Whitman, Requardt & Associates, LLP
Engineers · Architects · Environmental Planners Est. 1915

MEMORANDUM

Date: 7/27/2018; Rev. 8/21/2018, Rev. 1/25/2019

To: Monica Paylor, WRA
From: J. Blake Burroughs, WRA
Steve Mogilnicki, WRA (reviewer)
Subject: Rock Rippability & Excavation at I-95, Wilmington, DE

Work Order Number: 031987.006
Contract Number: T201407404

Project: Rehabilitation of I-95 from I-495 to North of Brandywine River Bridge

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Rock rippability is assessed along the I-95 alignment in the Wilmington, Delaware area. The project area spans between the I-95/I-495 Interchange in the South and the I-95/U.S. 202 Interchange in the North. I-95 between 4th Street and Delaware Avenue will be regraded to add clearance underneath existing bridges. Based upon Semi-Final plans developed in early 2018, I-95 between 4th Street and Delaware will be lowered approximately 2 feet. This analysis is based on available information without new on-site work.

Geologic Conditions

The site is located in the Piedmont Physiographic Province, which has deformed crystalline bedrock. The bedrock underlying the majority of the site is the Brandywine Blue Gneiss, according to the Bedrock Geologic Map of the Piedmont of Delaware and Adjacent Pennsylvania (2000) by W. S. Schenck and others, M. O. Plank, and L. Srogi. The Brandywine Blue Gneiss consists of medium- to coarse-grained granulites and gneisses composed of plagioclase, quartz, orthopyroxene, brown-green hornblende, magnetite, and ilmenite. The Gneiss contains thin, discontinuous fine-grained mafic layers.

The Brandywine Blue Gneiss originally formed in the Ordovician Period of earth history. When freshly broken, the rock is a bluish color. The Brandywine Blue Gneiss belongs to the Wilmington Complex, which forms the crystalline bedrock underlying much of the city of Wilmington.

Near the Northern extent of the alignment, at approximately Station 1470+00, the Rockford Park Formation underlies I-95. The Rockford Park Gneiss is a banded gneiss consisting of thin, fine- to medium-grained felsic layers of quartz and plagioclase and thin, fine-grained mafic layers of plagioclase, pyroxene and hornblende. The Rockford Park Gneiss is also part of the Wilmington Complex.

Rock Rippability Assessment

Rock rippability is typically assessed using rock outcrops, seismic velocity data, borings, and strength data from unconfined compressive strength tests (UCS) of rock samples. Seismic data is not available for this project.

Aerial images from Google Earth show bedrock is exposed on both sides of I-95 between 6th and 8th Streets. Access to the rock outcrops appears difficult because the Interstate is fenced off from the surrounding residential streets.

Borings drilled in 2017 by Walton Corporation were available for review, including ten borings drilled on the shoulder of I-95 between 4th Street and near Delaware Avenue as well as six borings at the proposed Ramp D which is approximately one-half mile southwest of 4th Street. Engineering & Testing Services, Inc. (ETS), performed UCS testing on thirteen samples of Brandywine Blue Gneiss from the reviewed borings. Table 1, attached to this memo, summarizes the results of the borings and UCS testing.

The reported UCS of the Brandywine Blue Gneiss ranges between 8,715 psi (60 MPa) and 59,740 psi (410 MPa) in thirteen tests. It would be difficult to impossible to rip Brandywine Blue Gneiss having UCS values in the reported range. Bell (*Engineering in Rock Masses*), relates rock hardness to excavation characteristics. For UCS values ranging between approximately 2,900 psi (20 MPa) and 10,000 psi (70 MPa), rock excavation would require "Extremely hard ripping or blasting". Rock exceeding 10,000 psi is not considered rippable.

At this time, UCS data for the Rockford Park Gneiss is not available for this project.

Data from test holes performed by Cardno using geoprobe and vacuum digging methods was available for review including 84 test holes drilled within the area of proposed lowering between 4th Street and Delaware Avenue on I-95. The provided data included the digging method, location, ground surface elevation and refusal depth for each test hole. Several test holes included comments stating the reason for refusal was due to existing utilities, reinforcement structures or foundation structures. 61 of the 84 test holes did not include a reason for refusal, refusing between 1 foot and 7 feet below existing grade. Seven of the test holes reached the target depth of 8 feet below surface without refusing.

Rock Excavation

Semi-Final plans were developed in 2018 by the project team including, Tylin International, Pennoni Associates Incorporated, RJM Engineering and WRA. The plans show proposed lowering depths of I-95 Northbound (NB) and I-95 Southbound (SB) between 4th Street and Delaware Avenue.

Table 2. Wilmington Viaduct Proposed Lowering

Location	Approximate Station Range	Proposed Lowering Depth NB I-95 (ft.)	Proposed Final Elevation NB I-95 (ft.)	Proposed Lowering Depth SB I-95 (ft.)	Proposed Final Elevation SB I-95 (ft.)
Between 4th and 5th Streets	1320+50 to 1323+50	2.2	70.6	2.0	70.8
Between 5th and 6th Streets	1323+50 to 1326+00	2.0	69.3	1.7	69.5
Between 6th and 7th Streets	1326+00 to 1329+00	1.9	69.2	1.8	69.3
Between 7th and 8th Streets	1329+00 to 1332+50	1.9	71.3	1.8	71.4
Between 8th and 9th Streets	1332+50 to 1337+50	1.9	74.4	1.8	74.5
Between 9th and 10th Streets	1337+50 to 1341+00	2.0	77.5	1.8	77.6
North of 10th Street	1341+00 to 1343+00	2.3	79.2	1.8	79.7

Based on the estimates in Table 2, the road will be lowered approximately 2 feet between 4th and Delaware Avenue. Visible rock outcrops between 6th Street and 9th Street strongly suggest that excavation in this area would encounter non-rippable bedrock below the existing road surface in much or all of this area.

Excavation Methods

Rock strength data from the collected cores of the Brandywine Blue Gneiss suggest that rock within the project limits is not rippable using common rock excavation methods as defined in Natural Resources Conservation Service (NRCS) Specifications for Construction Contracts. NRCS Construction Specification 21 defines common rock excavation as materials that can be excavated, transported and unloaded using wheel tractor-scrapers with push tractors and heavy ripping equipment, such as single tooth, machine mounted ripping attachments. However, rock excavation is feasible when conventional methods are supplemented with additional equipment such as rock splitters or hydraulic hammers.

Rock splitting involves drilling several holes within the rock to be excavated in a precise pattern into which the splitting mechanism is then placed. Generally, rock splitting operations utilize either a single splitting mechanism or a manifold that has three splitting mechanisms. The initial split of the rock will create a gap in the rock that is typically

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about 0.75-inches. After the initial split, “enlarging feathers” are added to the splitting mechanism that creates a larger gap within the rock that allows for larger, conventional excavation equipment to remove the rock. Mr. John Rogalo, a technical advisor with Elco International Inc., provided insight into the potential feasibility and rough production estimates if rock splitting were to be used on this project. Given the strength of the rock based on the collected cores, it is estimated that rock splitting will yield 15 to 20 cubic yards per day when using the manifold with 3 splitting mechanisms or 5 or less cubic yards per day when using the single splitter. This production rate is only for splitting operations and does not include excavation, drilling or other support activities. The memo from Mr. Rogalo is attached for reference. Mr. Rogalo states that rock splitters are being utilized on a similar project to this one. In later correspondence, Mr. Rogalo provided details on the project including production rates for rock excavation. The example project was excavation for a trench that was 60 feet long, 3 feet wide (at bottom) and required rock excavation depths varying between 3 feet and 3.5 feet. Although the exact location of the example project was not provided, the excavated rock was from the Lake Hopatcong Intrusive Suite in Northern New Jersey and consisted of Granite, Syenite and Gneiss. On average, the production rate, including drilling, splitting and excavation ranged between 7.5 and 12.5 cubic yards per day. This rate was for a 1-man operation, using three C12 rock splitters with enlarging feathers and a bobcat 337 for excavation.

