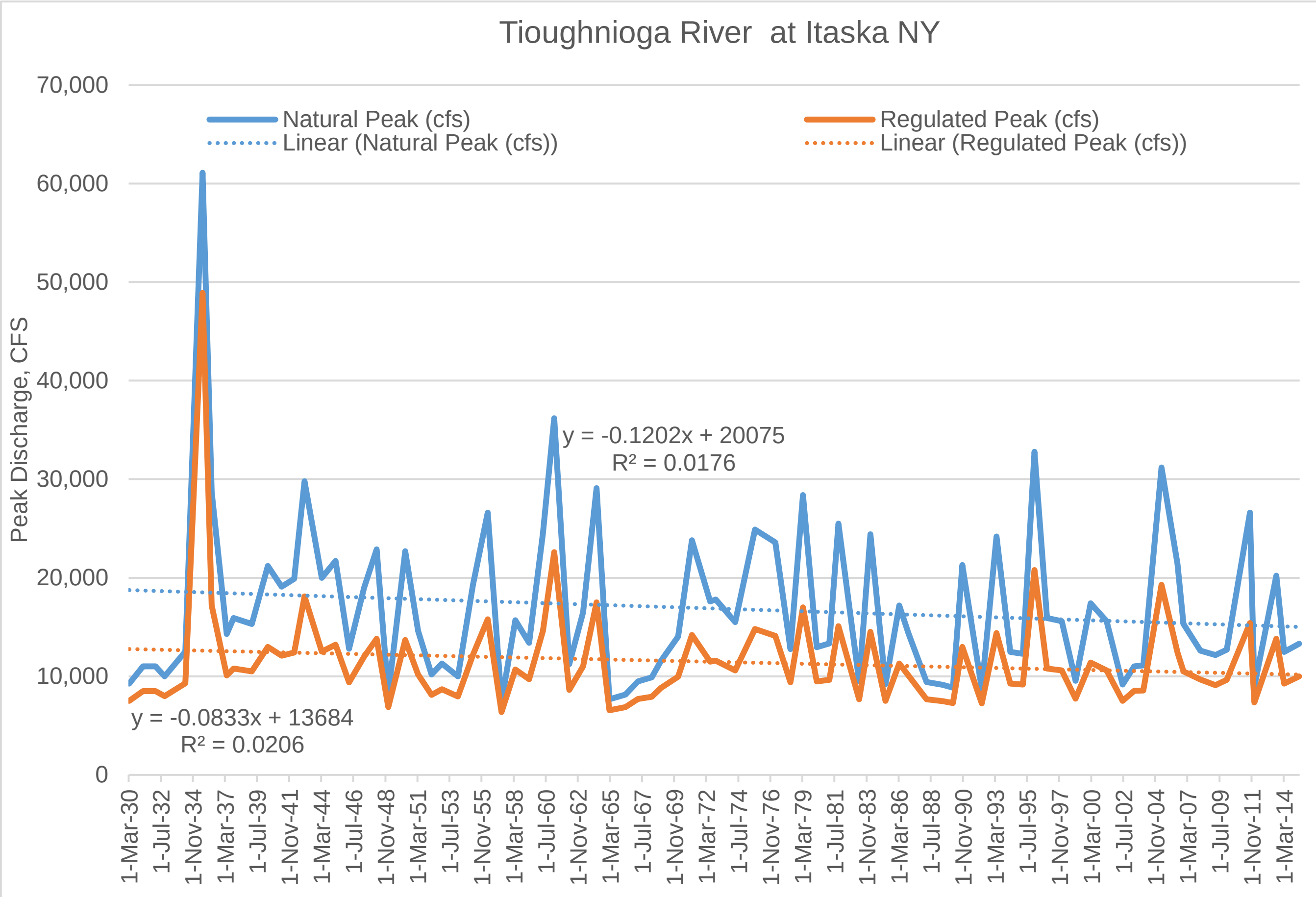


Using above regression equation for peak flow changes, projected flow change is positive for 50-year project life cycle and is shown in the table below.

Date	Natural Peak (cfs)	Regulated Peak (cfs)
1/1/2025	28,780	22,774
1/1/2075	29,166	22,836
Change	1.3%	0.3%

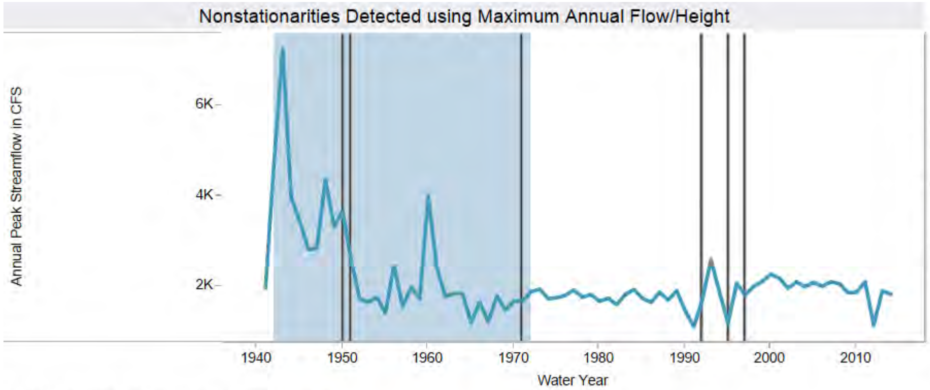
USGS Gage (1511500) Tioughnioga River at Itaska NY

Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)	Date	Natural Peak (cfs)	Regulated Peak (cfs)
8-Mar-30	9,250	7,500	5-Mar-64	29,100	17,500	24-Jan-99	9,560	7,730
27-Mar-31	11,000	8,500	13-Feb-65	7,680	6,560	28-Feb-00	17,400	11,400
13-Feb-32	11,000	8,500	25-Apr-66	8,150	6,870	10-Apr-01	15,600	10,600
6-Oct-32	10,000	8,000	29-Mar-67	9,500	7,700	16-Jun-02	9,170	7,500
1-Apr-34	12,500	9,300	23-Mar-68	9,910	7,930	5-Apr-03	11,000	8,520
8-Jul-35	61,100	48,900	19-Nov-68	11,560	8,810	11-Dec-03	11,100	8,570
18-Mar-36	28,700	17,200	6-Feb-70	14,030	9,970	3-Apr-05	31,200	19,300
7-Apr-37	14,300	10,100	16-Feb-71	23,800	14,200	28-Jun-06	21,400	12,400
24-Oct-37	15,900	10,800	23-Jun-72	17,600	11,500	16-Nov-06	15,300	10,500
20-Feb-39	15,300	10,500	25-Nov-72	17,800	11,600	6-Feb-08	12,600	9,670
9-Apr-40	21,200	13,000	5-Apr-74	15,500	10,600	9-Mar-09	12,170	9,110
7-Apr-41	19,100	12,100	26-Sep-75	24,900	14,800	25-Jan-10	12,700	9,650
17-Mar-42	19,900	12,400	13-Mar-77	23,600	14,100	8-Sep-11	26,600	15,400
30-Dec-42	29,800	18,100	1-Apr-78	12,750	9,390	27-Jan-12	8,930	7,360
17-Mar-44	20,000	12,500	6-Mar-79	28,400	17,000	9-Aug-13	20,200	13,800
22-Mar-45	21,700	13,200	22-Mar-80	12,960	9,490	30-Mar-14	12,470	9,260
7-Mar-46	12,800	9,400	20-Feb-81	13,320	9,650	9-Apr-15	13,300	9,990
6-Apr-47	19,000	12,000	28-Oct-81	25,500	15,100			
20-Mar-48	22,900	13,800	30-Apr-83	9,480	7,680			
6-Jan-49	8,170	6,880	15-Feb-84	24,400	14,500			
5-Apr-50	22,700	13,700	15-Mar-85	9,200	7,520			
31-Mar-51	14,600	10,200	15-Mar-86	17,200	11,300			
11-Mar-52	10,200	8,100	26-Nov-86	14,400	10,100			
11-Dec-52	11,300	8,680	26-Mar-88	9,430	7,660			
17-Feb-54	9,980	7,970	12-May-89	9,140	7,480			
11-Mar-55	19,300	12,200	17-Feb-90	8,840	7,300			
5-Apr-56	26,600	15,800	24-Oct-90	21,300	13,000			
6-Apr-57	7,390	6,370	27-Mar-92	8,750	7,250			
7-Apr-58	15,700	10,700	11-Apr-93	24,200	14,400			
2-Apr-59	13,400	9,700	16-Apr-94	12,480	9,260			
1-Apr-60	24,500	14,600	8-Mar-95	12,300	9,170			
26-Feb-61	36,200	22,600	19-Jan-96	32,800	20,800			
31-Mar-62	11,220	8,640	2-Dec-96	15,900	10,800			
27-Mar-63	16,500	11,000	8-Jan-98	15,600	10,600			



Date	Natural Peak (cfs)	Regulated Peak (cfs)
1/1/2025	14,587	9,881
1/1/2075	12,392	8,359
Change	-15.0%	-15.4%

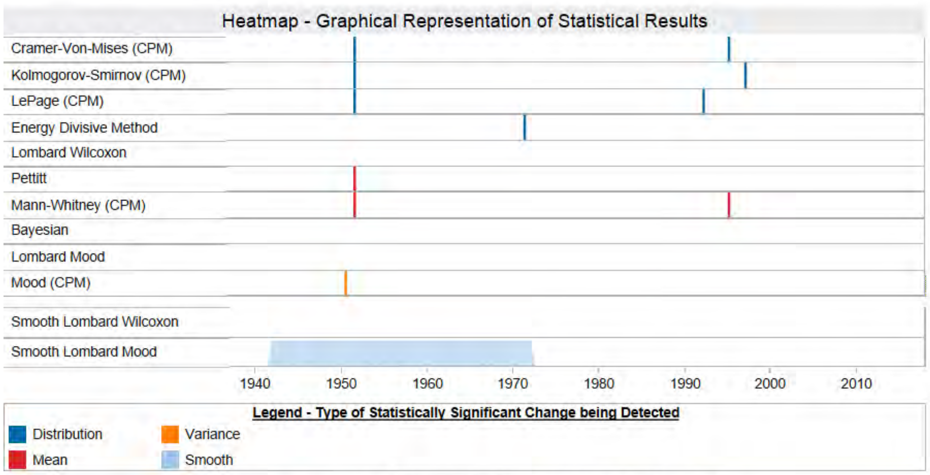
ATTACHMENT 5: USACE NONSTATIONARITY DETECTION (NSD) TOOL RESULTS

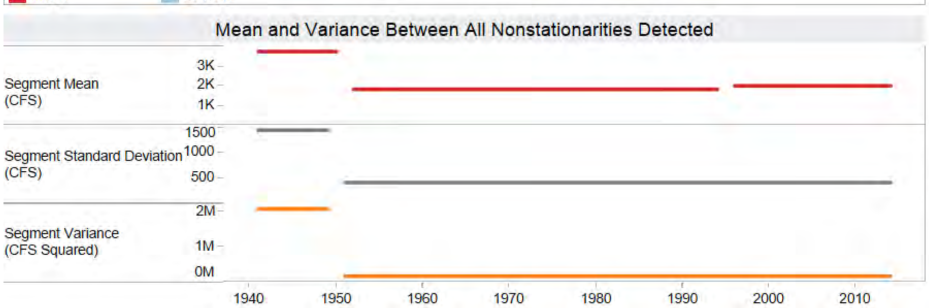


This gage has a drainage area of 103.0 square miles.

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.





Parameter Selection

- (●) Instantaneous Peak Streamflow
- ( ) Stage

Site Selection

Select a state
NY

Select a site
1500000 - OULEOUT CREEK AT EAST SIDNEY..

Timeframe Selection
1940 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
(Default: 20)
20

CPM Methods Sensitivty
(Default: 1,000)
1,000

Bayesian Sensitivty
(Default: 0.5)
0.5

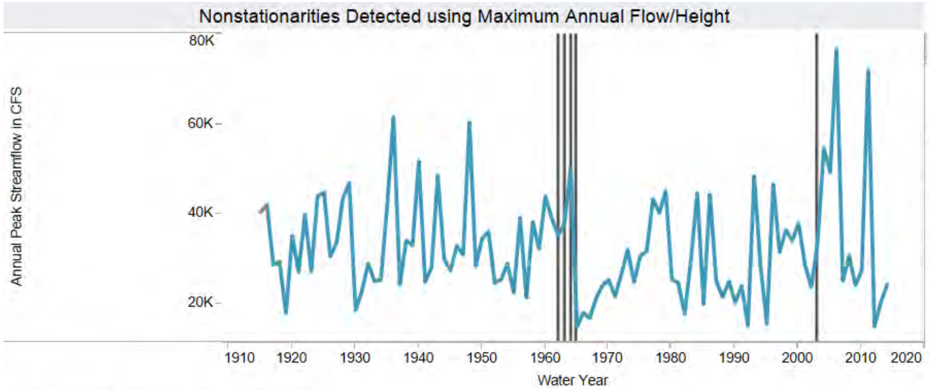
Energy Divisive Method Sensitivty
(Default: 0.5)
0.5

Larger Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
(Default: 0.05)
0.05

Pettitt Sensitivity
(Default: 0.05)
0.05

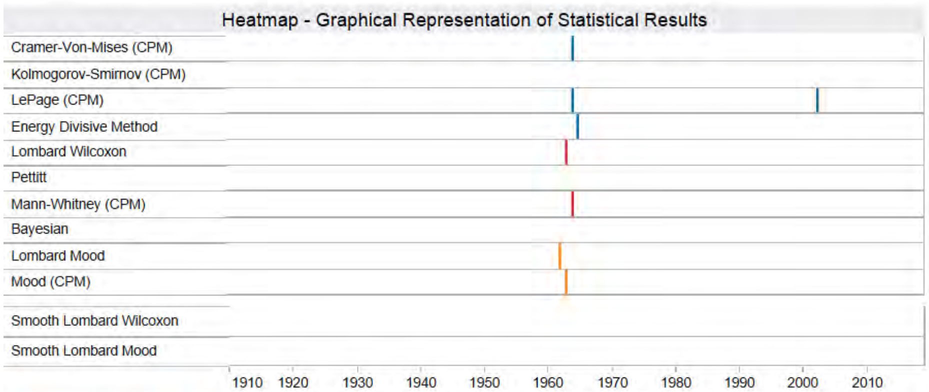
Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



This gage has a drainage area of 2,232 square miles.

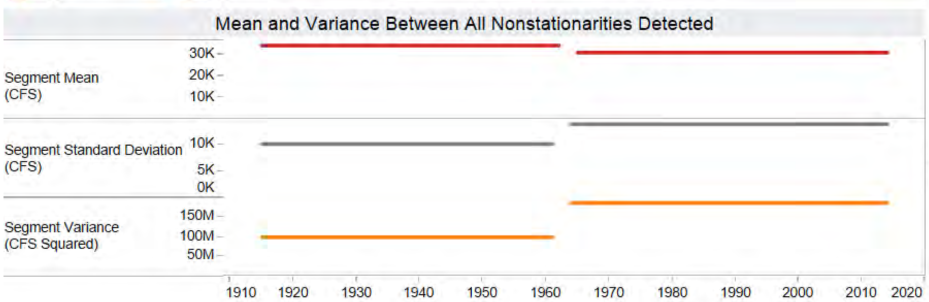
The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.



Legend - Type of Statistically Significant Change being Detected

Distribution
Variance
Mean
Smooth



Parameter Selection

◉ Instantaneous Peak Streamflow
○ Stage

Site Selection

Select a state
NY

Select a site
1503000 - SUSQUEHANNA RIVER AT CONKLI..

Timeframe Selection
1915 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
(Default: 20)
20

CPM Methods Sensitivty
(Default: 1,000)
1,000

Bayesian Sensitivty
(Default: 0.5)
0.5

Energy Divisive Method Sensitivty
(Default: 0.5)
0.5

Larger Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
(Default: 0.05)
0.05

Pettitt Sensitivity
(Default: 0.05)
0.05

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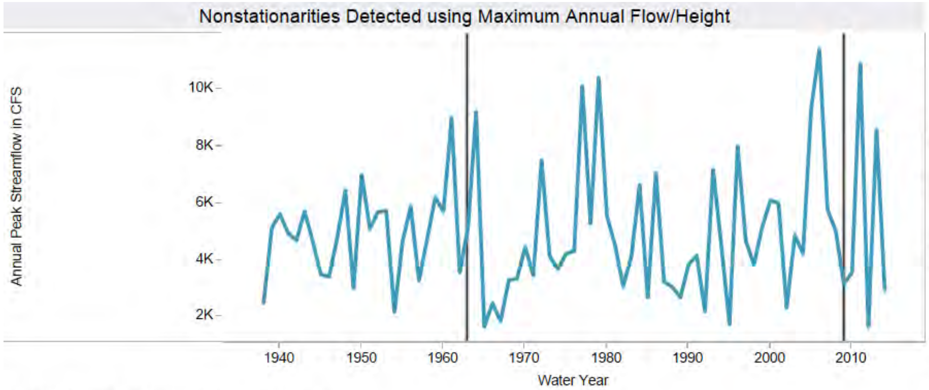
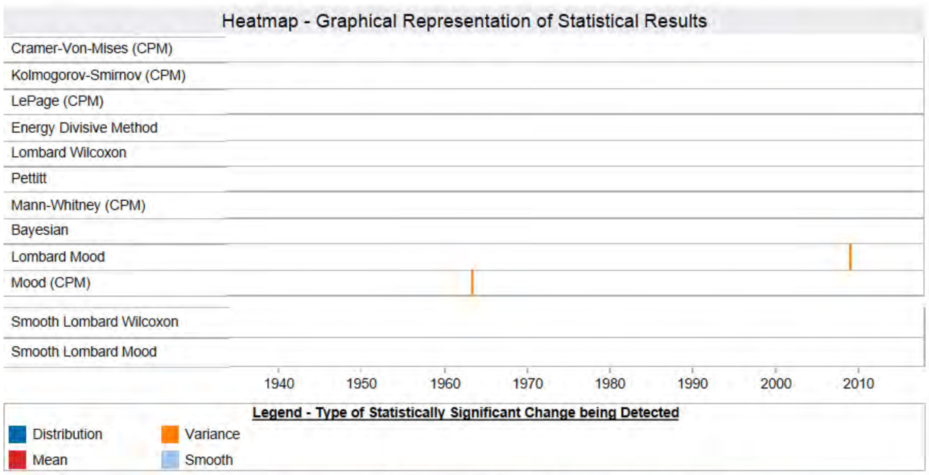
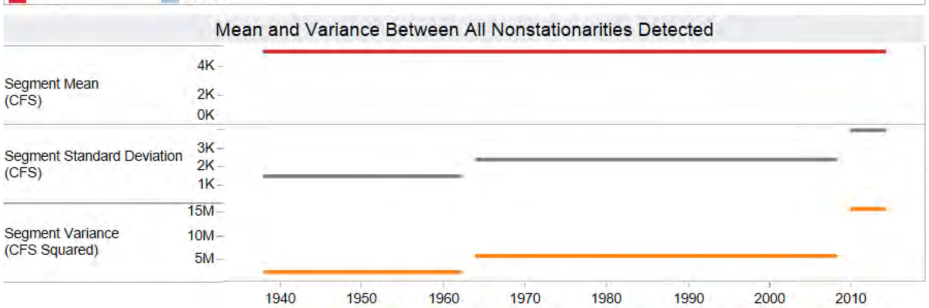


This gage has a drainage area of 263.0 square miles.

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.





Parameter Selection

- (•) Instantaneous Peak Streamflow
- ( ) Stage

Site Selection

Select a state
NY

Select a site
1505000 - CHENANGO RIVER AT SHERBURN..

Timeframe Selection
1937 to 2065

Sensitivity Parameters

(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).

Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
(Default: 20)

20

CPM Methods Sensitivty
(Default: 1,000)

1,000

Bayesian Sensitivty
(Default: 0.5)

0.5

Energy Divisive Method Sensitivty
(Default: 0.5)

0.5

Larger Values will Result in More Nonstationarities Detected

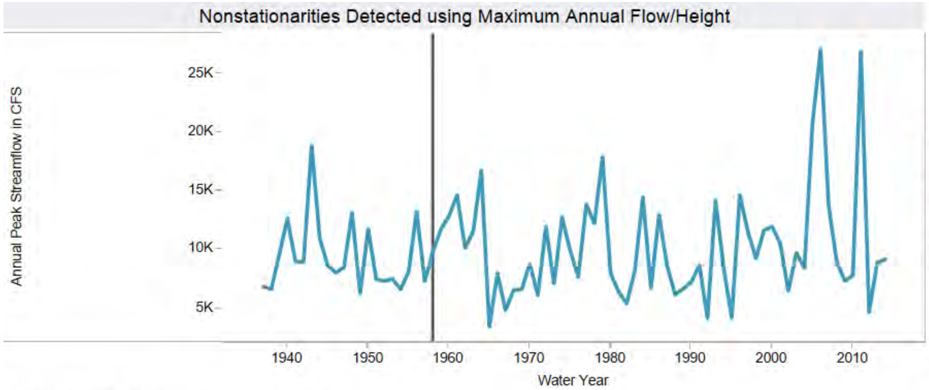
Lombard Smooth Methods Sensitivity
(Default: 0.05)

0.05

Pettitt Sensitivity
(Default: 0.05)

0.05

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



This gage has a drainage area of 593.0 square miles.

Parameter Selection
- Instantaneous Peak Streamflow
- Stage

Site Selection

Select a state
NY

Select a site
1507000 - CHENANGO RIVER AT GREENE NY

Timeframe Selection
1937 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
(Default: 20)
20

CPM Methods Sensitivty
(Default: 1,000)
1,000

Bayesian Sensitivty
(Default: 0.5)
0.5

Energy Divisive Method Sensitivty
(Default: 0.5)
0.5

Larger Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
(Default: 0.05)
0.05

Pettitt Sensitivity
(Default: 0.05)
0.05

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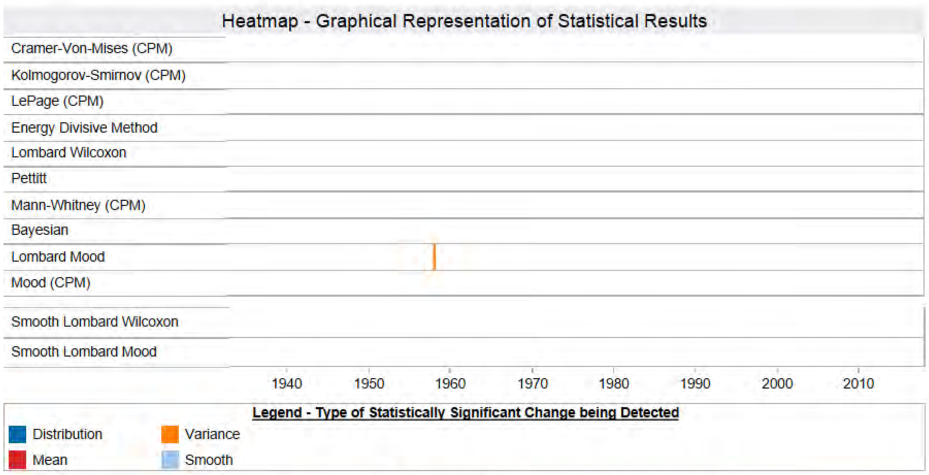
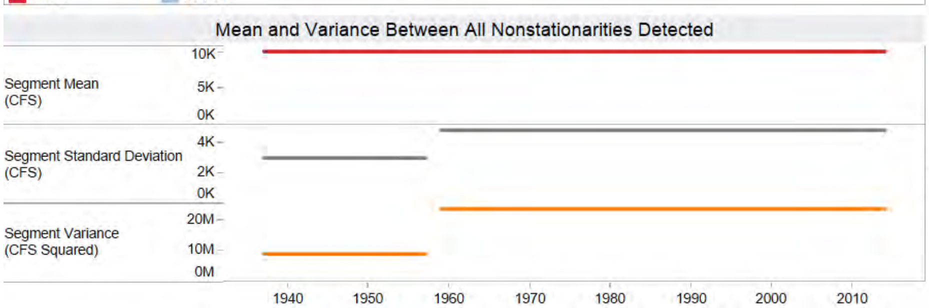
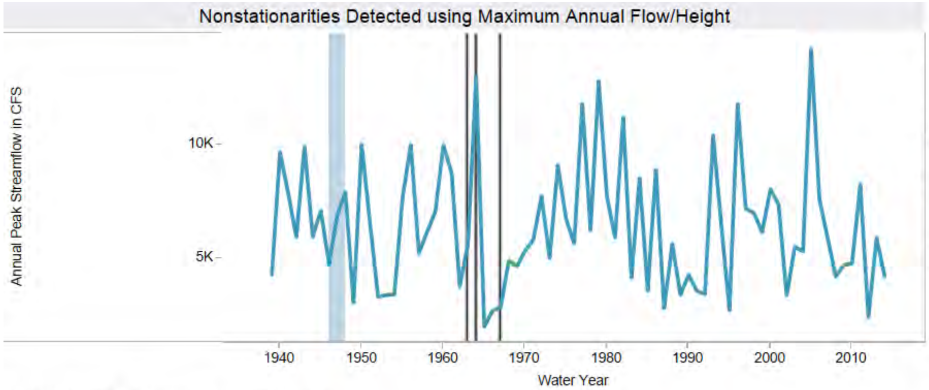
The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.







This gage has a drainage area of 292.0 square miles.

Parameter Selection

- Instantaneous Peak Streamflow (selected)
- Stage

Site Selection

Select a state
NY

Select a site
1509000 - TIOUGHNIOGA RIVER AT CORTLA..

