ROCKAWAY RIVER AND DEN BROOK
DENVILLE TOWNSHIP
MORRIS COUNTY, NEW JERSEY
CAP SECTION 205
FLOOD RISK MANAGEMENT STUDY

APPENDIX C
CIVIL ENGINEERING

September 2025

U.S. Army Corps of Engineers
North Atlantic Division – New York and Baltimore Districts
In partnership with the New Jersey Department of Environmental Protection

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1 Introduction

1.1 Purpose and Scope of Appendix A – Civil Engineering

The purpose of this appendix is to present the Civil Engineering investigations/studies conducted for the Section 205 Feasibility Study, Denville Flood Risk Management Project. This Appendix investigated and evaluated a holistic way of protecting the study area from inundations associated with storm frequencies ranging from the 100-year (1% Annual Exceedance Probability [AEP]) to the 25-year (4% AEP). Many flood risk management structures were assessed, evaluated and ranked as partially and marginally feasible through the project matrix elimination process in Section 3.6.3 of the Main Report and the three flood protection structures selected were floodwall, Jersey barrier and Road Elevation as a flood protection line. The Non-Federal Sponsor, the Township of Denville, recommended a by-pass culvert as an additional flood control structure.

This civil engineering design investigation resulted in the preliminary design of these three structures at strategic locations as a product of Hydrologic and Hydraulic (H&H) studies given water surface elevations at multiple control areas critical to the flood protection of the study area. The designs were enough to generate baseline Quantities and Cost Estimates to determine the cost of all the structural alternatives within the project for the feasibility study.

2 Existing Conditions

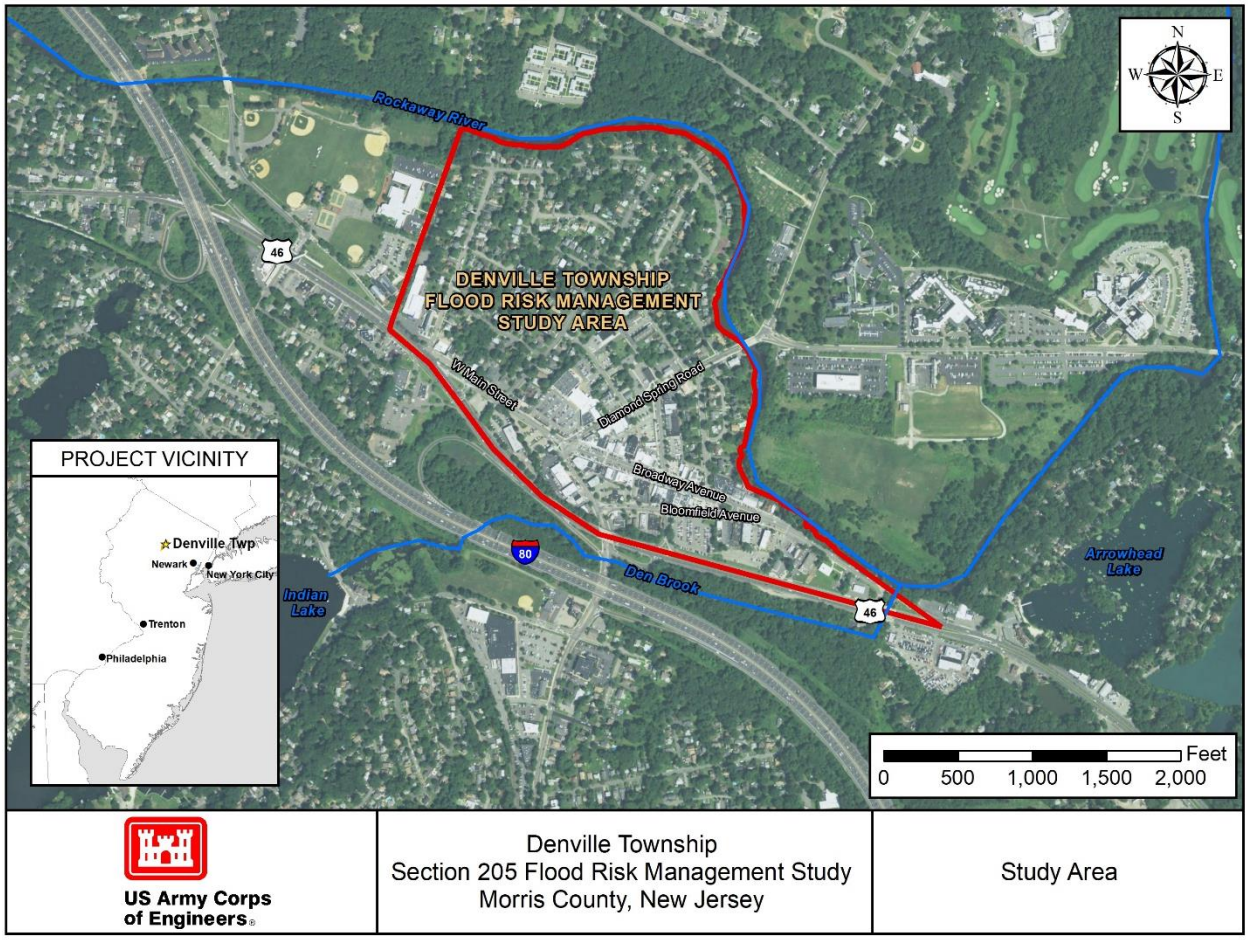
2.1 Study Area

The study area covered by this Appendix includes the area south of the Rockaway River reach starting along the river station approximately 250 feet northeast of the intersection of St Mary's Place and Riverside Drive and ends at the intersection of Bloomfield Avenue and Route 46 in Denville, New Jersey. See Figure 1, Study area.

2.2 Site Description

The site consists of mix residential and commercial buildings. It is approximately 0.21 square mile and bounded on the North by the Rockaway River, on the South by US Route 46, on the east by Rockaway River and on the West by St. Mary's Place. It ranges in altitude approximately 500 feet above sea level (NAVD88) at its lowest point, on the south side near Den Brook, to its highest point of approximately 520 feet above sea level about 114 feet south of Riverside Drive and about 70 feet west of Myers Avenue .The north side of the site consist of thick woody vegetation and trees near the Rockaway River stream banks while most of the site is gradual in rise and fall of elevation with urban development responsible for covering most of the natural ground with pavement and other forms of development cover materials other than grass and meadows. Denville has a network grid of major roads. Major roadways running in the north and south directions are Myers Avenue, Hinchman Avenue, and Diamond Spring Road. Major roadways running in the east and west directions are Orchard street, Church Street, West Main Street and Broadway.

Figure 1: Study Area, Township of Denville, Morris County, New Jersey



3 Applicable Design Standards and Criteria

3.1 General

Improvements to site protection form floodwaters are required to follow federal, state, and local standards. This appendix combines all these standards to come up with the most effective safe design. Emphasis is on the use of USACE engineering circulars and manuals. The road elevation standards and specifications for Municipal Roadway and County Roadway of New Jersey was supplied by the Sponsor. Below is the list of standards referenced.

1. AASHTO 2018. A Policy on Geometric Design of Highway and Streets.197263
2. EM 1110-2-2102, Waterstops and Other Preformed Joint Materials for Civil Works Structures, USACE, Washington DC; September 1995.
3. EM 1110-2-2104, Strength Design for Reinforced-Concrete Hydraulic Structures, USACE, Washington DC; August 2003.
4. EM 1110-2-2502, Retaining and Flood Walls, USACE, Washington DC; 29 September 1989.
5. EM 1110-2-2705 - Structural Design of Closure Structures for Local Flood Protection Projects
6. ENGINEERING PRINCIPLES AND PRACTICES Chapter 5-Design of Floodwalls and Levees, FEMA (44 CFR60.3(c)(2))
7. Standard Specifications for Municipal Roadway and County Roadway in New Jersey

3.2 Design Criteria

The floodwalls for all of the Alternative 1 variation were designed to the maximum water surface elevation inundation for the 1% AEP, 2% AEP, and 4% AEP, (100-year, 50-year and the 25-year storm) plus three feet freeboard. The floodwall for Alternative 2 and all of its variations was designed to the maximum water surface elevation inundation for the 4% plus 6 inches. The foundation of the selected T-wall was designed to have the lightest possible footing base and the smallest possible width given the restrictions associated with the uncertain soil conditions. Flow rate for the maximum cubic footage of water passing into the bypass culvert was supplied by the H&H Engineer. The specifications for the culvert were supplied by the Sponsor. The roadway elevation design incorporated the existing road undergoing reclamation and the proposed elevated portion used the new materials.

3.2.1 Civil

AutoCAD Civil 3D was used to create the alignments, profiles, cross sections and layouts for the floodwalls, road elevations and Jersey barrier protective structures with design guidance from EM 1110-2-2502, Retaining and Flood Walls and ENGINEERING PRINCIPLES AND PRACTICES Chapter 5-Design of Floodwalls and Levees, FEMA (44 CFR60.3(c)(2)). Specifications, base design and preliminary estimates from the Sponsor and flow rates from the H&H engineer enable the complete design of the bypass culvert. The design heights were set, thickness set, and foundation dimensions generated considering frost depth in Denville, New Jersey.

3.2.2 Structural and Geotechnical

Global stability criteria for sliding, overturning, bearing, ware evaluated in accordance USACE Engineering Manual 1110-2-2100 (EM 1110-2-2100) Chapter 3, as applicable for Structural Engineering. The minimum factors of safety for the stability of T-wall with ordinary site information, as defined in EM 1110-2-2100, are listed in Table 1. The failure mechanisms (sliding, overturning, and bearing) are described in Chapter 3 of EM 1110-2-2100.

The floodwater levels design requirements were provided by the Civil Engineer. The floodwall design was an iterative process. Due to soil unit weight and footings length constraints, and after several iterations, the T-wall design with the key was selected. The heel, toe, and wall widths were iteratively designed until safety factors were in accordance with USACE Engineering Manual 1110-2-2100. See Exhibit 16 to 18.

It is important to note that the structural design used the conservative safety factors due to the absence of soil boring logs. In addition, a conservative soil unit weight and allowable bearing pressure were utilized and viewed/approved by the Geotechnical Engineer.

Geotechnical desktop soil research and investigation was conducted using similar historical projects conducted in the area with similar project conditions. Combined with Engineering Judgment, Table 2 was developed. Foundation final design is normally recommended during “Plans and Specifications” in accordance with the available soil borings and load combinations derived from EM 1110-2-2104.

Table 1: Safety Factors for Floodwall Structural Design

Condition	Usual (U)	Unusual (N)	Extreme (X)	Reference
Sliding	2.0	2.6	2.2	EM 1110-2-2100 (Table 3-2)
Overturning	1.2	1.5	1.5	EM 1110-2-2100 (Table 3-5)
Bearing	__	2000psf	2000psf	Recommended By Geotechnical
Overturning	100% Base in Compression	75% Base in Compression	Resultant within Base	EM 1110-2-2100 (Table 3-5)

Table 2: Soil Unit Weight Used for Floodwall Structural and Foundation Design

Parameter / Soil type	Moist Unit Weight, γ_{moist} (pcf)	Saturated Unit Weight, γ_{sat} (pcf)	Friction Angle, Φ (degree)	Cohesion, c (psf)
Fine Grained Alluvial Sands (aquifer)	118	120	30	0

3.3 Design Considerations

The Civil Engineering design considered the "Best fit Flood Risk Management" (FRM) structures to avoid to the maximum extent possible flood displacement using standard design interactions to optimize the FRM structures that would protect the most structures in the study area. The design ensured that residents near the stream have the maximum use of their back yard property by placing the wall as close as possible to the stream. The design established an average 35 feet distance from the stream edge where possible to reclaim as much floodplain as possible and to accommodate the base of the footings and maintenance transportation needs. The design endeavored to maintain the prescribe 15 feet easement from any encroachment at 90 percent of the time, except on steep banks where it was not possible.