Another supplemental method is hydraulic hammering involves machine mounted hammer attachments that can employ a variety of chipping tools to break apart the rock to a size that can be removed and transported off-site using heavy machinery. Indeco, a hydraulic hammer manufacturer, manufactures a variety of hydraulic hammers that vary from 200 ft/lbs of force per blow to 25,000 ft/lbs per blow. Indeco produced a chart which correlates the rock breaking production of the hammers they manufacture with the compressive strength of rock for various construction applications. The chart, which is attached to this memo, shows production rates for rock up to compressive strengths of 43,500 psi (300 MPa).

Other rock excavation methods that may be considered include hydraulic cutter heads or diamond rock saws.

Conclusions

Several rock cores of Brandywine Blue Gneiss were obtained from 2017 borings within the limits of the proposed road lowering along the I-95 corridor in Wilmington, Delaware. Reported Unconfined compressive strength values of the cored rock ranged between 8,715 psi (60 MPa) and 59,740 psi (410 MPa). Borings which encountered rock drilled on I-95 between 4th Street and Delaware Avenue had refusal depths ranging between 3.5 feet and 18 feet below surface. Although boring results suggest that rock will not be encountered within the limits of the proposed road lowering, rock outcrops on either side of I-95 suggest that rock will be encountered near the ground surface. Geoprobe test holes performed within the road lowering limits resulted in geoprobe refusals varying between 1 foot and 7 feet below surface, however test hole method information was limited. WRA was not present during the soil boring nor geoprobe investigations.

If rock removal is needed, common excavation machinery is incapable of excavating rock at the upper end of reported compressive strength values. Excavating the rock using specialty equipment in conjunction with common machinery is feasible. Specialty equipment may include rock splitters, hydraulic hammers, hydraulic cutter heads or rock saws.

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J. Blake Burroughs

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References

1. Plank, M. O., Schenck, W.S., and Srogi, LeeAnn, 2000, Bedrock geology of the Piedmont of Delaware and adjacent Pennsylvania: Delaware Geological Survey, Report of Investigations No. 59, scale 1:24,000

2. Bell, F. G. Engineering in Rock Masses. Butterworth-Heinemann, 1992., pg. 416

3. National Engineering Handbook Part 642 Specifications for Construction Contracts, Natural Resources Conservation Service, 2001, rev. 2009, Chapter 2, Section 21, Page 1

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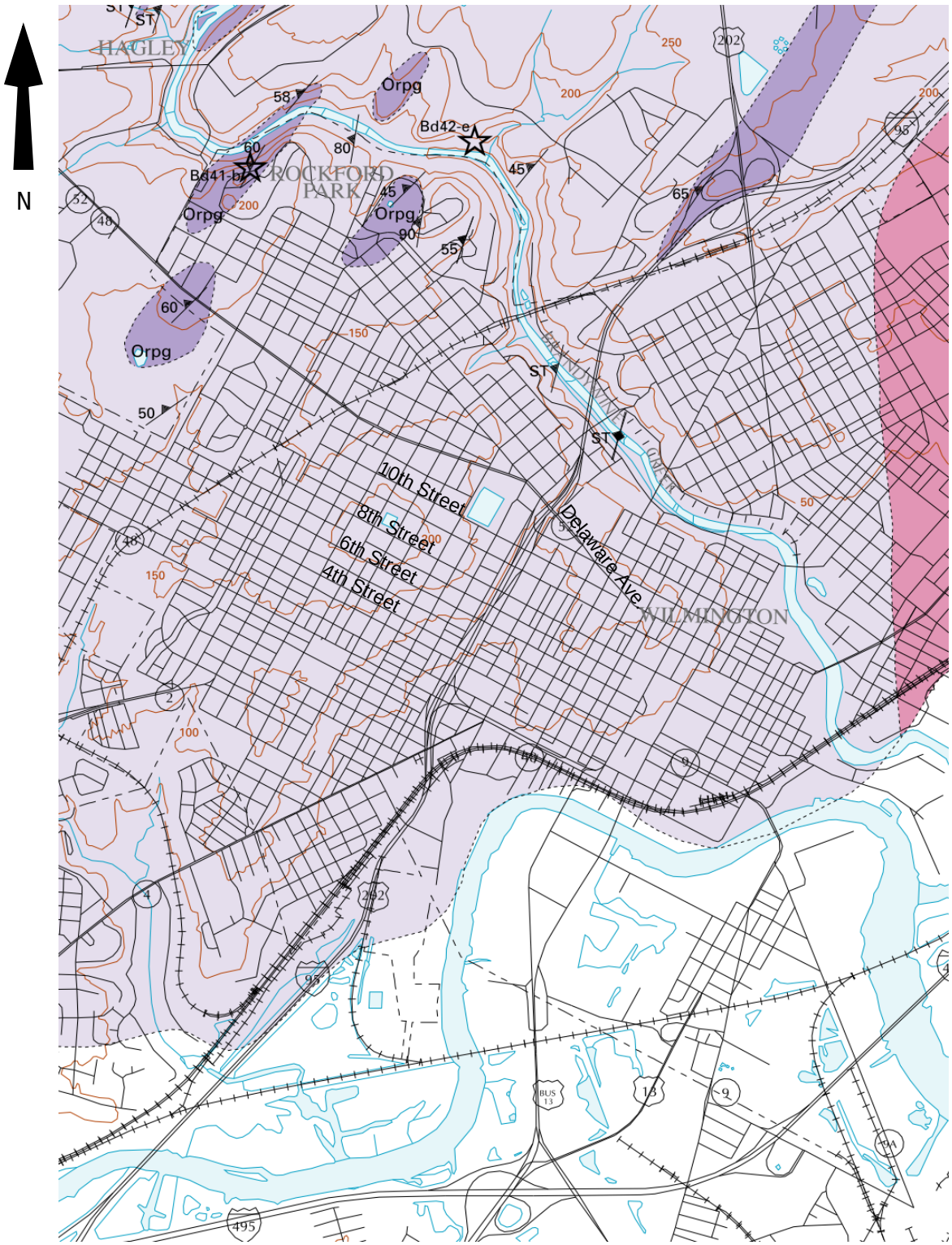