Timeframe Selection
1937 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
(Default: 20)
20

CPM Methods Sensitivty
(Default: 1,000)
1,000

Bayesian Sensitivty
(Default: 0.5)
0.5

Energy Divisive Method Sensitivty
(Default: 0.5)
0.5

Larger Values will Result in More Nonstationarities Detected

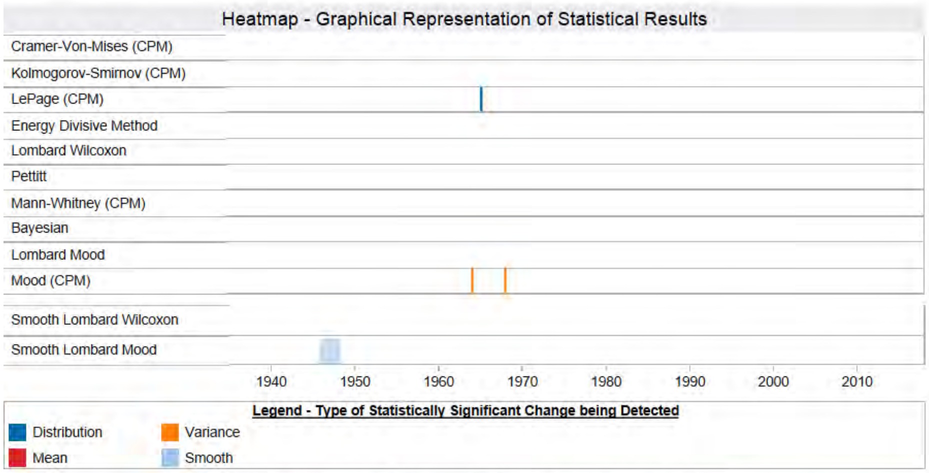
Lombard Smooth Methods Sensitivity
(Default: 0.05)
0.05

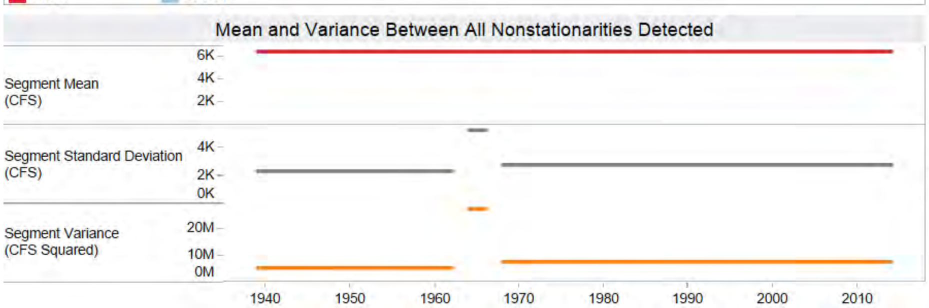
Pettitt Sensitivity
(Default: 0.05)
0.05

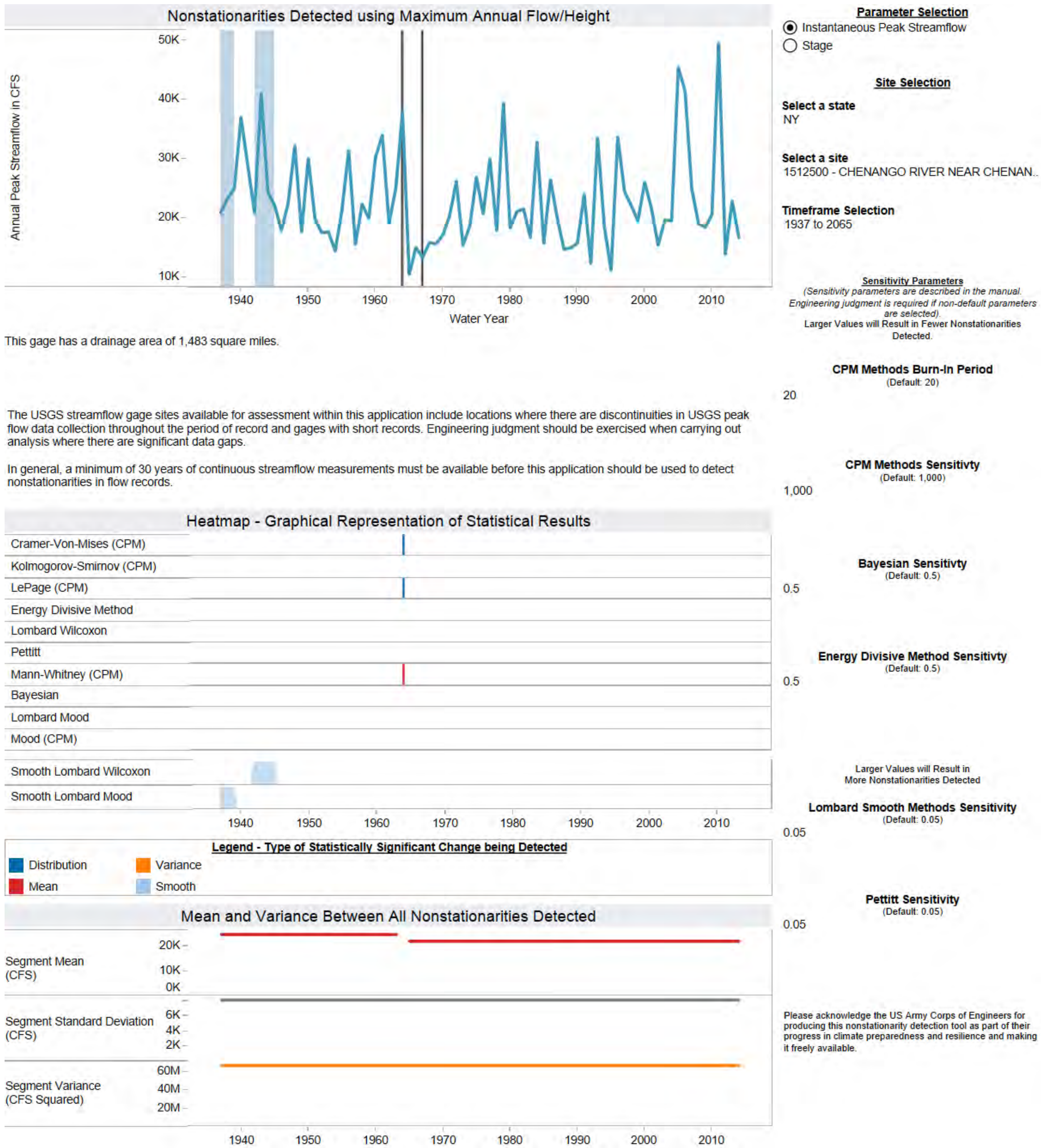
Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

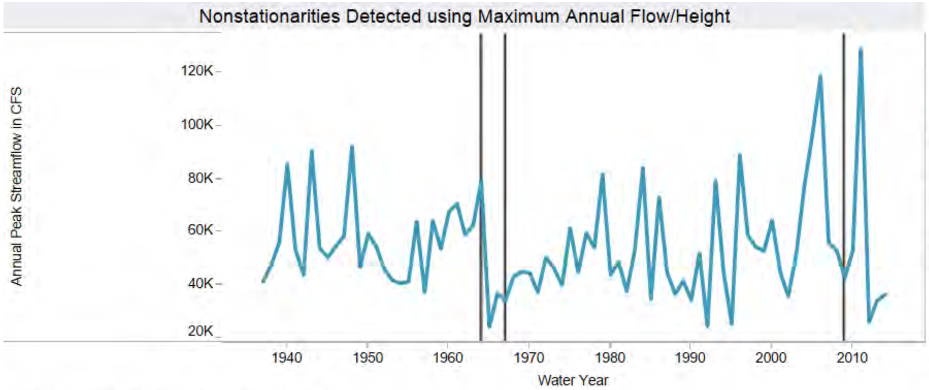
The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.





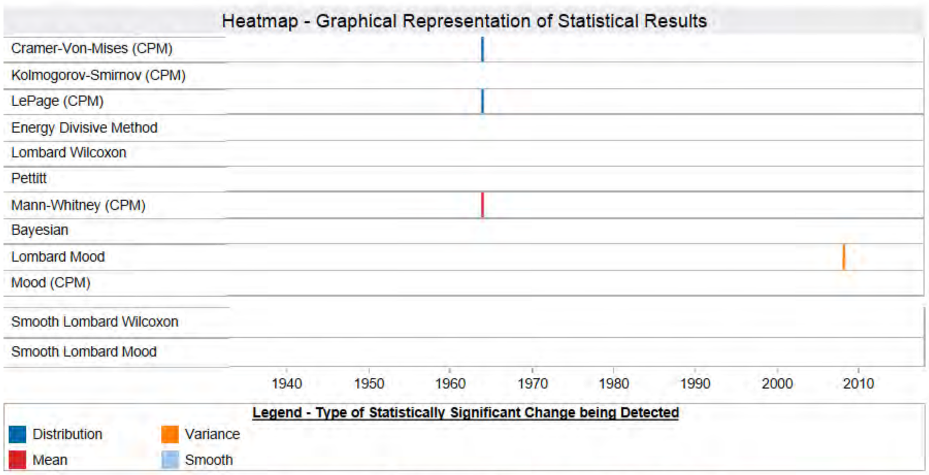

Nonstationarities Detected using Maximum Annual Flow/Height
Annual Peak Streamflow in CFS
50K
40K
30K
20K
10K
1940 1950 1960 1970 1980 1990 2000 2010
Water Year
This gage has a drainage area of 1,483 square miles.
The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.
In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.
Heatmap - Graphical Representation of Statistical Results
Cramer-Von-Mises (CPM)
Kolmogorov-Smirnov (CPM)
LePage (CPM)
Energy Divisive Method
Lombard Wilcoxon
Pettitt
Mann-Whitney (CPM)
Bayesian
Lombard Mood
Mood (CPM)
Smooth Lombard Wilcoxon
Smooth Lombard Mood
Legend - Type of Statistically Significant Change being Detected
Distribution
Variance
Mean
Smooth
Mean and Variance Between All Nonstationarities Detected
Segment Mean (CFS)
20K
10K
0K
Segment Standard Deviation (CFS)
6K
4K
2K
Segment Variance (CFS Squared)
60M
40M
20M
Parameter Selection
Instantaneous Peak Streamflow
Stage
Site Selection
Select a state
NY
Select a site
1512500 - CHENANGO RIVER NEAR CHENAN..
Timeframe Selection
1937 to 2065
Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected)
Larger Values will Result in Fewer Nonstationarities Detected.
CPM Methods Burn-In Period
(Default: 20)
20
CPM Methods Sensitivty
(Default: 1,000)
1,000
Bayesian Sensitivty
(Default: 0.5)
0.5
Energy Divisive Method Sensitivty
(Default: 0.5)
0.5
Larger Values will Result in More Nonstationarities Detected
Lombard Smooth Methods Sensitivity
(Default: 0.05)
0.05
Pettitt Sensitivity
(Default: 0.05)
0.05
Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

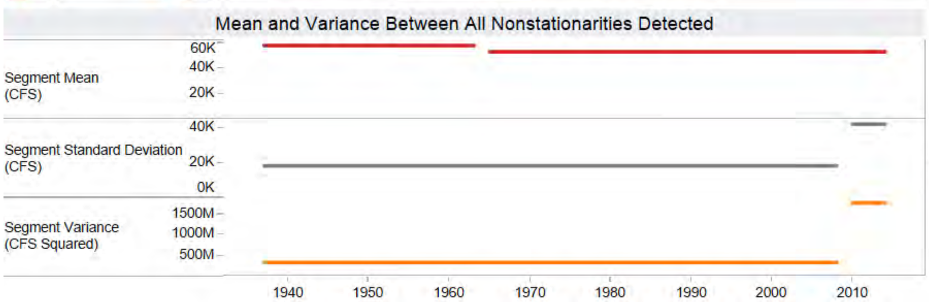


This gage has a drainage area of 3,941 square miles.

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.





Parameter Selection

◉ Instantaneous Peak Streamflow

○ Stage

Site Selection

Select a state
NY

Select a site
1513500 - SUSQUEHANNA RIVER AT VESTAL ..

Timeframe Selection
1937 to 2065

Sensitivity Parameters

(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).

Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
(Default: 20)

20

CPM Methods Sensitivty
(Default: 1,000)

1,000

Bayesian Sensitivty
(Default: 0.5)

0.5

Energy Divisive Method Sensitivty
(Default: 0.5)

0.5

Larger Values will Result in More Nonstationarities Detected

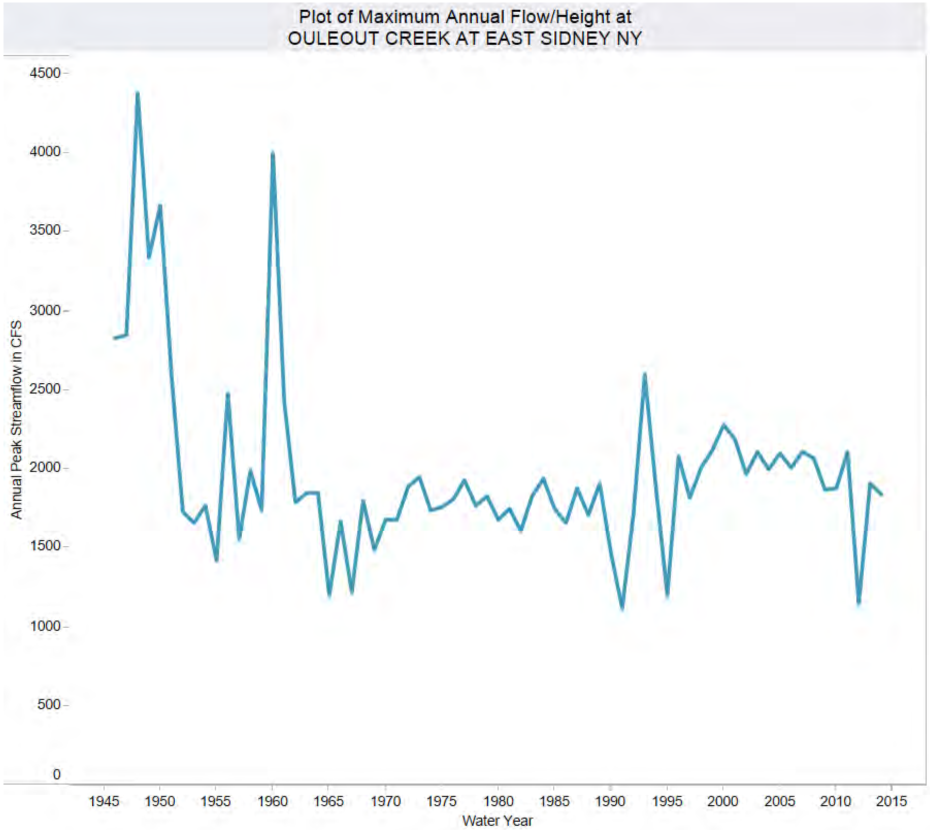
Lombard Smooth Methods Sensitivity
(Default: 0.05)

0.05

Pettitt Sensitivity
(Default: 0.05)

0.05

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



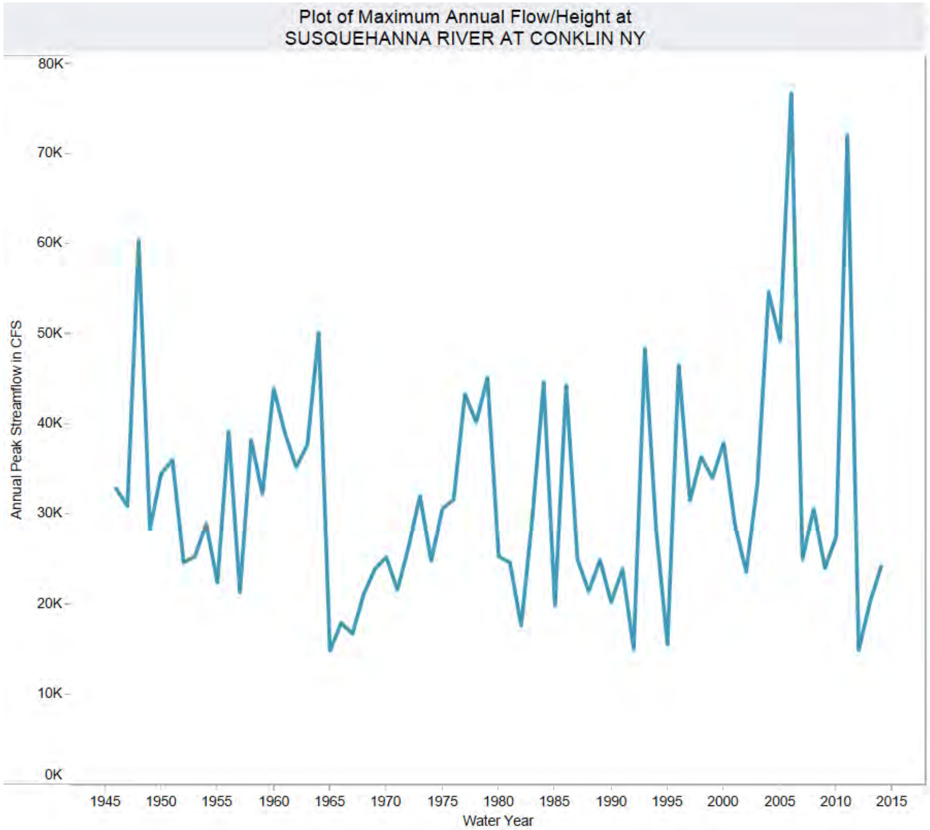
Timeframe Selection
1946 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.667.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.865.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



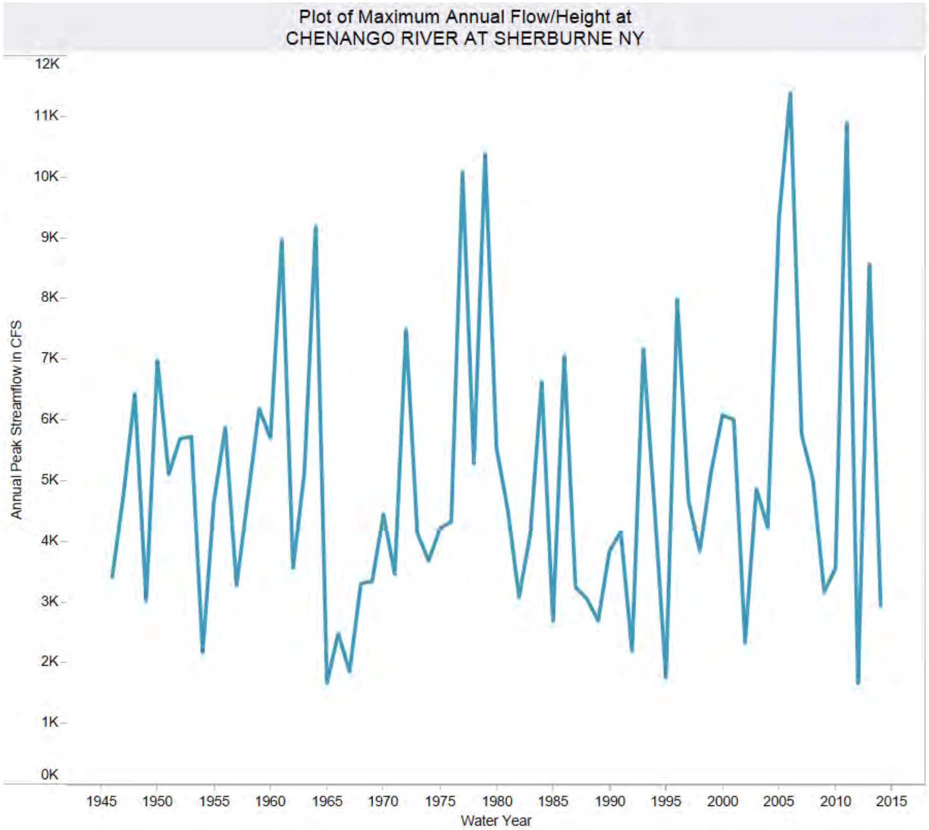
Timeframe Selection
1946 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.776.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.665.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



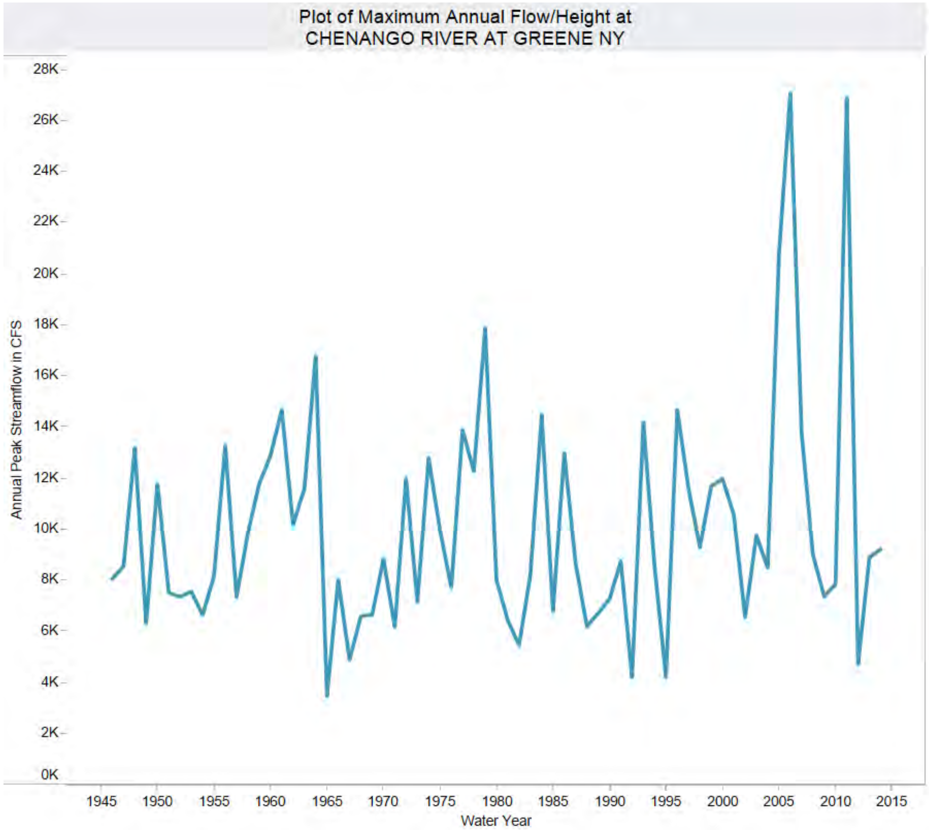
Timeframe Selection
1946 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.864.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.939.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



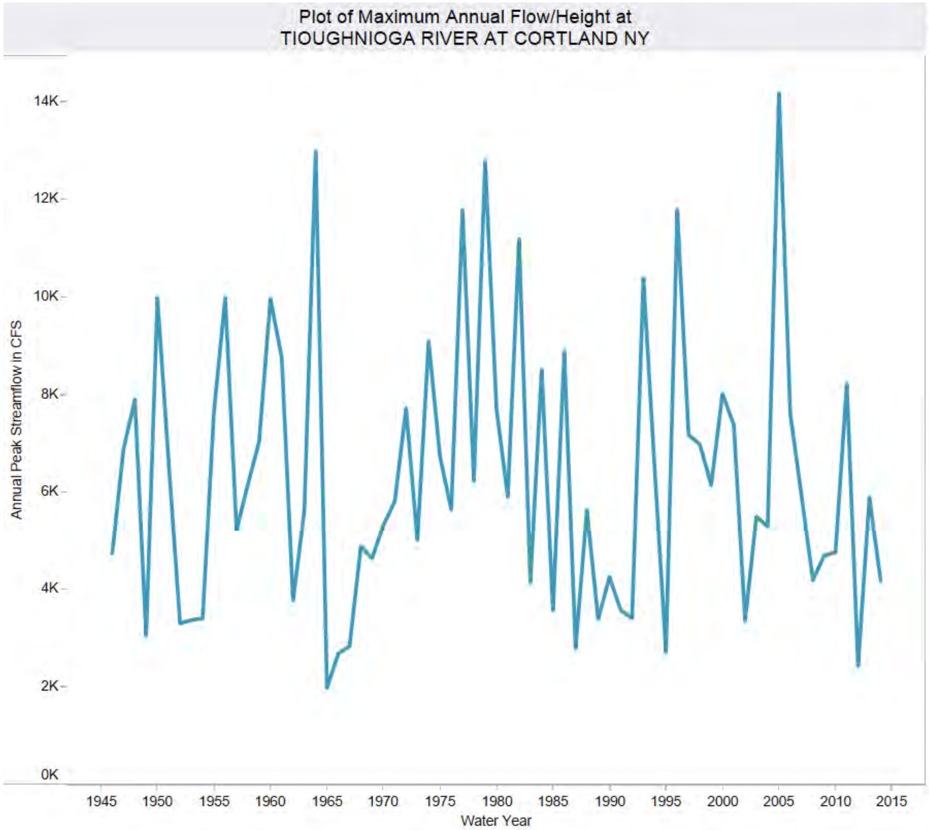
Timeframe Selection
1946 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.379.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.407.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



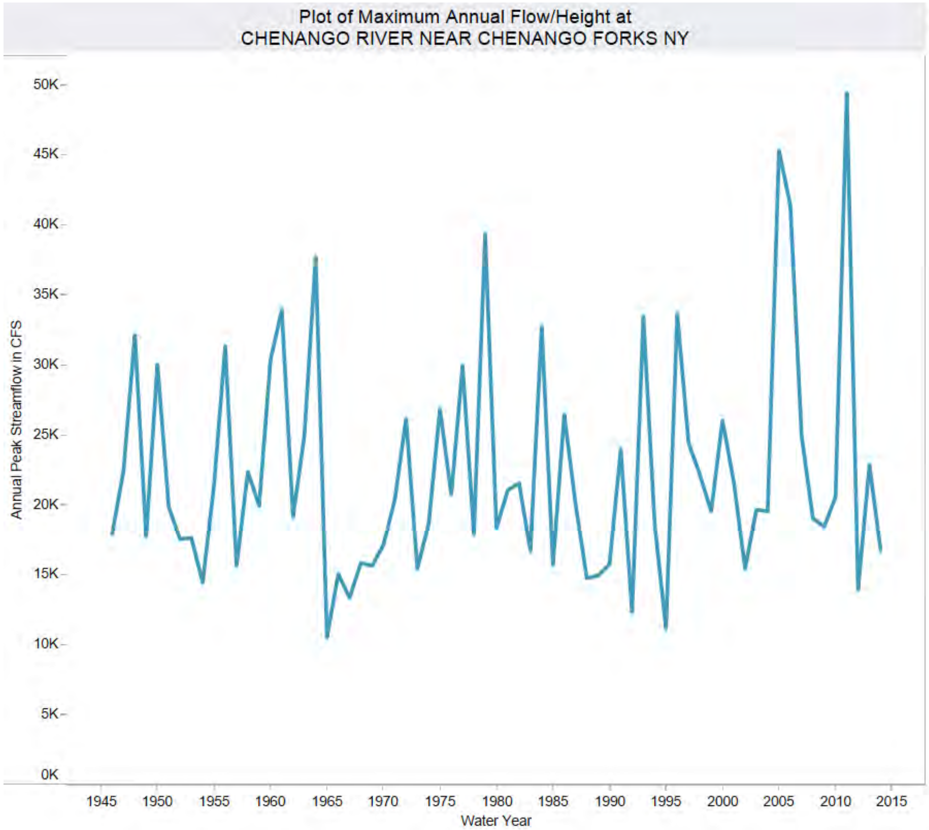
Timeframe Selection
1946 to 2065

<u>Monotonic Trend Analysis</u>

<u>Is there a statistically significant trend?</u>
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.885.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.854.

<u>What type of trend was detected?</u>
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



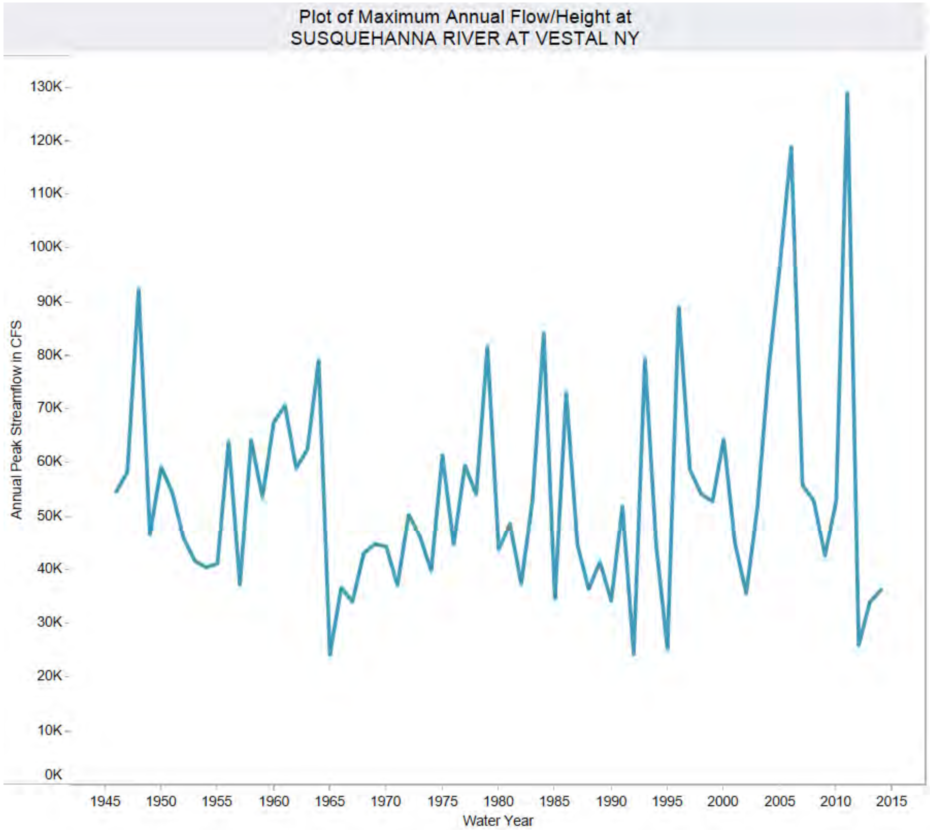
Timeframe Selection
1946 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.682.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.672.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.