The Sponsor's request dictated the design of Alternative 2 and 3. Alternative 2 was based on two modified versions of the Sponsor's initial concept from the project's Federal Interest Determination, FID report. Research enabled the design team to drop the requirement for 3 feet of freeboard to 6 inches of freeboard for Alternative 2. The designs utilized more of the dense graded aggregates for the roadway elevation because it was the cheapest of the base courses.

3.3.1 Interior Drainage

Interior drainage always forms a part of the FRM structure. Interior drainage represents all water runoff, seepage (water going under or thorough the levee), and water collection on the landward side of the levee system. The analysis for interior must identify and demonstrate the potential runoff paths from the impacted drainage area. Since the design was on the feasibility level, 10 interior drainage areas were

assigned to this the floodwall system for all the Alternatives 1 based on the identified low areas on the landscape and Professional engineering judgment advice from the Hydrology and Hydraulic (H&H) section.

3.3.2 Utility Incorporation into the Design

The Civil Engineering teamwork in close cooperation with the Project Sponsor and acquired two utility maps from them. The maps were scaled and all points of utility crossings for all proposed structures were consider for existing utility protection and structural encasement and the cost reflected as part of the design and construction cost.

4 Alternatives Evaluated

4.1 General

The CAP Section 205 feasibility study requires a holistic involvement of several alternatives to get the most responsive design that results in the best Benefit Cost Ratio (BCR) within the limit of the authorization. This section of the appendix explains how the alternatives were developed, the rationale behind them and their descriptions.

4.2 Alternative Development and Description

The alternatives were developed based on the total protection from flood frequency inundation. The Civil Engineer endeavored to protect practically to the maximum extent possible all structure specified within the study area with respect to the frequency inundation with all the design considerations mentioned above. Alternative 2, requested by the Sponsor, protects a limited amount of structures. Alternative 3 takes all inundation floodwater up to the 4% AEP (25-year equivalent) storm event away from the study area, bypasses it around the site, and discharges it downstream at a hydraulically feasible predetermined location. Any inundation greater than the 4% AEP storm event will flood the study area under this alternative. See Table 3 for structures features for all alternatives.

Table 3: Structures Features for All Alternatives

Alternative	Feature	Beginning Station	End Station	HEC-RAS Station (If applicable)	Top Elevation (Approximate)	Average Height (ft)	Length (ft)	Location
1a	Floodwall	0+00	34+41.68		514.00	12.54	3,441.69	Mary's Place and Riverside Drive/ Diamond Spring Road Bridge
1a, b	Floodwall	34+41.68	35+21.54		512.00		79.86	Near Diamond Spring Road Bridge
1a, b	Floodwall	35+21.54	47+08.69		514.95	9.03	1,267	East of Diamond Spring Road Bridge/ back of 106 Broadway
1a, b	Floodwall	47+08.69	56+18		510.50	7.82	909.31	106 Broadway/ northwest of the intersection of Bloomfield Avenue and Route 46
1a, b	Floodwall	56+62.46	75+66		510.75	5.47	1, 893	Route 46 westbound lane/ Route 53 under the East Main Street/ Route 46 overpass
1a, b	Closure Structure I01	25+59.51	27+86.14		514.80	11.75	226	Directly opposite 21 Riverside Drive Property
1a, b,	Closure Structure I02	56+10.25	56+62.46		510.57	7	53	Bloomfield Avenue
1a, b	Closure Structure I03	57+55.03	57+89.32		510.61	6	34	Entrance from Route 46 westbound into Enrite Gas station.
1a	Closure Structure I04	58+14.97	58+48.52		510.63	6.5	33	Second entrance from Route 46 westbound into Enrite Gas station
1a	Closure Structure I05	58+78.86	59+16.37		510.65	5.33	38	Close the third entrance from Route 46 westbound into Enrite Gas
1a	Closure Structure I06	62+87.85	63+18.54		510.72	4.33	31	Along Route 46 and it will be blocking the Firestone Complete Auto Care Tire shop
1a	Closure Structure I07	71+02.55	71+49.88		510.75	2.00	47	Located along Route 46 and it will be blocking the Exit from Route 46 westbound into the Bloomfield Avenue
1a, b	Closure Structure I08	72+07.99	72+36.71		510.75	Tie into HG	29	HG=High Ground, will be closing off the exit from Bloomfield Avenue into Route 46 westbound
1a, b	Closure Structure I09	75+62.21	76+53.02	2355	510.75	6.75	91	Provide protection against floodwaters passing under Rout 46 overpass/East Main Street

1a, b	Closure Structure I10	34+76.38	35+29.49		513	8	53	Will close off Diamond Spring Road Bridge on the south side of the Rockaway River
1a,b								
1c,d	Floodwall	0+00	34+41.68		513.00	11.1	3,441.69	Same location matching Alternative 1a for the same station
1c,d	Floodwall	34+41.68	35+21.54		512.00	8.09	79.86	Same location matching Alternative 1a for the same station
1c,d	Floodwall	35+21.54	47+08.69		510.50	6.29	1,267	Same location matching Alternative 1a for the same station
1c,d	Floodwall	47+08.69	56+18		510.25	5.10	909.31	Same location matching Alternative 1a for the same station
1c,d	Floodwall	56+62.46	75+66		510.25	5.37	1, 893	Same location matching Alternative 1a for the same station
1c,d	Closure Structure I01	25+59.51	27+86.14		513.00	11.75	226	Directly opposite 21 Riverside Drive Property
1c,d	Closure Structure I02	56+10.25	56+62.46		510.25	5.37	53	Bloomfield Avenue
1c	Closure Structure I03	57+55.03	57+89.32		510.25	5.37	34	Entrance from Route 46 westbound into Enrite Gas station.
1c	Closure Structure I04	58+14.97	58+48.52		510.25	5.37	33	Second entrance from Route 46 westbound into Enrite Gas station
1c	Closure Structure I05	58+78.86	59+16.37		510.25	5.37	38	Close the third entrance from Route 46 westbound into Enrite Gas
1c	Closure Structure I06	62+87.85	63+18.54		510.25	5.10	31	Along Route 46 and it will be blocking the Firestone Complete Auto Care Tire shop
1c,d	Closure Structure I07	71+02.55	71+49.88		510.25	5.10	47	
1c,d	Closure Structure I08	72+07.99	72+36.71		510.25	5.10	29	HG=High Ground, will be closing off the exit from Bloomfield Avenue into Route 46 westbound
1c,d	Closure Structure I09	75+62.21	76+53.02	2355	510.25	5.10	91	Provide protection against floodwaters passing under Rout 46 overpass/East Main Street. Tie into HG

1c,d	Closure Structure I10	34+76.38	35+29.49		510.50	8.09	53	Close off Diamond Spring Road Bridge on the south side of the Rockaway River
1e,f	Floodwall	0+00	34+41.68		512.50	9.57	3,441.69	Same location matching Alternative 1a for the same station
1e,f	Floodwall	34+41.68	35+21.54		510.00	6.44	79.86	Same location matching Alternative 1a for the same station
1e,f	Floodwall	35+21.54	47+08.69		508.50	5.39	1,267	Same location matching Alternative 1a for the same station
1e,f	Floodwall	47+08.69	56+18		508.50	3.69	909.31	Same location matching Alternative 1a for the same station
1e,f	Floodwall	56+62.46	75+66		508.25	3.12	1, 893	Same location matching Alternative 1a for the same station
1e,f	Closure Structure I01	25+59.51	27+86.14		512.50	9.57	226	Directly opposite 21 Riverside Drive Property
1e,f	Closure Structure I02	56+10.25	56+62.46		508.25	3.12	53	Bloomfield Avenue
1e	Closure Structure I03	57+55.03	57+89.32		508.25	3.12	34	Entrance from Route 46 westbound into Enrite Gas station.
1e	Closure Structure I04	58+14.97	58+48.52		508.25	3.12	33	Second entrance from Route 46 westbound into Enrite Gas station
1e	Closure Structure I05	58+78.86	59+16.37		508.25	3.12	38	Close the third entrance from Route 46 westbound into Enrite Gas
1e	Closure Structure I06	62+87.85	63+18.54		508.25	3.12	31	Along Route 46 and it will be blocking the Firestone Complete Auto Care Tire shop
1e,f	Closure Structure I09	75+62.21	76+53.02	2355	508.25	3.12	91	Provide protection against floodwaters passing under Rout 46 overpass/East Main Street. Tie into HG
1e,f	Closure Structure I10	34+76.38	35+29.49		508.50	3.00	53	Close off Diamond Spring Road Bridge on the south side of the Rockaway River
2a,b,bsens	Corey Road	0+00	2+65		508.75	4.12	265	

2a,b,bsens	Gardner Road	0+00	7+56		508.75	3.78	756	
2a,b,bsens	Hinchman Ave	0+00	2+28		508.75	3.32	228	
2a,b	Orchard St.	21+50	24+10		506.25	3.30	260	
2a,b	Diamond Spring Rd	0+00	6+22		506.25	1.36	622	
2a	2nd Avenue	26+00	34+82		507.00	3.41	732	
2a,b,bsens	Along Route 46	48+00	61+32		506.50	3.2	1332	
2a,b,bsens	Closure at Rt 46 Overpass	0+00	2+63		507.25	2.5	263	
2a	3rd St. along Rockaway River	32+60	50+51		506.00	5.8	1791	
2b, bsens	Short Wall along the Rockaway	0+00	9+91		506.00	5.5	991	
2a	Closure Structure I01	26+00	25+87		507.00	3.40	13	Located at Second Avenue and Diamond Spring Road Intersection
2a	Closure Structure I02	34+82			507.00	3.40	14	At the end of the of Second Avenue Jersey Barrier
2a,b, bsens	Closure Structure I03	47+34.94	47+87.94		506.00	5.25	53	Will cross Bloomfield Avenue
2a,b, bsens	Closure Structure I04	1+20.13	2+28.13		507.25	2.4	108	Provide protection against floodwaters passing under Route 46 overpass/East Main Street. Tie into HG

4.3 Description of Alternatives

4.3.1 Alternative 1a: 1% AEP (100-yr) Level of Performance (LOP), with 10-Stop Log Structures

Alternative 1a is the design of a floodwall around the partial perimeter of the study area exposed to high floodwaters from the Rockaway River and Den Brook. This alternative was designed to keep floodwaters associated with the 1% AEP storm event from inundating the select area. The beginning segment of the floodwall consists of three sub-segments distinguished by average heights above grade. The first sub-segment commences approximately 40 feet west of St. Mary's Place and Riverside Drive intersection, goes in the easterly direction along Riverside Drive for about 100 feet, then extends north toward the Rockaway River for about 105 feet, bends right about 95 degrees approximately 35 feet south from the edge of the river's bank and continues to run parallel to the river in the easterly direction and ends on the west side of the Diamond Spring Road Bridge near Station 34+41.68. The second sub-segment starts from East of Diamond Spring Road Bridge, Station 35+21.54, and runs parallel with the Rockaway River and terminates at the back of 106 Broadway. The third sub-segment commences at the back of 106 Broadway and runs parallel to the Rockaway River and terminates approximately 706 feet northwest of the intersection of Bloomfield Avenue and Route 46 at the proposed closure structure across Bloomfield Avenue.

