TOWN OF OLIVE LOCAL FLOOD ANALYSIS

28A BRIDGE REPLACEMENT AND BOICEVILLE STUDY AREA FLOOD MITIGATION STRATEGIES TOWN OF OLIVE ULSTER COUNTY, NEW YORK

Prepared for:

Cornell Cooperative Extension of Ulster County
Ashokan Watershed Stream Management Program
PO Box 667
Shokan, NY 12481

Prepared by:

Woidt Engineering & Consulting, PC
11 South Washington Street
Binghamton, New York 13903

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1.0 Project Background

The existing 28A bridge over Esopus Creek in the Hamlet of Boiceville, located within the Town of Olive, NY is scheduled to be replaced within the next five years. The bridge replacement design is ongoing. Concurrently, the Town of Olive is completing a Local Flood Analysis (LFA) to understand the causes of flooding and their potential mitigation solutions. The LFA has identified that the overbank flooding beginning at the 28A bridge and extending approximately 1,700' upstream is detrimental to the community. The flooding limits includes critically vital infrastructure such as Fire Station #1, the Boiceville IGA supermarket and the Town of Olive Sewage Treatment Plant. There are also multiple other businesses and residences that have been subject to flooding resulting in repetitive damage. This vicinity of Esopus Creek and it's associated floodplain will be referred to as the Boiceville Study Area.

Woidt Engineering and Consulting P.C. (WEC) has been retained to complete the analysis of the Boiceville Study Area and coordinate the flood mitigation solutions with the New York City Department of Environmental Protection (DEP). DEP is the project owner of the 28A bridge replacement and has contracted with WPS to lead the bridge design effort. WPS is also partnered with URS Corporation who is providing the hydraulic modeling for the bridge design.

A preliminary Federal Emergency Management Agency (FEMA) flood insurance study (FIS) was completed in 2013. The hydraulic model used to complete the preliminary FIS analysis was the US Army Corps of Engineers hydraulic engineering software program (HEC-RAS). Survey information obtained in the fall of 2011 and updated hydrology was used to develop the HEC-RAS model (called the Preliminary Effective Model). The hydraulic modeling results included a detailed study of the Boiceville project area producing water surface elevations for the 10-year, 50-year, 100-year and 500-year return interval floods.

2.0 Methodology

A Existing Conditions Modeling

FEMA's preliminary effective model was obtained and duplicated by DEP's hydraulic consultant (URS). The duplication results for cross sections in the Boiceville Study Area can be observed in Table A1 in Appendix A. In 2015, additional cross sections were surveyed upstream and downstream of the existing 28A bridge at approximate 100' intervals to support the hydraulic modeling efforts and design of the proposed 28A bridge. Some of these cross sections were located approximately at the same locations as the preliminary effective model cross sections.

The 2015 channel bed elevations of the two cross sections surveyed at the upstream and downstream face of the existing 28A bridge were approximately 1.5' higher than the elevations surveyed in 2011. It is speculated that this condition was caused the formation of scour holes after major storm events in 2011 (Hurricane Irene and Tropical Storm Lee). Typically scour holes at bridges develop after a large storm event then fill back in with sediment over time thus explaining the increase in channel bed elevation at the 28A Bridge. As the 2015 survey is more representative of current conditions, it was utilized in subsequent hydraulic modeling. This corrected model is known as the URS corrected model.

During the review of the URS corrected model, it was noted that the way the contraction and expansion coefficients entered in the model varied from what was used in the FEMA preliminary model. In the FEMA preliminary model, the contraction and expansion values of 0.3 and 0.5 respectively were used at the two upstream cross sections and one downstream crossing adjacent to the 28A Bridge. Contraction and expansion values of 0.1 and 0.3 respectively were

used at all the other cross sections. In the URS corrected model, the values of 0.3 to 0.5 were used in five cross sections upstream and two cross sections downstream of the 28A crossing. WEC adjusted the coefficients in the URS corrected model to match the way they were used in the FEMA preliminary effective model.

Utilizing the URS Corrected model, WEC added three additional cross sections (cross sections 8899, 9399 and 9786) to the hydraulic model to support analysis of various flood mitigation alternatives. The location of these cross sections are shown in Figure A1 (Appendix A). Floodplain topography for the added cross sections were developed using the same LiDAR (light detection and ranging) data that was used as part of the FEMA preliminary effective model. Channel elevations for the additional sections were developed using an interpolation function of the HEC-RAS program using adjacent surveyed cross sections. This model is known as the WEC Corrected model. The hydraulic results of the URS Corrected model, WEC Corrected Model are shown in Table A1, Appendix A.

B. Proposed 28A Bridge Alternatives

Two 28A bridge alternatives have been proposed by WPS. The roadway/bridge deck profile, bridge width, superstructure depth and pier shape are roughly the same for both alternatives. Alternative 1 features a longer overall clear span and features three piers with four spans. Alternative 2 has a shorter overall bridge span and features two piers with three spans. The bridge geometrics for both alternatives were developed by WPS and hydraulically modeled by URS.

Alternative 1 features a 130' longer clear span than the existing 28A bridge span. Alternative 2 has approximately the same clear span as the existing bridge. The existing bridge's arches have been replaced with "V" shaped piers which is featured in both proposed bridge alternatives. The "V" shaped pier is impractical to model using the HEC-RAS program so a substitute pier shape, generally equivalent in obstruction area, was developed by URS using the pier function in the HEC-RAS program. URS also completed conceptual proposed grading at the bridge's upstream and downstream cross sections.

WEC inserted each URS bridge geometrics and proposed grading into the WEC Corrected model and created a separate hydraulic model for each alternative. In the Alternative 1 model, the ineffective flow areas immediately upstream and downstream of the proposed bridge were adjusted to account for the longer clear span. Ineffective flow areas typically define areas of the cross section that will contain water that is not actively being conveyed. Ineffective flow areas are often used to describe portions of a cross section in which water will pond, but the velocity of that water, in the downstream direction, is close to zero. As such, the HEC-RAS program discounts this area when calculating hydraulic outputs (water surface elevations, etc.). This is an important concept as it effects the proposed conditions modeling results. In general, a ratio of 1:1 (1' upstream for every 1' of increased clear span width) was used to adjust the ineffective flow areas upstream and downstream of the bridge. It is noted that FEMA's preliminary effective model, utilized a significant amount of the floodplain as ineffective flow area when modeling the existing conditions adjacent to the 28A Bridge. It is unclear why such a large amount of ineffective flow was used, particularly in locations where it appears that floodwaters are effectively flowing downstream, such as areas adjacent to the top of channel bank.

The results of the two proposed bridge alternatives are shown in Table A2, Appendix A. In addition, three specific points of analysis results are included in Table 1 (see below). The points of interest are located at Fire Station #1 (cross section 8758), the Town of Olive Sewage Treatment Plan Access Road (cross section 8899) and at the IGA supermarket (cross section 9339) as shown on Figure A1 in Appendix A. As can be observed in Table A2, Alternative 1 results in a rise of the 100-year return interval water surface elevation at and upstream of the bridge

when compared to the WEC Corrected model (existing conditions). Typically a bridge crossing causes a constriction to flow and when the constriction is reduced through an increased waterway opening, there can be a localized increase of water surface elevation at the bridge but upstream water surface elevations generally decrease. The localized increase in water depth at the bridge is due to the hydraulic condition when velocities drop through the bridge and corresponding increases in water surface occur (see water surface profiles in Figure A2, Appendix A).