Timeframe Selection
1946 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.713.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.647.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

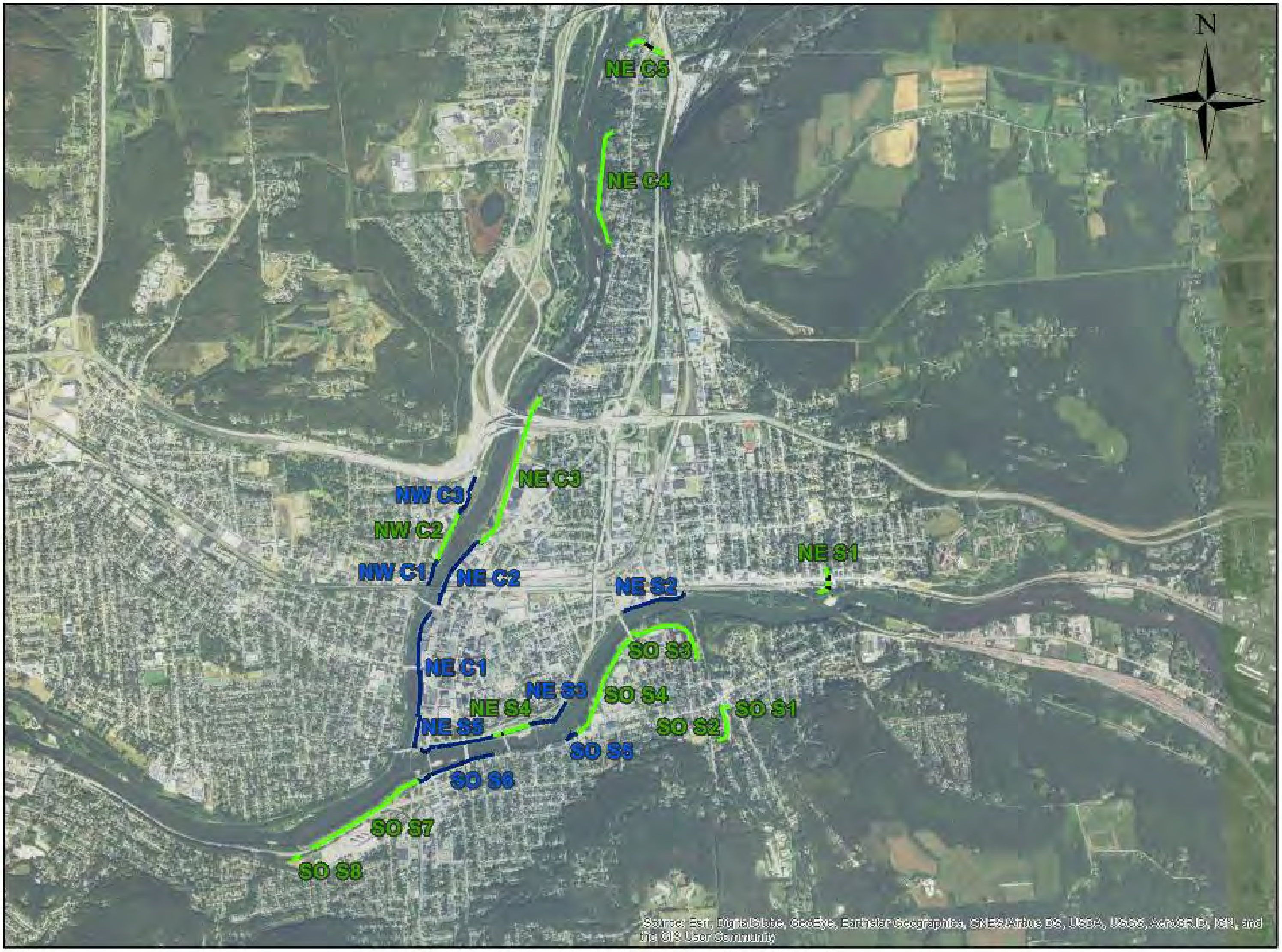
ATTACHMENT 6: CONCEPT DESIGN QUANTITIES

ATTACHMENT 7: SURVEYED TOP OF PROTECTION PROFILE COMPARISONS

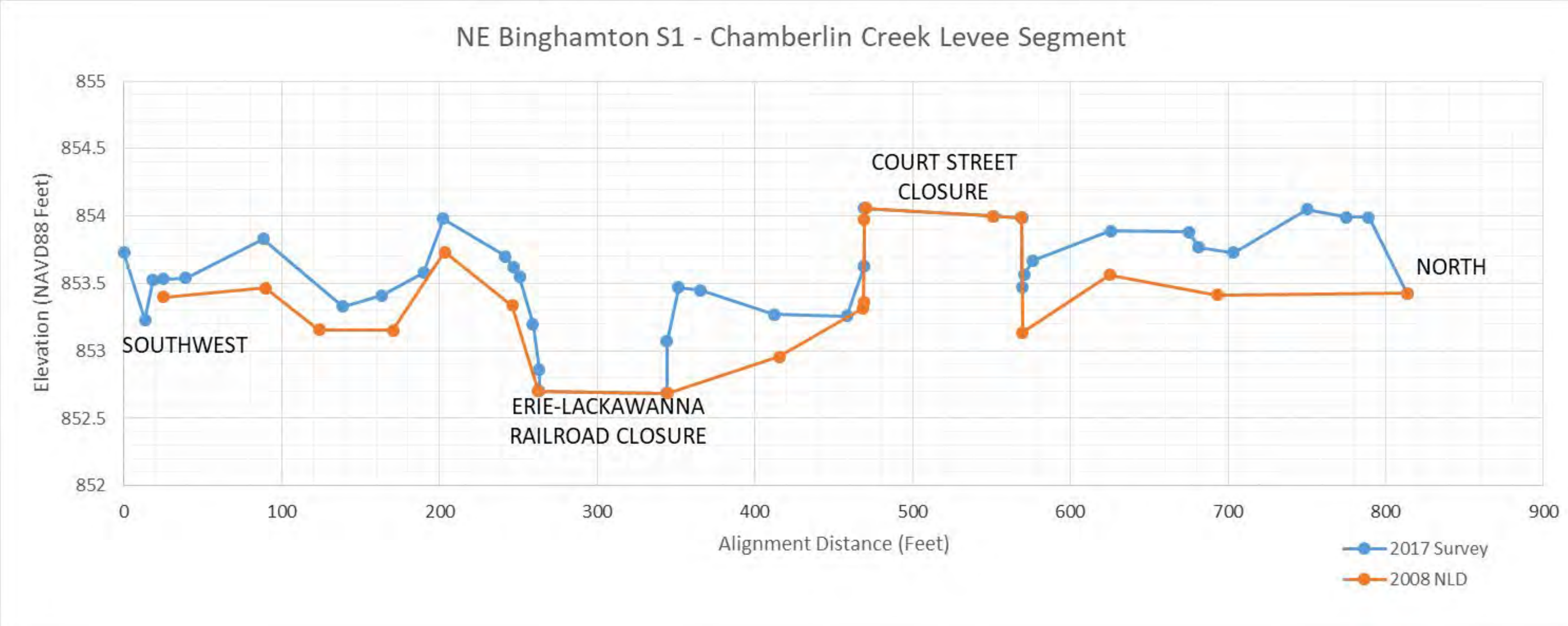
The USACE Pittsburgh District surveyed the top of protection for all of the levee systems in NYSDEC Region 7 including Binghamton/Port Dickinson, Endicott-Johnson City-Vestal, Fairmont Park, Nichols, Whitney Point, Lisle, Greene, and Oxford, including capturing cross- sections at Nichols and Whitney Point. The surveyed locations, excluding Oxford are shown in the figure below. The purpose of this survey is to help identify low points in the levees/floodwalls included in the National Levee Database. The civil engineering team then created profiles to compare the two datasets and corrected elevations in the NLD by comparing profile elevations versus the as-builts. The profile comparisons, NLD update notes, and reference maps are included in this section. Elevations were captured and processed in New York Central State Plane, NAD 83 Coordinate System horizontal datum and NAVD88 vertical datum. The horizontal system was converted to NAD 83 Geographic Coordinate System to match the existing data in the NLD. The surveyor stated in the survey memorandum that the data provided should not be used to replace the NLD due to differences in datums that could not be controlled; but rather to use the data for its original intent, to identify the low spots in each levee system in the NLD. It is also important to note that horizontal variations at tie-ins results in differences in these profiles at those locations since both surveys are capturing different spots at the levee tie-in. Additionally, a geoid difference between the two surveys (Pittsburgh 2017 and NLD in 2008) may be contributing to overall differences between the two datasets. No changes were made in cases where consistent differences were observed that may be attributed to geoid/datum differences.

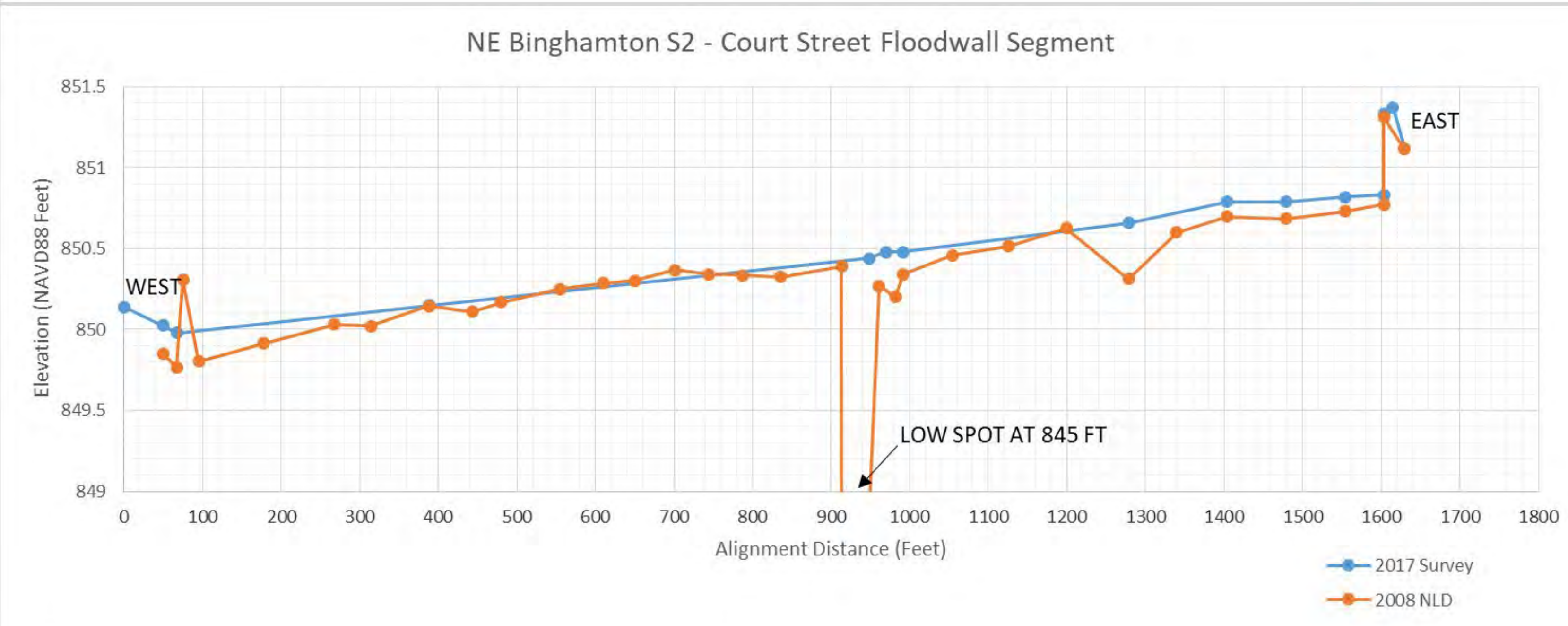
BINGHAMTON FLOOD RISK MANAGEMENT PROJECT

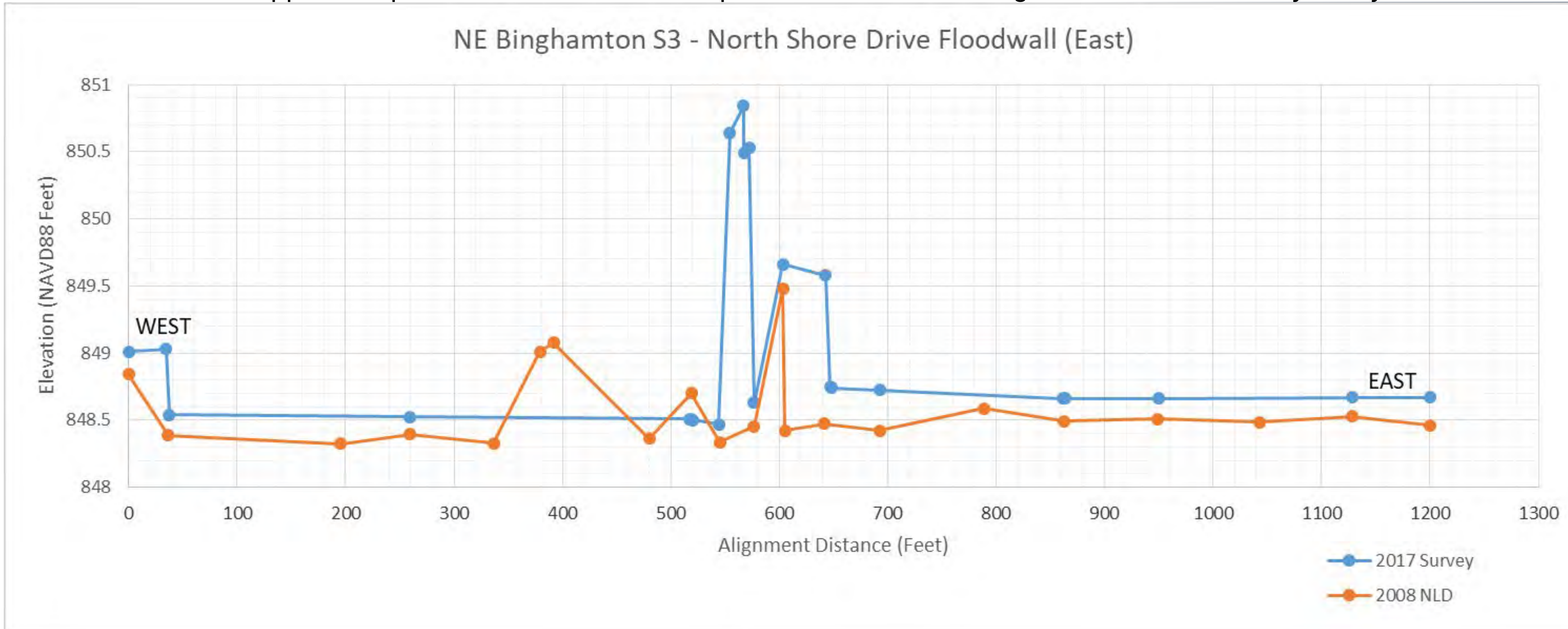
The numbers in this map correspond to each profile created for the FRM project. Notes for NLD changes are included after all of the profiles.

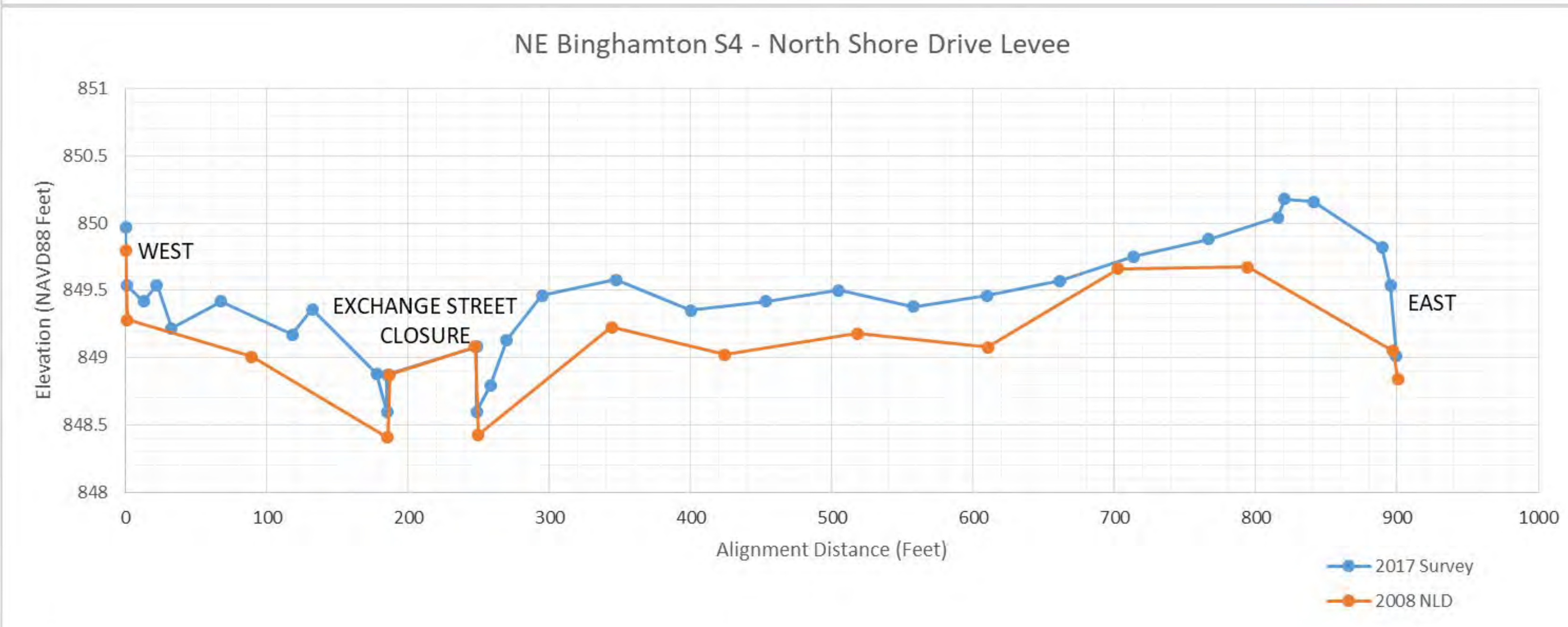


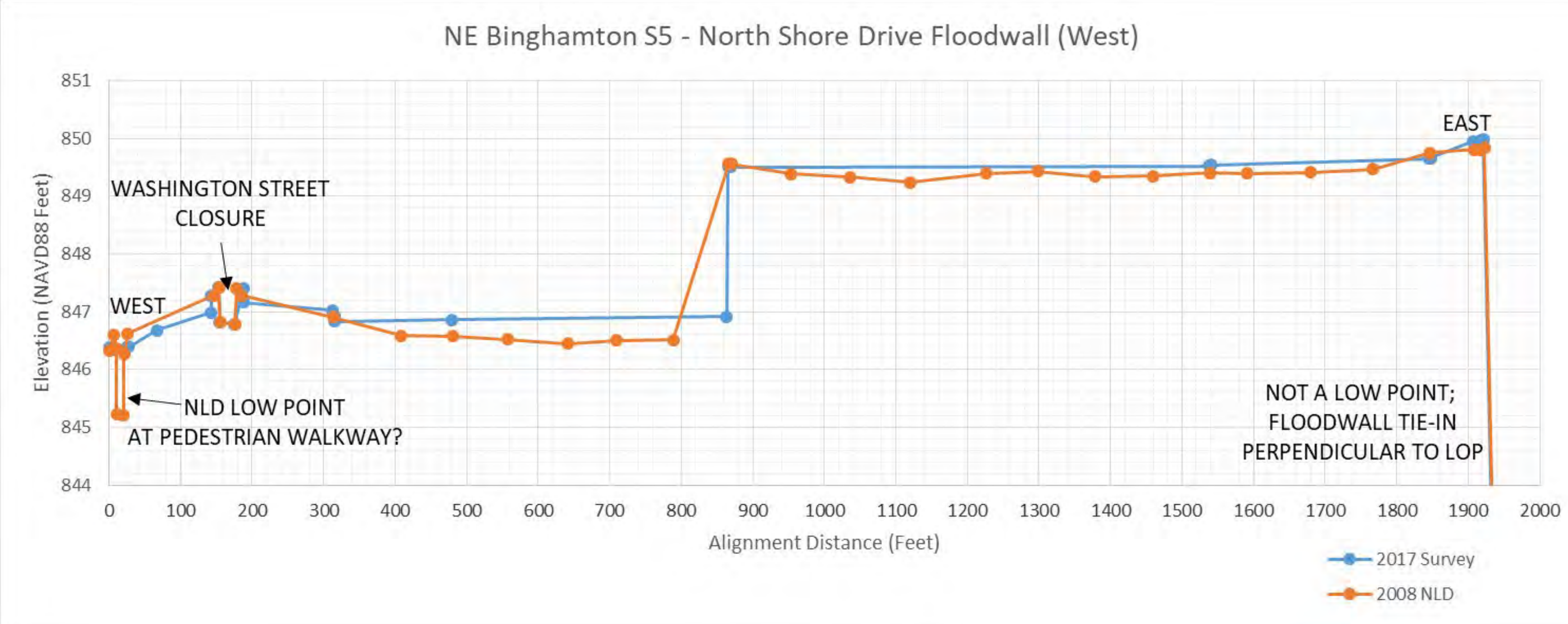
BINGHAMTON NORTHEAST PROFILES

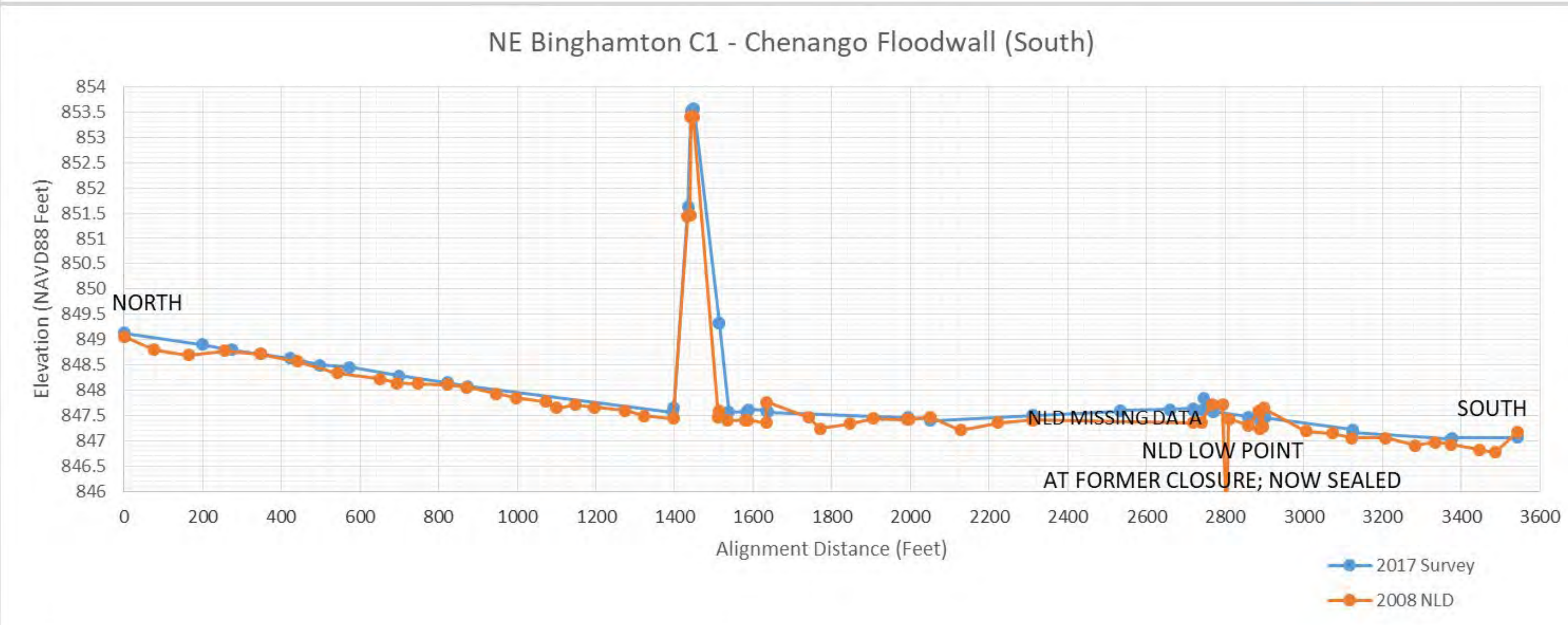


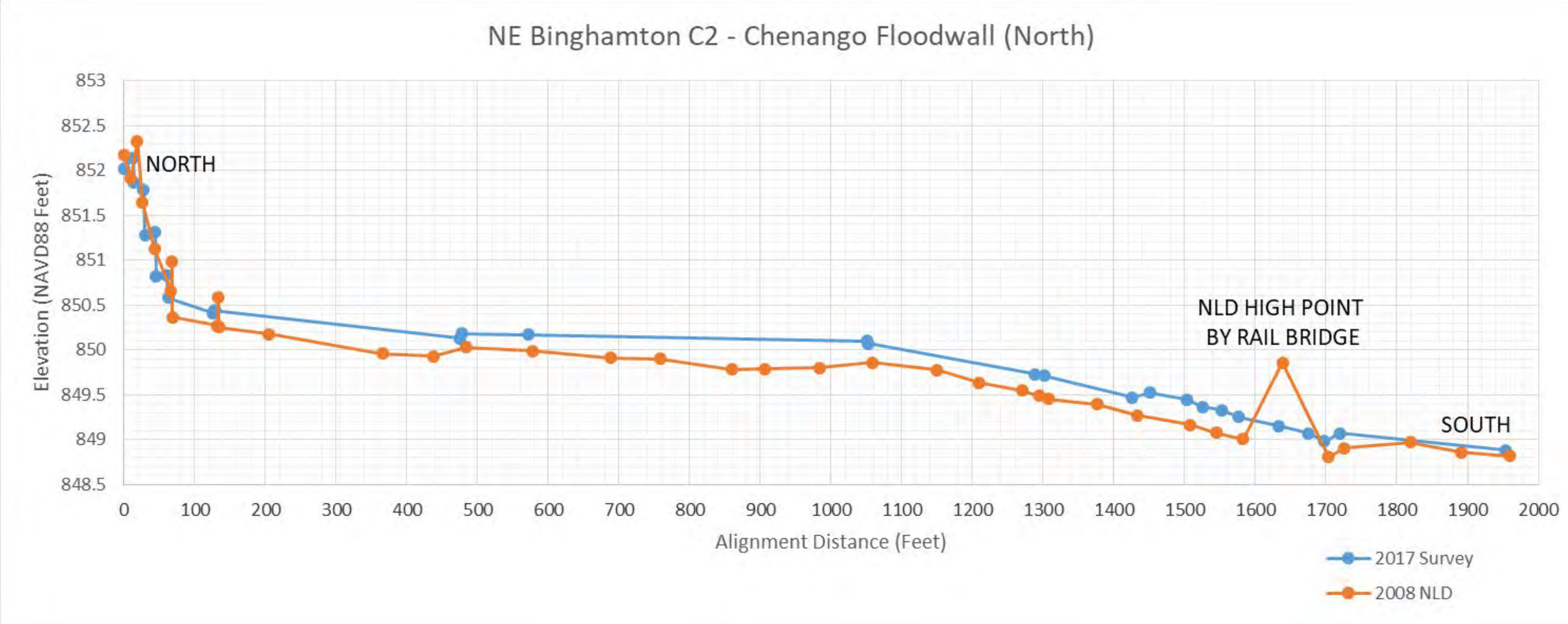


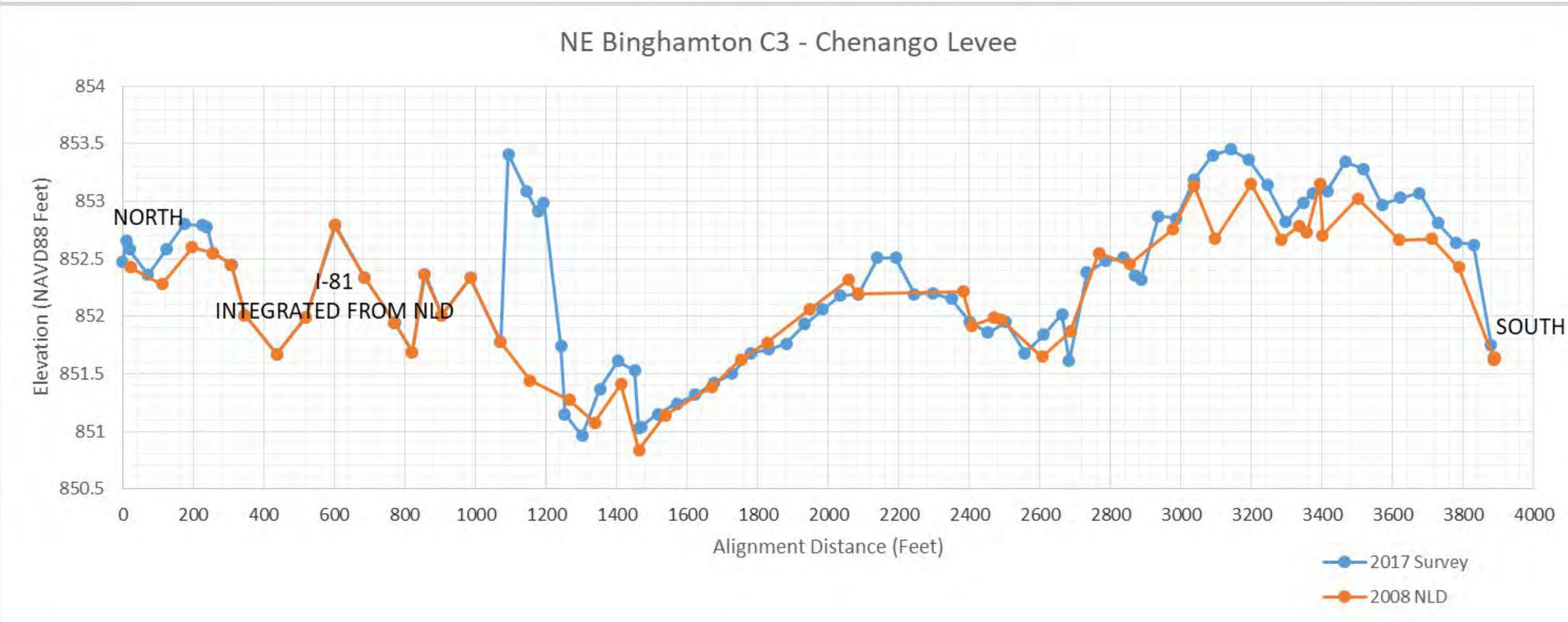

NE Binghamton S3 - North Shore Drive Floodwall (East)
Elevation (NAVD88 Feet)
851
850.5
850
849.5
849
848.5
848
WEST
EAST
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Alignment Distance (Feet)
2017 Survey
2008 NLD