The first sub-segment of the floodwall has an average height of 12.54 feet above grade and measures approximately 3,441.69 linear feet from Station 0+00 to Station 34+41.69. The second sub-segment of the floodwall has an average height of 9.03 feet above grade and measures approximately 1,267 linear feet from station 34+41.69 to station 47+08.69. The third sub-segment of the floodwall has an average height of 7.82 feet above grade and measures approximately 909.31 linear feet from Station 47+08.69 to station 56+18.

The ending segment of Alternative 1a design is the part of the floodwall with the shortest height. It starts from the closure structure across Bloomfield Avenue Sta 56+62.46 and runs approximately 90 feet south on the east side of Enrite property and connects with a 90 degree right turn along the shoulder of Route 46 westbound lane. This proposed floodwall runs from East to West for approximately 1,893 feet and terminates at station 75+66 and meets the proposed closure structure at Route 53 under the East Main Street/ Route 46 overpass. The floodwall segment along Route 46 averages 5.47 feet above grade. The total length of Alternative 1a floodwall excluding closure structures is 7,026 feet. Alternative 1a was designed with 3.0 feet of freeboard across all the top heights of all the proposed flood control structures.

There are 10 closure structures under Alternative 1a. Closure structure labeled I01 is located along Riverside Drive East (Sta 25+59.51 to 27+86.14, 40°53'46.4"N 74°28'30.2"W), directly opposite 21 Riverside Drive property. It is about 226 feet long. This is a deed restricted area by FEMA and it is termed by the Township as Denville Park Meadows. The deed restriction is the reason for the closure structure design. Closure structure labeled I02 will cross Bloomfield Avenue approximately 706 feet northwest of the intersection of Bloomfield Avenue and Route 46 (Sta 56+10.25to Sta 56+62.46, 40°53'23.6"N 74°28'18.1"W) and connects on the Enrite Gas Station Property, 190 US-46, Denville. It is approximately 53 feet long. Closure structure labeled I03 will close the first entrance from Route 46 westbound into Enrite Gas station. It is located at edge of the property around the Bloomfield Avenue curve (Sta 57+55.03 to Sta 57+89.32, 40°53'24.0"N 74°28'16.7"W). It measures about 34 linear feet. Closure structure labeled I04 will close the second entrance from Route 46 westbound into Enrite Gas station (Sta 58+14.97 to Sta 58+48.52, 40°53'23.1"N 74°28'18.3"W) and its length is approximately 33 feet. Closure structure labeled I05 will close the third entrance from Route 46 westbound into Enrite Gas

station (Sta 58+78.86 to Sta 59+16.37, 40°53'23.3"N 74°28'19.2"W) and it is approximately 38 feet long. Closure structure labeled I06 is located along Route 46 and it will be blocking the Firestone Complete Auto Care Tire shop at 180 US-46 (62+87.85 to Sta 63+18.54,40°53'25.3"N 74°28'22.7"W) from floodwaters. The length of the tire shop entrance is about 31 feet. Closure structure labeled I07 is located along Route 46 (Sta 71+02.55 to Sta 71+49.88, 40°53'26.3"N 74°28'34.4"W) and it will be blocking the Exit from Route 46 westbound into the Bloomfield Avenue. The entrance to this exit is about 47 feet long with sidewalks. Closure structure labeled I08 will be closing off the exit from Bloomfield Avenue into Route 46 westbound (72+07.99 to Sta 72+36.71, 40°53'26.6"N 74°28'35.8"W). It is about 29 feet long.

Closure structure labeled I09 will provide protection against floodwaters passing under Route 46 overpass/East Main Street (Sta 75+62.21 to Sta 76+53.02, 40°53'27.5"N 74°28'40.4"W) from entering the BP Gas Station and Christ the King Church premises. Closure structure I09 is approximately 91 feet long. Closure structure labeled I10 will close off Diamond Spring Road Bridge on the south side of the Rockaway River (Sta 34+76.38 to Sta 35+29.49, 40°53'39.9"N 74°28'28.7"W) approximately 156 feet northeast of where Riverside Drive ends and intersects Diamond Spring Road. It is about 53 feet long.

All closures structures are in the form of stop logs displayed on maps in the H&H Appendix.

4.3.2 Alternative 1b: 1% AEP (100-yr) LOP, with 6-Stop Log Structures

Alternative 1b is a modification of Alternative 1a. All the flood protection structures and dimensions remain the same as in Alternative 1a except the removal of closure structures I03, I04, I05 and I06. The locations of the proposed closures will be replaced with permanent floodwall and the alternative will permanently limit access from U.S Route 46 to the Enrite Gas Station and the Firestone Complete Auto Care Tire shop. Access to the businesses will only be provided from Bloomfield Avenue.

4.3.3 Alternative 1c: 2% AEP (50-yr) LOP, with 10-Stop Log Structures

Alternative 1c is a modification of Alternative 1a. All the flood control structures are identical except for their heights because Alternative 1c was designed for the 2% AEP storm event with floodwaters of lower heights than that of the 1% AEP storm event. For Alternative 1c, the first sub-segment of the floodwall has an average height of 11.1 feet above grade. The second sub-segment of the floodwall has an average height of 8.09 feet above grade and the third sub-segment of the floodwall has an average height of 6.29 feet above grade. The floodwall segment along Route 46 averages 5.10 feet above grade.

4.3.4 Alternative 1d: 2% AEP (50-yr) LOP, with 6-Stop Log Structures

Alternative 1d is a modification of Alternative 1c. All the flood protection structures and dimensions remain the same as in Alternative 1c except the removal of closure structures I03, I04, I05 and I06. The locations of the proposed closures will be replaced with permanent floodwall and the alternative will permanently limit access from U.S Route 46 to the Enrite Gas Station and the Firestone Complete Auto Care Tire shop. Access to the businesses will only be provided from Bloomfield Avenue.

4.3.5 Alternative 1e: 4% AEP (25-yr) LOP, with 8-Stop Log Structures

Alternative 1e is a modification of Alternative 1a. All the flood control structures are identical except for their heights because Alternative 1e was designed for the 4% AEP storm event with floodwaters of far lower heights than that of the 1% AEP. For Alternative 1e, the first sub-segment of the floodwall has an average height of 9.57 feet above grade. The second sub-segment of the floodwall has an average height of 6.44 feet above grade and the third sub-segment of the floodwall has an average height of 5.39 feet above grade. The floodwall segment along Route 46 averages 3.69 feet above grade. Due to the low elevation of the water level under this alternative, closure structure I07and I08 were not needed and had to be eliminated from this option.

4.3.6 Alternative 1f: 4% (25-y) LOP, with 4-Stop Log Structures

Alternative 1f is a modification of Alternative 1e. All the flood protection structures and dimensions remain the same as in Alternative 1e except the removal of closure structures I03, I04, I05 and I06. The locations of the proposed closures will be replaced with permanent floodwall and the alternative will permanently limit access from U.S Route 46 to the Enrite Gas Station and the Firestone Complete Auto Care Tire shop. Access to the businesses will only be provided from Bloomfield Avenue.

4.3.7 Alternative 2a: 4% (25-yr) LOP, with 4-Stop Log Structures

Alternative 2a is the design of flood control protection for a flood prone perimeter area within the overall project area created by the 4% AEP storm event inundation floodwaters. This design protection is a combination of elevating five roadways serving as a flood protection line, the construction of a Jersey barrier along the center line of second avenue, the construction of a floodwall covering about 1,024 feet along the Rockaway River, the construction of a short floodwall along Route 46 eastbound and the placement of a short segment of floodwall to accommodate a closure structure along East Main Street /Route 53 under the Route 46 overpass.

The elevation of Corey Road commences approximately 141 feet from the intersection of Corey Road and Riverside Drive, runs in the southerly direction for approximately 265 feet and terminates near its intersection with Spruce Road. Corey Road raises to its highest point of approximately 4.12 feet at Station 2+64. Gardner Road raising starts at the intersection with Corey Road and runs in the easterly direction for approximately 756 feet and terminates approximately 117 feet beyond the intersection with Hinchman Avenue. Gardner Road raises to the peak height of approximately 3.78 feet at station 1+00. Hinchman Avenue Road raising commences from approximately 100 feet north of the intersection with Gardner Road and moves in the southerly direction for approximately 228 feet. At its highest point above the existing road, it measures 3.32 feet. Orchard Street raising commences approximately 30 feet southeast of the intersection with Clark Street and runs in the Southeasterly direction for approximately 260 feet and ends at the intersection of Diamond Spring Road. Orchard Street raises to a height of 3.30 feet. Diamond Spring Road raising starts from the Diamond Spring Road Bridge and runs southwesterly for approximately 622 feet and ends at approximately 31 feet northeast of the intersection of Diamond Spring Road and First Avenue. It raises to the top height of 1.36 feet. Second Avenue Jersey barrier construction starts at the intersection of Second Street and Diamond Spring Road and runs toward the south for approximately 732 feet. It raises to a constant top height of 3.41 feet. The Rockaway River Floodwall connects to the Second Avenue Jersey barrier with a closure structure. This floodwall runs from the edge of the Second Avenue pavement toward Rockaway River along an alleyway near Edward B. Jones Financial Building and bends slightly right approximately 35 feet south of the river's edge and continued running parallel with the river until a reaches the end of 106 Broadway property. At 106 Broadway, the floodwall makes a 90-degree right turn toward Bloomfield Avenue for about 63 feet then turns left at 90-degree and runs parallel with the shoulder of Bloomfield Avenue then terminates about 706 feet northwest of Bloomfield Road and Route 46 intersection. A small segment of that floodwall connects by closure structure across Bloomfield Avenue for about 200 feet and makes a 90- degree right turn along Route 46 and extends for about 127 feet and stops. The total length of the Rockaway River Floodwall is 1791 feet and has an average height of 5.58 feet above grade. The short floodwall, which runs parallel to Route 46 eastbound, measures approximately 1332 feet and has a top height above grade of 3.2 feet. It is located on edge of the eastbound lane shoulders.

The last part of Alternative 2a design protection consist of 155 feet of floodwall constructed on the East side of Route 53/East Main Street connected to a 108-feet closure structure which would block the

floodwater protruding through the Route 46 underpass. The top height of that floodwall and closure structure is 2.5 feet above the Route 53/East Main Street pavement surface. Alternative 2a was designed with 0.50 foot of freeboard across all the top heights of all the proposed flood control structures.