In the case of Alternative 1, the increase in water surface elevation occurs at the bridge and also extends to upstream cross sections through the Boiceville Area. It is WEC's opinion that this condition exists due to the very large excavation of floodplain associated with the 4-span bridge alternative modeled by URS. URS proposed grading lowers the stream bank elevation and floodplain approximately 8' which results in very large difference between the bank elevations upstream and downstream of the bridge. This produces much lower velocities through the bridge and higher water surface elevations. It is speculated that this increase is so dramatic that the hydraulic model does not properly balance itself with upstream cross sections and their large ineffective flow areas. As such, WEC adjusted the proposed grading to a more reasonable 3' excavation depth. The hydraulic results of this option, Alternative 1A, is shown in Table 1 and Table A2, Appendix A. As can be observed from the results, there is a notable reduction (0.4') in water surface elevations when compared with Alternative 1.

Alternative #2 (the Three Span bridge) model showed a water surface reduction of 1.2' close to the bridge and 0.45' at the IGA supermarket. Alternative #2 has less of the bridge's superstructure and piers obstructing the 100-year flood flows than the existing bridge configuration (more area blocked due to arch design). This reduction in flow obstruction improves the efficiency of the proposed bridge to convey flood water assuming the area between the "V" wings is able to convey water as discussed above.

Table 1 100-year Water Surface Elevations Proposed Bridge Alternatives

Point of Analysis	WEC Corrected Model (existing conditions)	Alternative 1 (change from existing)	Alternative 1A (change from existing)	Alternative 2 (change from existing)
	100-year WSEL	100-year WSEL	100-year WSEL	100-year WSEL
1 - Fire Station Cross Section 8758	632.2	632.6 (+0.4)	632.3 (+0.1)	631.5 (-0.7)
2- Sewage Treatment Plant Cross Section 8899	632.9	633.2 (+0.3)	632.9 (0.0)	632.4 (-0.5)
3- Boiceville IGA Market Cross Section 9339	632.5	632.7 (+0.2)	632.4 (-0.1)	631.8 (-0.7)

C. Proposed Flood Mitigation Strategies

The proposed flood mitigation strategies which were modeled in this assessment are shown in Table 2 and graphically in Figure A1, Appendix A. These mitigation strategies were reviewed, vetted and approved for analysis by the Town's Flood Advisory Committee. These strategies are the proposed-flood mitigation strategies for solving the flooding problems in the Boiceville Study Area which may be influenced by the bridge replacement alternatives. The purpose of this analysis is to see which proposed hydraulic strategy will work best with the two proposed 28A bridge alternatives. Table 1 shows the proposed URS grading at the four span bridge caused a minor increase in water

surface elevation that continues upstream to the Boiceville IGA Market. The proposed WEC grading resulted in a notably less increase in water surface elevation. Therefore, the proposed WEC grading will be used with the proposed flood mitigation strategies associated with the four span option. The cross sections used for the four span bridge and the three span bridge alternatives can are shown in Figures A6 and A7 respectively in Appendix A.

Table 2: Modeled Bridge Alternatives and Flood Mitigation Strategies

Mitigation Plan #	HEC-RAS Plan Name	Bridge Alternative	Mitigation Strategy Number	Floodplain Manipulation Area (FM)	Average Floodplain Excavation Depth (ft)	Berm/Wall Alignment Number	Building Relocations
1	Plan 1	1	2	A&B	6	N/A	N/A
2	Plan 2	1	2	A&B	6	1 & 2	N/A
3	Plan 3	1	3	A &B&C	6	3	4,5,6,7
4	Plan 4	2	2	A&B	6	1 & 2	N/A
5	Plan 5	2	2	A&B	6	1 & 2	N/A

3.0 Proposed Conditions Hydraulic Modeling Approach and Results

A Plan #1: Bridge Alternative 1 with Mitigation Strategy #1

Plan #1 features a floodplain bench excavated into the floodplain with its elevation set to approximately the 2.0-year return interval (RI) flood's water surface elevation. The 2-year RI flood elevation is often used as a metric to design floodplain reconnection since a 2.0-year RI is a frequent flooding event that should connect and be conveyed into a floodplain. The average depth between the existing ground in the existing floodplain and the 2.0-year RI flood's water surface elevation is approximately 6' as shown in Table 2. The extents of the proposed floodplain bench were set from where the 2.0-year RI water surface intersects original ground near the top of channel bank landward to where critical infrastructure exists. The proposed floodplain bench grading is relatively flat with a slight grade towards Esopus Creek. It is proposed that the floodplain bench be a maintained as an open grassed area.

It can be observed that Plan #1 shows a reduction of water surface elevations ranging from approximately 0.2' to 2.2' upstream of the bridge during the 100-year return interval flood as seen in Table A3. This reduction in water surface elevation is beneficial because it does reduce inundation depths and resulting flood damages at the points of analysis as seen in Table 3. However the creation of a floodplain bench alone does not resolve the flooding problem at the three points of analysis.

B. Plan #2: Bridge Alternative 1 with Mitigation Strategy #2

Plan #2 utilizes the same floodplain bench as Plan #1 but also includes levees to protect flooding of critical infrastructure at the three critical analysis points. The location of the proposed levee is shown in Figure A1 along Alignment #1 and Alignment #2. As shown in Table 3, there is very little change between water surface elevations between plans #1 and #2. This can also be seen graphically in Figure A3 (note: in Figure A3, the profile line for plan #2 sits on top of the profile line for plan #1). This is due to the levees being placed in areas of ineffective flow thus the presence of the levee does not have much effect on water surface elevations. As previously discussed, even

though there may be water in an ineffective flow areas, this water is assumed not to be moving and therefore the area is not used by the HEC-RAS program in its water surface calculations.

C. Plan #3: Bridge Alternative 1 with Mitigation Strategy #3

To understand if increasing the amount of floodplain manipulation (increasing the size of the floodplain bench) would reduce flood water elevations even more, the size of the floodplain bench was increased upstream of the bridge to convey more floodwater through the Boiceville Study Area. The floodplain bench geometry in this plan is similar to Plan #1, but the Plan #2 bench features a wider width beginning at cross section 9621 and ending at cross section 8899. The extent of the floodplain bench for Plan 3 is shown in Figure A1, Appendix A, and the plan's 100-year water surface elevations are seen in Table #3.

At the Analysis Point #1, there is no change in water surface reduction from Plan #1 and Plan #2 since the floodplain bench dimensions are the same from the bridge upstream to this point (cross section 8758). At Analysis Point #2 and Analysis Point #3, there is a water surface reduction (although as not as great as Plan #1 and Plan #2). This is due to the wider floodplain bench creating areas of slower moving water which results in higher water surface elevations. Therefore, it appears that any additional floodplain widening more than what has been modeled in Plan #1 and Plan #2 does create additional benefits in flood water reductions. It is also noted that this plan would require the removal of several commercial buildings.