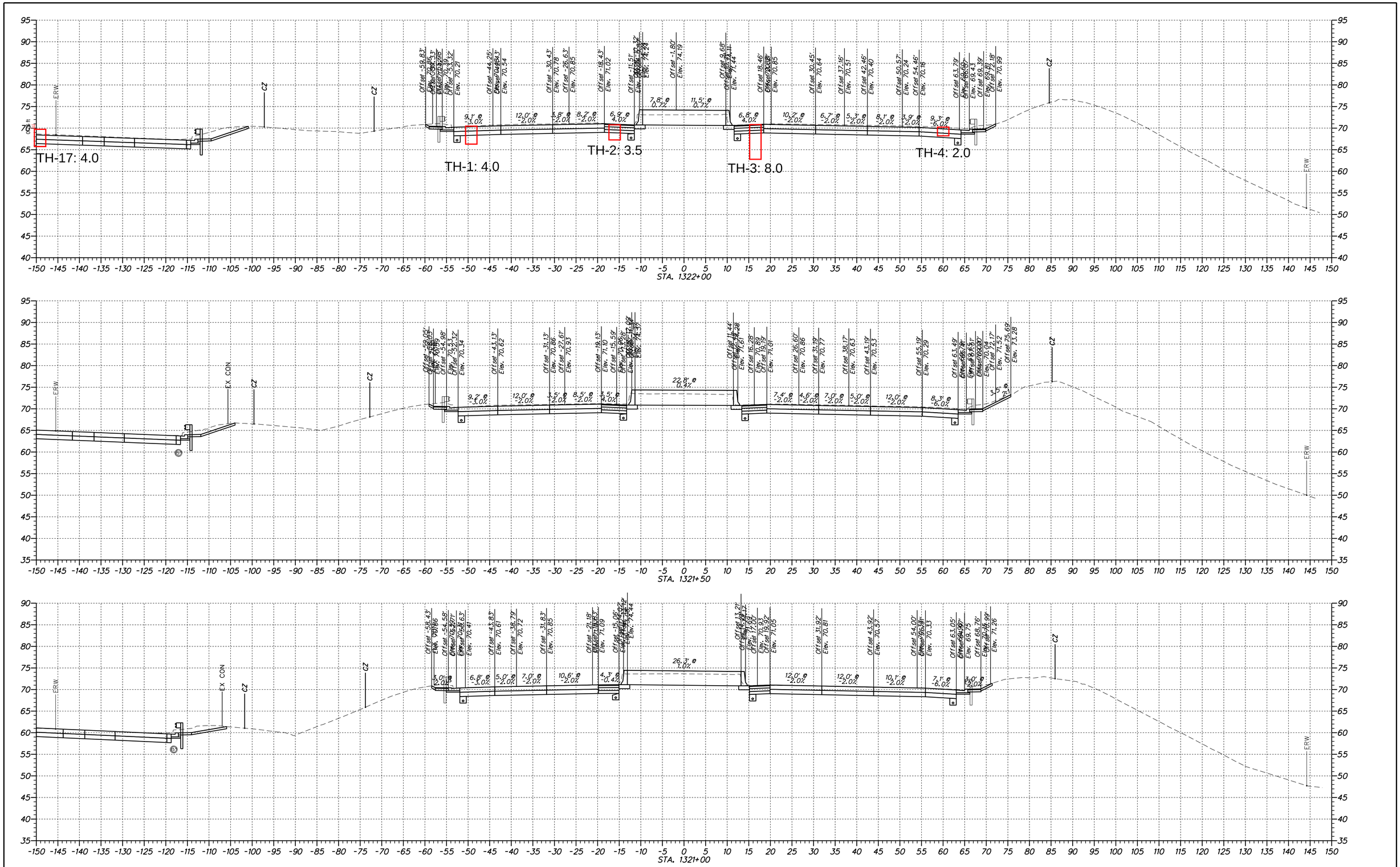
WHITMAN, REQUARDT AND ASSOCIATES, LLP *-Engineers-* 801 S. CAROLINE STREET BALTIMORE, MARYLAND 21231	**GEOLOGIC SITE MAP** **WILMINGTON VIADUCT** REFERENCE: Schenck, W.S., Plank, M.O., Srogi L., (2000). *Bedrock Geologic Map of the Piedmont of Delaware and Adjacent Pennsylvania*	DATE August, 2018 SCALE N.T.S.

MEMORANDUM

Table 1: Summary of Data from Existing Borings

Boring Name	Approximate Location	Approximate Land Surface Elevation (ft.)	Depth to Rock (ft.)	Top of Rock Elevation (ft.)	Length of Rock Cored (ft.)	Core Recovery Range (%)	RQD Range (%)	Depth of UCS Tested Sample (ft.)	UCS (psi)	UCS (MPa)
WB-5	I-95 North at 5th Street	71.5	18.0*	53.5*	10.0	30 - 100	8 - 100	22.0 – 23.0	19,684	135.7
WB-6	N. Jackson Street at 5th Street	73.5	13.0	60.5	10.0	88	60	NA	NA	NA
WB-7	I-95 North, near Delaware Ave.	90.5	14.5	76.0	10.0	75 – 100	17 - 85	17.5 – 18.0	8,715	60.1
WB-9	I-95 North at 4th Street	70.0	NA	NA	0.0	NA	NA	NA	NA	NA
WB-10	I-95 North at 5th Street	69.0	3.5	65.5	10.0	100	43 - 95	5.5 – 6.5	26,232	180.9
WB-11	I-95 South at 7th Street	70.0	11.0	59.0	10.0	80 – 100	65 - 100	16.0 – 18.5	18,538	127.8
WB-12	I-95 North at 9th Street	75.0	5.0	70.0	10.0	100	52 - 100	9.0 – 10.0	29,603	204.1
WB-13	I-95 South at 9th Street	76.5	13.5	63.0	10.0	100	73 – 100	21.5 – 22.5	26,888	185.4
WB-17	N. Adams Street at 9th Street	96.0	39.0*	57.0*	5.0	50	23	43.0 – 43.5	23,940	165.1
WB-18	N. Adams Street at 10th Street	94.5	40.0*	54.5*	40.0	0 – 33	0	NA	NA	NA
R-2	Ramp D	37.8	45.5	-7.7	10.0	33 – 95	0 - 50	45.5 – 50.5	35,536	245.0
R-3	Ramp D	38.5	39.5	-1.0	10.0	70	30 - 35	39.0 – 44.0	59,740	411.9
R-5	Ramp D	38.8	42.0	-3.2	10.0	72 – 77	38 - 53	47.0 – 52.0	25,346	174.7
R-6	Ramp D	44.0	37.1	6.9	10.0	98	86 - 95	37.0 – 42.0	15,848	109.3
R-9	Ramp D	28.2	42.0	-13.8	10.0	98 – 100	67 - 100	42.0 – 47.0	22,396	154.4
R-10	Ramp D	26.0	22.5	3.5	10.0	73 – 100	73	22.0 – 27.0	14,467	99.7

Note: * Driller boring log indicates boulder was encountered. Listed depth and elevations represent top of bedrock based on review of boring logs.