Alternative 2a has 4 closure structures. Closure structure labeled I01 is located at Second Avenue and Diamond Spring Road Intersection (Sta 26+00 to 25+86, 40°53'38.2"N 74°28'32.3"W). This closure measures about 13 feet in length. Closure structure labeled I02 is at the end of the of Second Avenue Jersey Barrier (Sta 34+82, 40°53'31.5"N 74°28'31.5"W) and it measures 14 feet. Closure structure labeled I03 will cross Bloomfield Avenue (Sta 47+34.94, 40°53'25.1"N 74°28'18.8"W). It is further northwest from Enrite Gas Station than the closure structure in Alternative 1a. It is approximately 655 feet southwest of 106 Broadway and is approximately 53 feet long. Closure structure labeled I04 is located under Rout 46 overpass/East Main Street (Sta 1+20.13, 40°53'27.5"N 74°28'40.4"W). It will close off Route 53. It is 108 linear feet.

4.3.8 Alternative 2b: 4% AEP (25-yr) LOP, with 4-Stop Log Structures

Alternative 2b is a modification of alternative 2a. Alternative 2b removes the protection line, which is represented by a Jersey barrier structure, from Second Avenue and takes it further east near the Rockaway River. Near the Rockaway River, this alternative design changes the protection structure to a floodwall. It also removes a short segment of the Rockaway River floodwall that was connected to the second avenue Jersey barrier. All road elevation protective structures and freeboard for Alternative 2a remains in place. The new Rockaway River floodwall forms a flood protection line that commences east of the Diamond Spring Road Bridge and runs in a southerly direction parallel to the river and connects to the floodwall described in Alternative 2a that runs along an alleyway near Edward B. Jones Financial Building. The front of Edward B. Jones Financial Building faces Second Avenue and is located approximately 141 feet north of the intersection of Second Avenue and Broadway. The rest of the Rockaway floodwall, the short floodwall along Route 46, and other protection structures remain the same as described in Alternative 2a, except for the absence of two closure structures. Alternative 2b has two closure structures. Closure structure labeled I04 and Closure structure labeled I03 in 2a above.

4.3.9 Alternative 2b Sensitivity: 4% AEP (25-yr) LOP, with 2-Stop Log Structures

Alternative 2b sensitivity is a modification of Alternative 2b. In Alternative 2b sensitivity, the elevating of Orchard Street and Diamond Spring Road are eliminated. Snyder Road is raised to a top height of 4.28 feet. All other flood protection structures remain the same as Alternative 2b.

4.3.10 Alternative 3: 4% AEP (25-yr) LOP, Divert Flow with a 8'x20' Box Culvert

Alternative 3 is the design of a 20-foot wide by 8-foot-high by-pass culvert that will take a substantial amount of the 4% AEP storm floodwaters away from the project area and redirect it further downstream. This alternative consists of a stream diversion structure located approximately 75 feet upstream of HEC-RAS River Station 34260. This diversion structure will divert floodwater into the three-sided open bottom by-pass box culvert approximately 6,600 linear feet and discharge that floodwater through an outlet structure designed to reduce excessive energy while discharging the waters.

4.3.11 Alternative 4a-c: Non-Structural Treatments

A nonstructural alternative is one in which the physical mechanism and extent of flooding is largely unchanged but the existing buildings within the floodplain are adapted, or the regulatory framework that governs new development is modified to reduce the damage incurred during flood events. The analysis of nonstructural treatments considered three physical measures and various nonphysical measures such as evacuation plans, land use regulation, flood emergency preparedness plans, flood insurance, flood

mapping, flood warning systems, risk communication, and zoning. The three physical measures can be described under the following:

- Elevation: For this study, elevation refers to increasing the height of the foundation of a structure at least equal to or greater than the design flood elevation to reduce damages from flooding. Elevation can be performed using fill material, on extended foundation walls, on piers, post, piles, or columns. Elevation is also a very successful technique for reinforced concrete slab-on-grade structures.

- Dry floodproofing: Dry floodproofing allows floodwater to reach the structure but reduces the flood damage by preventing water from getting inside the structure by sealing openings, installing watertight barriers, and waterproofing exterior walls. Structures with foundation types that do not allow for elevations or wet floodproofing could be protected with dry floodproofing. In some instances, the dry floodproofing offered risk reduction during more infrequent storms (2 percent and 1 percent AEP).

- Wet floodproofing: This is generally applied to structures with a main floor elevation already above the design storm, but that would still incur significant damages due to the presence of basements and vulnerable utilities. This measure allows floodwater to enter lower, non-living space areas via vents and openings to reduce the effects of hydrostatic pressure and reduce flood-related damages to the foundation of the structure. Vulnerable utilities are raised or relocated above flood elevations. As floodwaters recede, any remaining water is pumped out of the structure.

4.4 Rational for Alternative 1 and Variations of Design

Alternative 1a was designed to protect the maximum amount of structures at the least possible feasible cost associated with the 1% AEP inundation from the Rockaway River and Den Brook. Alternative 1b would lower the cost of the Alternative 1a by eliminating the cost of four closure structures. Alternative 1c would give total protection to the study area for 2% AEP inundation. Alternative 1d will reduce the cost of Alternative 1c by eliminating the cost of four closure structures. Alternative 1e would give protection from floodwaters associated with the 4% AEP while Alternative 1f would reduce the cost to the project by the elimination of four closure structures.

4.5 Rational for Alternative 2 and Variations of Design (updates)

Because Alternative 1 and all of its variations were too expensive and above the threshold for the CAP 510 program, the PDT initiated Alternative 2. Because Alternative 2 was designed to reduce cost considerably, it was designed to protect against the 4% AEP storm event and it protected limited number of homes. Alternative 2a differs from Alternative 2b by elimination the Jersey barrier on Second Street and designing a floodwall at the back of all the properties along the Rockaway River commencing from Diamond Spring Road Bridge.

4.6 Rational for Alternative 3 Design

In a continuous effort order to reduce cost and cater to all the Sponsor's requirements, Alternative 3 was suggested by the Sponsor and the PDT utilize its effectiveness. It was designed to collect to the maximum extent possible, floodwaters associated with the 4% AEP, and transfer that water away from the study area. This alternative unfortunately was one of the costliest.

4.7 Rational for Alternative 4a-c Design

An iterative process was performed to refine the nonstructural plan and arrive at the selected plan for nonstructural measures. First, the 372 structures within the 1 percent AEP floodplain were grouped into clusters by neighborhood blocks, generally bounded by roads, as they shared similar flood characteristics within the study area. A matrix from the USACE National Nonstructural Committee (NNC) was utilized to develop proposed nonstructural measures to be applied to the structures. The Benefit-Cost Ratio (BCR) for each cluster was computed for various LOPs and the clusters with negative net benefits were dropped, which included 227 structures. The structures within the seven clusters that showed positive net benefits in the first iteration were further evaluated.

The costs and benefits for each cluster were refined in coordination with the NNC, and annualized costs and benefits of nonstructural measures were redeveloped for the remaining seven clusters. The clusters were then aggregated by various levels of protection: 10 percent AEP, 4 percent AEP, and 2 percent AEP, which produced the three iterations of Alternative 4 (a through c). Once overall BCRs were developed for the nonstructural alternatives, the structures in the seven clusters were optimized per USACE policy. The purpose of the optimization was to reasonably maximize the net benefits of a proposed Recommended Plan, which for this study was Alternative 4b.

5 References

1. AASHTO, 2011. *A Policy on Geometric Design of Highways and Streets*, 6th Edition, American Association of State Highway and Transportation Officials, 2011.

2. Choi, Ying-Kit. (2017). *Principles of Applied Civil Engineering Design, producing drawings, specifications, and cost estimates for heavy civil projects*. 2nd Edition. ASCE Press, Reston Virginia.

Exhibit 1 - V-101: Existing Condition Showing 1% AEP Inundation

Inundated area

Exhibit 2 - V-102: Existing Condition Showing 2% AEP Inundation

Inundated area

Exhibit 3 - V-103: Existing Condition Showing 4% AEP Inundation

Inundated area

Exhibit 4 - C-101: Proposed Condition, Alternative 1a-1b Showing 1% AEP Protection of Study Area

Exhibit 5 - C-102: Proposed Condition, Alternative 1c-1d Showing 2% AEP Protection of Study Area