D. Plan #4: Bridge Alternative 2 with Mitigation Strategy #1

Since the floodplain manipulation of Plan #1 and Plan #2 produced the greatest reduction in water surface elevations, the same floodplain bench geometry was used in conjunction with the proposed three span bridge and can be seen in Figure A1. The only modification to this geometry occurred at the first cross section upstream of the bridge (cross section 8461) where the floodplain bench dimensions were narrowed to ease the transition of the floodplain bench through the narrower clear span of the proposed bridge as shown in Figure A5 in Appendix A.

This plan shows a slight reduction of water surface elevations at Analysis Points #3 and #2 and a slight rise at Point #1 (Table 3 and in Table A3). The rise at Point #1 can be attributed to constriction of floodwaters as the flood flows transition from the wide floodplain bench into the narrower three span bridge. For this reason it is unlikely that any floodplain manipulation which increases the floodplain width wider than the clear span of the proposed three span bridge will result in a notable decrease in water surface elevations adjacent to the bridge.

E. Plan #5: Bridge Alternative 2 with Mitigation Strategy #2

Plan #5 utilizes the same floodplain bench as Plan #4 but also includes levees to protect flooding of critical infrastructure at the three critical analysis points. The location of the proposed levee is shown in Figure A1 along Alignment #1 and Alignment #2. There is a slight variation of the levee alignment from what is shown in Figure A1 at cross section 8461 since the floodplain bench dimensions were narrowed to ease the transition of the floodplain bench through the narrower clear span of the proposed bridge. Therefore the levee alignment at cross section 8641 was adjusted to follow the floodplain transition.

As shown in Table 3, there is very little change between water surface elevations between Plan #4 and Plan #5. This can also be seen graphically in Figure A4 (note: in Figure A4, the profile line for plan #5 sits on top of the profile line for plan #4). This is due to the levees being placed in areas of ineffective flow thus the presence of the levee does not have much effect on water surface elevations. Water depths under existing and proposed conditions are shown

in Table 3. The locations of water depth for Analysis Point #1 is the driveway in front of the fire station, Point #2 is along the driveway halfway between the sewage treatment plant and State Route 28 and for Point #3 is located at the parking lot directly in front of the IGA.

Table 3: Results of Modeled Bridge Alternatives and Flood Mitigation Strategies

Plan Number	NA	1	2	3	4	5
HEC-RAS Model Name	WEC Corrected Model- existing conditions	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
1 - Fire Station Cross Section 8758 WSEL & (Water depth-ft)	632.2 (7.4)	631.4 (6.6)	631.4 (0.0)	631.4 (0.0)	632.6 (7.8)	632.6 (0.0)
2- Sewage Treatment Plant Cross Section 8899 WSEL & (Water depth-ft)	632.9 (6.9)	631.5 (5.5)	631.5 (0.0)	632.4 (0.0)	632.7 (6.7)	6.7 (0.0)
3- Boiceville IGA Market Cross Section 9339 WSEL & (Water depth-ft)	632.5 (5.2)	631.4 (4.1)	631.4 (0.0)	632.5 (0.0)	632.4 (5.1)	632.4 (0.0)

This trend is also seen at the 50-year return interval (RI) flood as shown in Table A4, Appendix A. The points of analysis area are still inundated (albeit much less than the 100-year flood) without the use of a levee system. Plan #1 and Plan #2 offer the greatest reduction in water surface elevations (approximately the same) but Analysis Points #1, #2, and #3 are still inundated by 3.2', 2.3' and 1.7' respectively.

4.0 Conclusion and Recommendations.

Five proposed flood mitigation strategies were modeled with the two proposed bridge alternatives. None of the five proposed flood mitigation strategies resulted in enough of a reduction of 100-year water surface elevations that floodplain manipulation (provision of floodplain benches) alone would prevent inundation of critical infrastructure in the Boiceville Study area. As such, all flood mitigation strategies in the Boiceville Study area will require supplemental flood protection facilities such as an earthen levee or concrete flood wall to prevent 100-year flooding at all points of analysis (Fire Station #1, Sewage Treatment access road and the IGA supermarket).

The two best proposed flood mitigation strategies which resulted in the greatest reduction in water surface elevations are Plan #1 and Plan #2. Use of floodplain manipulation (a floodplain bench) in conjunction with the four span bridge will reduce water surface elevations up to 2.2'. The next best plan which reduced water surface elevations the most was the proposed three span bridge without any floodplain manipulation or supplemental levees.

Based on the analysis results, it is recommended that the Town of Olive first determine if construction and maintenance of flood protection facilities is a financially feasible option. This decision will be heavily influenced by the probability of obtaining project funding. It is noted that funding of flood protection facilities such as levees are not supported by NYCDEP and the competiveness of other potential funding sources may severely limit the chance of securing project funding. If the Town does elect to pursue project funding for flood protection facilities, Plan 2 would provide the greatest reduction of floodwater elevations thus reducing the height of the levee, its construction costs and improving it's benefit to cost ratio. Conversely, if the Town does not feel flood protection facilities such as levees are a financially feasible option, then it appears that either Plan 1 (the four span bridge with the flood plain bench or

Alternative #2, the three span bridge without any flood mitigation would provide the most the most cost effective flood reduction benefits. It is noted that the four span bridge alternative would be substantially more expensive than the three span bridge alternative and the modest reductions in flooding extents may not be economically warranted. With either of these alternatives, there will still be flooding of critical infrastructure at larger storm events. As such, in conjunction with the proposed bridge improvements, it is recommended that the Town consider investigating other flood protections measures such as relocation of facilities out of the floodplain or elevating or flood proofing of critical facilities.

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Mitigation Strategy Number	Floodplain Manipulation (FM)	Average Floodplain Excavation Depth (ft)	Berm/Wall Alignment Number	Berm/Wall Height	Building Relocation	Note
1	A&B	6	N/A	N/A	N/A	
2	A&B	6	1 & 2	3	N/A	Raise driveway to treatment plant
3	A &B&C	6	3	3	4,5,6,7	Driveway to treatment plant inundated at 10-year RI. Alignment #3 will share the same alignments as #1 and #2 in some locations and drawn separately for clarity.