DELAWARE
DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

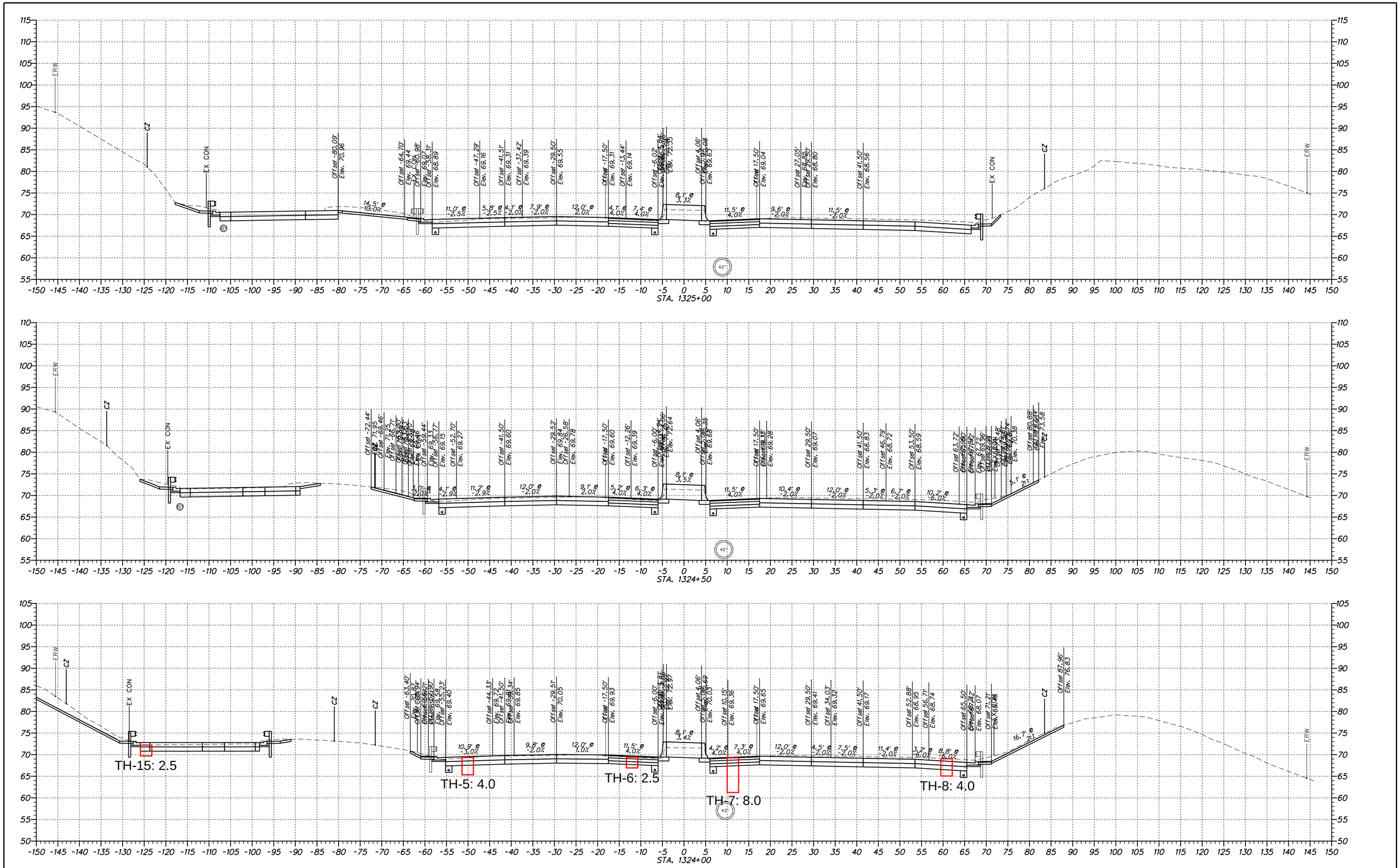
SCALE
0 10 20 30
FEET

REHABILITATION OF I-95
FROM I-495 TO NORTH OF
BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	
T201407404	DESIGNED BY:	JAD
COUNTY	CHECKED BY:	BRT
NEW CASTLE		

CROSS SECTIONS
STA. 1321+00 TO STA. 1322+00

SHEET NO.
37
TOTAL SHTS.
161



DELAWARE DEPARTMENT OF TRANSPORTATION	ADDENDUMS / REVISIONS	SCALE 0 10 20 30 FEET	**REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE**	CONTRACT T201407404 / COUNTY NEW CASTLE / BRIDGE NO. / DESIGNED BY: JAD / CHECKED BY: BRT	**CROSS SECTIONS** STA. 1324+00 TO STA. 1325+00

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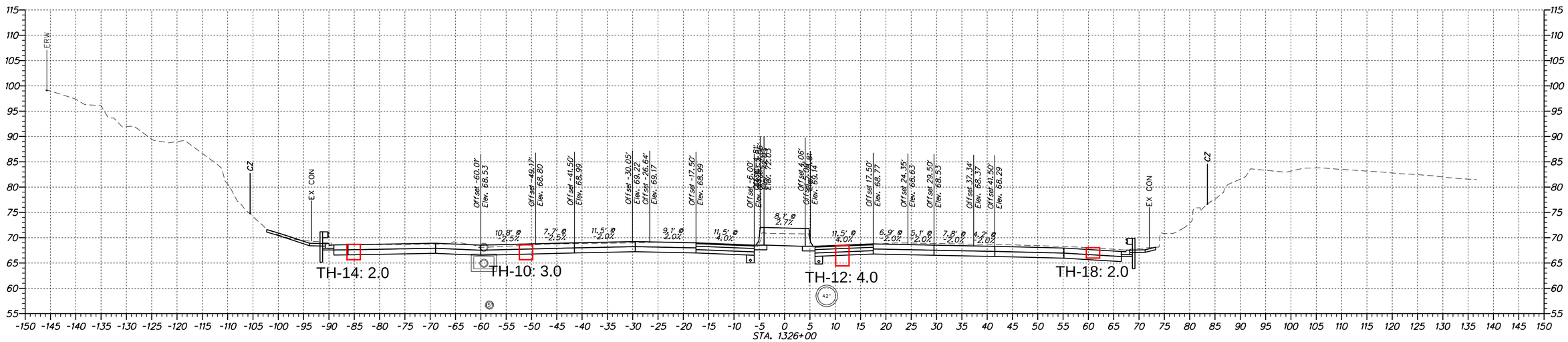
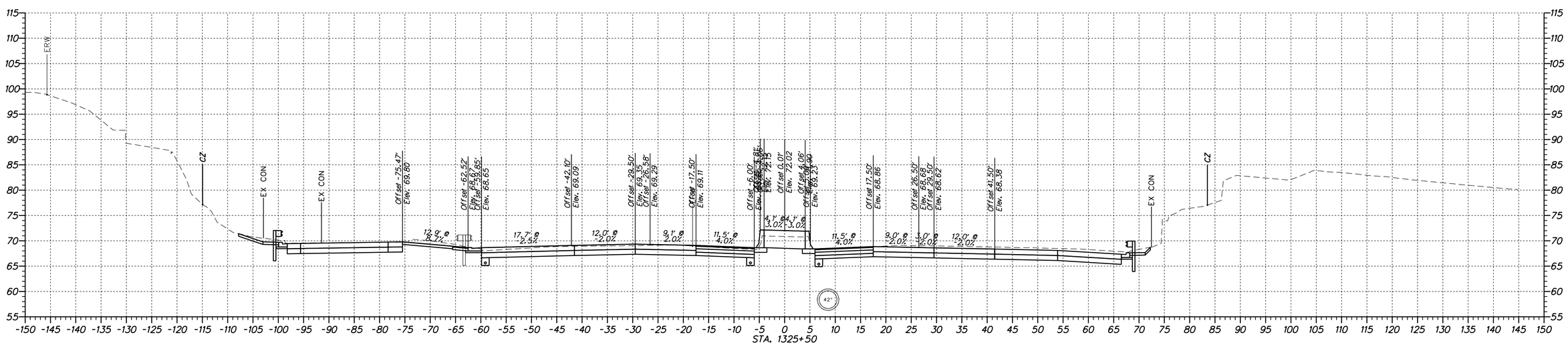
TOTAL SHTS. 161





DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

SCALE 0 10 20 30 FEET

REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

CROSS SECTIONS
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TOTAL SHTS.
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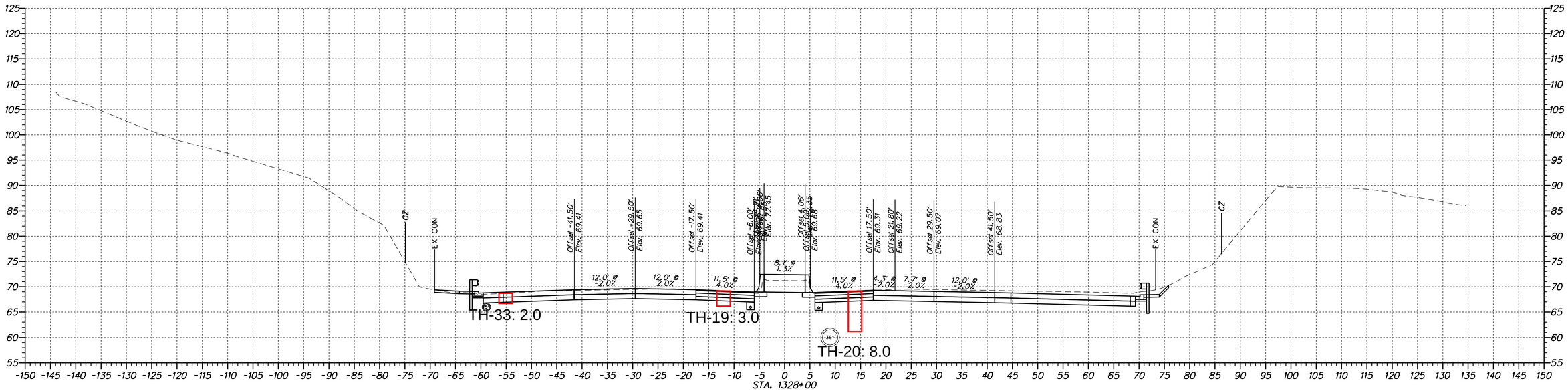

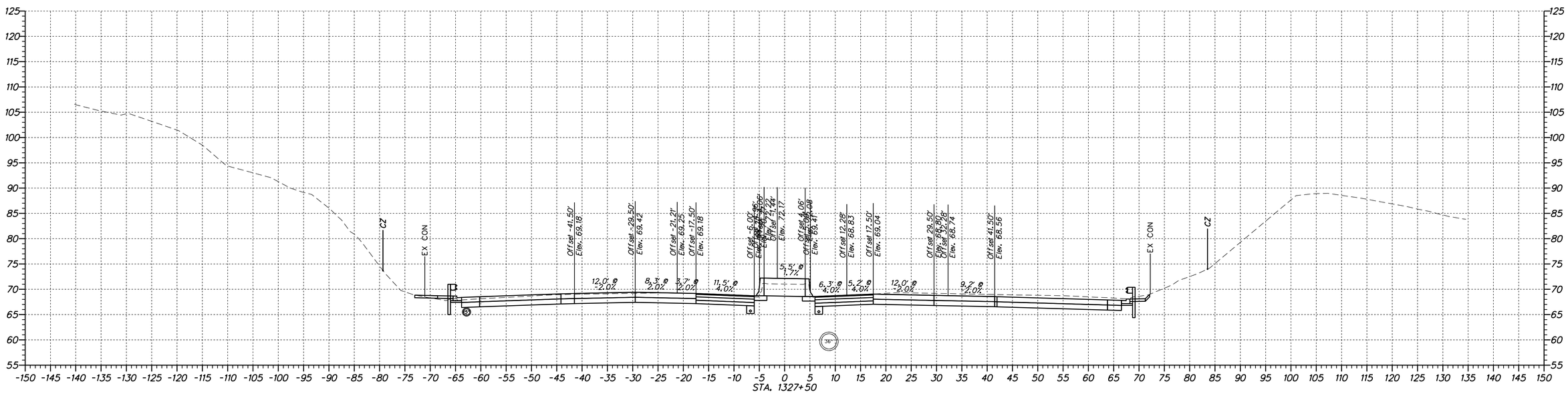

DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS	

SCALE
0 10 20 30
FEET

REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

CROSS SECTIONS
STA. 1327+50 TO STA. 1328+00

SHEET NO.
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TOTAL SHTS.
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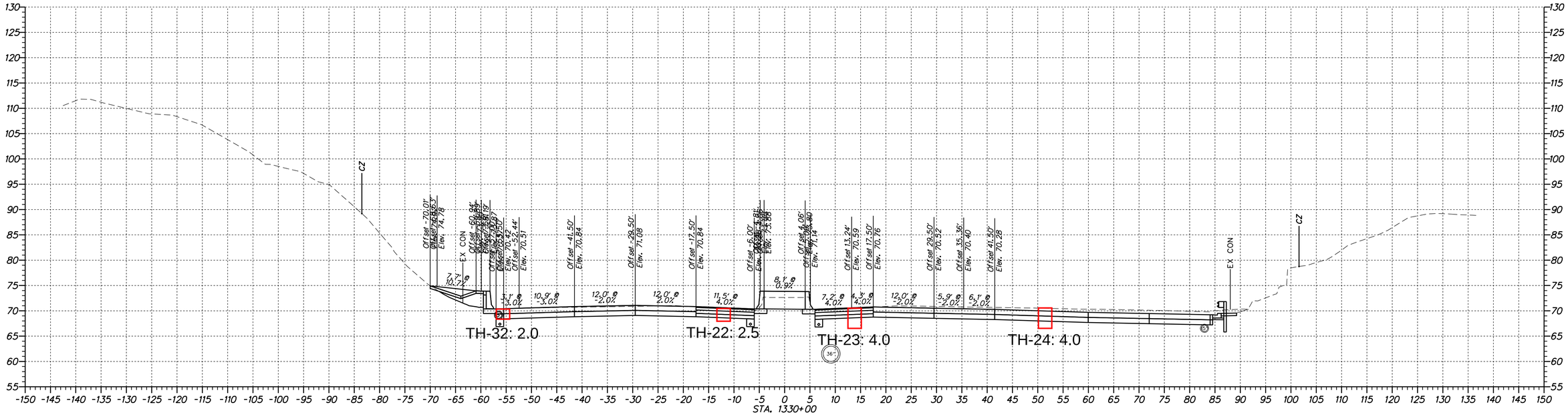