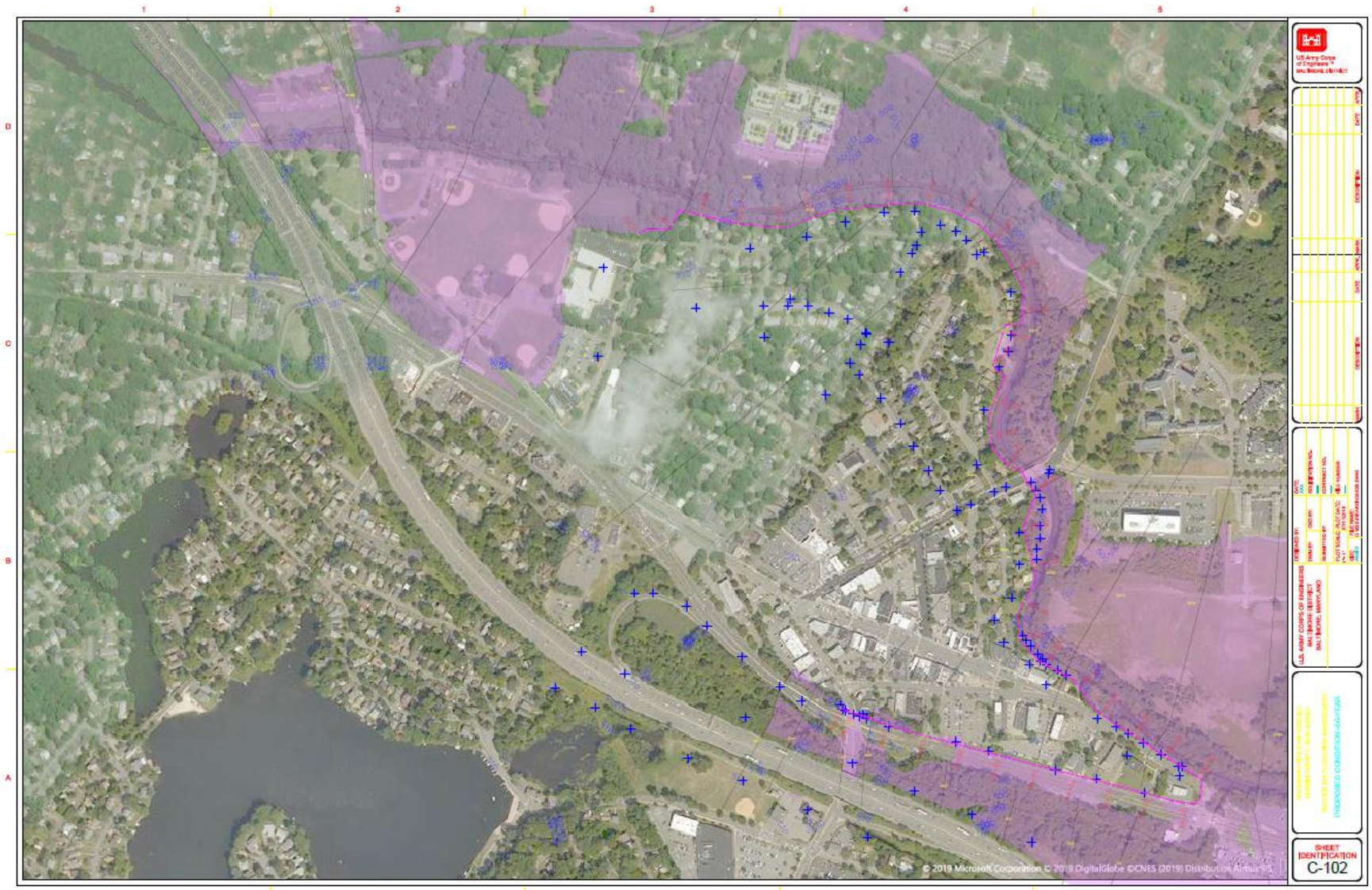
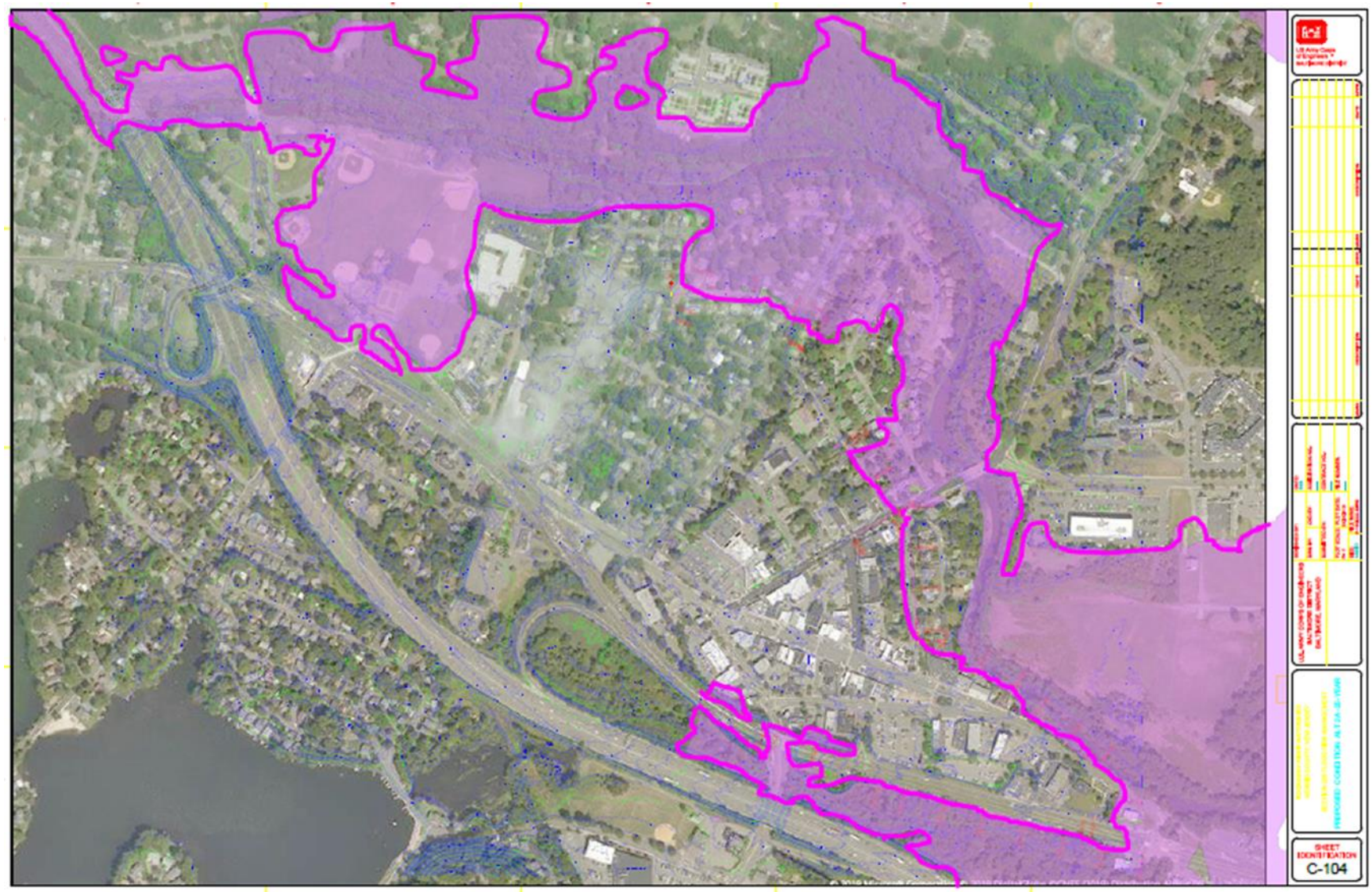


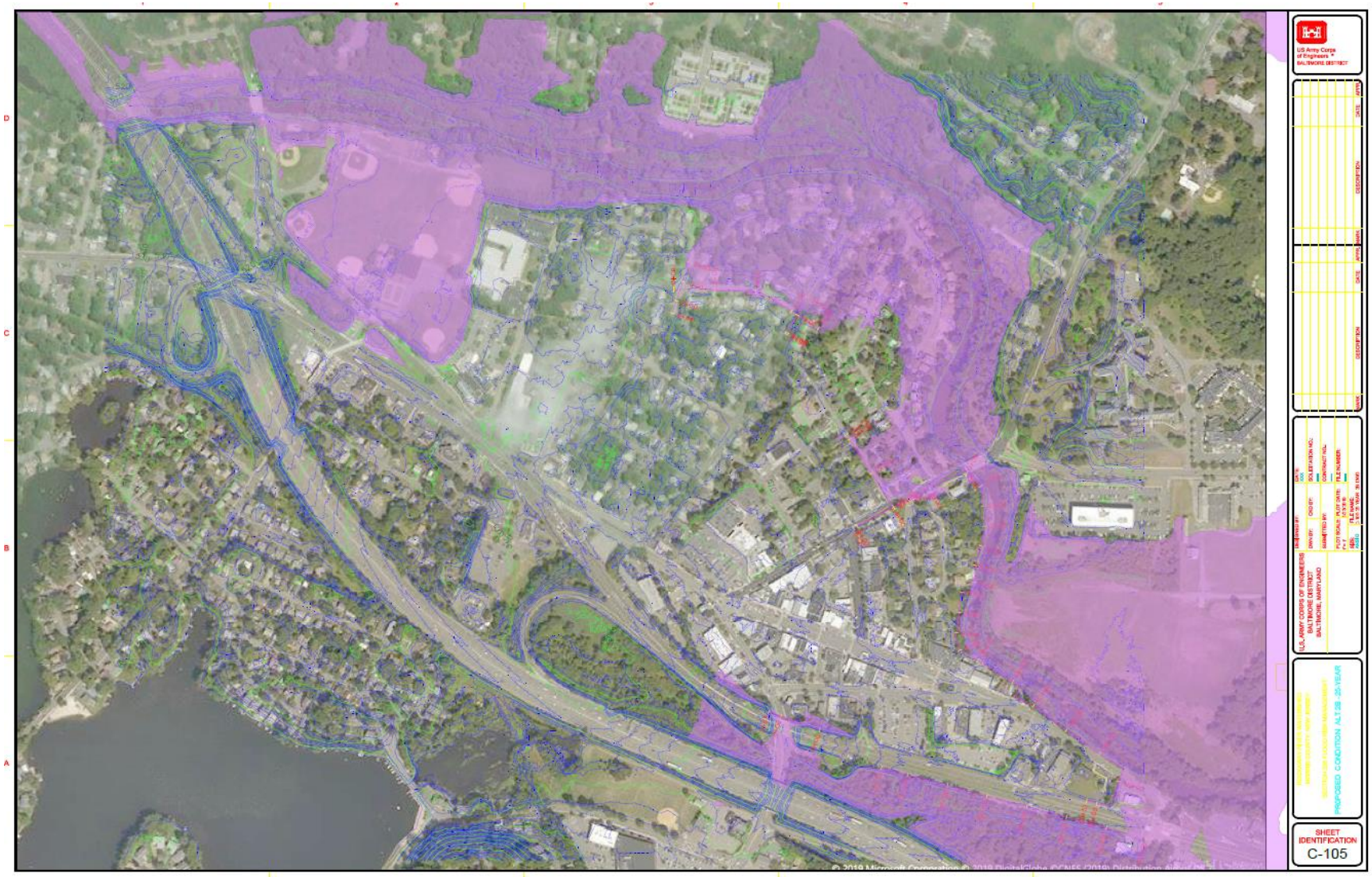
Exhibit 6 - C-103: Proposed Condition, Alternative 1e-1f Showing 4% AEP Protection of Study Area

Exhibit 7 - C-104: Proposed Condition, Alternative 2a Showing 4% AEP Protection of Study



Inundated area Alignment

Exhibit 8 - C-105: Proposed Condition, Alternative 2b Showing 4% AEP Protection of Study



Inundated areas Alignment Spot Elevation

Exhibit 9 - C-106 Proposed Condition Alternative 2b Sensitivity 4% AEP Protection of study Area