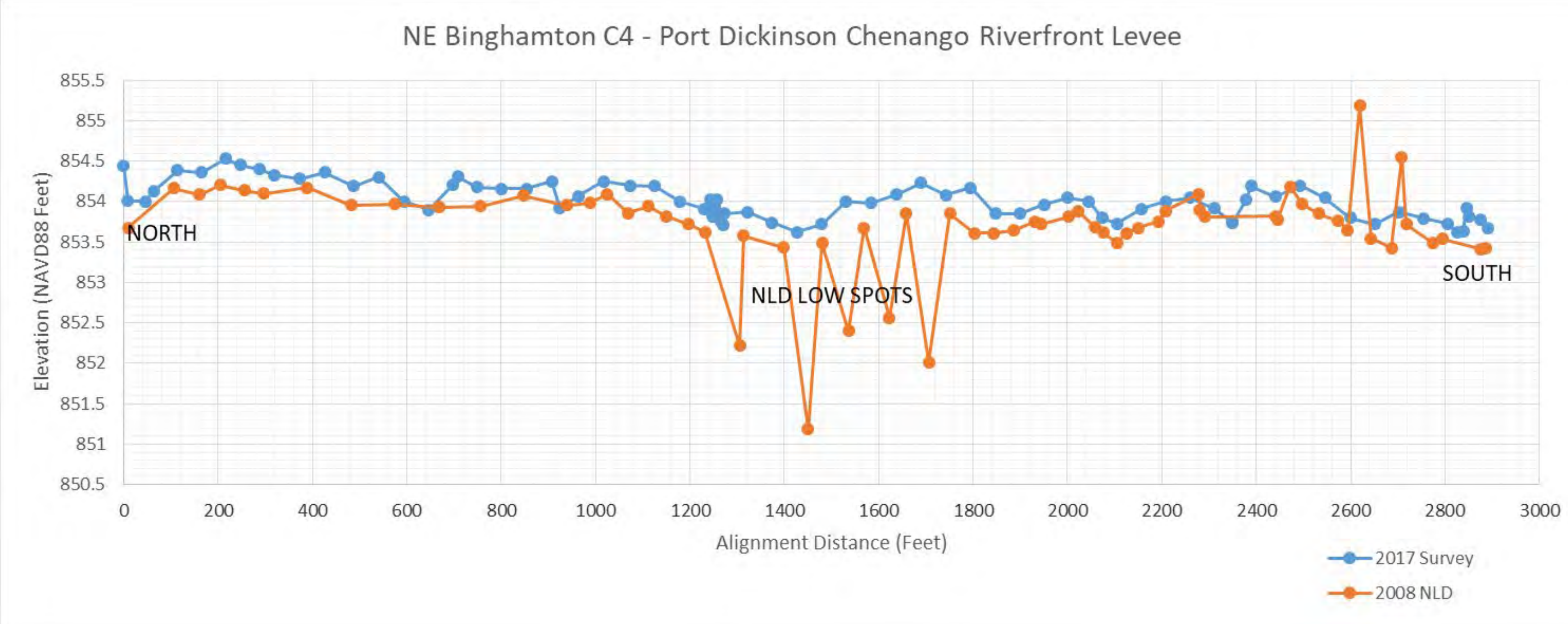

NE Binghamton S4 - North Shore Drive Levee
Elevation (NAVD88 Feet)
851
850.5
850
849.5
849
848.5
848
WEST
EXCHANGE STREET
CLOSURE
EAST
0
100
200
300
400
500
600
700
800
900
1000
Alignment Distance (Feet)
2017 Survey
2008 NLD


NE Binghamton S5 - North Shore Drive Floodwall (West)
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
WASHINGTON STREET CLOSURE
WEST
EAST
NLD LOW POINT AT PEDESTRIAN WALKWAY?
NOT A LOW POINT; FLOODWALL TIE-IN PERPENDICULAR TO LOP
2017 Survey
2008 NLD

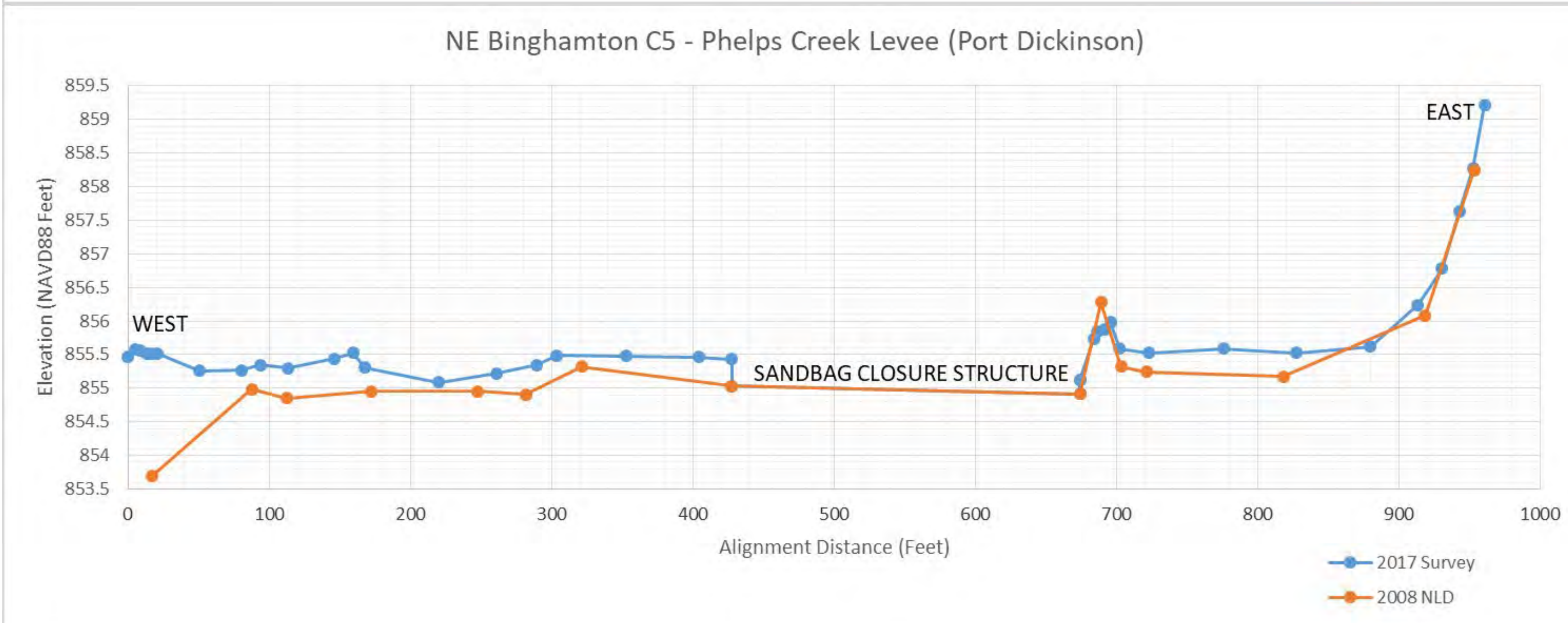

NE Binghamton C1 - Chenango Floodwall (South)
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
NORTH
SOUTH
NLD MISSING DATA
NLD LOW POINT AT FORMER CLOSURE; NOW SEALED
2017 Survey
2008 NLD


NE Binghamton C2 - Chenango Floodwall (North)
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
NORTH
NLD HIGH POINT
BY RAIL BRIDGE
SOUTH
2017 Survey
2008 NLD


NE Binghamton C3 - Chenango Levee
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
NORTH
I-81
INTEGRATED FROM NLD
SOUTH
2017 Survey
2008 NLD

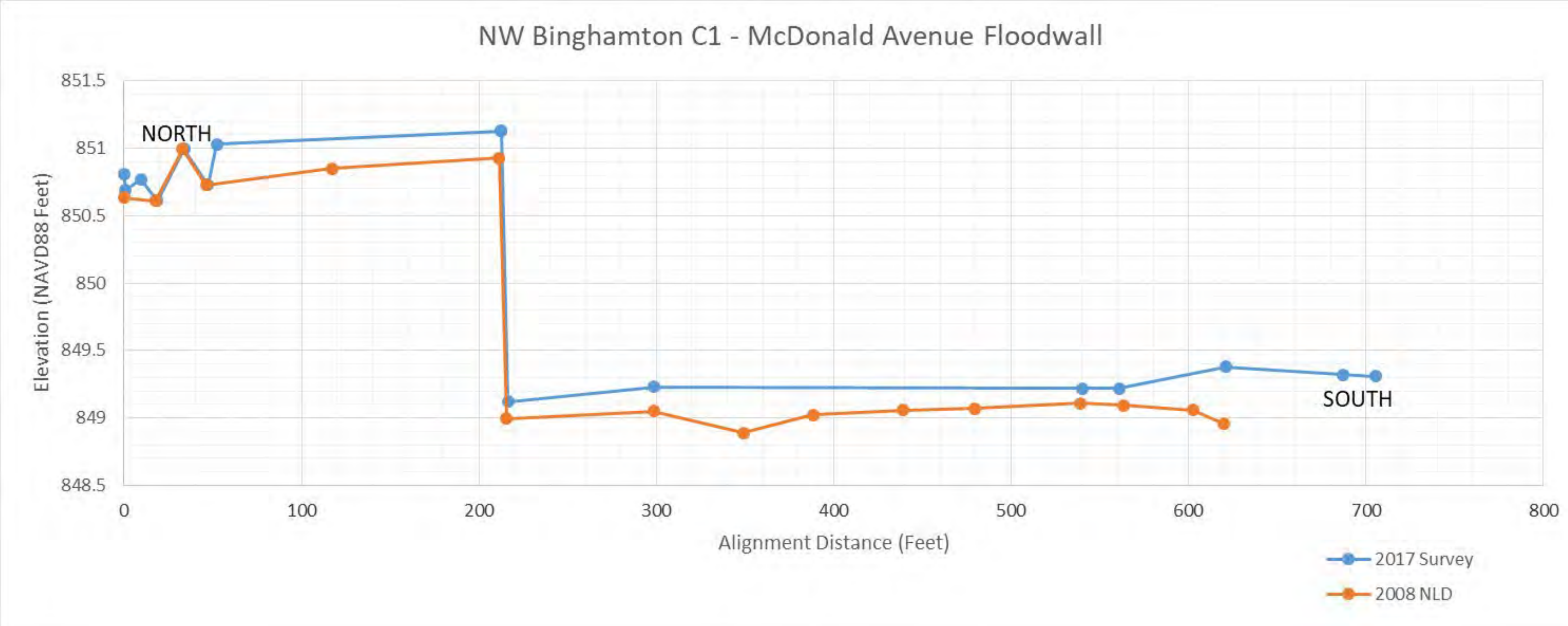


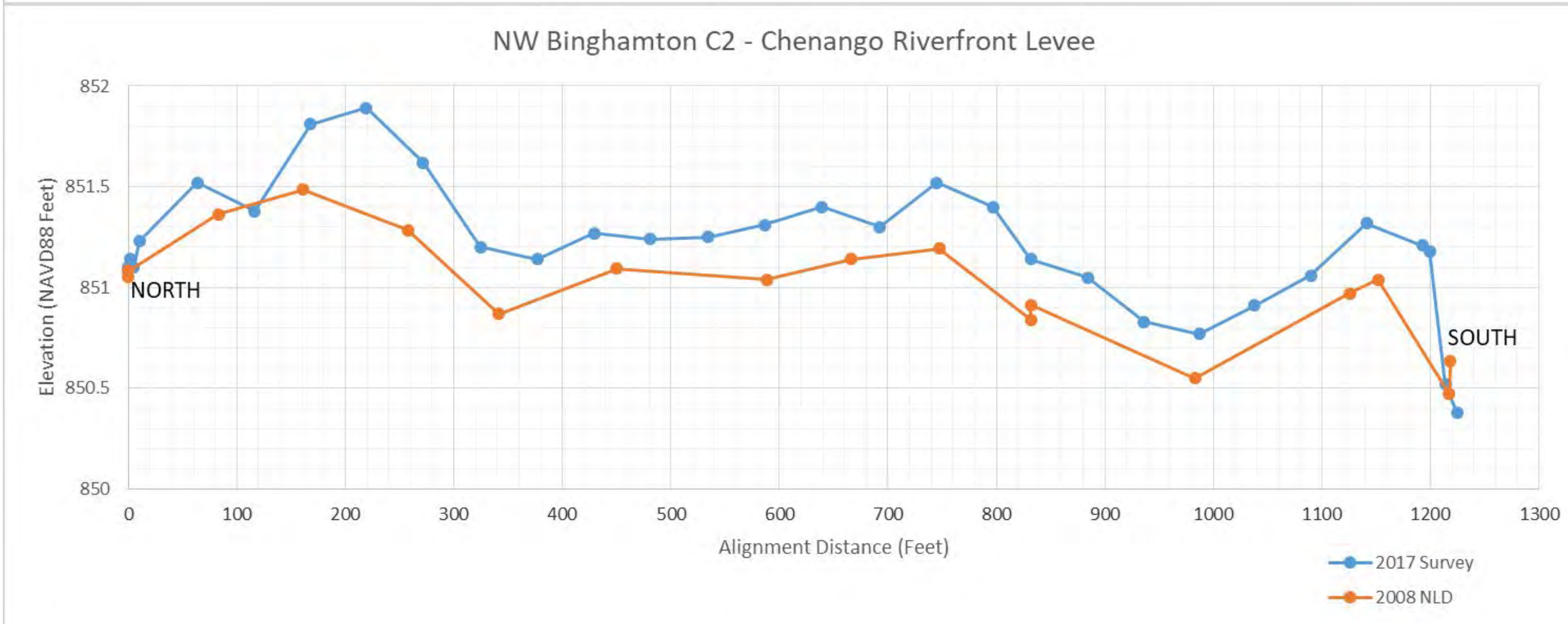
NE Binghamton C4 - Port Dickinson Chenango Riverfront Levee
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
NORTH
NLD LOW SPOTS
SOUTH
2017 Survey
2008 NLD

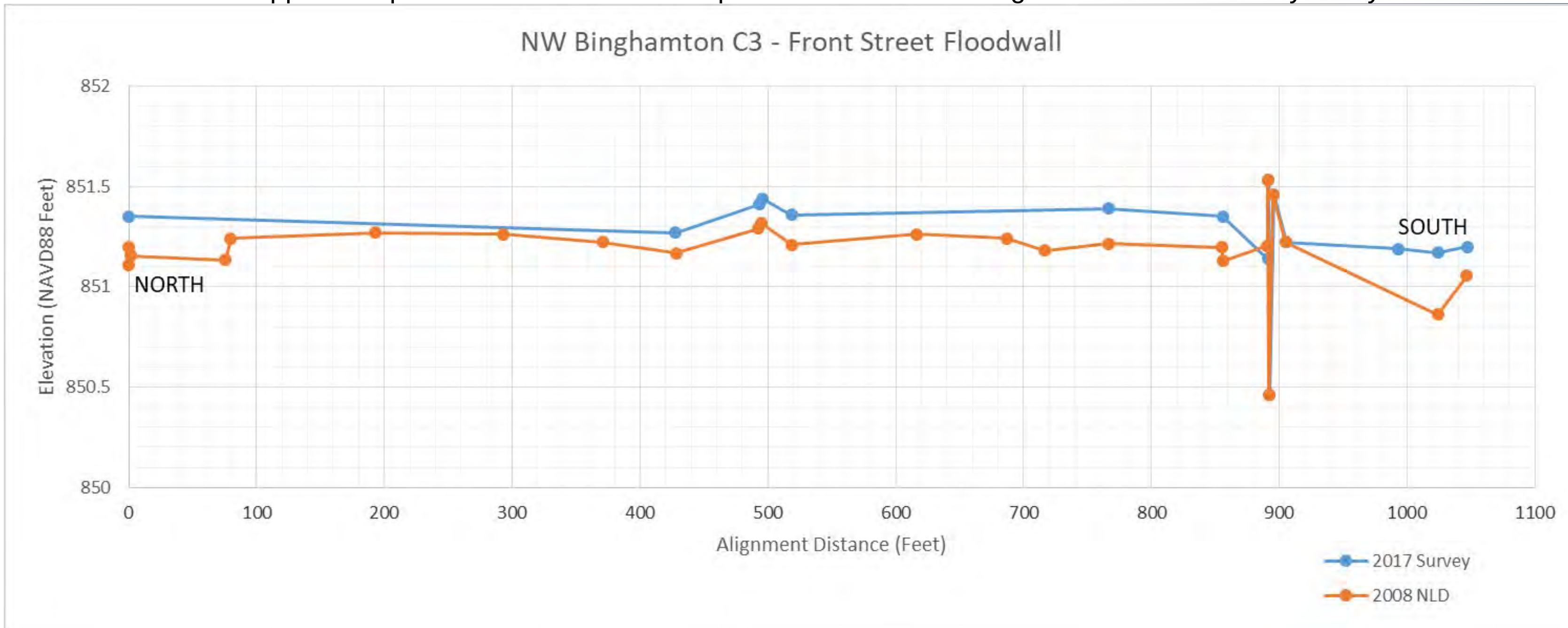


NE Binghamton C5 - Phelps Creek Levee (Port Dickinson)
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
WEST
SANDBAG CLOSURE STRUCTURE
EAST
2017 Survey
2008 NLD