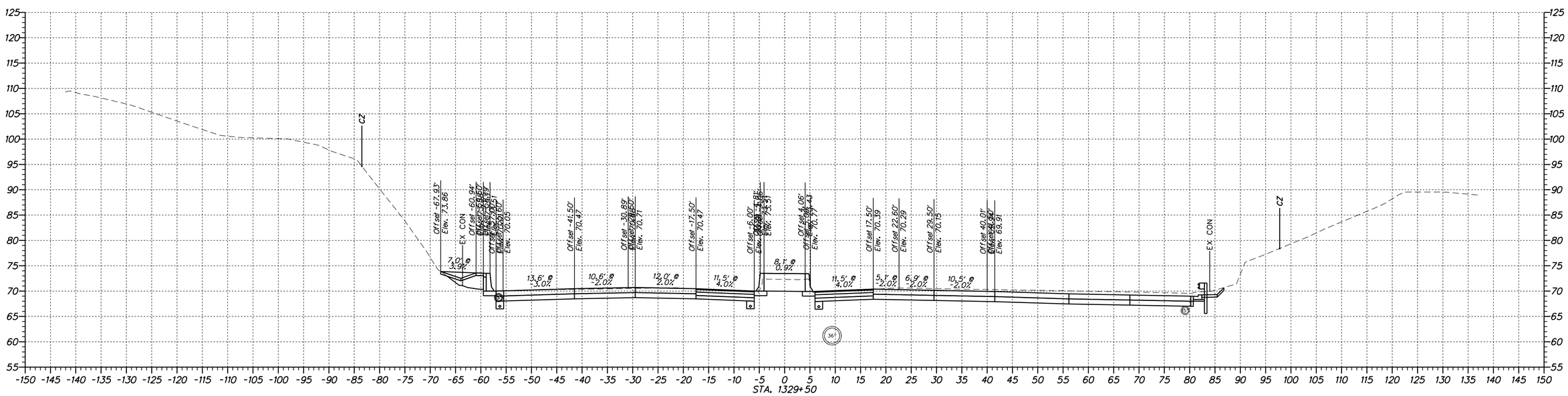

DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS	

SCALE
0 10 20 30
FEET

REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

CROSS SECTIONS
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TOTAL SHTS.
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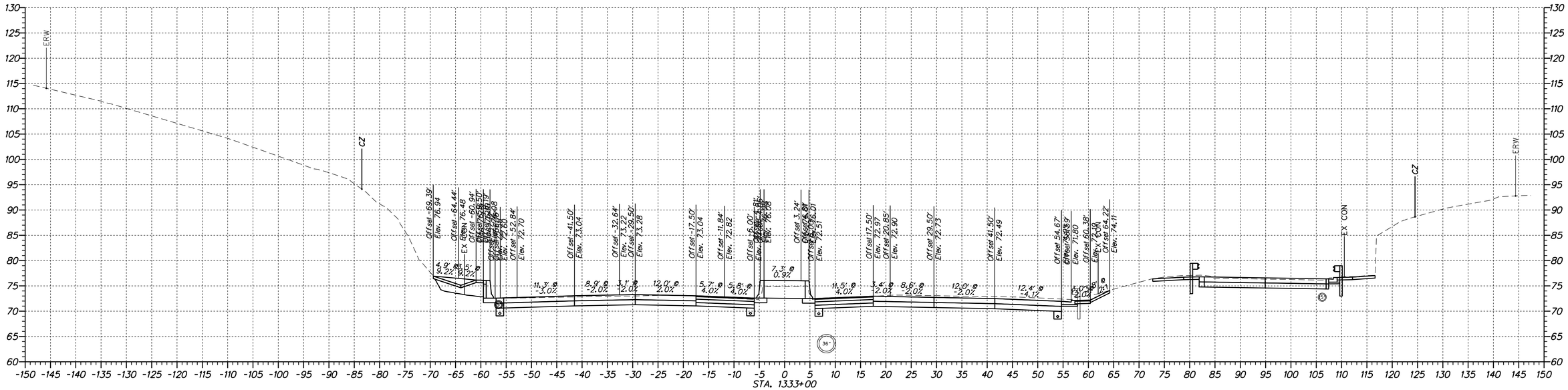

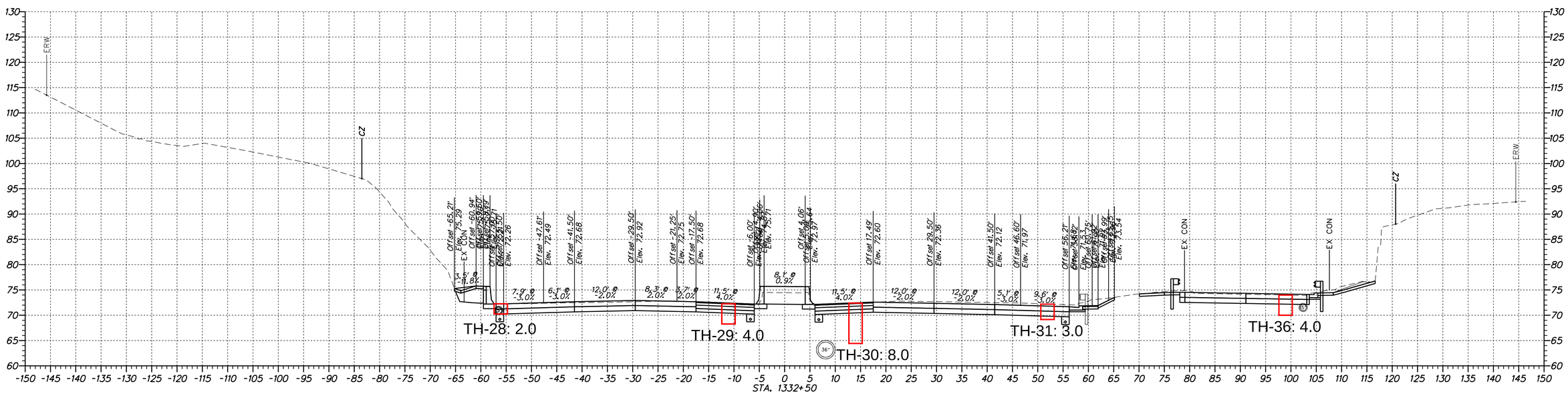

DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

SCALE 0 10 20 30 FEET

REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.
T201407404	DESIGNED BY: JAD
COUNTY	
NEW CASTLE	CHECKED BY: BRT

CROSS SECTIONS
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TOTAL SHTS.
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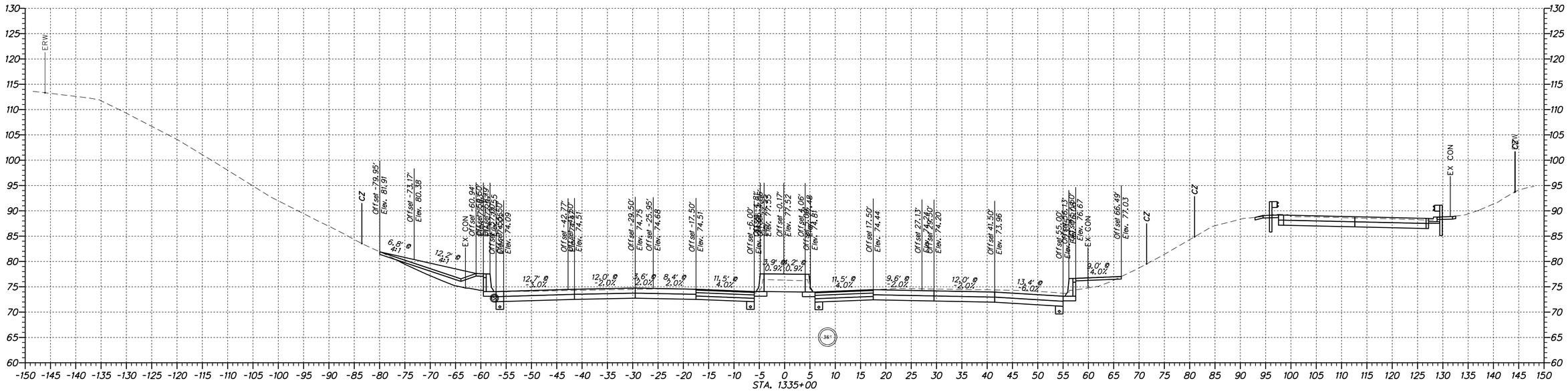