Exhibit 10 - C-107: Alternative 3 By-pass Culvert

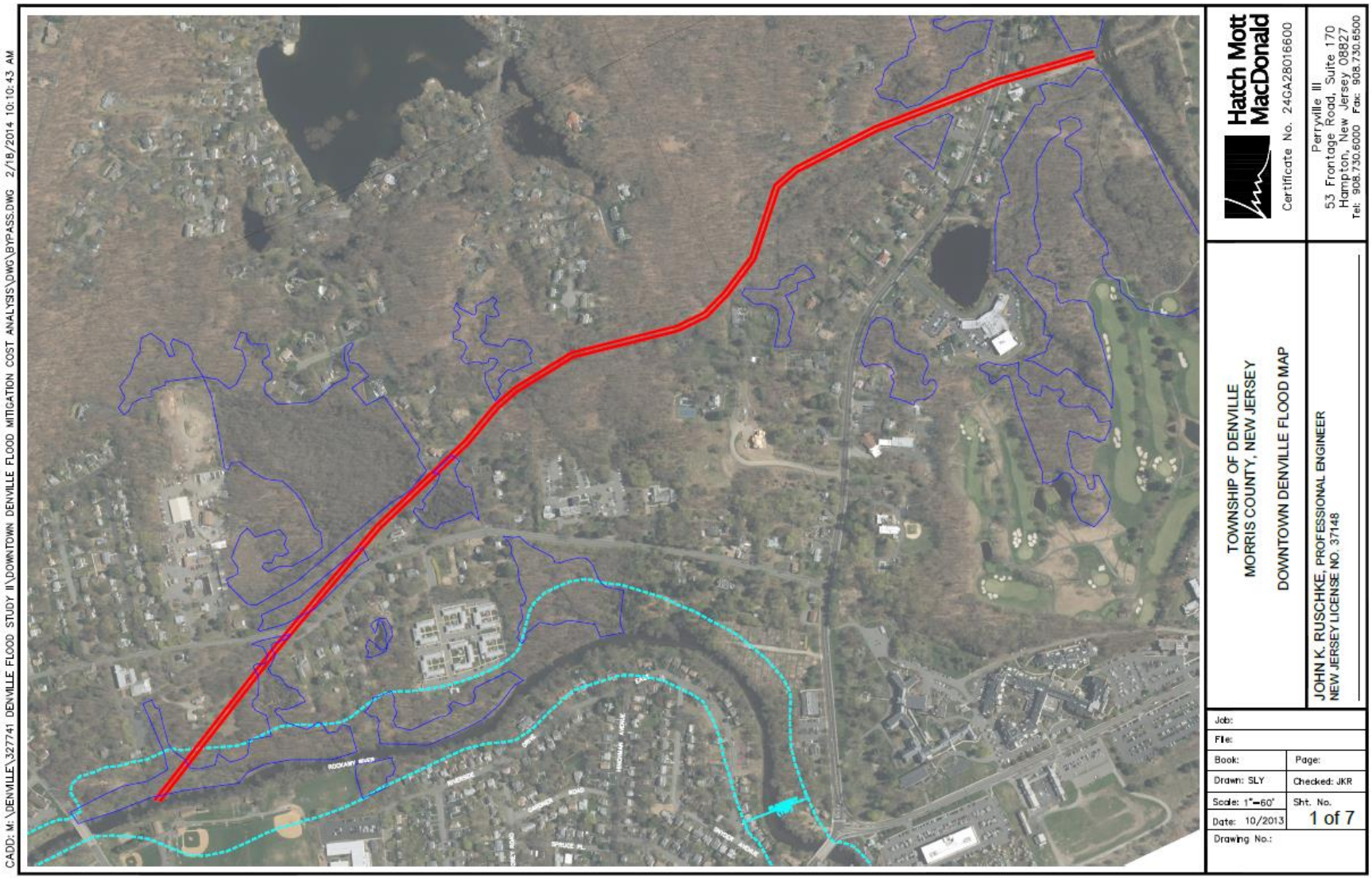


Exhibit 11 - C-201 Alternative 1 Profile 1% AEP

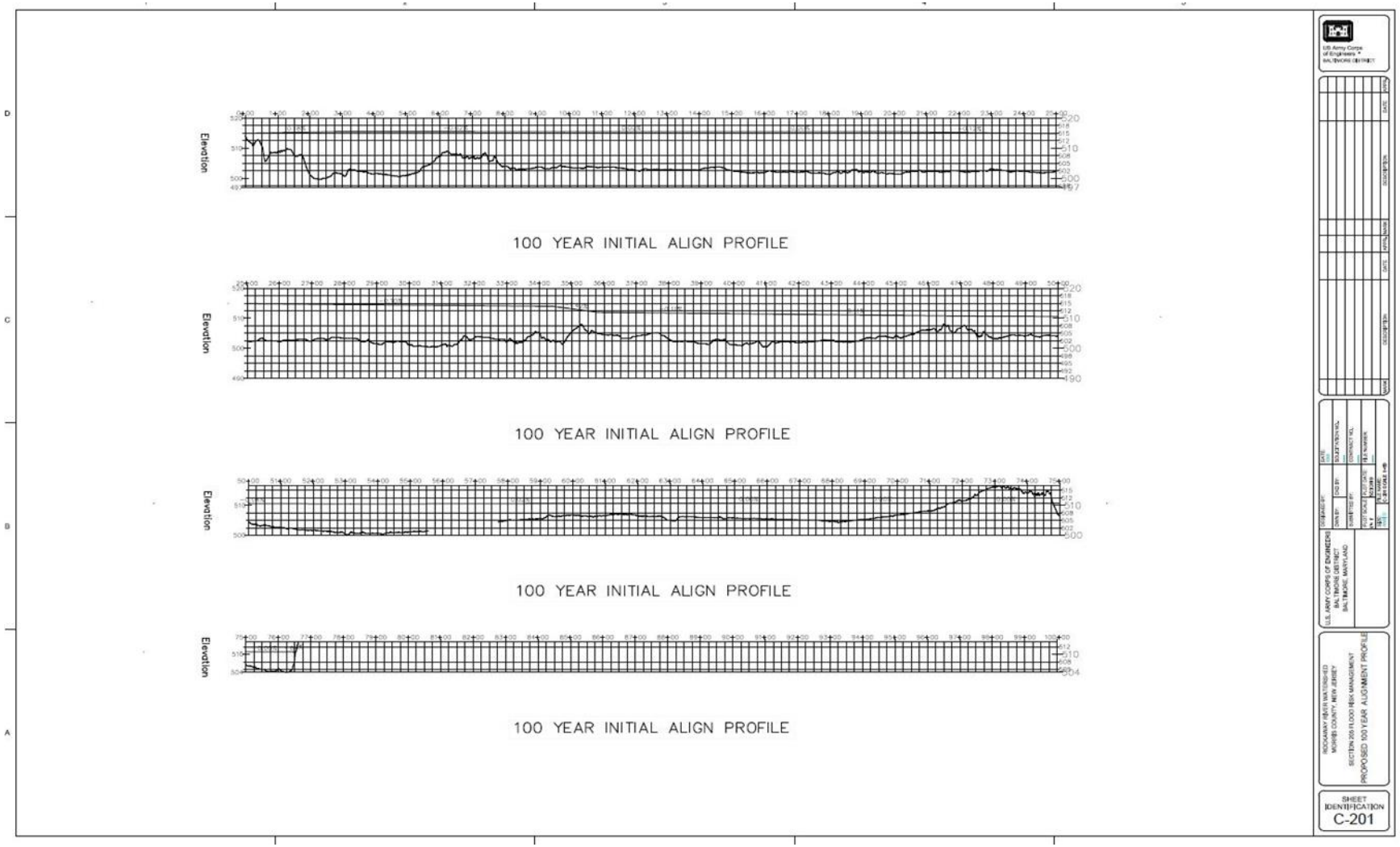


Exhibit 12 - C-202 Alternative 1 Profile 2% AEP

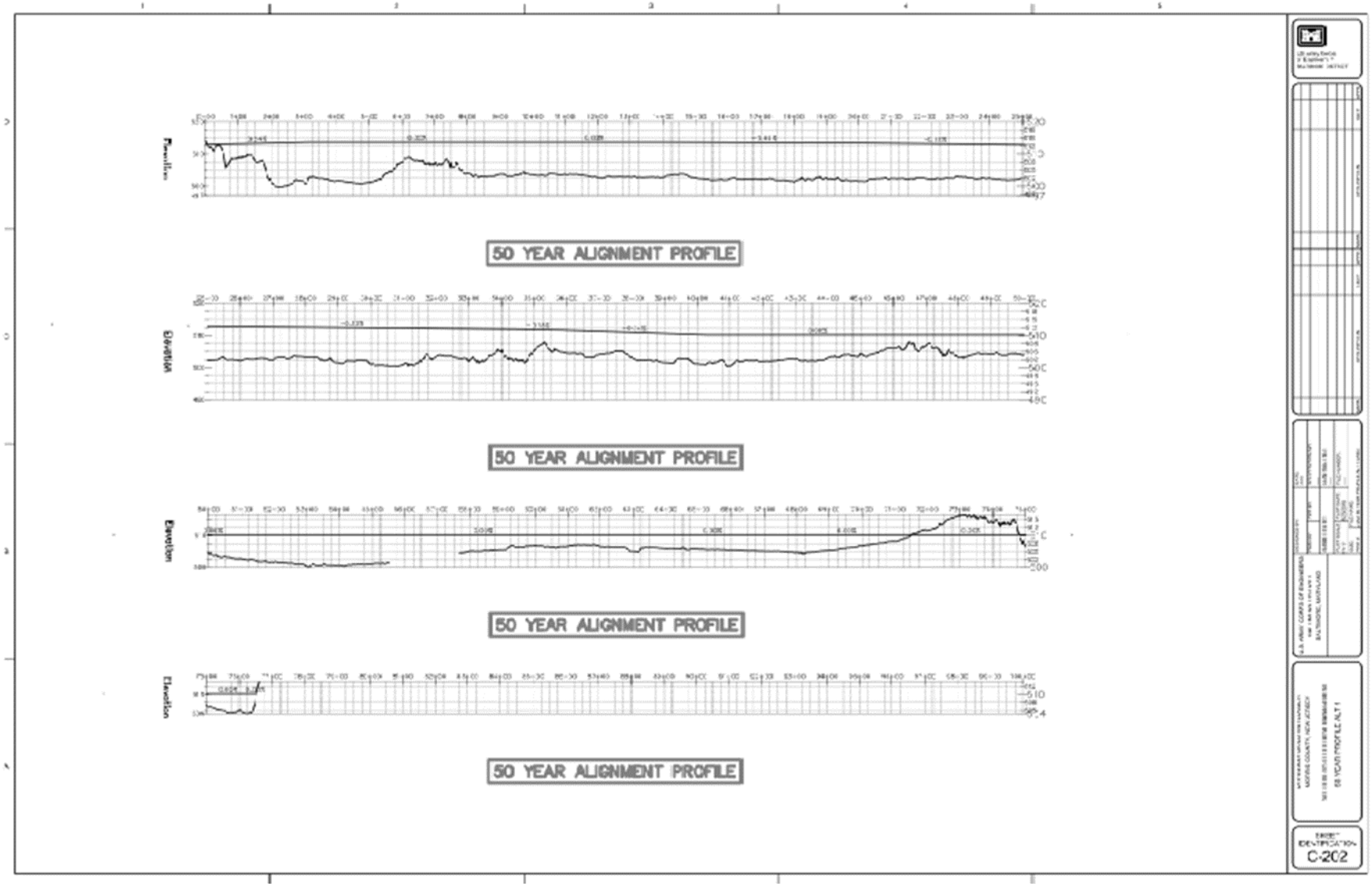


Exhibit 13 - C-203 Alternative 1 Profile -4% AEP

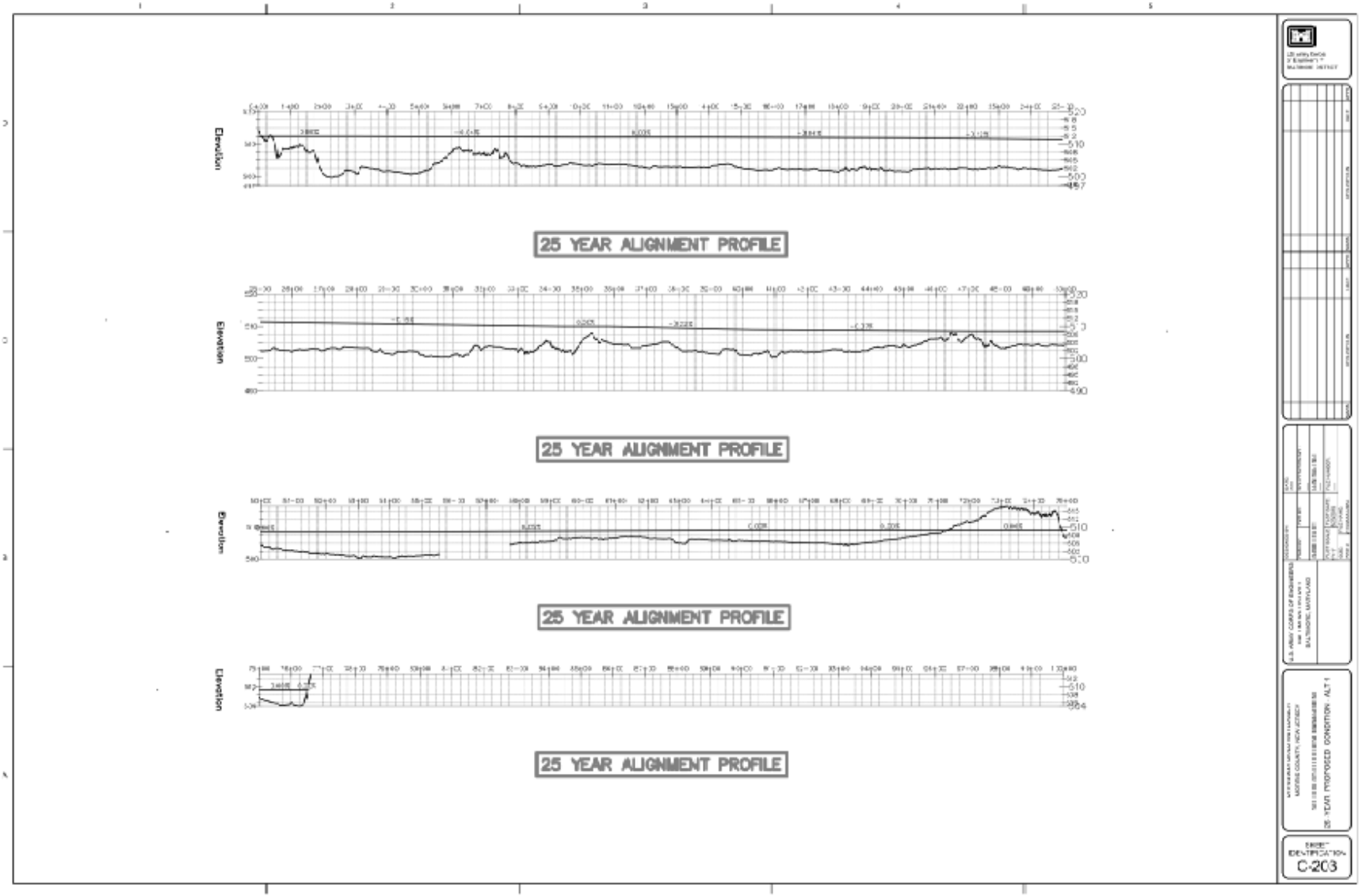


Exhibit 14 - C-204 Alternative 2 Profiles - Road Raising and Short floodwalls 4% AEP