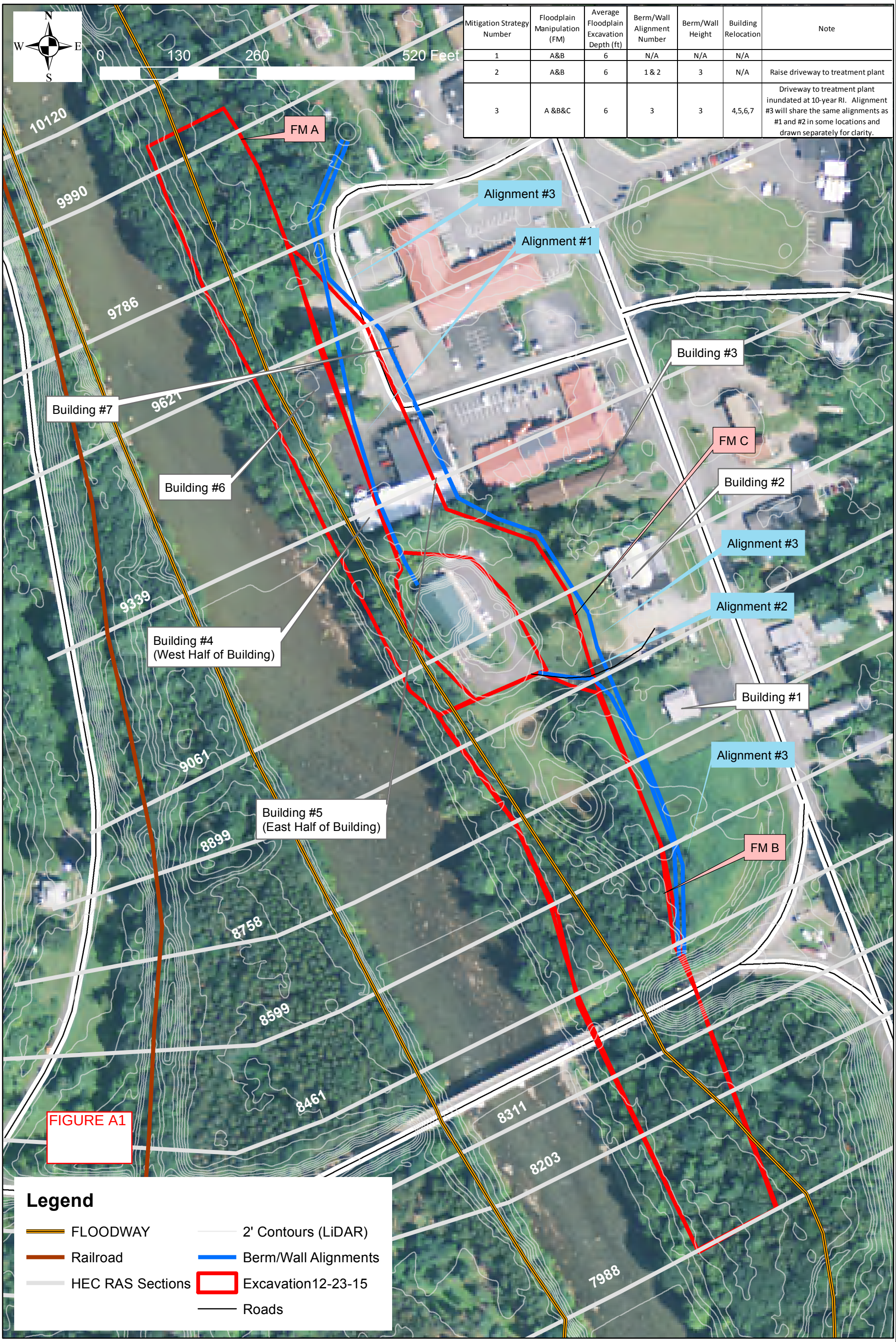

FIGURE NUMBER 1

PROJECT NO:

CHECKED BY: --

DRAWN BY: GDF

DESIGNED BY:

DATE: 10/9/15

Boiceville Study Area
Floodplain Mitigation Strategies

Town of Olive
Location Flood Analysis

Olive, Ultster County, NY

BACKGROUND PHOTO: 2013 NAIP

WELCOME TO TOWN OF OLIVE Est. 1823

Woidt Engineering

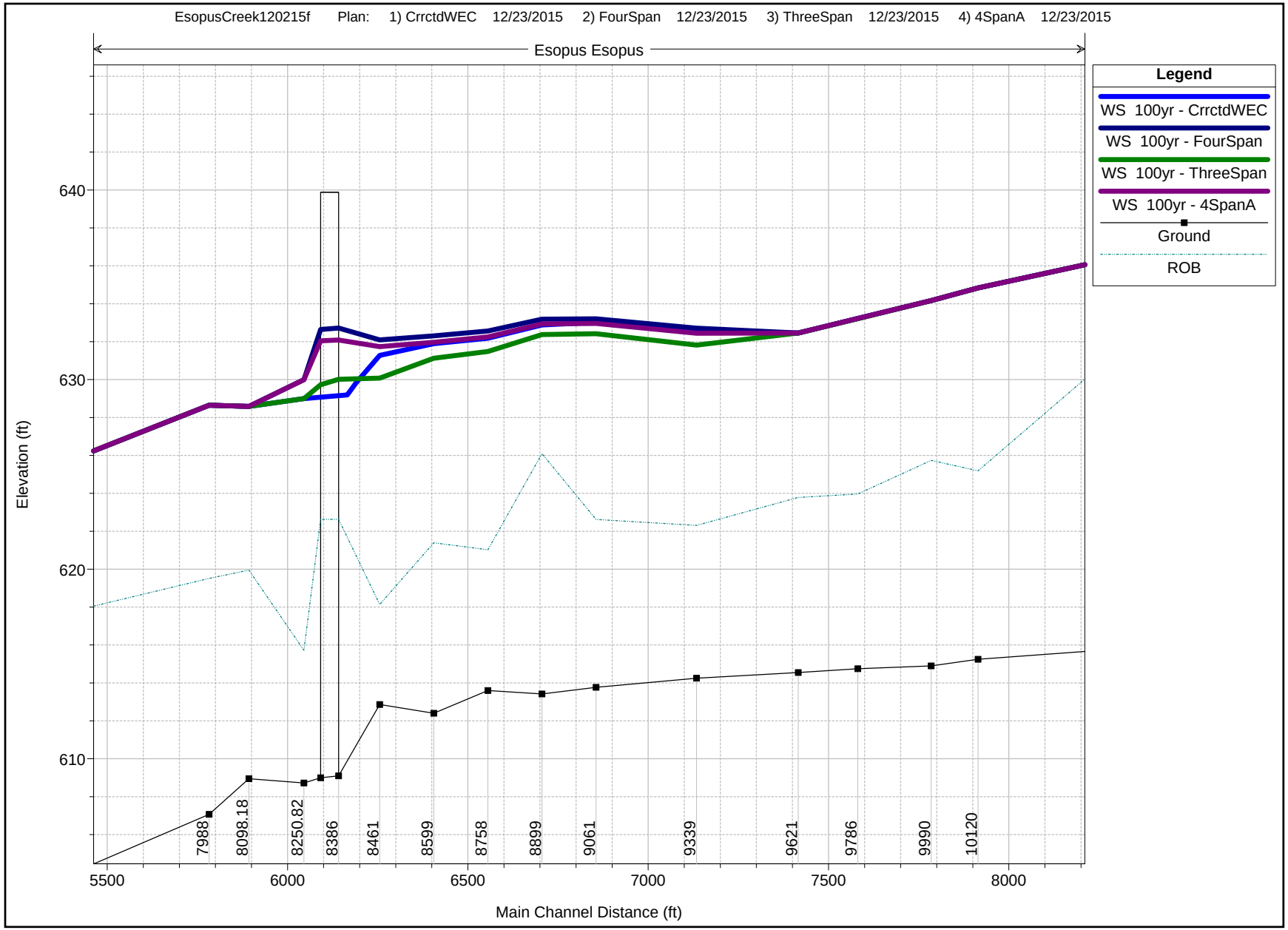
EsopusCreek120215f Plan: 1) CrrctdWEC 12/23/2015 2) FourSpan 12/23/2015 3) ThreeSpan 12/23/2015 4) 4SpanA 12/23/2015
Esopus Esopus
Legend
WS 100yr - CrrctdWEC
WS 100yr - FourSpan
WS 100yr - ThreeSpan
WS 100yr - 4SpanA
Ground
ROB
Elevation (ft)
640
630
620
610
7988
8098.18
8250.82
8386
8461
8599
8758
8899
9061
9339
9621
9786
9990
10120
5500
6000
6500
7000
7500
8000
Main Channel Distance (ft)