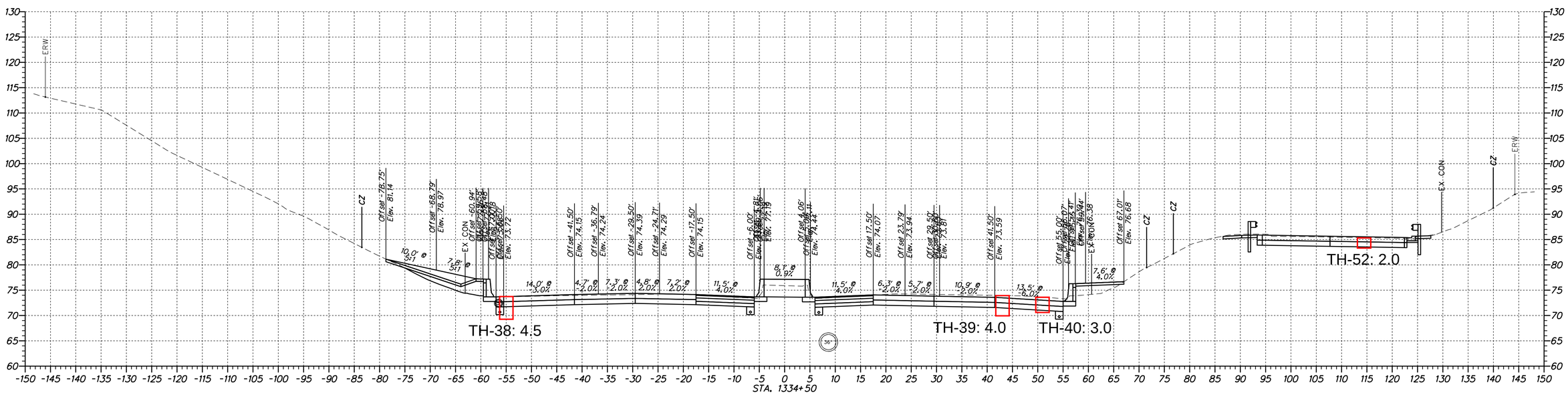

DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

SCALE 0 10 20 30 FEET

REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

CROSS SECTIONS
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TOTAL SHTS.
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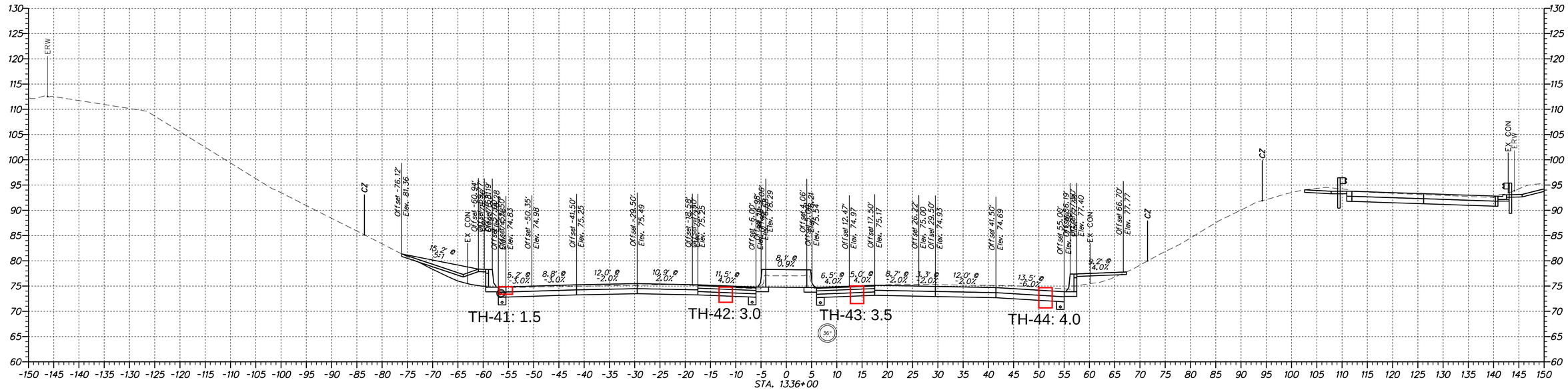

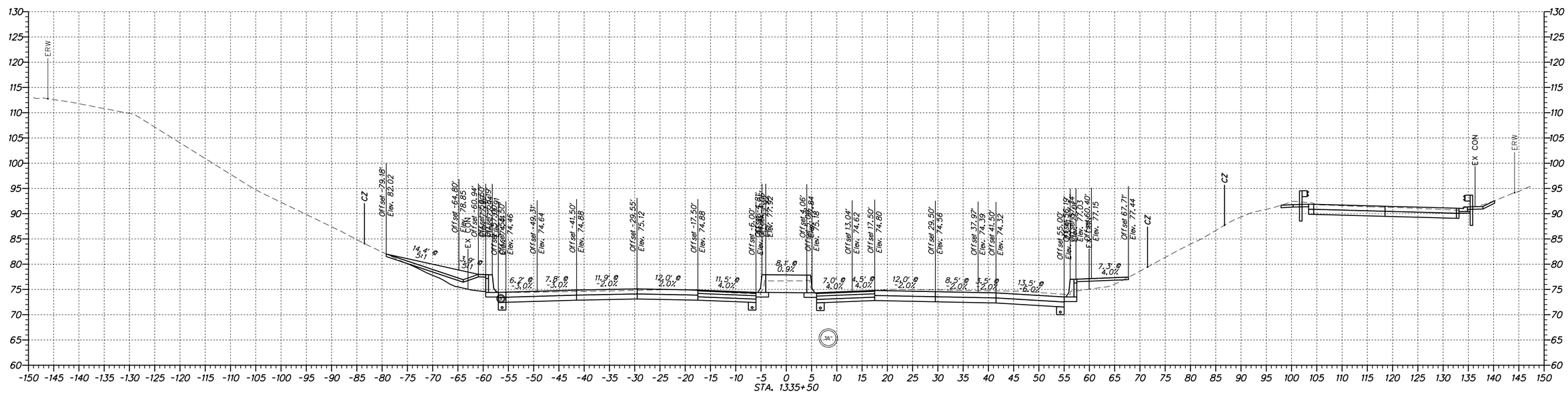

DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

SCALE 0 10 20 30 FEET

REHABILITATION OF I-95 FROM I-495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