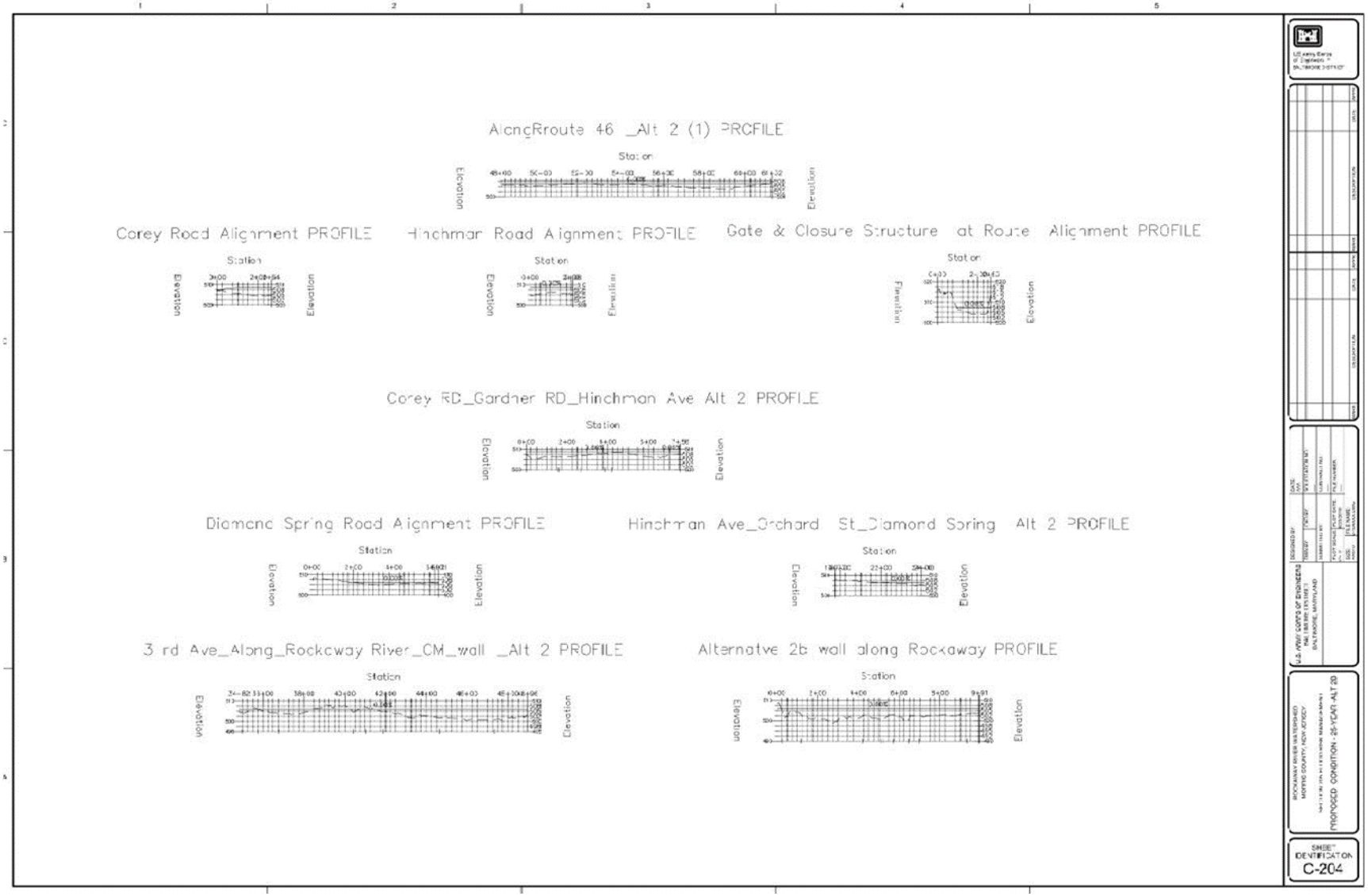


Exhibit 15 - C-205 Alternative 2B Snyder Rd Profile 4% AEP

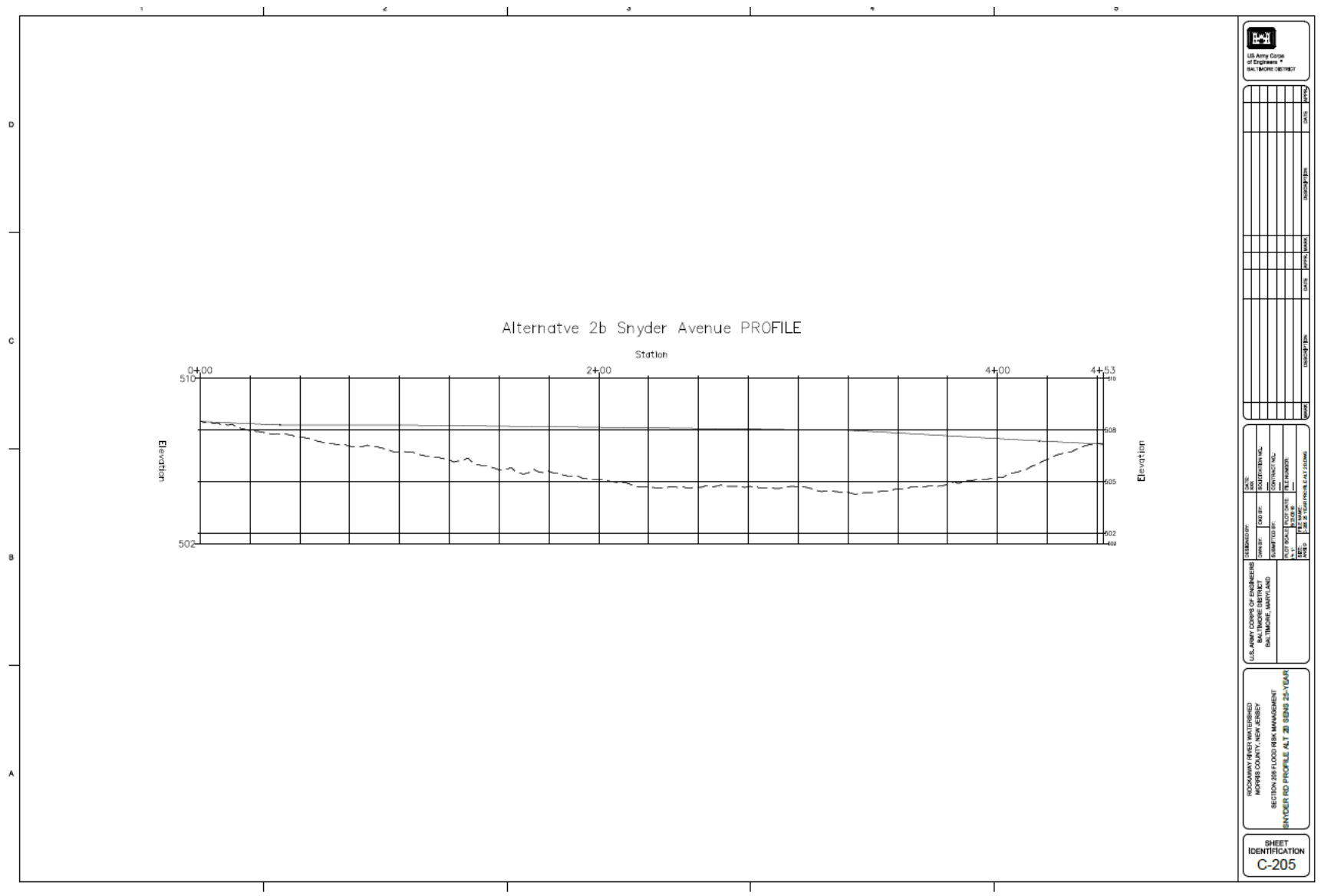


Exhibit 16 - SK-01: Typical Cross Sectional Detail Alternative 1a-1% AEP

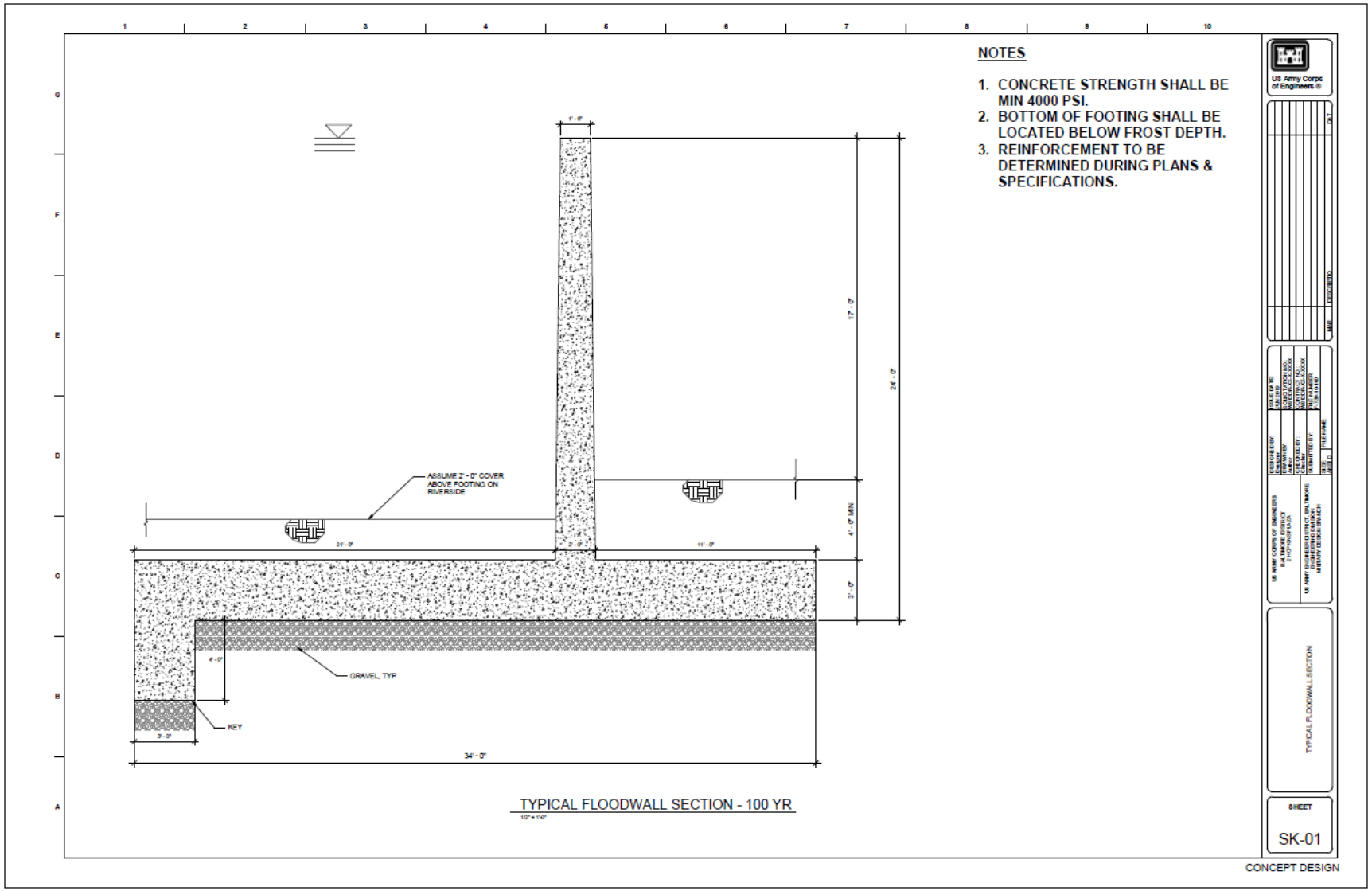