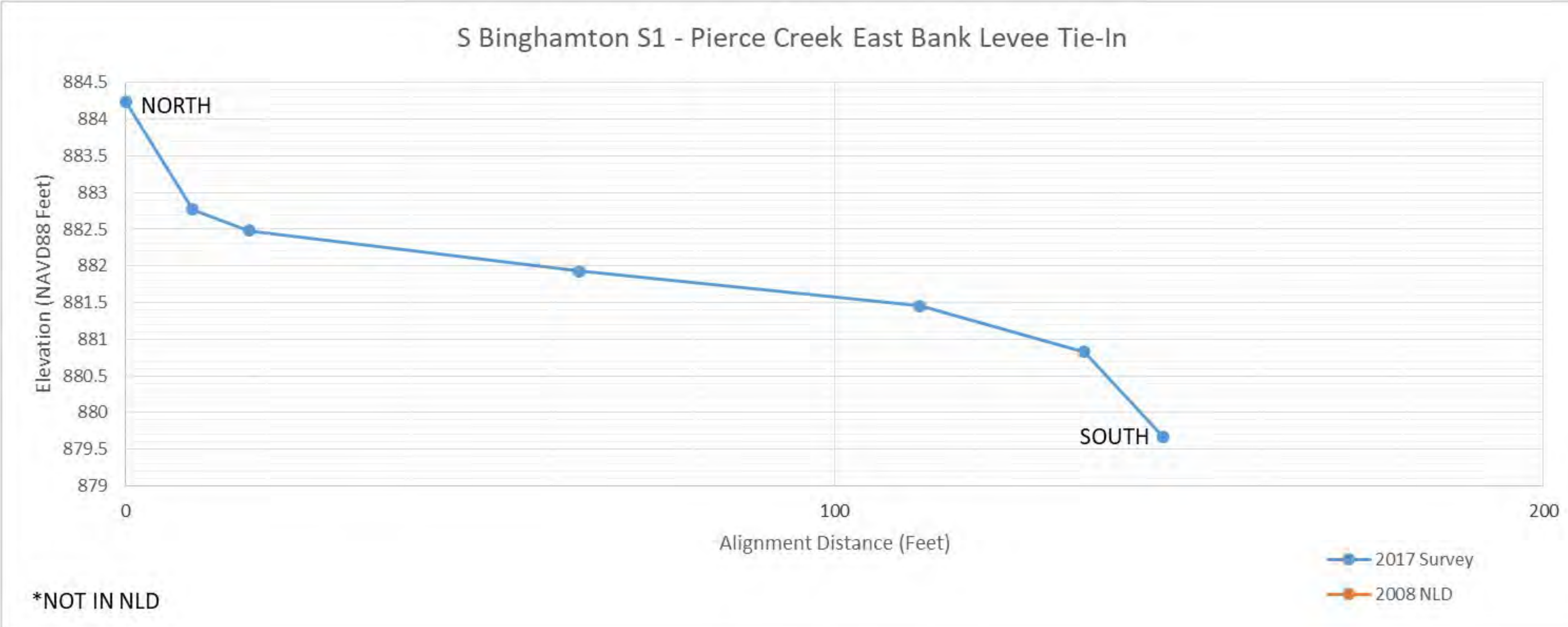
BINGHAMTON NORTHWEST PROFILES

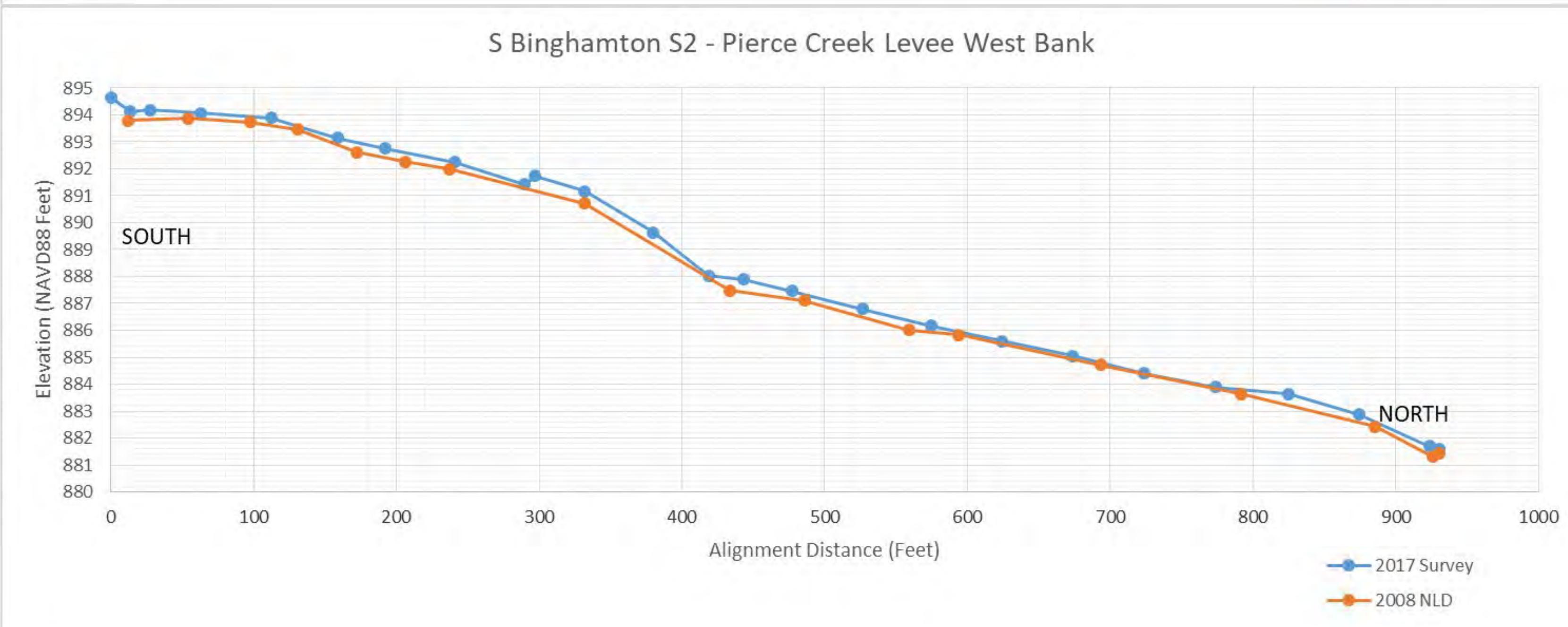


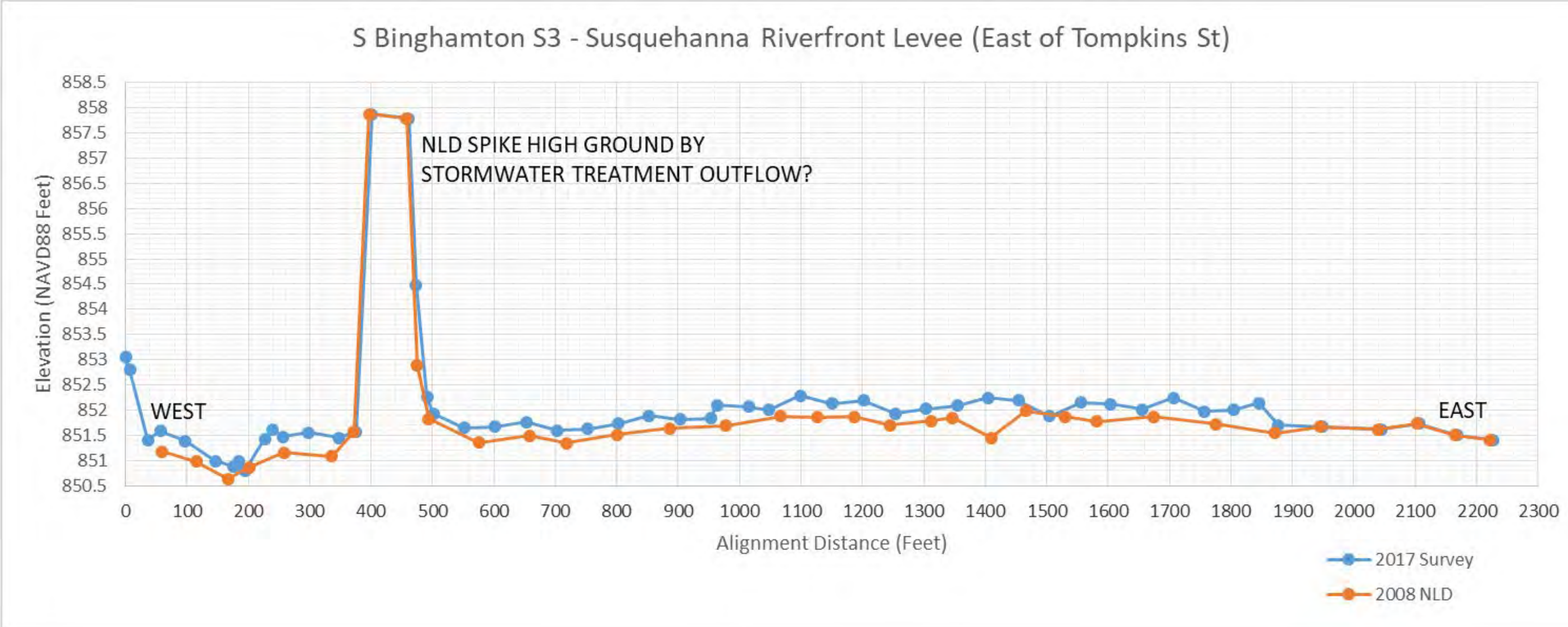


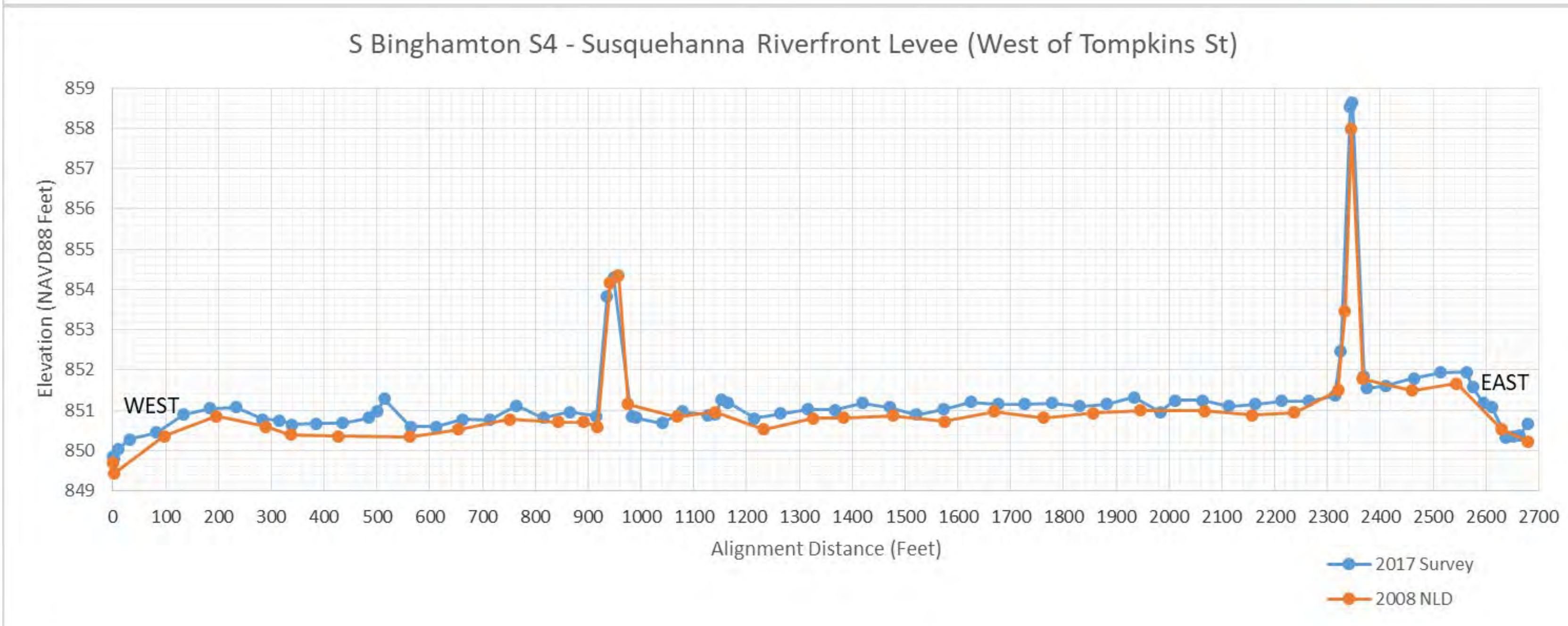

NW Binghamton C3 - Front Street Floodwall
Elevation (NAVD88 Feet)
852
851.5
851
850.5
850
0
100
200
300
400
500
600
700
800
900
1000
1100
Alignment Distance (Feet)
NORTH
SOUTH
2017 Survey
2008 NLD

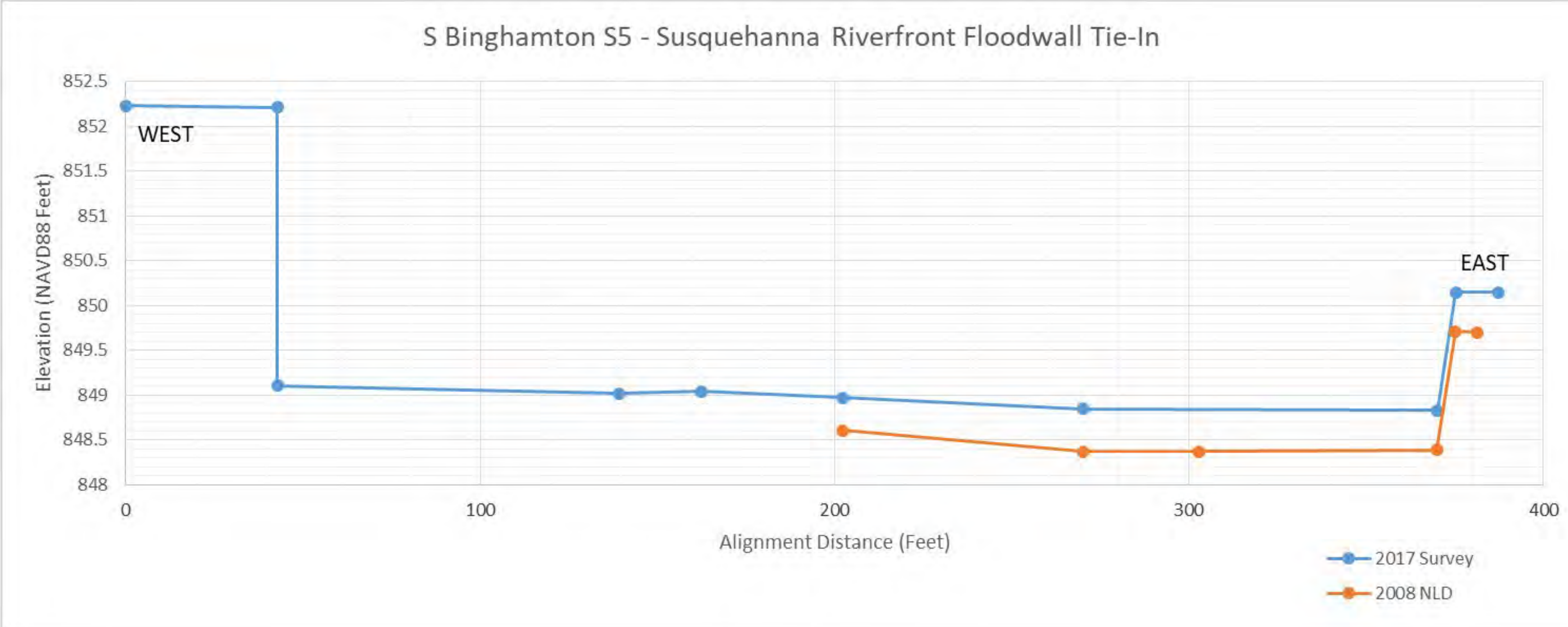
BINGHAMTON SOUTH PROFILES

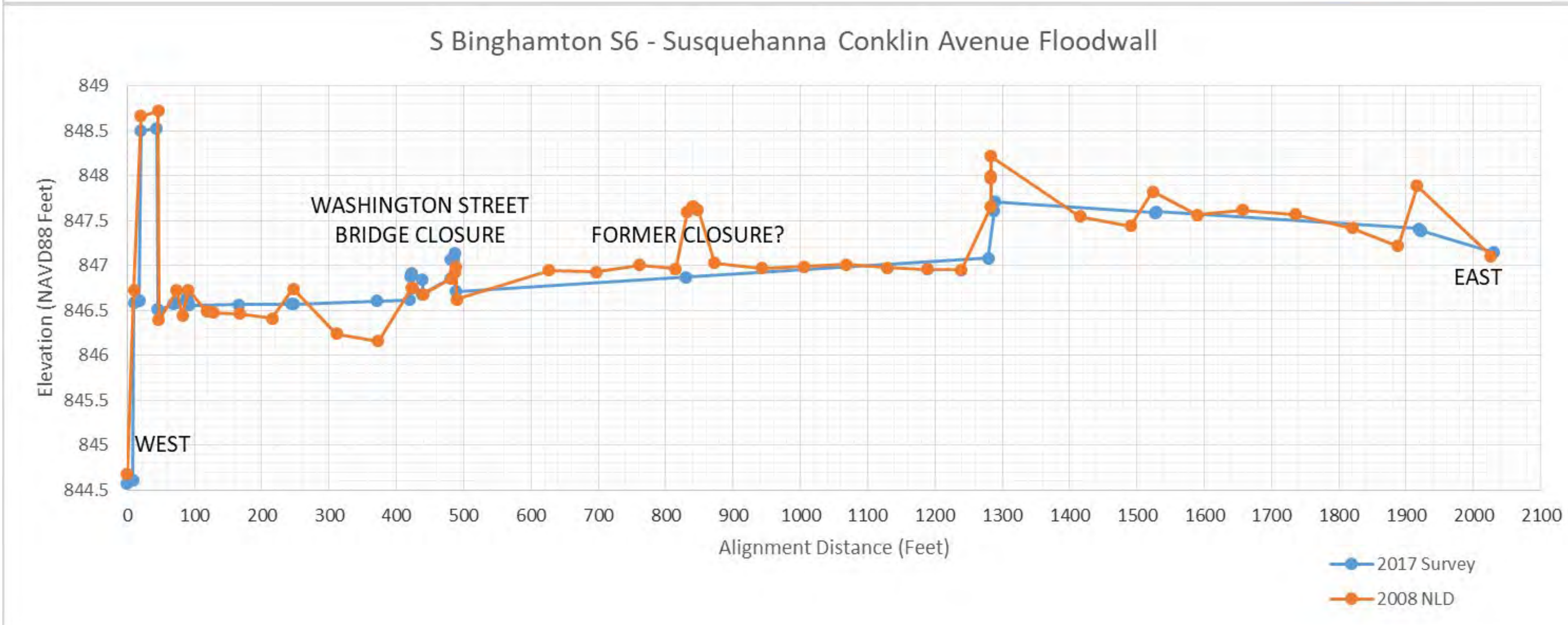


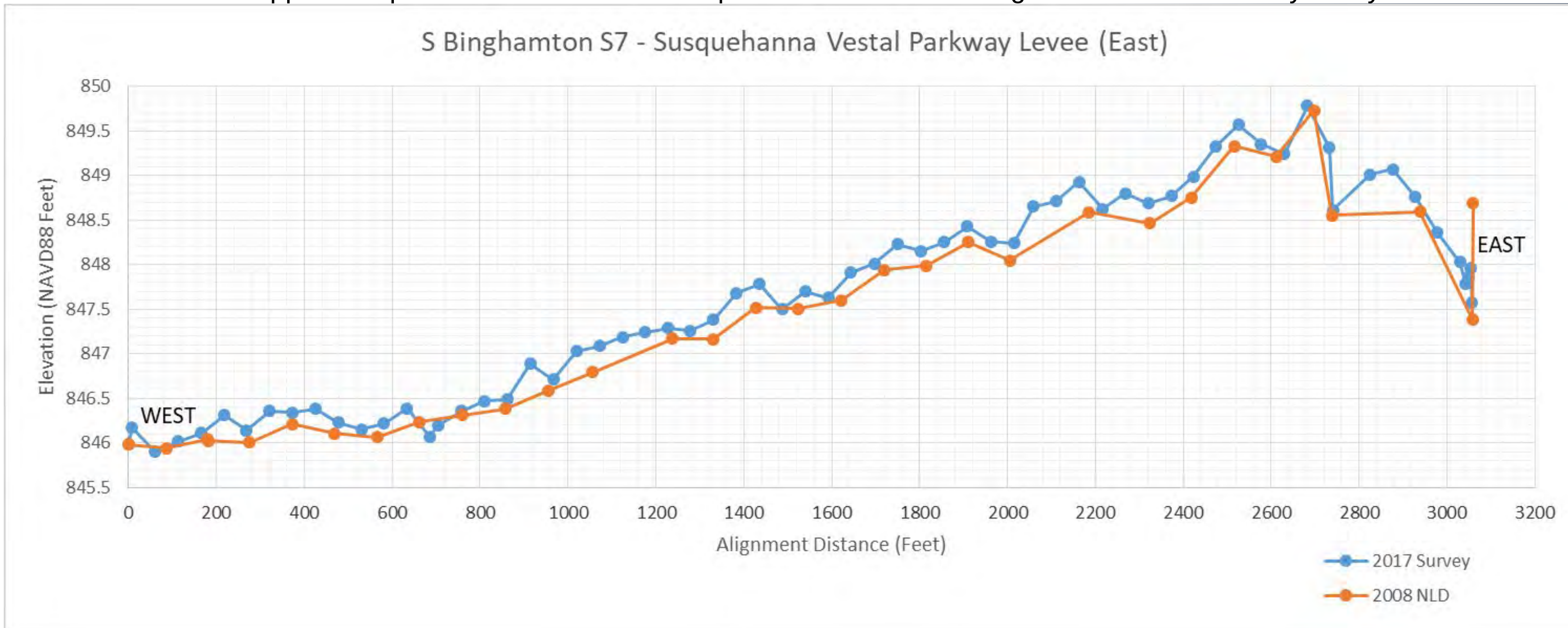


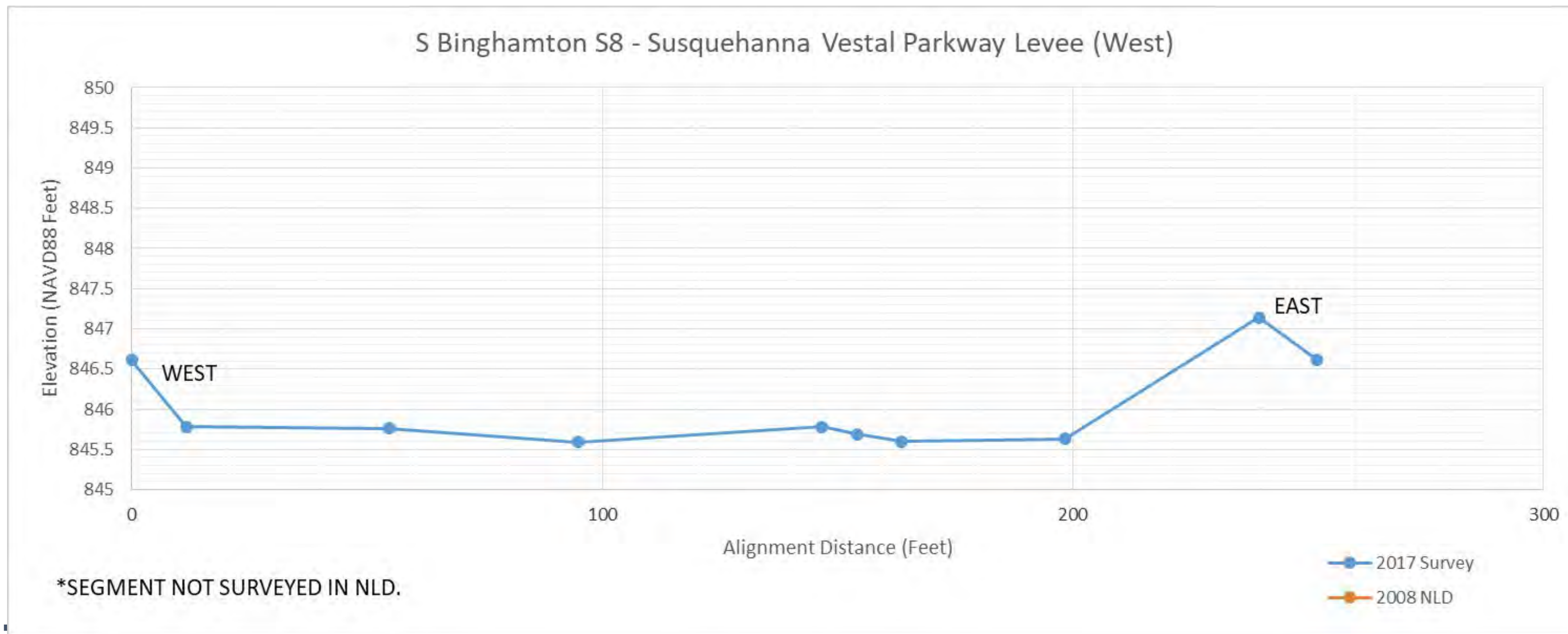

S Binghamton S3 - Susquehanna Riverfront Levee (East of Tompkins St)
NLD SPIKE HIGH GROUND BY
STORMWATER TREATMENT OUTFLOW?
WEST
EAST
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
2017 Survey
2008 NLD


S Binghamton S4 - Susquehanna Riverfront Levee (West of Tompkins St)
WEST
EAST
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
2017 Survey
2008 NLD


S Binghamton S5 - Susquehanna Riverfront Floodwall Tie-In
Elevation (NAVD88 Feet)
852.5
852
851.5
851
850.5
850
849.5
849
848.5
848
WEST
EAST
0
100
200
300
400
Alignment Distance (Feet)
2017 Survey
2008 NLD

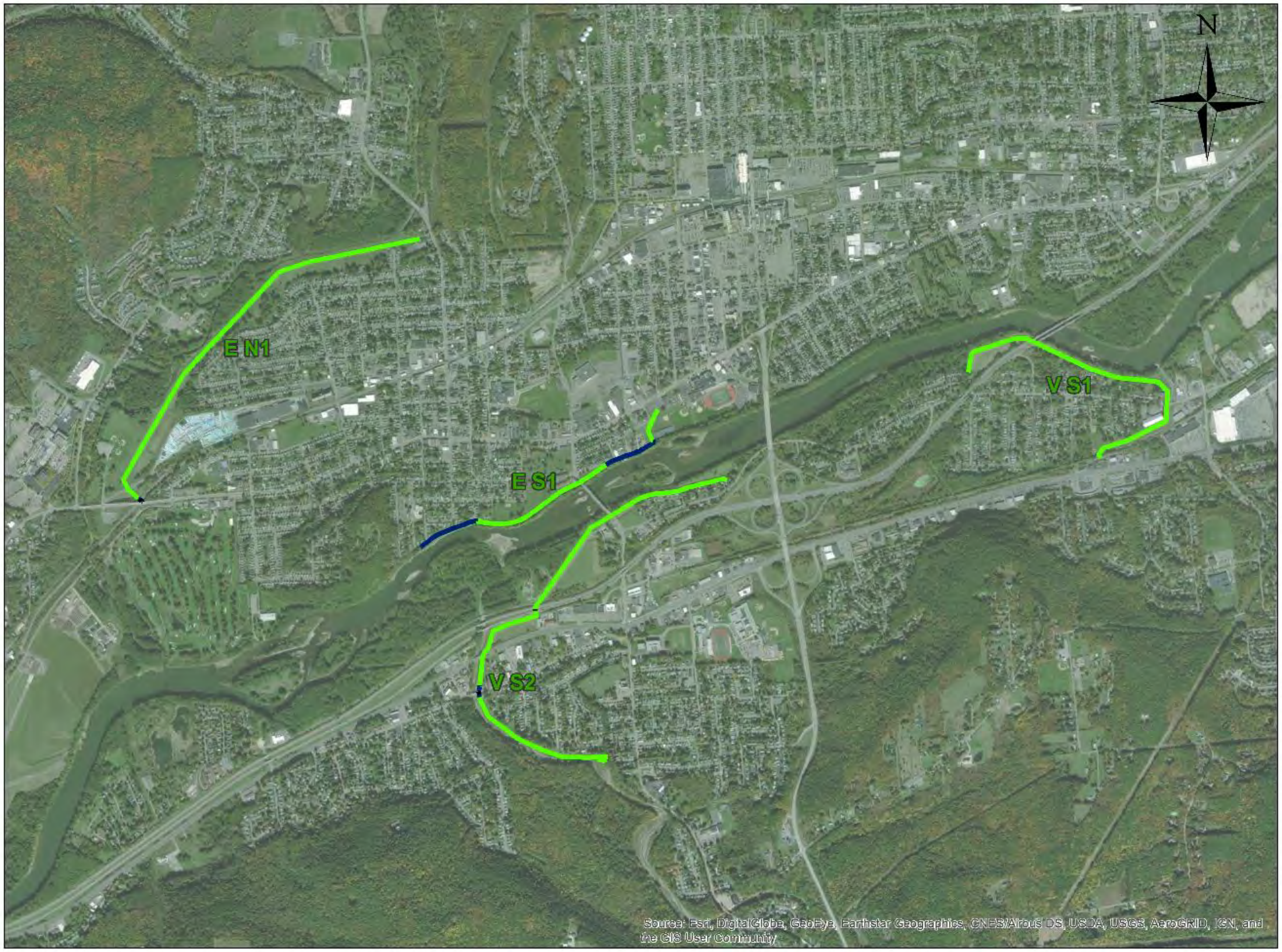

S Binghamton S6 - Susquehanna Conklin Avenue Floodwall
Elevation (NAVD88 Feet)
849
848.5
848
847.5
847
846.5
846
845.5
845
844.5
WASHINGTON STREET
BRIDGE CLOSURE
FORMER CLOSURE?
WEST
EAST
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Alignment Distance (Feet)
2017 Survey
2008 NLD


S Binghamton S7 - Susquehanna Vestal Parkway Levee (East)
Elevation (NAVD88 Feet)
850
849.5
849
848.5
848
847.5
847
846.5
846
845.5
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
Alignment Distance (Feet)
WEST
EAST
2017 Survey
2008 NLD

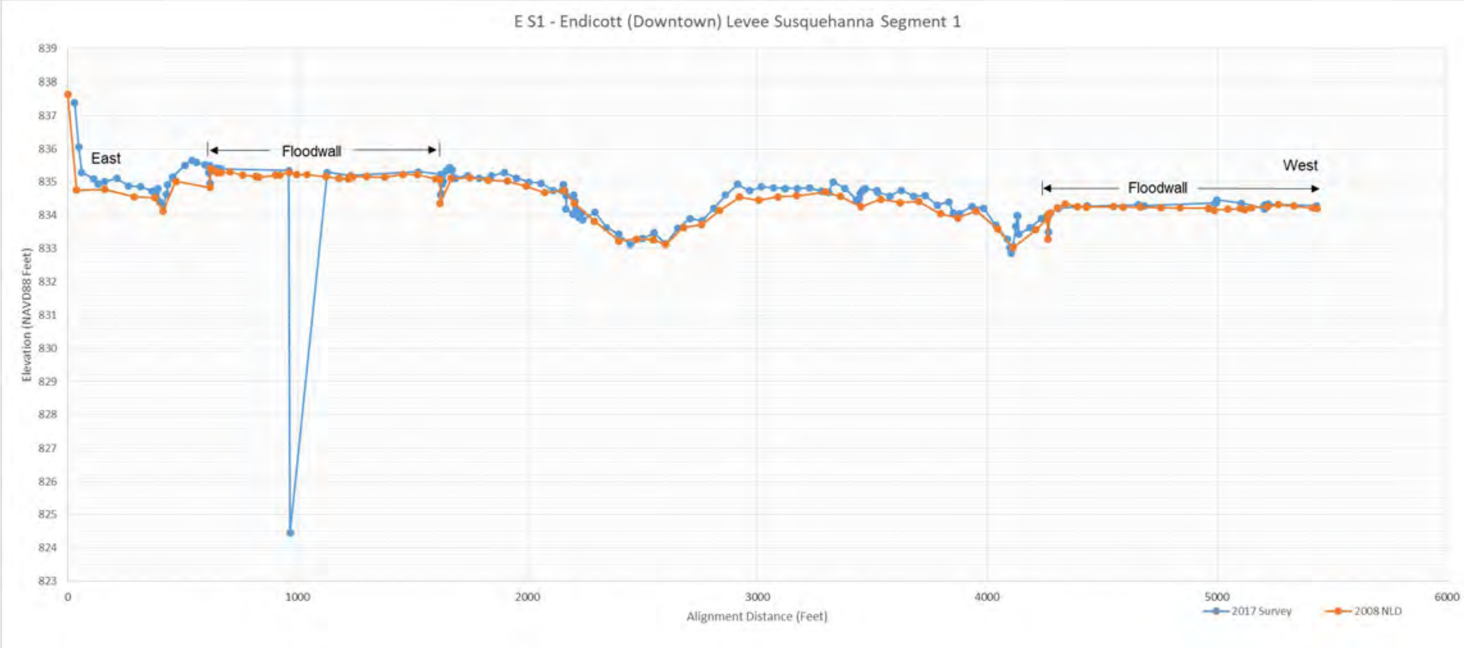

S Binghamton S8 - Susquehanna Vestal Parkway Levee (West)
Elevation (NAVD88 Feet)
850
849.5
849
848.5
848
847.5
847
846.5
846
845.5
845
0
100
200
300
Alignment Distance (Feet)
WEST
EAST
*SEGMENT NOT SURVEYED IN NLD.
2017 Survey
2008 NLD

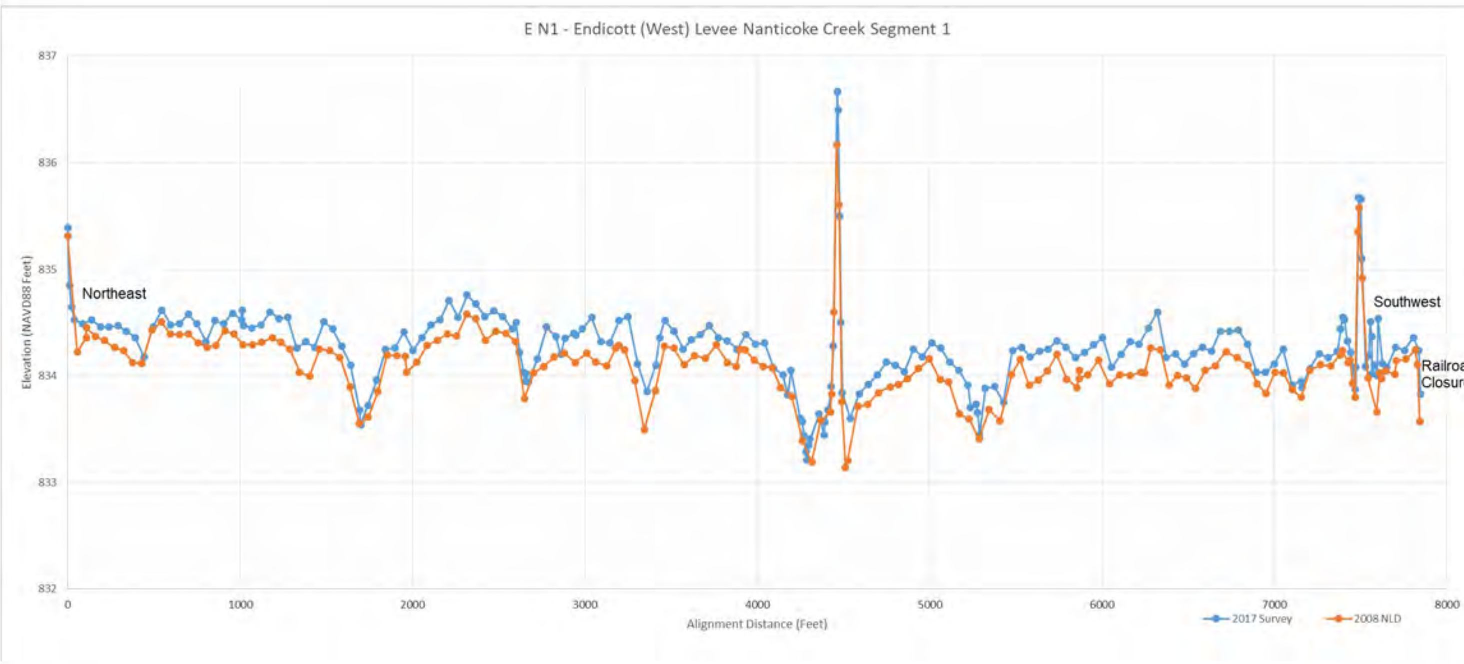
ENDICOTT AND VESTAL SYSTEMS (EJV FRM PROJECT)

The numbers in this map correspond to each profile created for the FRM project. No changes were recommended based on a review of comparison profiles in the FRM project.