FIGURE A2

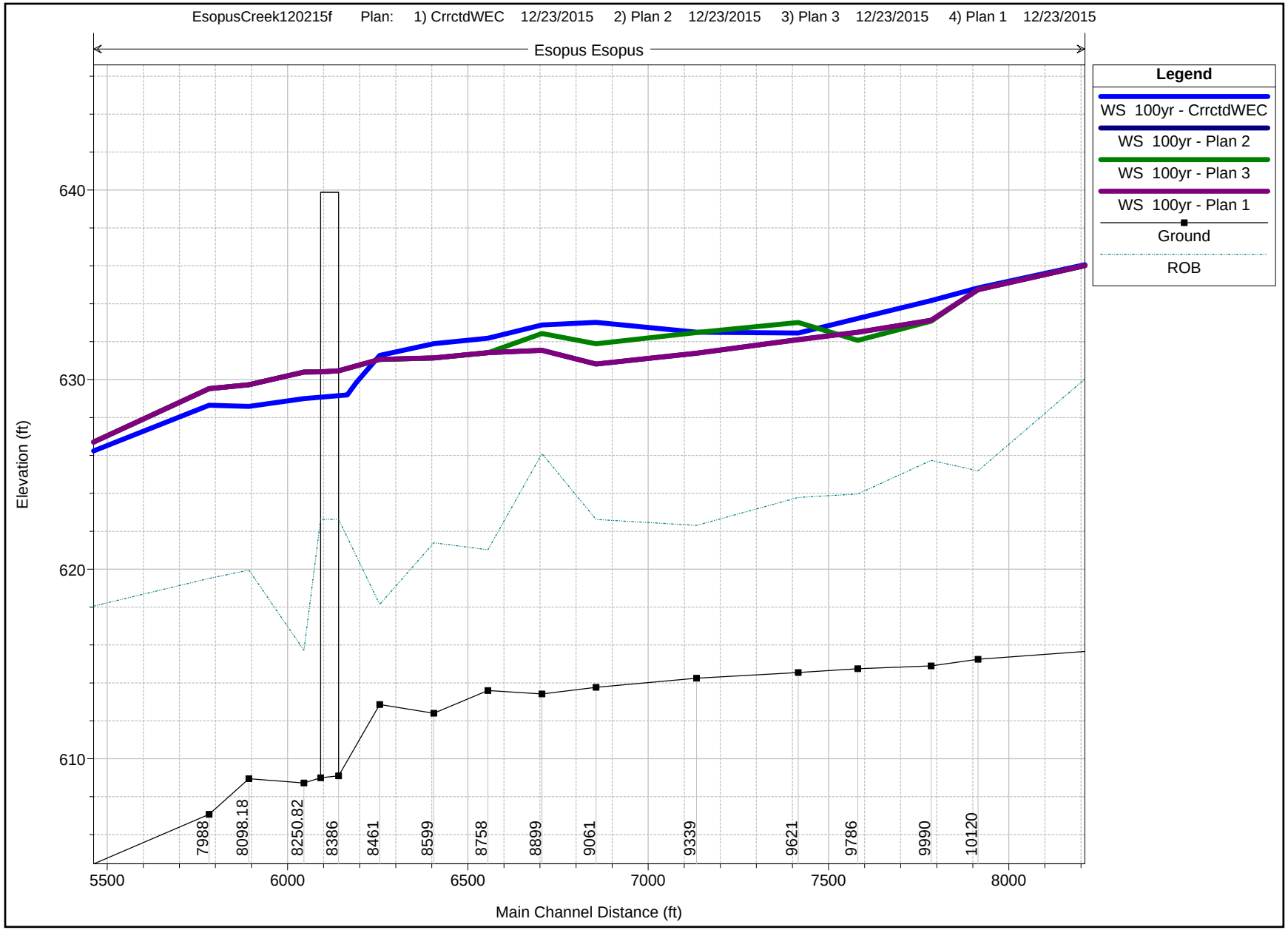
EsopusCreek120215f Plan: 1) CrrctdWEC 12/23/2015 2) Plan 2 12/23/2015 3) Plan 3 12/23/2015 4) Plan 1 12/23/2015
Esopus Esopus
Legend
WS 100yr - CrrctdWEC
WS 100yr - Plan 2
WS 100yr - Plan 3
WS 100yr - Plan 1
Ground
ROB
Elevation (ft)
640
630
620
610
7988
8098.18
8250.82
8386
8461
8599
8758
8899
9061
9339
9621
9786
9990
10120
5500
6000
6500
7000
7500
8000
Main Channel Distance (ft)