Exhibit 17-SK-02: Typical Cross Sectional Detail Alternative 1b-2% AEP

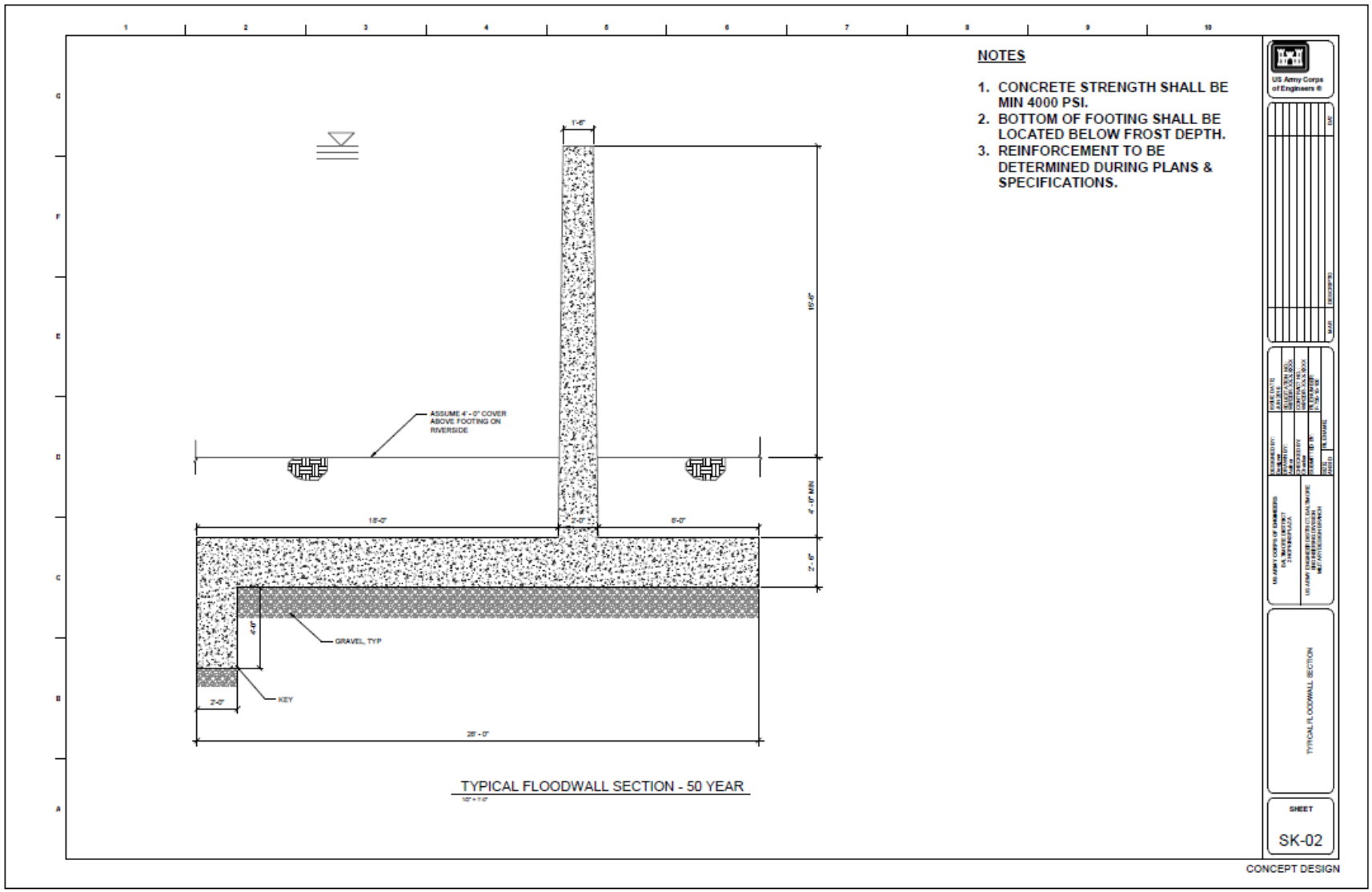


Exhibit 18-SK-03: Typical Cross Sectional Detail Alternative 1a 4% AEP

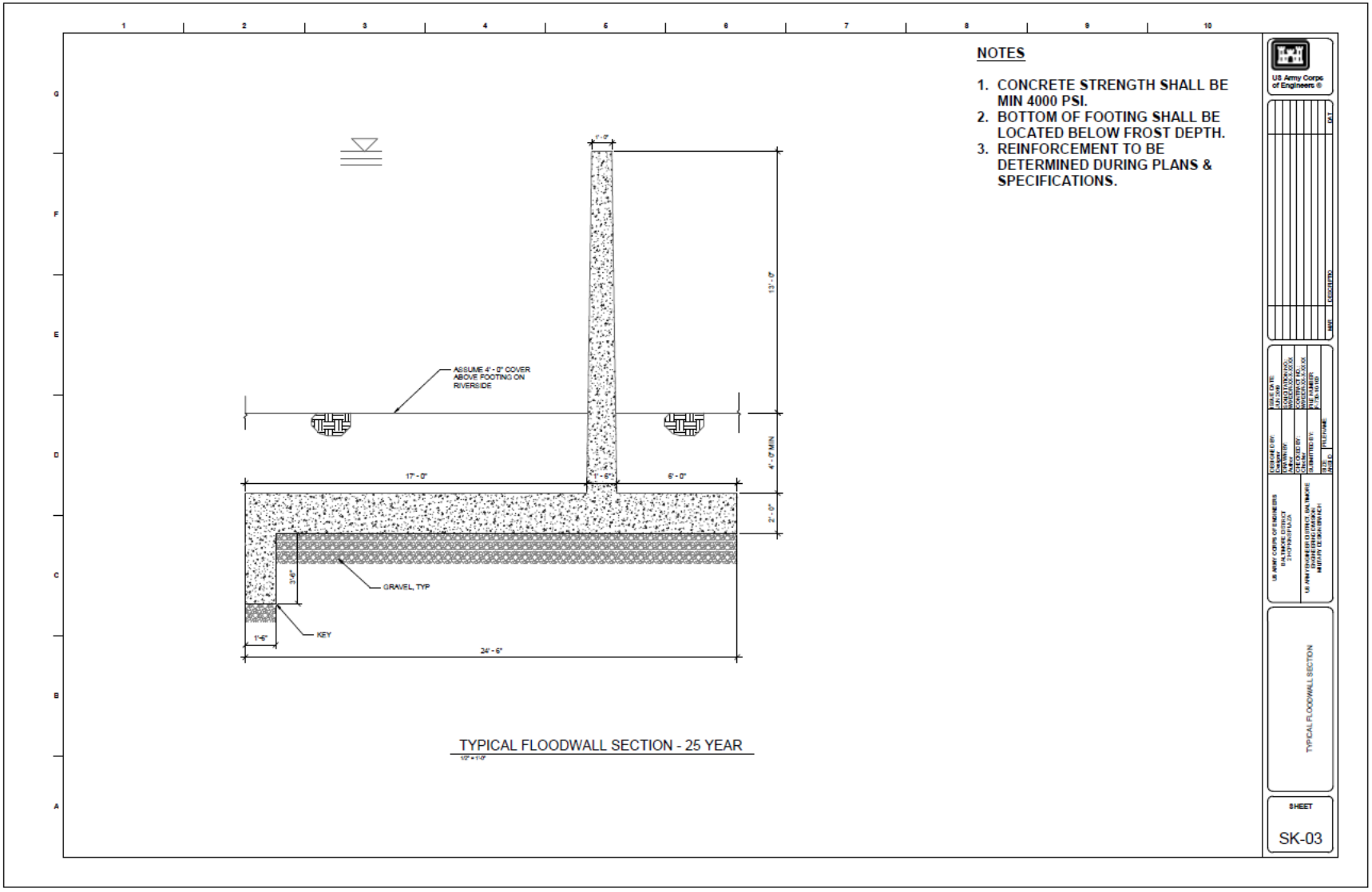


Exhibit 19-C-304: Typical Cross Sectional Detail Alternative 2a&b, 2b Sensitivity 4% AEP