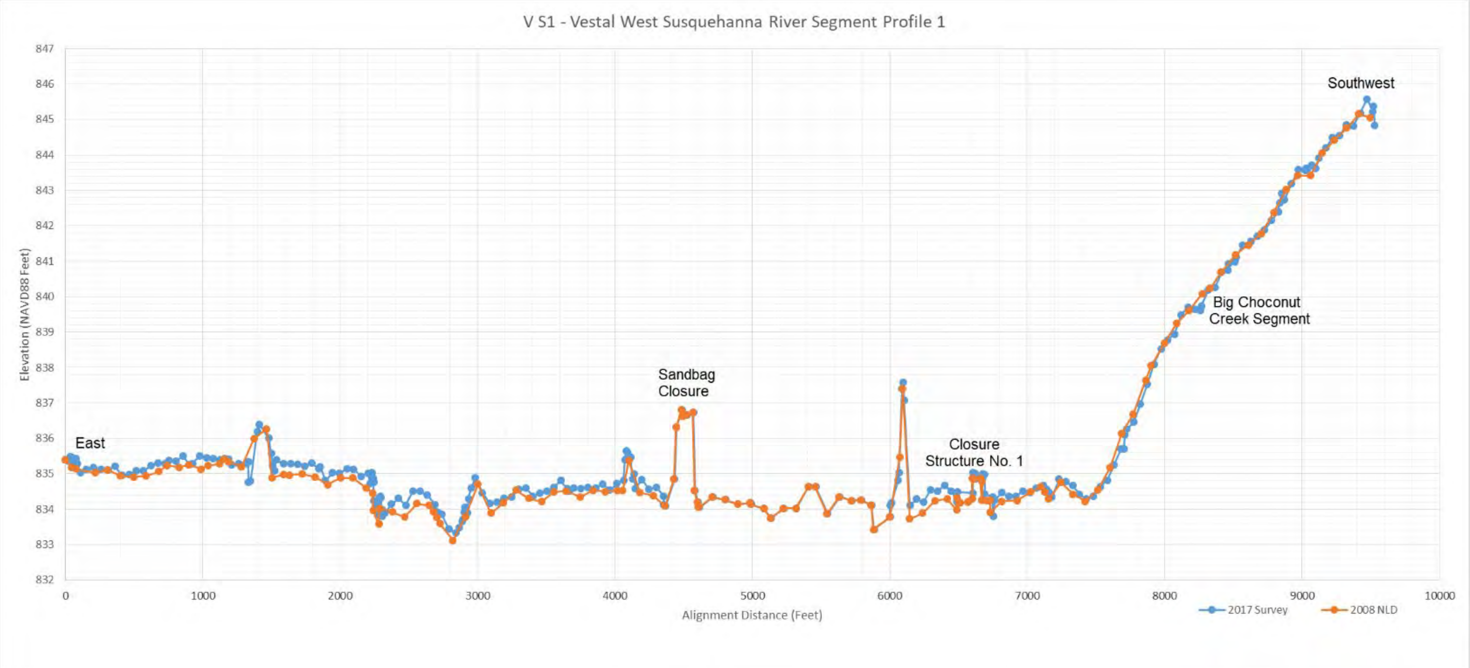


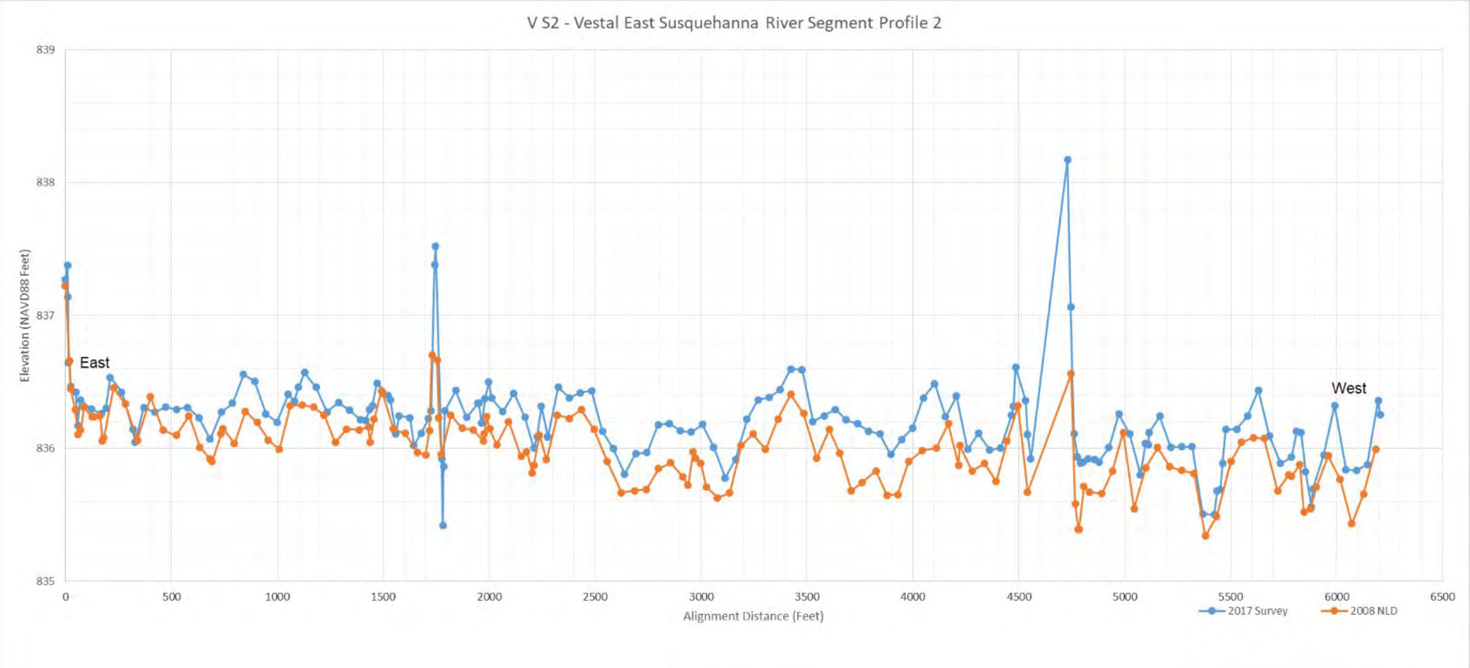
ENDICOTT SYSTEM PROFILES





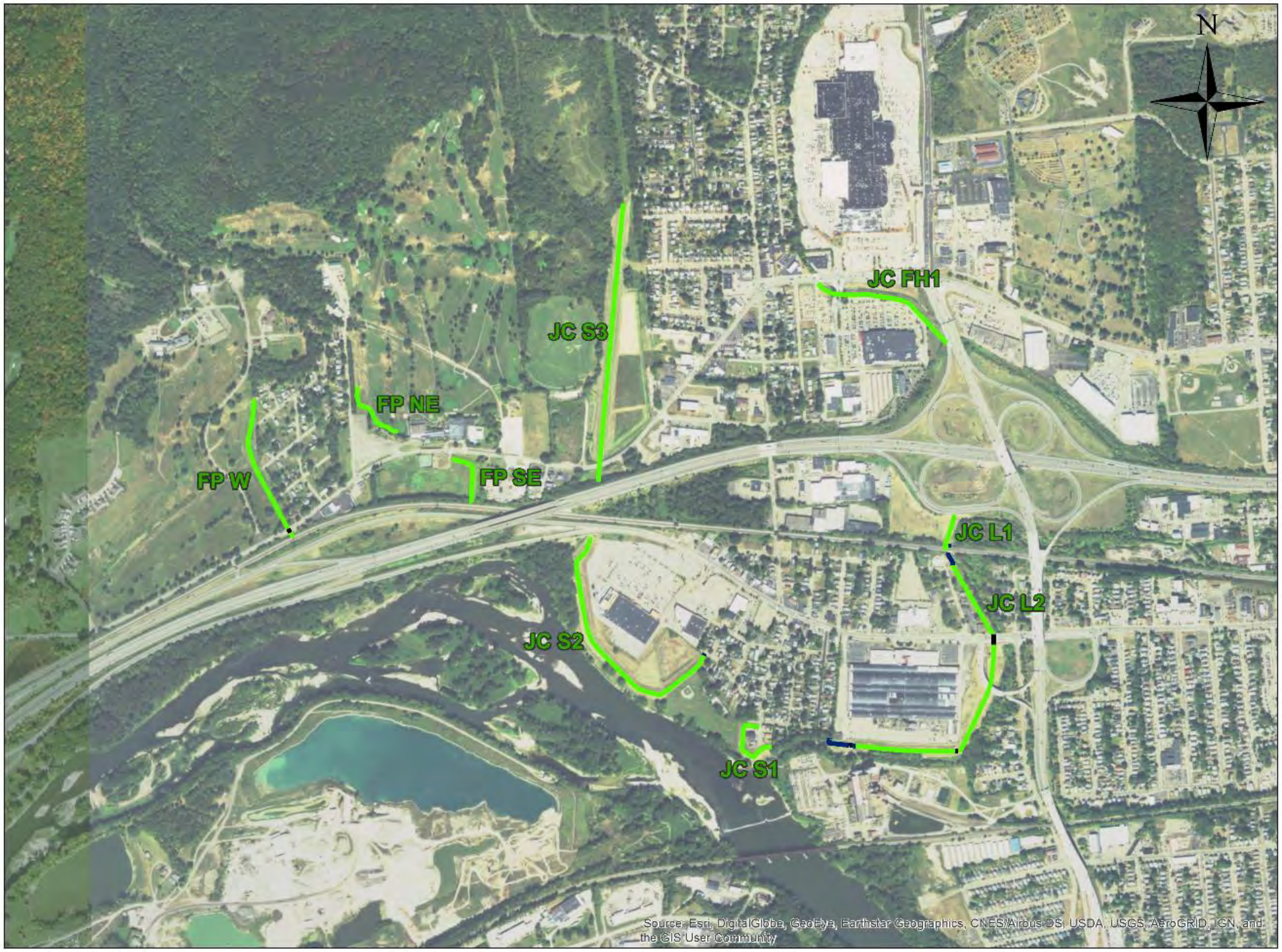
VESTAL SYSTEM PROFILES



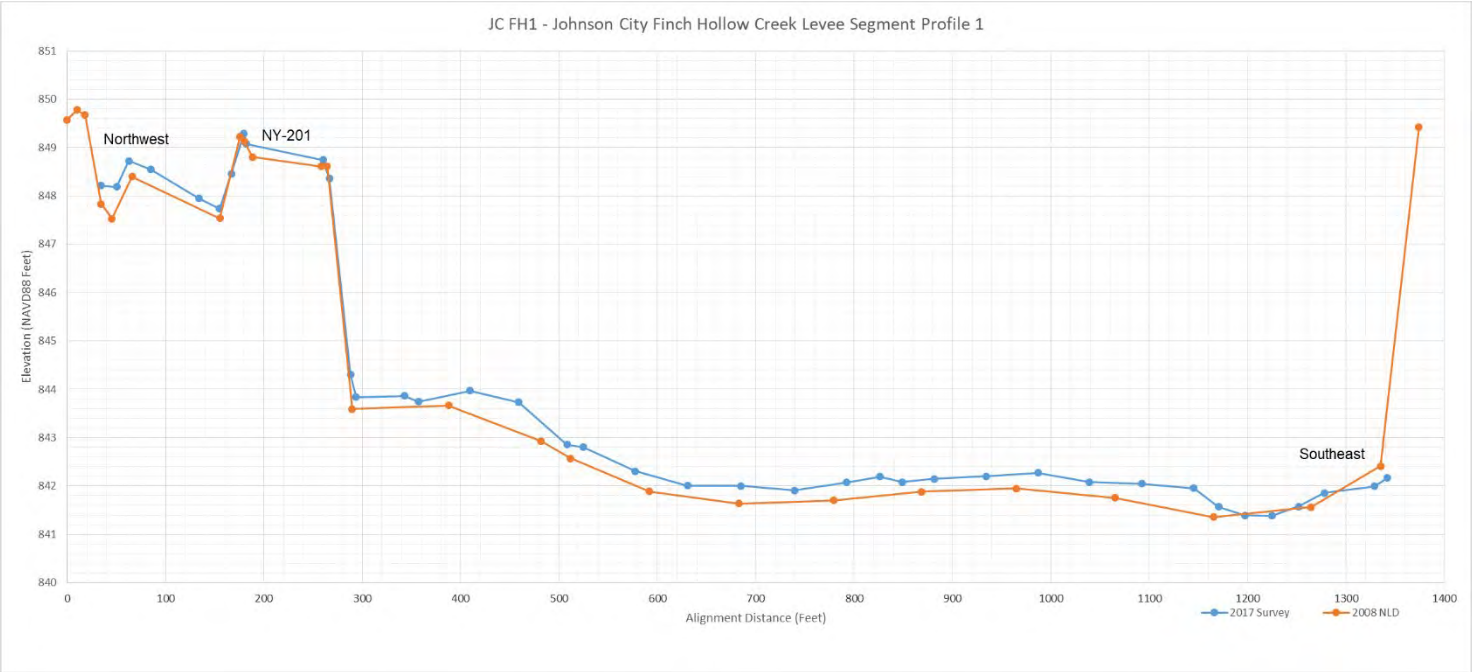


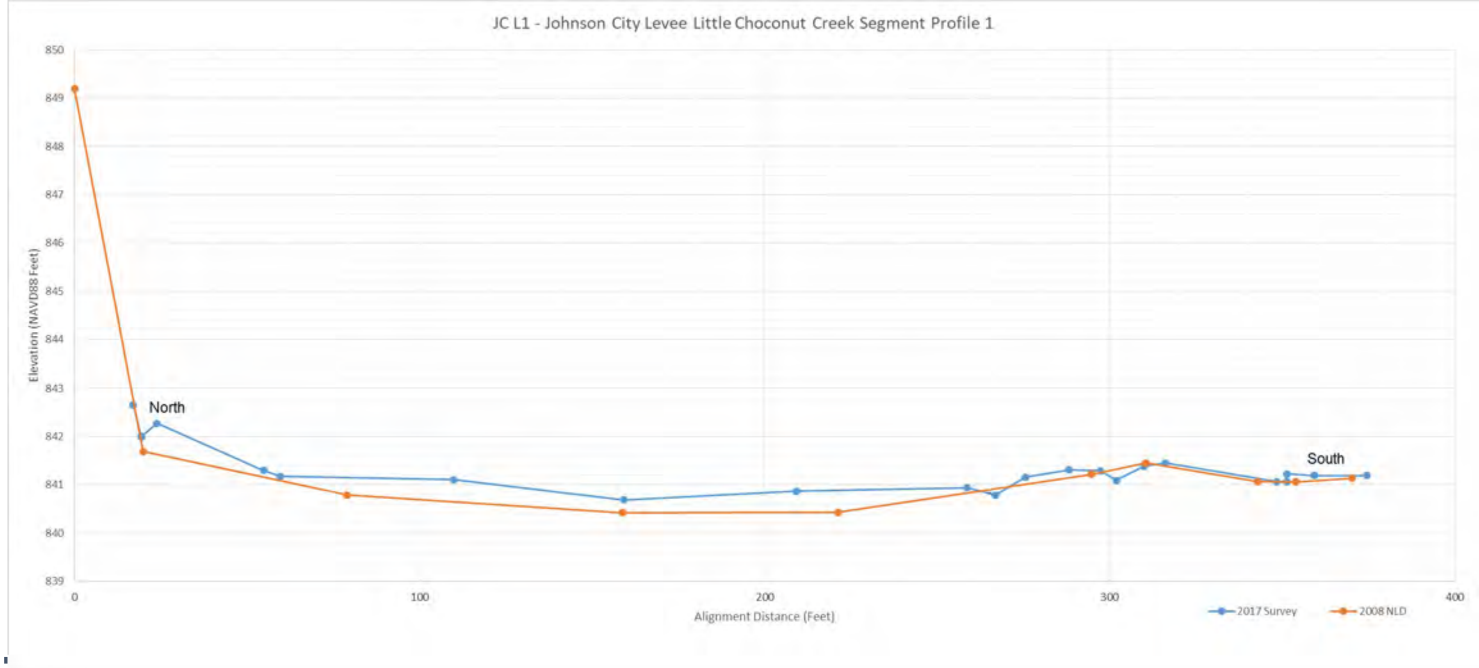
JOHNSON CITY SYSTEM (EJV FRM PROJECT); FAIRMONT PARK FRM PROJECT (NON-FEDERAL)

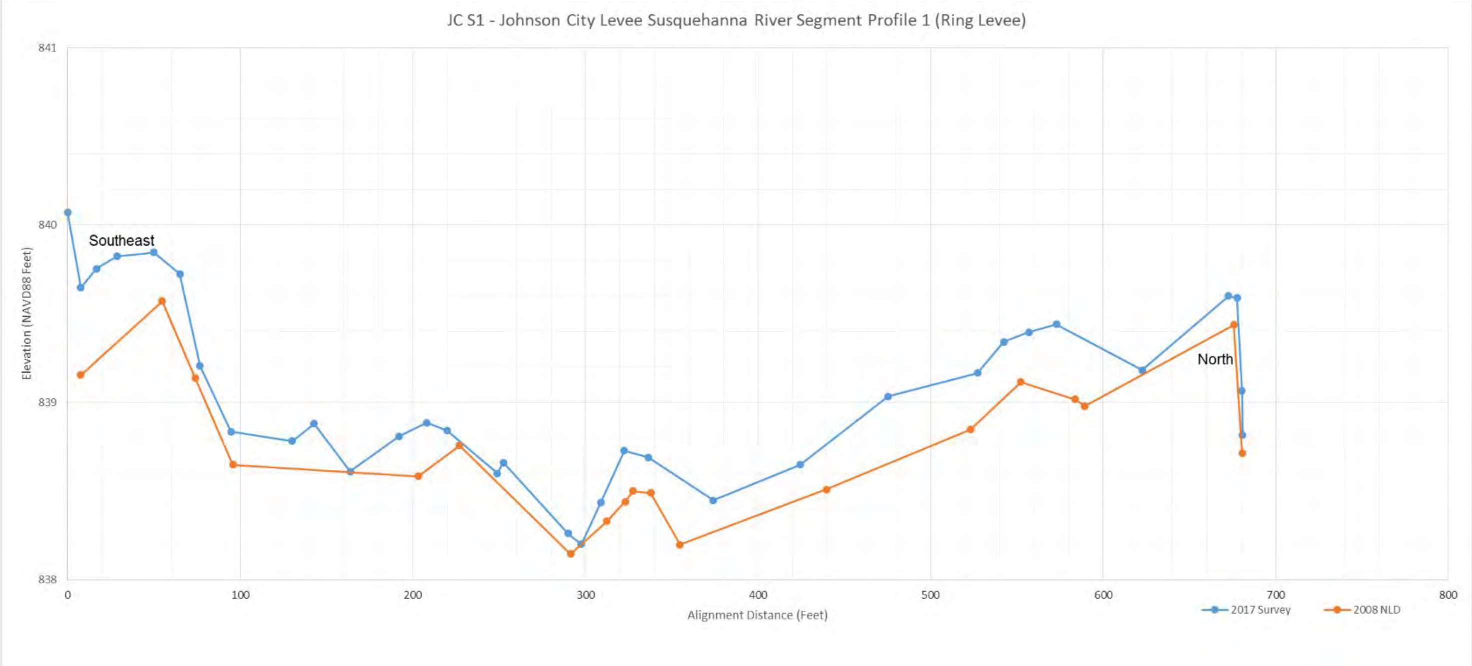
The numbers in this map correspond to each profile created for the FRM project. No changes were recommended based on a review of comparison profiles in the FRM project.