FIGURE A3

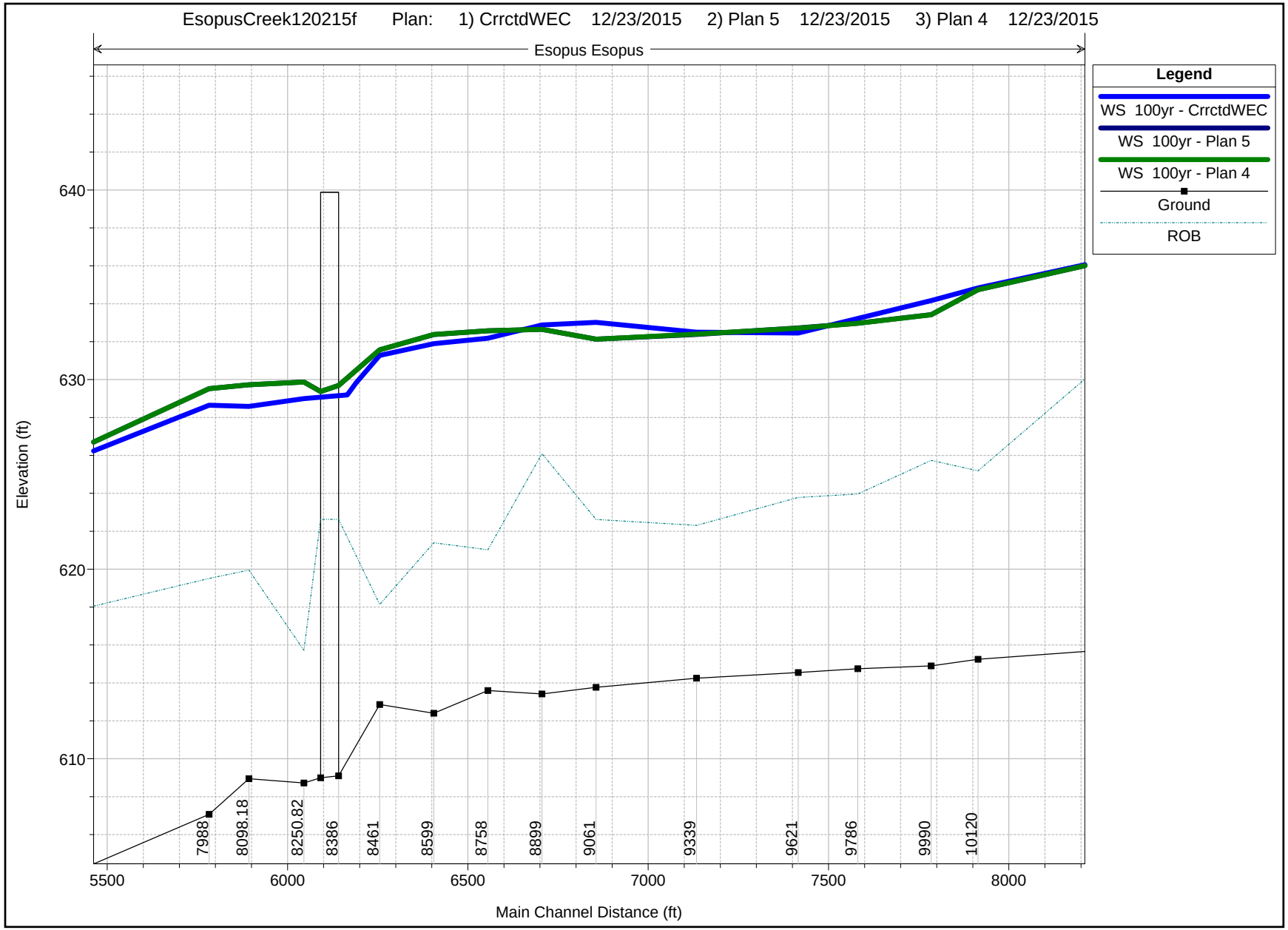
EsopusCreek120215f Plan: 1) CrrctdWEC 12/23/2015 2) Plan 5 12/23/2015 3) Plan 4 12/23/2015
Esopus Esopus
Legend
WS 100yr - CrrctdWEC
WS 100yr - Plan 5
WS 100yr - Plan 4
Ground
ROB
Elevation (ft)
640
630
620
610
7988
8098.18
8250.82
8386
8461
8599
8758
8899
9061
9339
9621
9786
9990
10120
5500
6000
6500
7000
7500
8000
Main Channel Distance (ft)

FIGURE A4

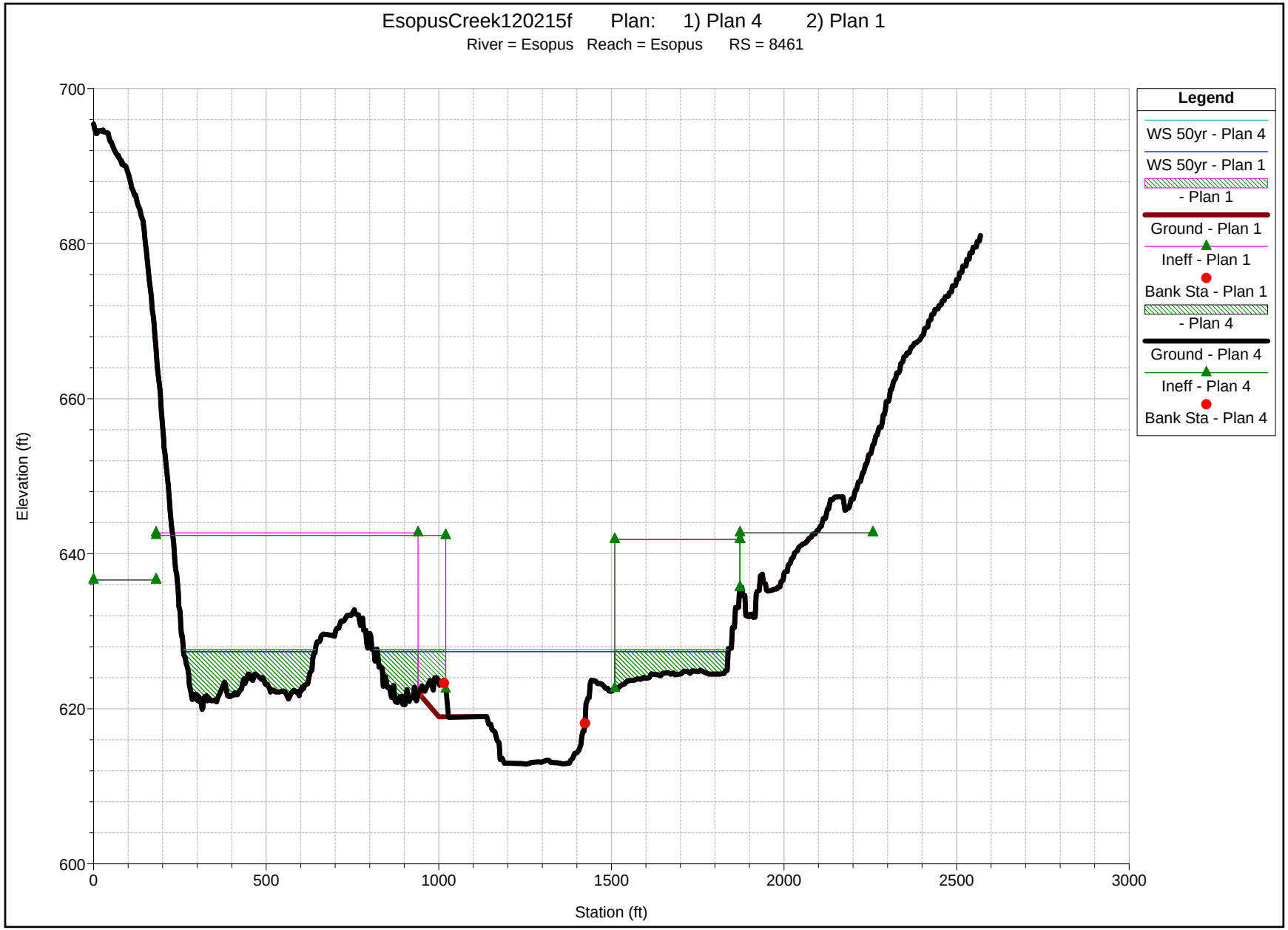
EsopusCreek120215f Plan: 1) Plan 4 2) Plan 1
River = Esopus Reach = Esopus RS = 8461
Elevation (ft)
700
680
660
640
620
600
0
500
1000
1500
2000
2500
3000
Station (ft)
Legend
WS 50yr - Plan 4
WS 50yr - Plan 1
- Plan 1
Ground - Plan 1
Ineff - Plan 1
Bank Sta - Plan 1
- Plan 4
Ground - Plan 4
Ineff - Plan 4
Bank Sta - Plan 4