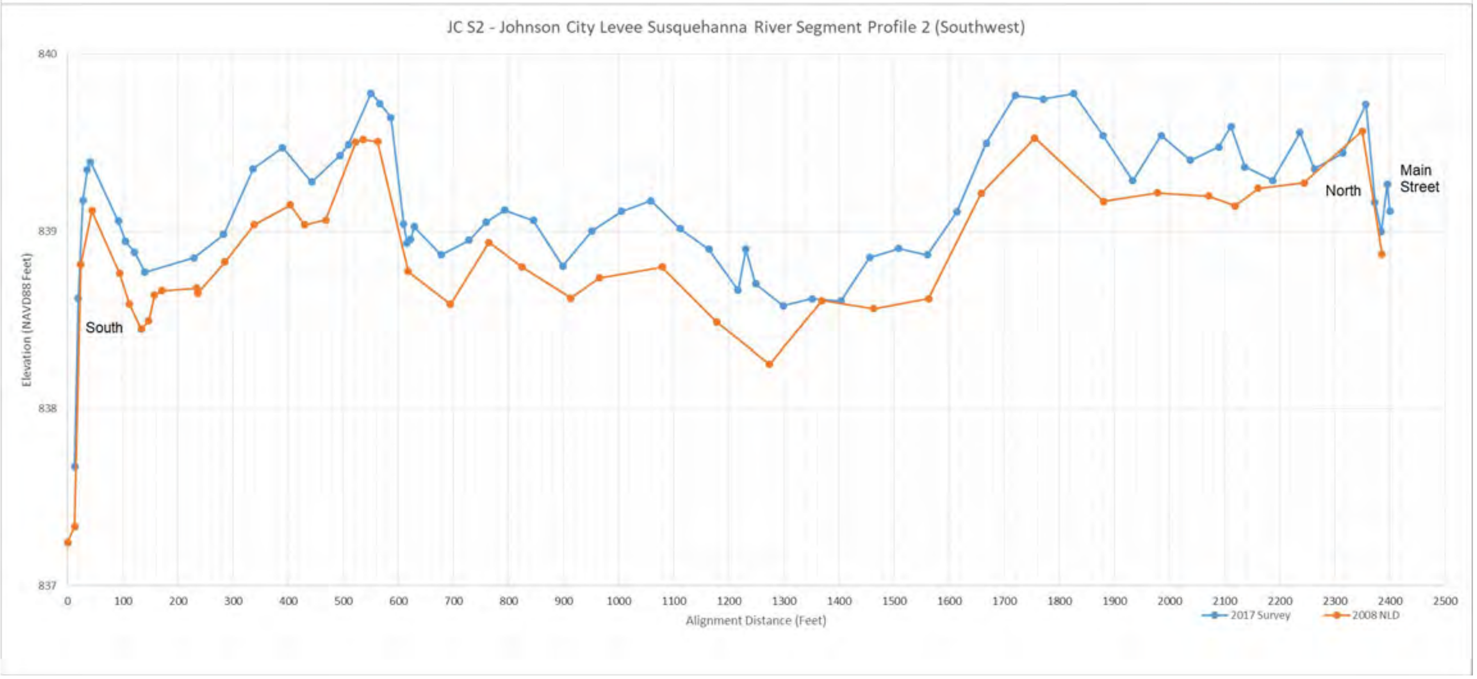


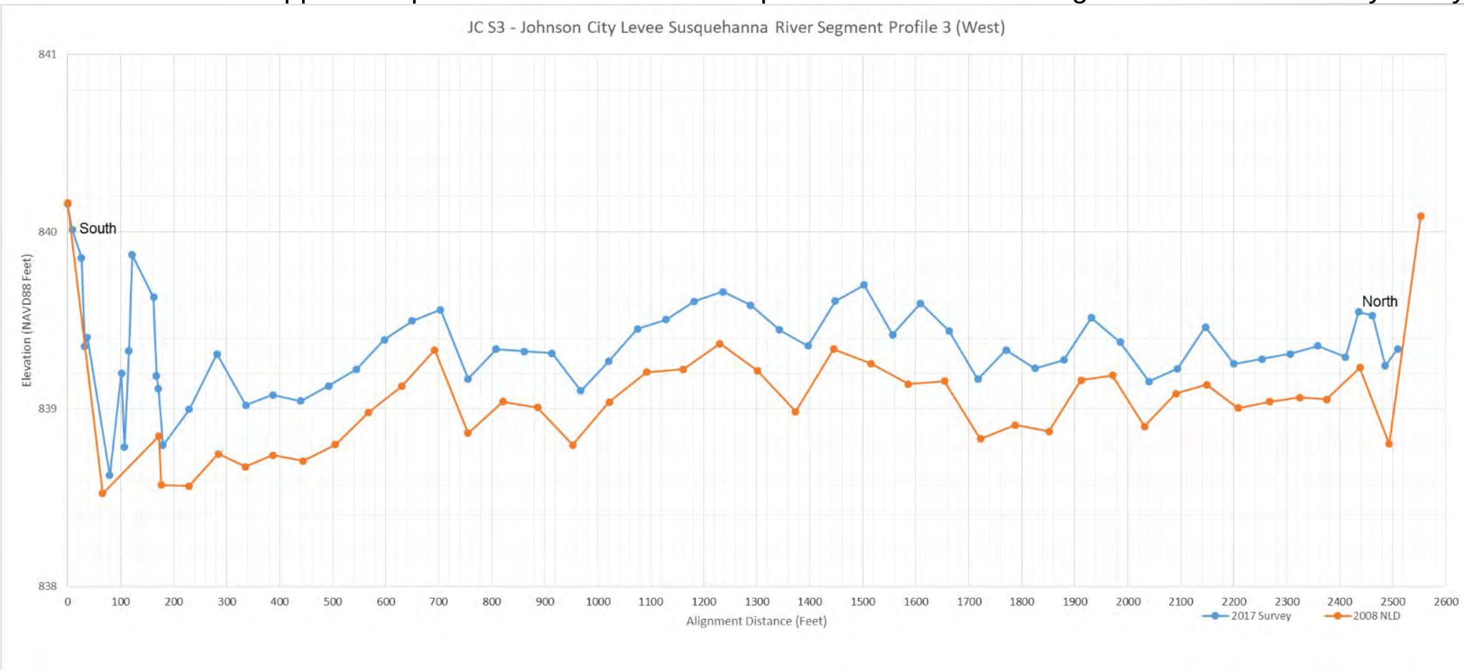
JOHNSON CITY SYSTEM PROFILES



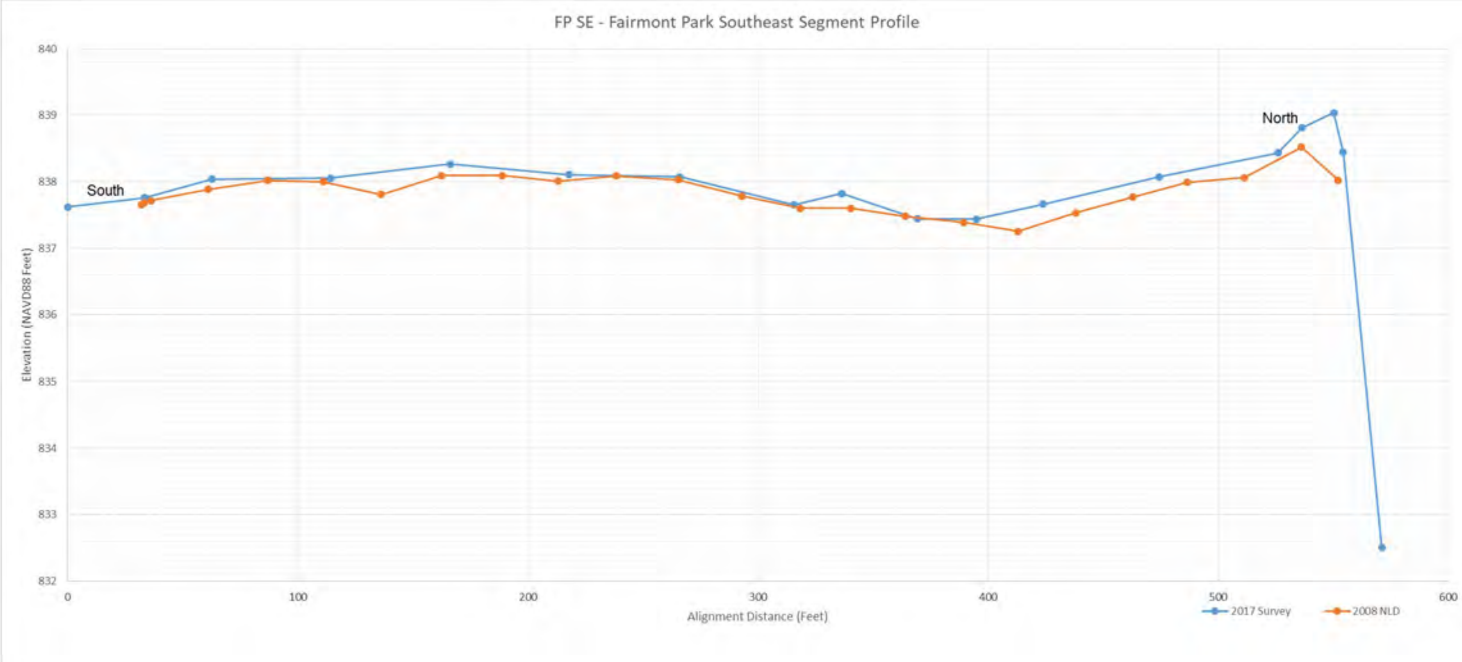


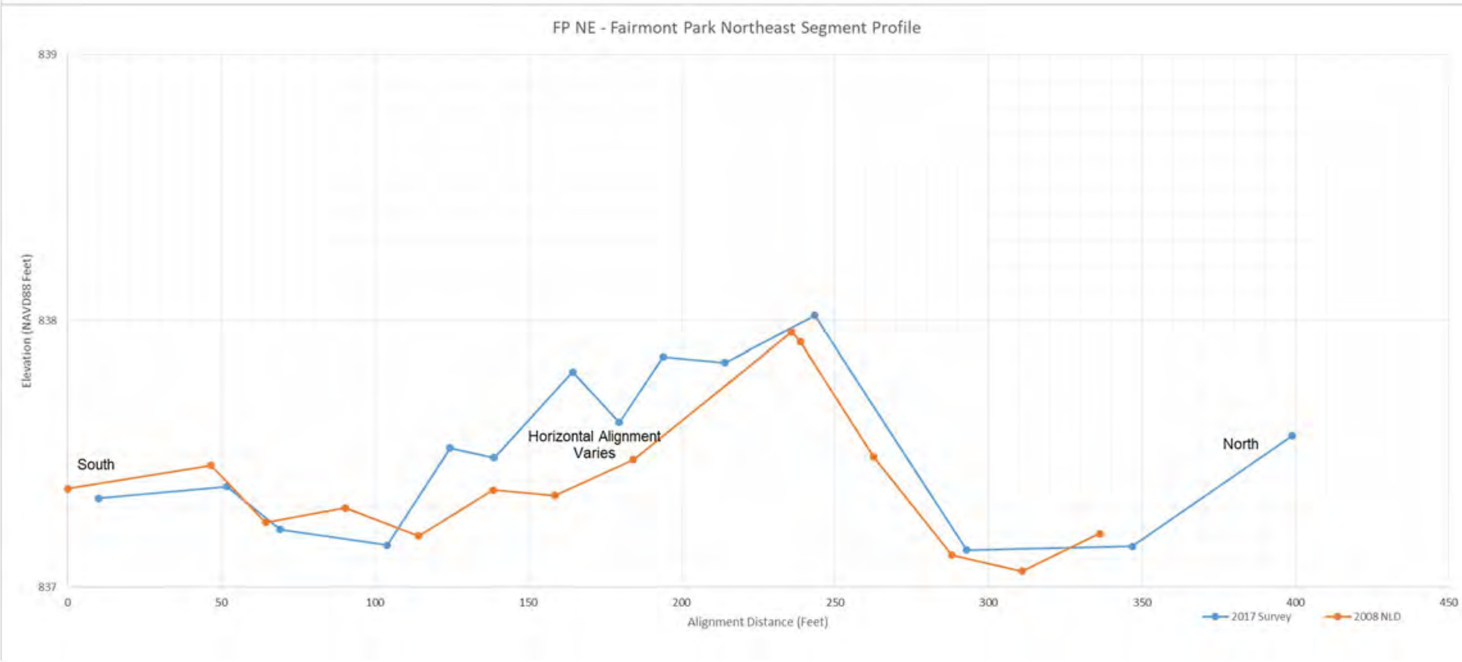

JC S1 - Johnson City Levee Susquehanna River Segment Profile 1 (Ring Levee)
Southeast
North
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
2017 Survey
2008 NLD

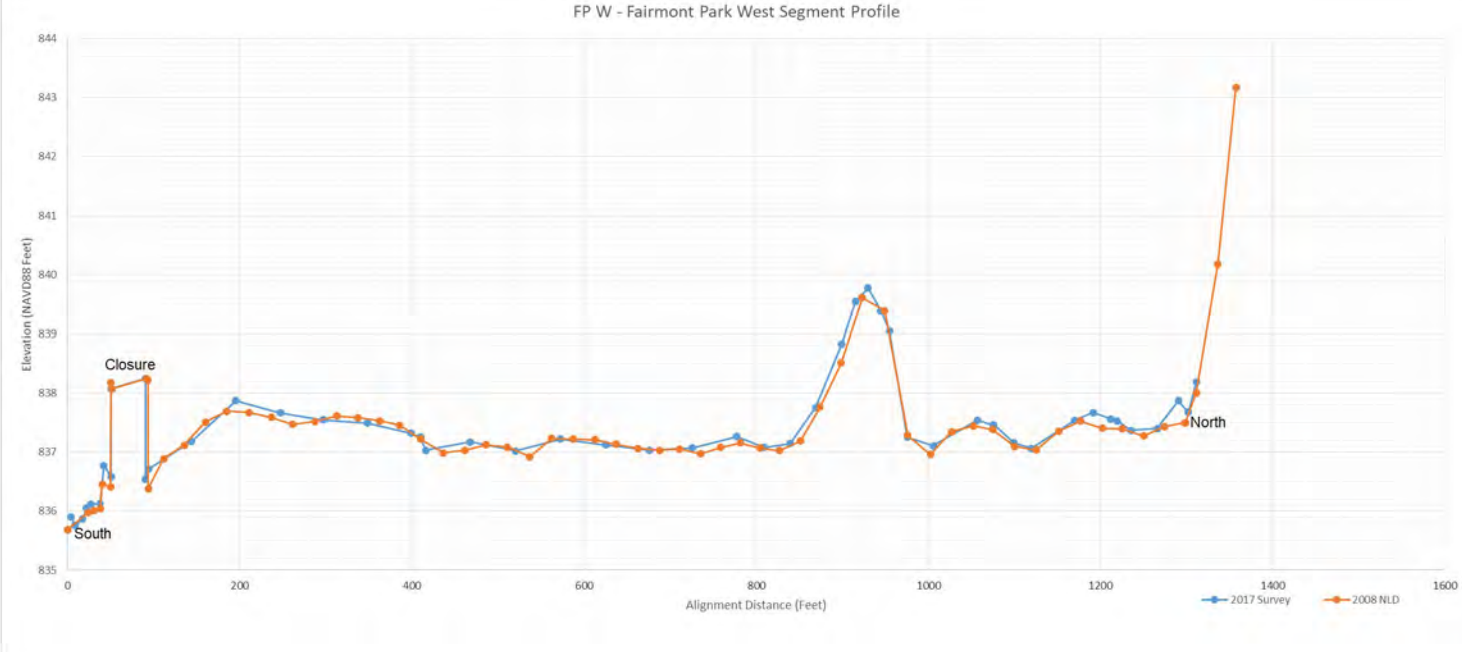

JC S2 - Johnson City Levee Susquehanna River Segment Profile 2 (Southwest)
South
North
Main Street
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
2017 Survey
2008 NLD


JC S3 - Johnson City Levee Susquehanna River Segment Profile 3 (West)
841
840
839
838
Elevation (NAVD88 Feet)
South
North
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Alignment Distance (Feet)
2017 Survey
2008 NLD

FAIRMONT PARK PROFILES



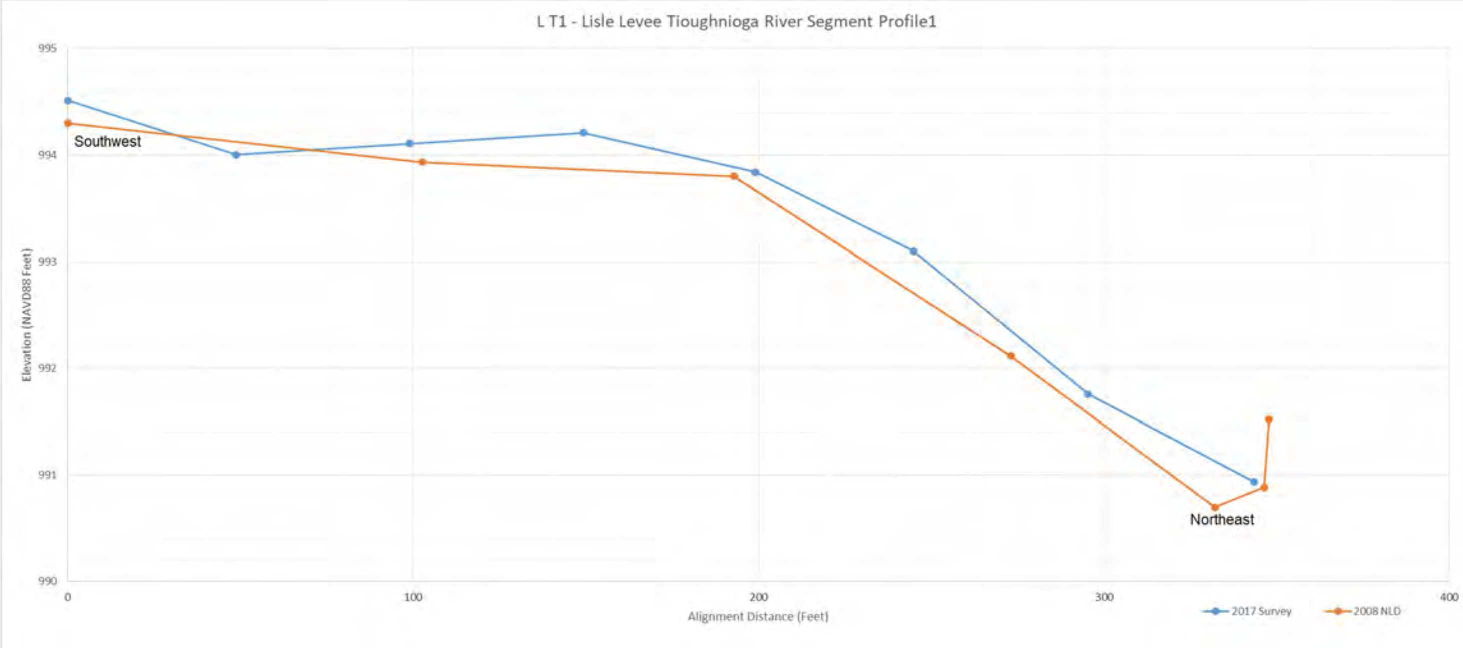


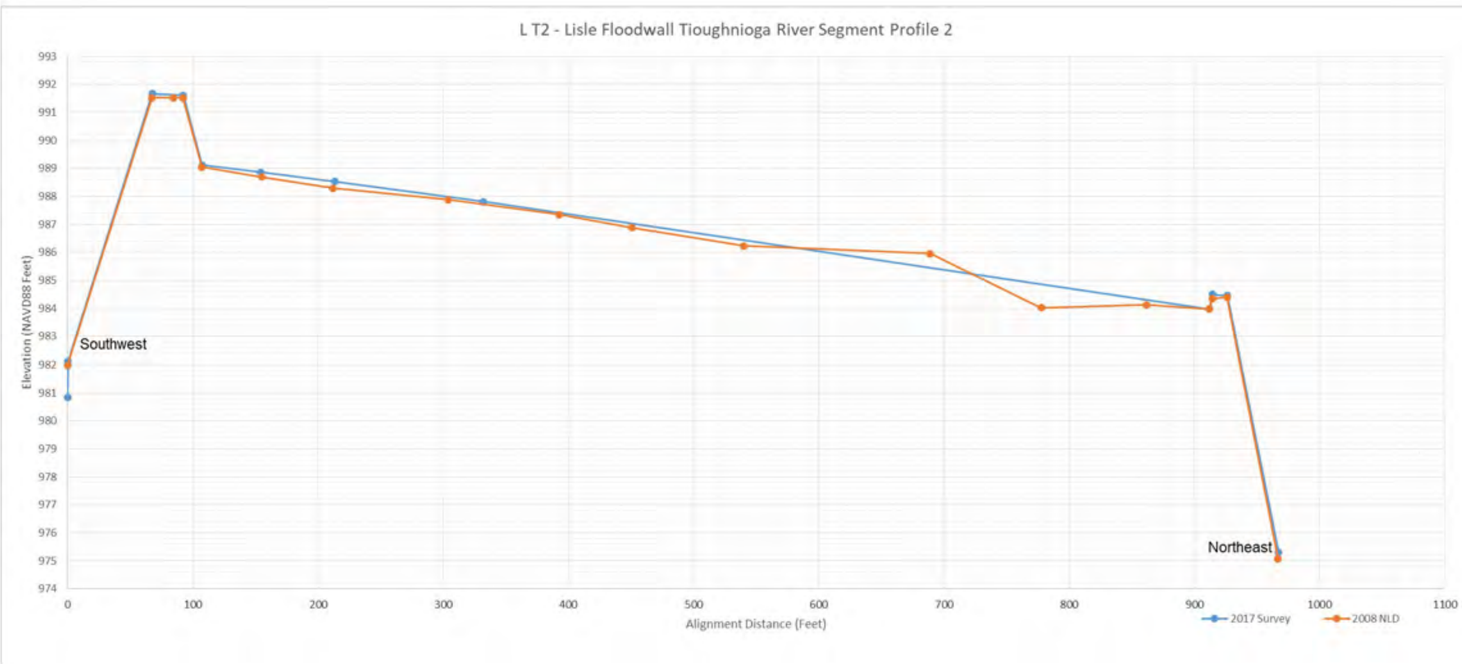

FP W - Fairmont Park West Segment Profile
Elevation (NAVD88 Feet)
844
843
842
841
840
839
838
837
836
835
Closure
South
North
0
200
400
600
800
1000
1200
1400
1600
Alignment Distance (Feet)
2017 Survey
2008 NLD

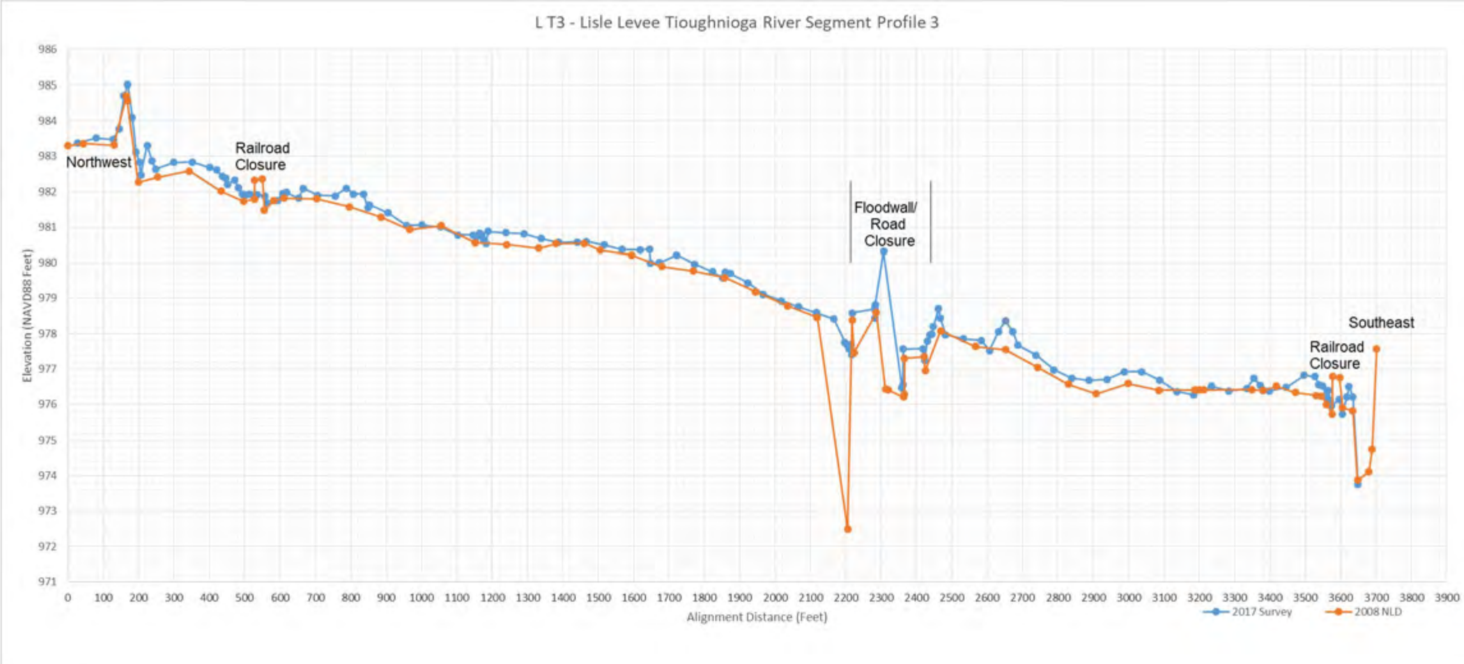
LISLE AND WHITNEY POINT FRM PROJECTS

The numbers in this map correspond to each profile created for the FRM project. Notes for NLD changes in Lisle are included after all of the profiles. No changes were recommended at Whitney Point based on a review of comparison profiles in the FRM project. Whitney Point cross-section data was inaccurate and discarded. Survey differences were observed near the USGS monument in Whitney Point.

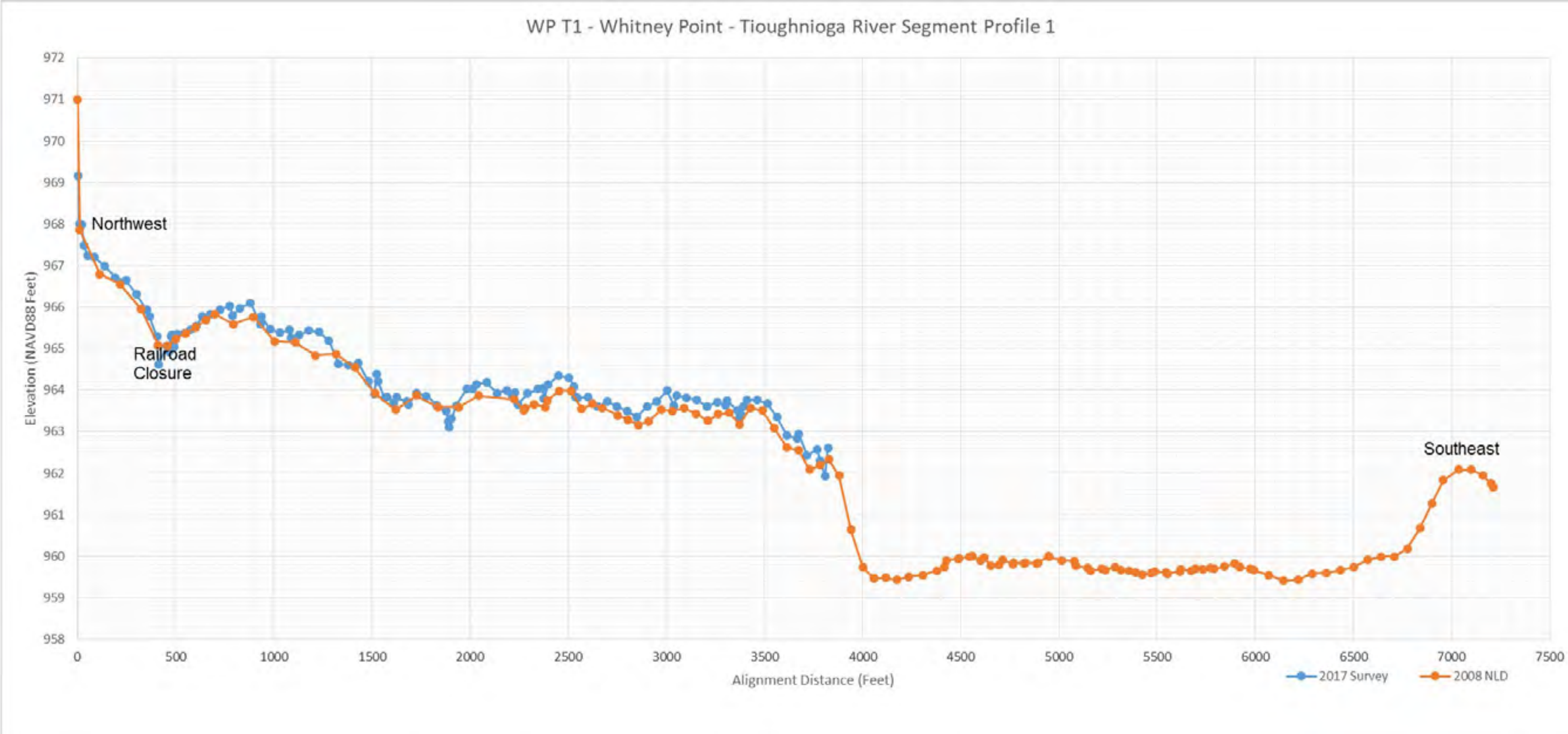
LISLE PROFILES






L T3 - Lisle Levee Tioughnioga River Segment Profile 3
Elevation (NAVD88 Feet)
Alignment Distance (Feet)
Northwest
Railroad Closure
Floodwall/ Road Closure
Southeast
Railroad Closure
2017 Survey
2008 NLD

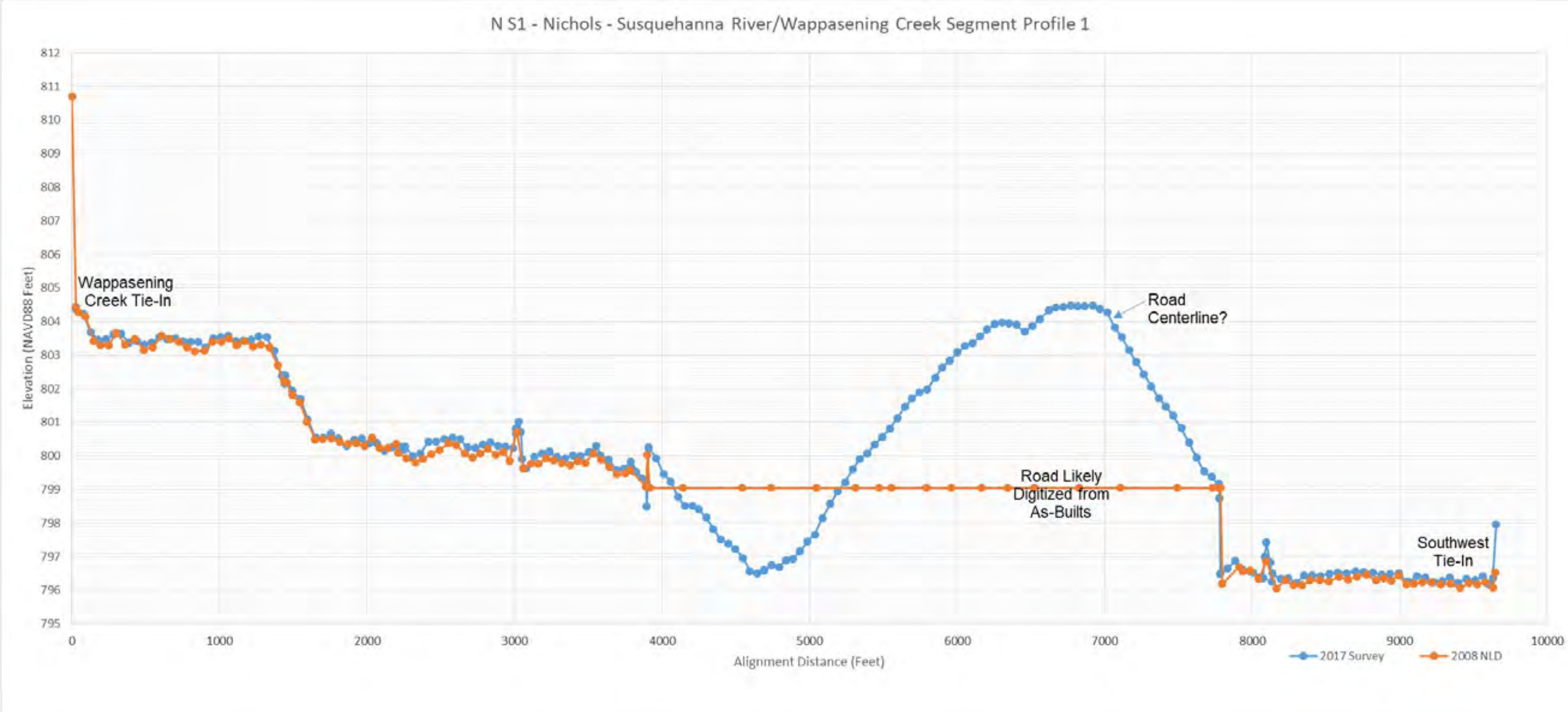
WHITNEY POINT PROFILES

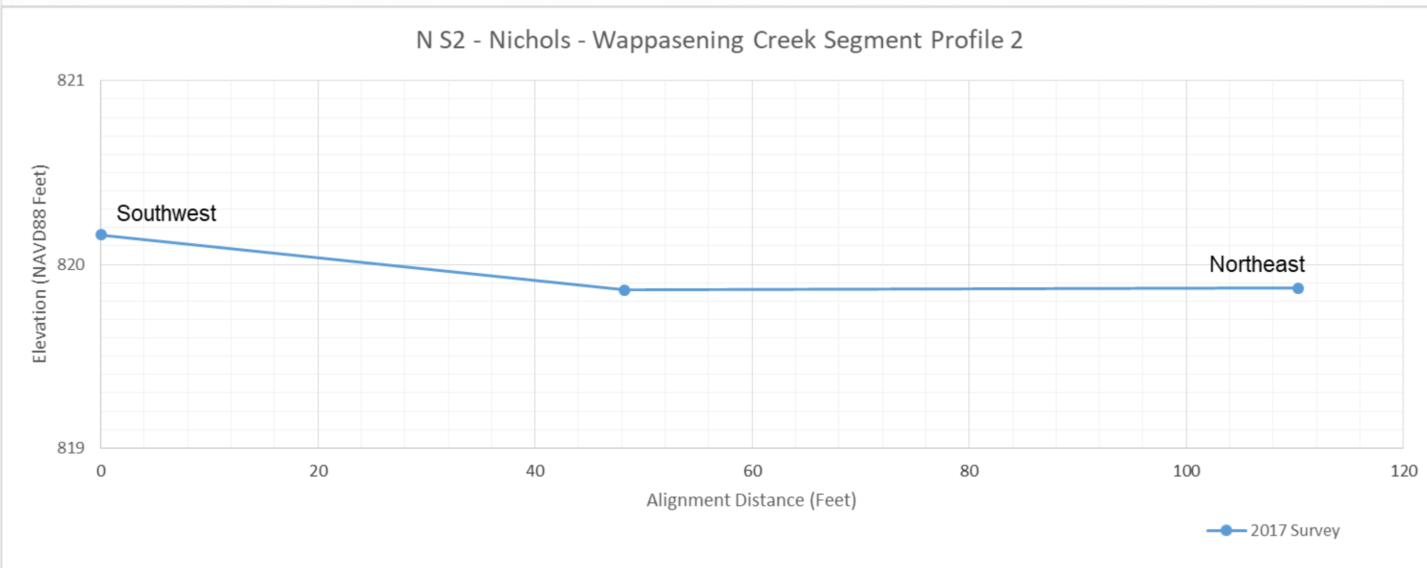


NICHOLS FRM PROJECT

The numbers in this map correspond to each profile created for the FRM project. Notes for NLD changes are included after all of the profiles.