FIGURE A5

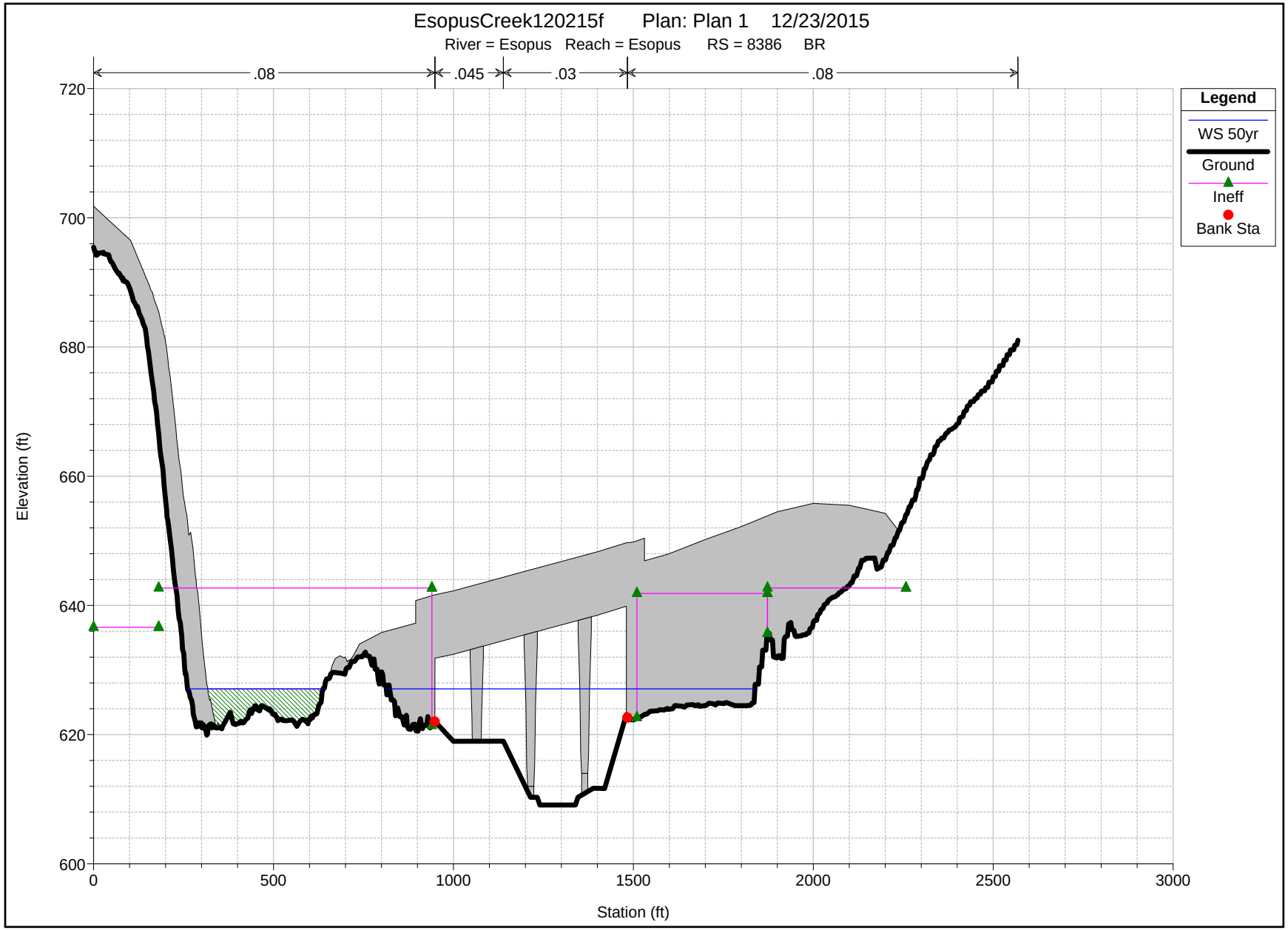
EsopusCreek120215f Plan: Plan 1 12/23/2015
River = Esopus Reach = Esopus RS = 8386 BR
.08
.045
.03
.08
Legend
WS 50yr
Ground
Ineff
Bank Sta
Elevation (ft)
720
700
680
660
640
620
600
0
500
1000
1500
2000
2500
3000
Station (ft)

FIGURE A6

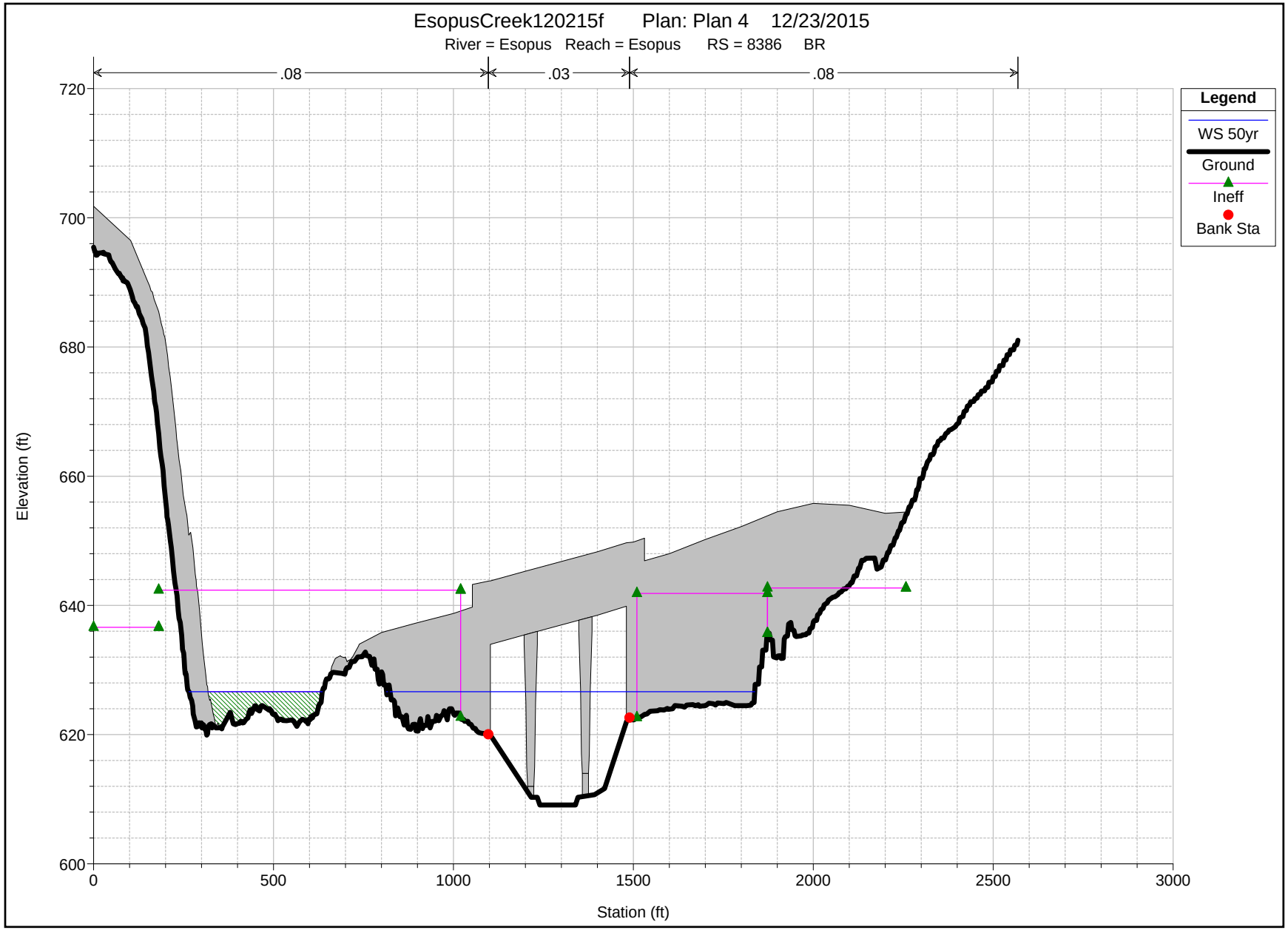
EsopusCreek120215f Plan: Plan 4 12/23/2015
River = Esopus Reach = Esopus RS = 8386 BR
.08
.03
.08
Legend
WS 50yr
Ground
Ineff
Bank Sta
Elevation (ft)
720
700
680
660
640
620
600
0
500
1000
1500
2000
2500
3000
Station (ft)

FIGURE A7

Table Number: A1					
Table Title: Comparison of Preliminary Effective,					
URS Corrected and WEC Corrected Models					
Date: 12/23/15					
	Preliminary Effective Model	URS Corrected		WEC Corrected	
Station	Water Surface Elevation	Water Surface Elevation	Delta	Water Surface Elevation	Delta
	ft	ft	ft	ft	ft
10120	634.68	634.68	0	634.84	0.16
9990	N/A	N/A		634.16	N/A
9786	N/A	N/A		633.22	N/A
9621	632.29	632.29	0	632.45	0.16
9339	N/A	N/A		632.5	N/A
9061	632.21	632.91	0.7	633.02	0.11
8899	N/A	632.88		632.88	0
8758	N/A	632.18		632.18	0
8599	N/A	631.89		631.89	0
8461	630.57	631.27	0.7	631.27	0
8386	BRIDGE				
8250.82	N/A	628.99		628.99	0
8098.18	N/A	628.58		628.58	0
7988	628.67	628.65	-0.02	628.65	0

Table Number: A2

Table Title: Comparison of WEC Corrected Models, Four Span, Four Span A and Three Span

Date: 12/23/15

	WEC Corrected	Four Span		Four Span A		Three Span	
Station	Water Surface Elevation	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta
	ft	ft	ft	ft	ft	ft	
10120	634.84	634.84	0	634.84	0	634.83	-0.01
9990	634.16	634.16	0	634.16	0	634.16	0
9786	633.22	633.22	0	633.22	0	633.21	-0.01
9621	632.45	632.45	0	632.45	0	632.45	0
9339	632.5	632.71	0.21	632.44	-0.06	631.82	-0.68
9061	633.02	633.21	0.19	632.96	-0.06	632.42	-0.6
8899	632.88	633.19	0.31	632.94	0.06	632.37	-0.51
8758	632.18	632.56	0.38	632.25	0.07	631.48	-0.7
8599	631.89	632.3	0.41	631.97	0.08	631.13	-0.76
8461	631.27	632.1	0.83	631.74	0.47	630.07	-1.2
8386	Bridge						
8250.82	628.99	630	1.01	630	1.01	628.99	0
8098.18	628.58	628.58	0	628.58	0	628.58	0
7988	628.65	628.65	0	628.65	0	628.65	0

Table Number: A3

Table Title: Comparison of Proposed Flood Mitigation Solutions- 100 year Flood

Date: 12/23/15

Station	WEC Corrected	Plan 1		Plan 2		Plan 3		Plan 4		Plan 5	
	Water Surface Elevation	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta
	ft	ft	ft	ft							
10120	634.84	634.74	-0.1	634.74	-0.1	634.75	-0.09	634.74	-0.1	634.74	-0.1
9990	634.16	633.12	-1.04	633.13	-1.03	633.08	-1.08	633.42	-0.74	633.43	-0.73
9786	633.22	632.49	-0.73	632.5	-0.72	632.07	-1.15	632.96	-0.26	632.97	-0.25
9621	632.45	632.1	-0.35	632.11	-0.34	633.01	0.56	632.71	0.26	632.72	0.27
9339	632.5	631.4	-1.1	631.38	-1.12	632.48	-0.02	632.4	-0.1	632.38	-0.12
9061	633.02	630.82	-2.2	630.82	-2.2	631.89	-1.13	632.13	-0.89	632.13	-0.89
8899	632.88	631.54	-1.34	631.54	-1.34	632.43	-0.45	632.65	-0.23	632.65	-0.23
8758	632.18	631.42	-0.76	631.42	-0.76	631.41	-0.77	632.57	0.39	632.57	0.39
8599	631.89	631.14	-0.75	631.14	-0.75	631.14	-0.75	632.38	0.49	632.38	0.49
8461	631.27	631.07	-0.2	631.06	-0.21	631.06	-0.21	631.57	0.3	631.57	0.3
8386	Bridge										
8250.82	628.99	630.39	1.4	630.39	1.4	630.4	1.41	629.87	0.88	629.87	0.88
8098.18	628.58	629.72	1.14	629.72	1.14	629.72	1.14	629.72	1.14	629.72	1.14
7988	628.65	629.52	0.87	629.52	0.87	629.52	0.87	629.52	0.87	629.52	0.87

Table Number: A4

Table Title: Comparison of Proposed Flood Mitigation Solutions- 50-year Flood

Date: 12/23/15

Station	WEC Corrected	Plan 1		Plan 2		Plan 3		Plan 4		Plan 5	
	Water Surface Elevation	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta	Water Surface Elevation	Delta
	ft	ft	ft	ft							
10120	632.5	631.72	-0.78	631.72	-0.78	631.69	-0.81	631.72	-0.78	631.72	-0.78
9990	631.64	631.09	-0.55	631.09	-0.55	630.66	-0.98	631.16	-0.48	631.16	-0.48
9786	631.35	630.42	-0.93	630.42	-0.93	629.51	-1.84	630.54	-0.81	630.54	-0.81
9621	630.19	629.99	-0.2	629.99	-0.2	630.6	0.41	630.14	-0.05	630.14	-0.05
9339	629.46	628.95	-0.51	628.94	-0.52	629.97	0.51	629.24	-0.22	629.24	-0.22
9061	629.75	627.51	-2.24	627.51	-2.24	628.23	-1.52	628.43	-1.32	628.44	-1.31
8899	629.46	628.25	-1.21	628.26	-1.2	629	-0.46	629.01	-0.45	629.01	-0.45
8758	628.59	628	-0.59	628.01	-0.58	628	-0.59	628.84	0.25	628.83	0.24
8599	628.22	627.56	-0.66	627.55	-0.67	627.56	-0.66	628.55	0.33	628.54	0.32
8461	627.31	627.37	0.06	627.37	0.06	627.37	0.06	627.62	0.31	627.62	0.31
8386	Bridge										
8250.82	626.16	626.94	0.78	626.94	0.78	626.95	0.79	626.62	0.46	626.62	0.46
8098.18	625.67	626.44	0.77	626.44	0.77	626.44	0.77	626.44	0.77	626.44	0.77
7988	625.67	626.31	0.64	626.31	0.64	626.31	0.64	626.31	0.64	626.31	0.64