NICHOLS PROFILES

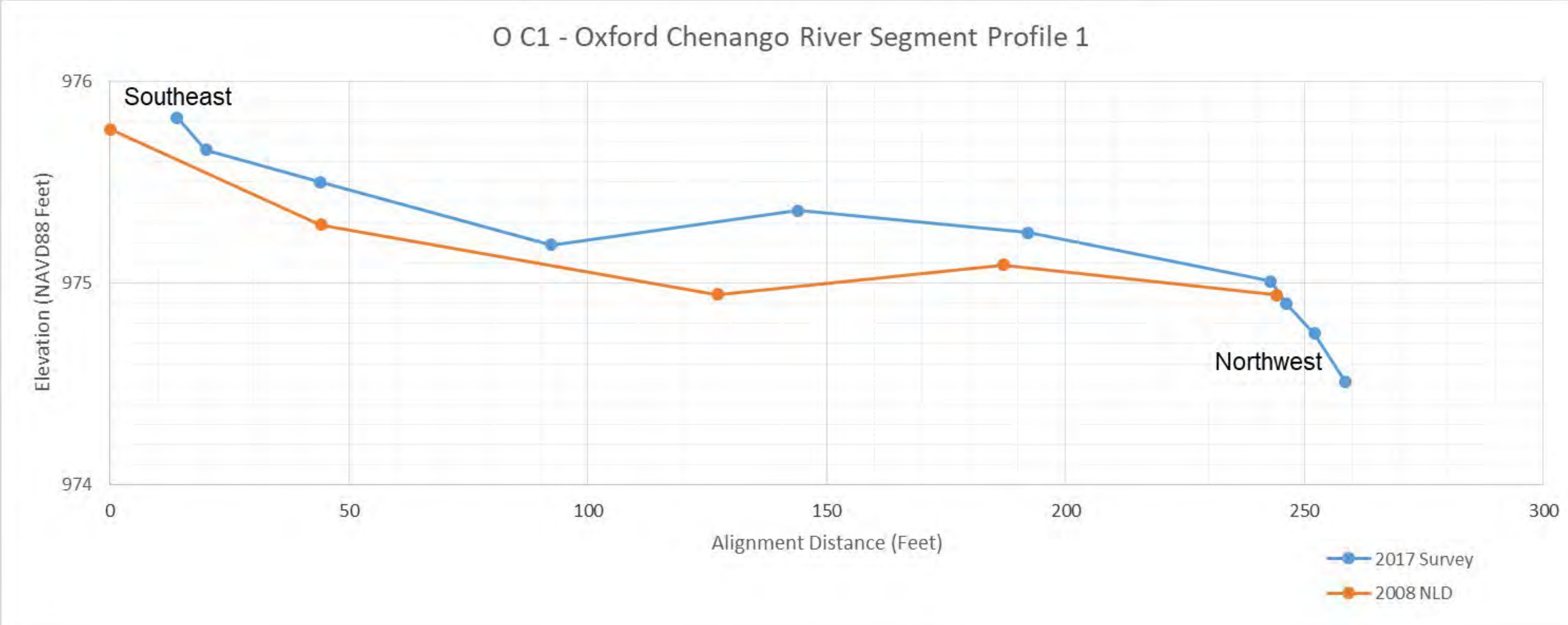


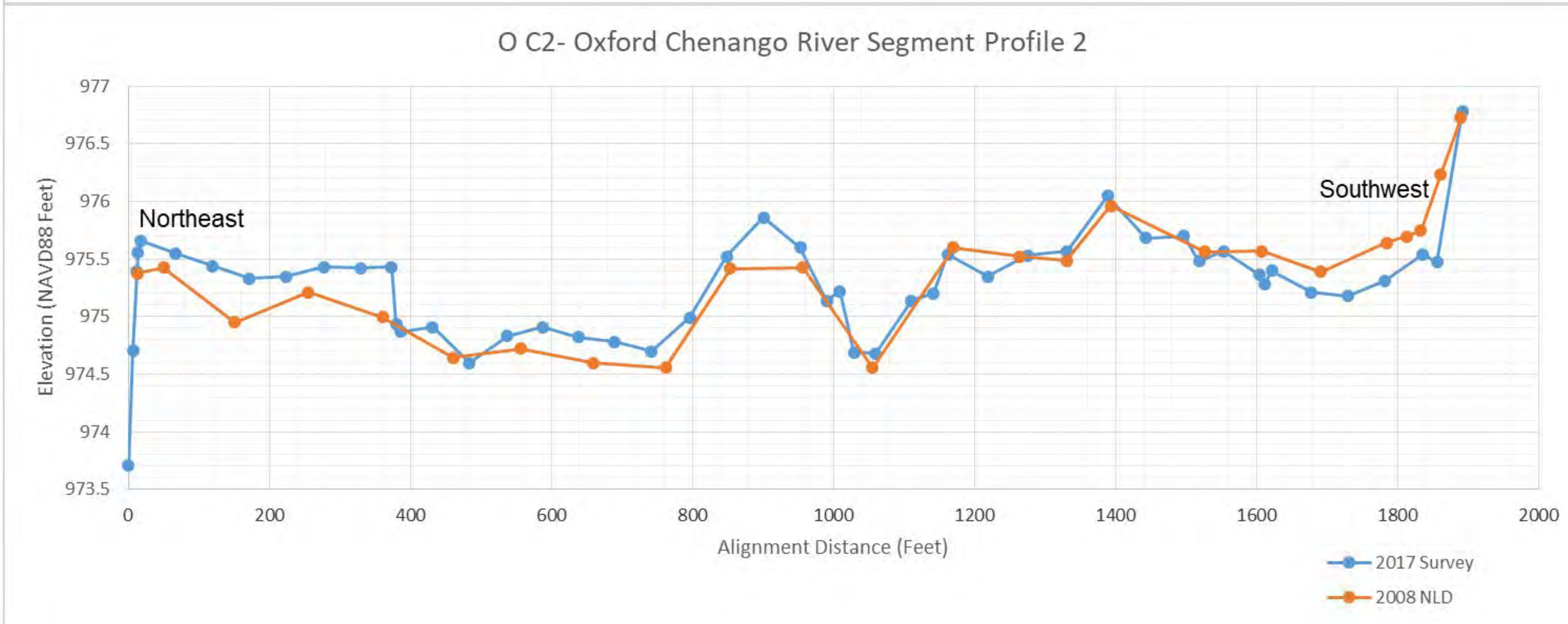


OXFORD FRM PROJECT

The numbers in this map correspond to each profile created for the FRM project. No changes were recommended based on a review of comparison profiles in the FRM project.

OXFORD PROFILES

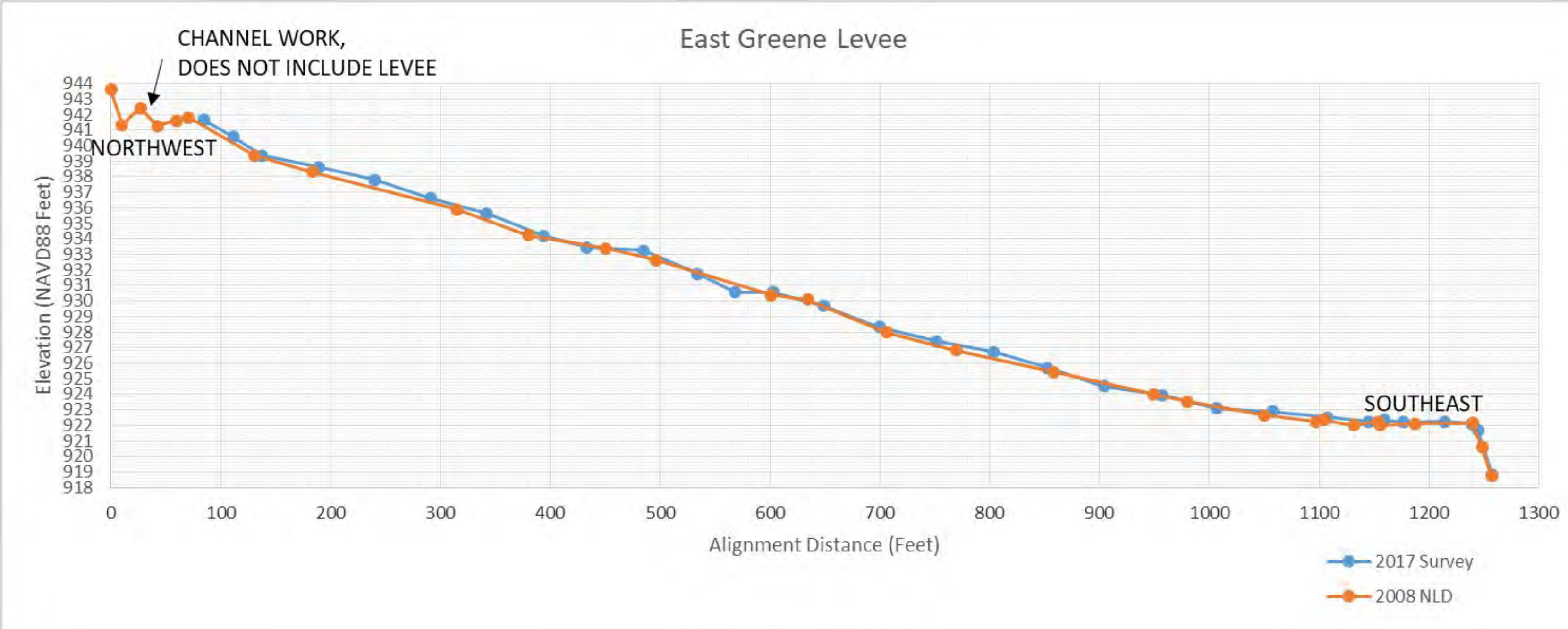


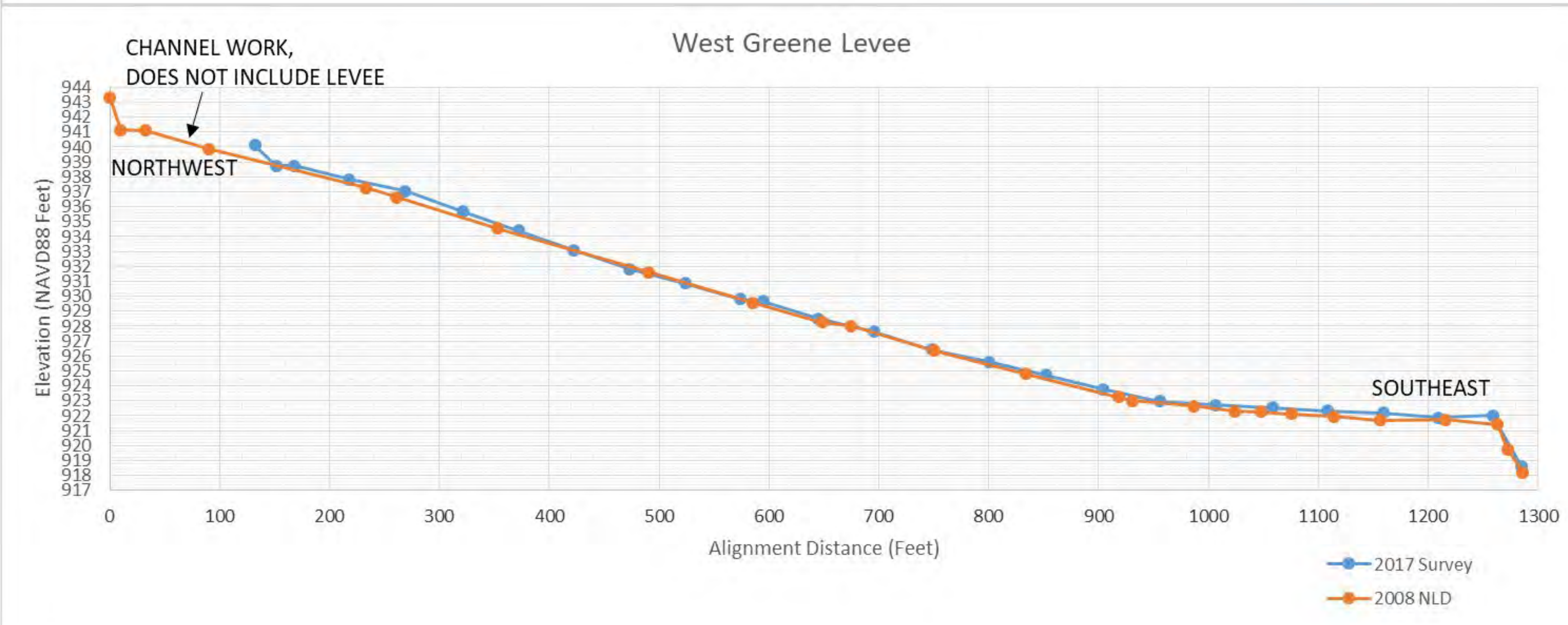


GREENE FRM PROJECT

The numbers in this map correspond to each profile created for the FRM project. Notes for NLD changes are included after all of the profiles.

GREENE PROFILES





BINGHAMTON NATIONAL LEVEE DATABASE UPDATES:

1) NE Binghamton (NE S1) – Chamberlin Creek segment updated with survey data in full due to NLD being lower throughout.
2) Ne Binghamton Court Street (NE S2) – high spot at M=80 feet in the NLD does not exist on the ground or as-builts, updated with survey data.
3) NE Binghamton Court Street Floodwall (NE S2) - corrected levee elevation at low spot at M=910 feet, Z=845 feet using survey data.
4) NE Binghamton North Shore Drive Floodwall (NE S3) – spike at M=~400 feet in the NLD; no change recommended since survey points were not collected near that location.
5) NE Binghamton North Shore Drive (NE S5) – identified low spot at Pedestrian Walkway in closure line, updated closure in full using as-built elevations.
6) NE Binghamton Chenango Floodwall (NE C1) – corrected low spot at M=2803 feet, Z=845 feet with survey data.
7) Port Dickinson Segment (NE C4) - replaced segment from M=1230 to 1750 feet in the NLD with survey data.
8) South Binghamton (South S1) – Pierce Creek East Bank Levee added to the NLD.
9) South Binghamton (South S8) - Susquehanna Vestal Parkway Levee (West) added to the NLD.

LISLE NATIONAL LEVEE DATABASE UPDATES:

1) Lisle Levee Tioughnioga River Segment (Lisle T3) – low spot at M=2205 feet, Z=972 feet, updated with survey data.
2) Lisle Closure (Lisle T3) – closure floodwalls missing from the NLD and have been added.
3) Lisle Floodwall Segment (L T2) – low spot at M=780FT. No change since no survey spot elevations captured near location.

NICHOLS NATIONAL LEVEE DATABASE UPDATES:

1) Nichols Wappasening Creek Segment (Nichols S2) – segment was previously digitized with no survey data; elevations from survey data added to the NLD.
2) Nichols Cross-Sections – Added surveyed cross sections to the NLD.

GREENE NATIONAL LEVEE DATABASE UPDATES:

1) Greene East – Significant differences in horizontal alignment observed. Replaced the full alignment in the NLD to more accurately represent actual location of the levee system. No significant differences in elevations throughout.
2) Greene West – Significant differences in horizontal alignment observed. Replaced the full alignment in the NLD to more accurately represent actual location of the levee system. No significant differences in elevations throughout.

ATTACHMENT 8: MIDDLE AND UPPER SUSQUEHANNA RIVER BASIN REFORESTATION ANALYSIS

Introduction

This analysis evaluates how reforestation within the Susquehanna River Basin would affect peak discharge at various locations within the basin during flood events. For this analysis, it was assumed that the land cover within the Middle and Upper Susquehanna River Basin is artificially changed such that no urbanization exists within the modeled area in the Susquehanna River Basin. It was assumed that the entire basin is reforested and no urbanization exists throughout the basin. Although this extreme reforestation scenario is not likely to occur, we ran this scenario to assess the impact of reforestation on stream flows in the Susquehanna River Basin generally, and in the USRB, specifically.

Method

The existing Corps Water Management System (CWMS) Susquehanna River Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) Model was at the Sherburne used to run the simulation and compare the existing conditions

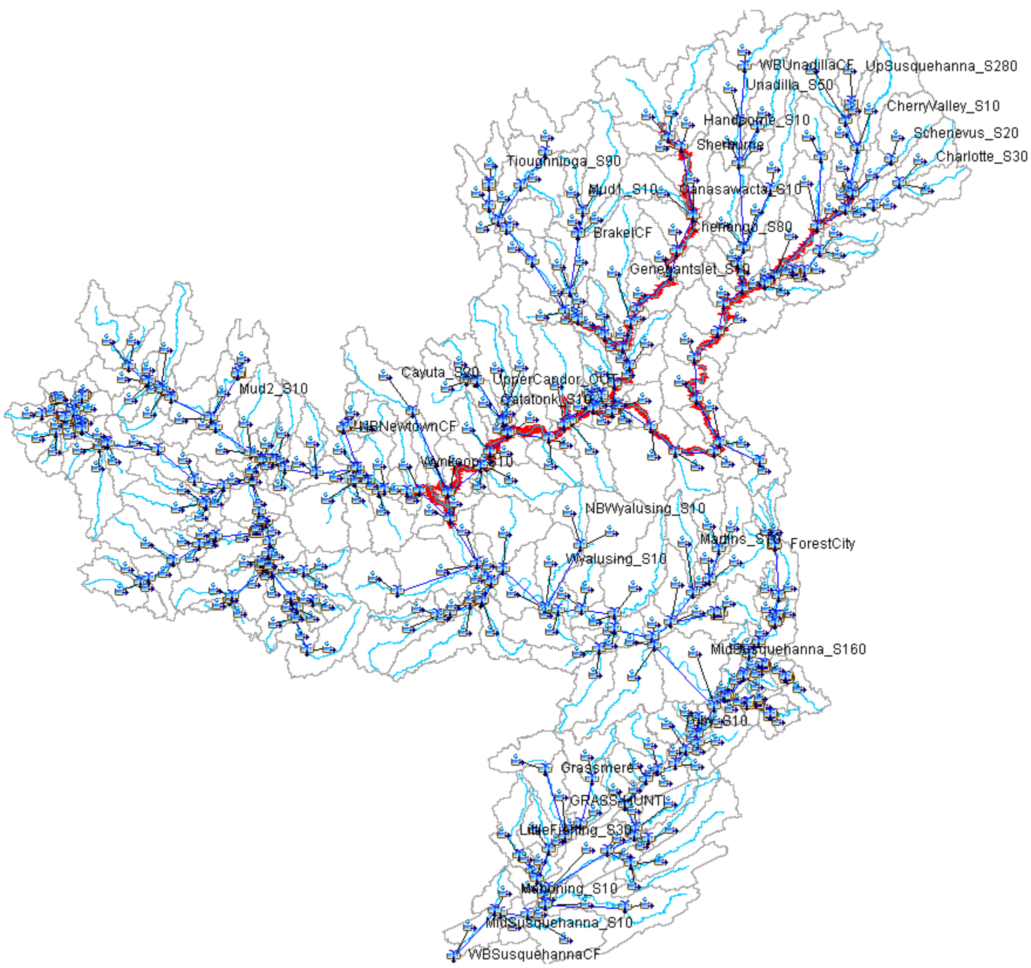


Figure 1: HEC-HMS Model for the Upper and Middle Susquehanna River Basin

and the hypothetical reforestation scenario for a specific historical event. The 26-30 June 2006 flood event was selected since the event was the third highest recorded stage at the Sherburne gage, and also resulted in high flows at Binghamton. The HEC-HMS portion of the CWMS model was calibrated to the June 2006 observed flow at gages throughout the watershed. Figure 1 shows the USRB modeling (red outline) within the Susquehanna River HEC-HMS model.

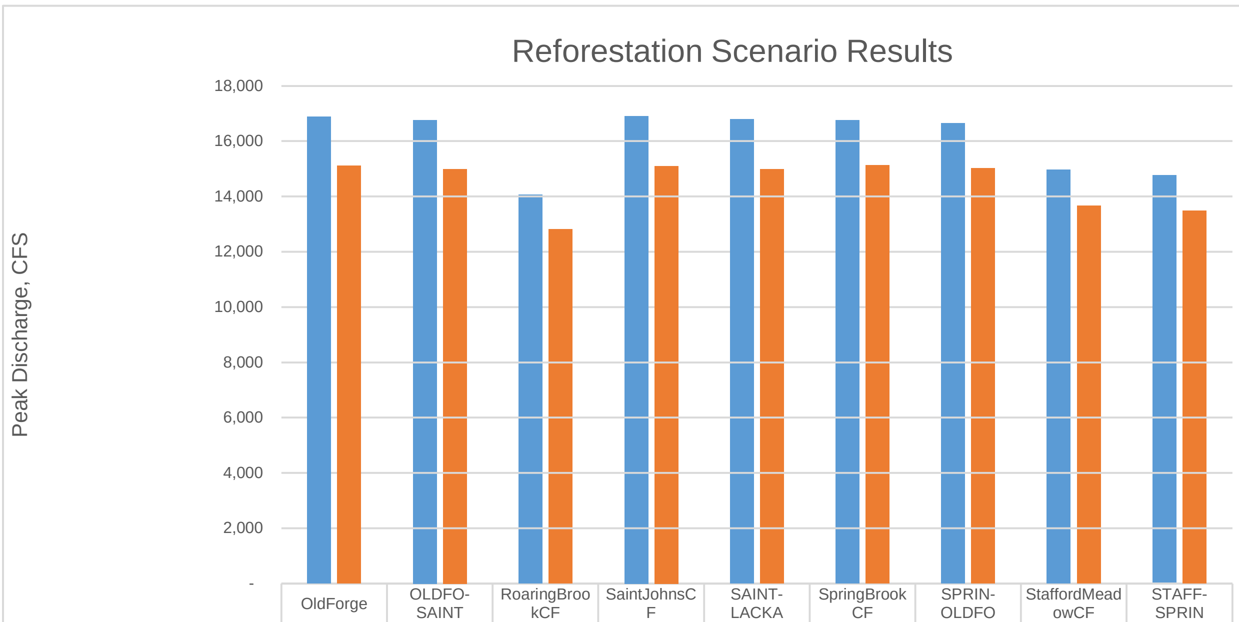
The HEC-HMS model was then modified to include the hypothetical reforestation throughout the modeled area, which includes the Middle Susquehanna and Upper Susquehanna River Basins. The percentage of urbanization was set to zero for all HEC-HMS hydrologic elements. The modified HEC-HMS model was run again, and compared against the original (existing) conditions peak discharges.

Results

Results for the 100% reforestation scenario of the Middle and Upper Susquehanna River Basin indicate that the maximum reduction in peak flow is 1,810 cfs in the Susquehanna River Basin, which is a 10.7% reduction from the existing conditions peak flow of 16,905 cfs. The largest reduction in peak discharges, shown in Table 1 below, is occurring near Roaring Brook Township, Pennsylvania. None of the observed changes in peak discharge are occurring in the USRB. Representative locations in Bainbridge, Conklin, Binghamton, and Waverly along the Upper Susquehanna River are included in Table 1 for reference. The peak discharge reduction due to reforestation is less than 5% in the USRB and representative locations are showing changes in discharge less than 1%. These small reduction will not significantly affect flooding within the USRB. Table 1 and Figure 2 compares the model peak flows for existing conditions versus revised peak flows in the Middle and Upper Susquehanna River Basin with the 100% reforestation scenario. Figure 2 shows hydrologic elements where peak discharge reduced more than 1,000 cfs and overall peak flow reduction is more than 5% and representative locations in the USRB (highlighted in blue).
According to the HEC HMS results, peak flow is reduced by an average of 3.4% in the USRB. It is evident from the model results that the reforestation has a negligible effect on peak discharge reduction.

Hydrologic Element	Drainage Area Sq. Mile	Existing Conditions			Reforestation Conditions			Change in Discharge	Percent Change
		Existing Conditions Peak Discharge (CFS)	Time of Peak	Volume IN	Reforestation Conditions Peak Discharge (CFS)	Time of Peak	Volume (IN)		
SaintJohnsCF	341.7	16,905	28Jun2006, 01:00	4.61	15,096	28Jun2006, 01:00	3.78	1809.6	10.70%
SAINT-LACKA	341.7	16,790	28Jun2006, 02:00	4.61	14,985	28Jun2006, 02:00	3.78	1805.3	10.80%
OldForge	334.86	16,884	28Jun2006, 00:00	4.68	15,111	28Jun2006, 00:00	3.85	1772.4	10.50%
OLDFO-SAINT	334.86	16,766	28Jun2006, 01:00	4.68	14,999	28Jun2006, 01:00	3.85	1766.7	10.50%
SPRIN-OLDFO	324.41	16,649	28Jun2006, 00:00	4.74	15,015	28Jun2006, 00:00	3.95	1634.3	9.80%
SpringBrookCF	324.41	16,759	27Jun2006, 23:00	4.73	15,125	27Jun2006, 23:00	3.95	1633.4	9.70%
STAFF-SPRIN	250.19	14,778	27Jun2006, 23:00	5.45	13,477	27Jun2006, 23:00	4.65	1300.9	8.80%
StaffordMeadowCF	250.19	14,965	27Jun2006, 21:00	5.45	13,665	27Jun2006, 21:00	4.65	1299.8	8.70%
RoaringBrookCF	235.84	14,058	27Jun2006, 21:00	5.45	12,808	27Jun2006, 21:00	4.65	1249.5	8.90%
Bainbridge	1,624.18	56,099	29Jun2006, 11:00	5.58	55,749	29Jun2006, 11:00	5.53	349.5	0.6%
Binghamton	2,290.15	71,460	29Jun2006, 00:00	6.16	71,200	29Jun2006, 00:00	6.1	260.3	0.4%
Conklin	2,235.47	72,616	28Jun2006, 17:00	6.11	72,344	28Jun2006, 17:00	6.06	272.5	0.4%
Waverly	4,775.90	131,797	29Jun2006, 03:00	5.53	131,105	29Jun2006, 03:00	5.46	691.9	0.5%

Table 10. HEC-HMS Model Results for Hydrologic Elements with Maximum Flow Reduction



	OldForge	OLDFO-SAINT	RoaringBrookCF	SaintJohnsCF	SAINT-LACKA	SpringBrook CF	SPRIN-OLDFO	StaffordMeadowCF	STAFF-SPRIN
Original Peak Discharge CFS	16,884	16,766	14,058	16,905	16,790	16,759	16,649	14,965	14,778
Revised Peak Discharge (CFS)	15,111	14,999	12,808	15,096	14,985	15,125	15,015	13,665	13,477