CROSS SECTIONS
STA. 1335+50 TO STA. 1336+00

SHEET NO.
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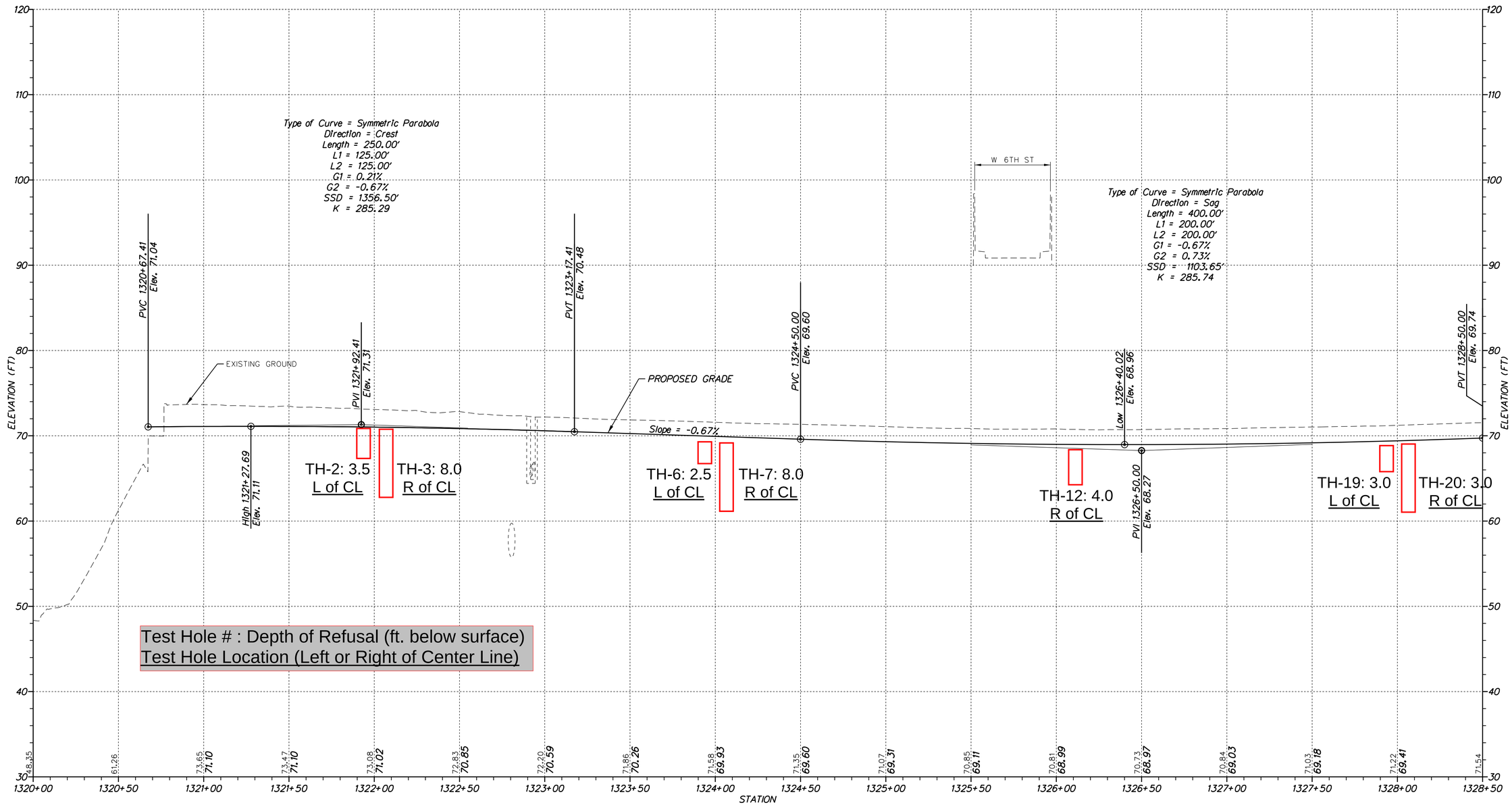
TOTAL SHTS.
161



I–95 SOUTHBOUND

PROJECT CENTER LINE
Developed 11/2018

PF–07

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

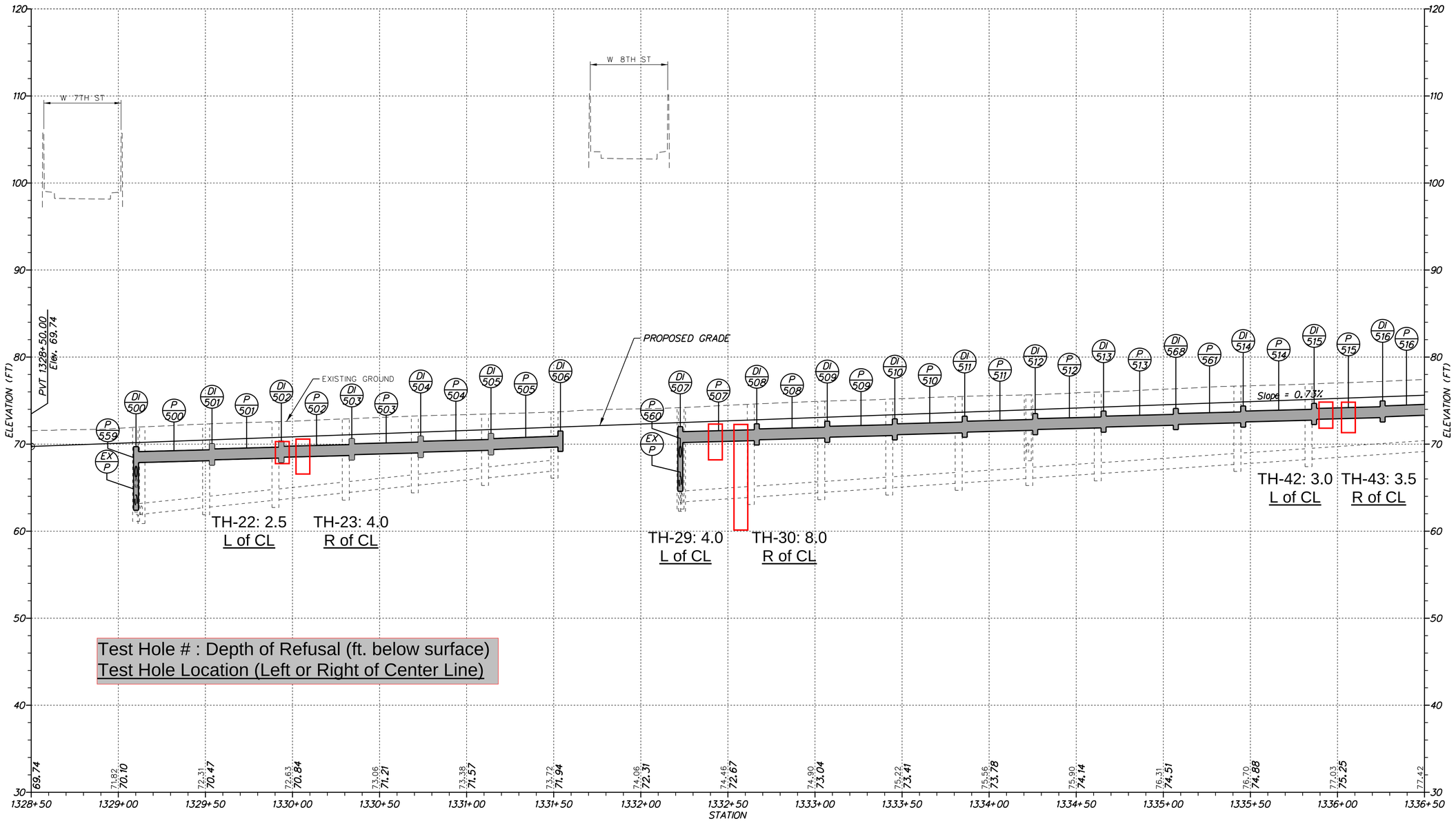
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–748, 1–751
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO.
1-96
TOTAL SHTS.
1 - 178



I–95 SOUTHBOUND

PROJECT CENTER LINE
Developed 11/2018

VERTICAL SCALE FEET 0 6 12 18

PF–08

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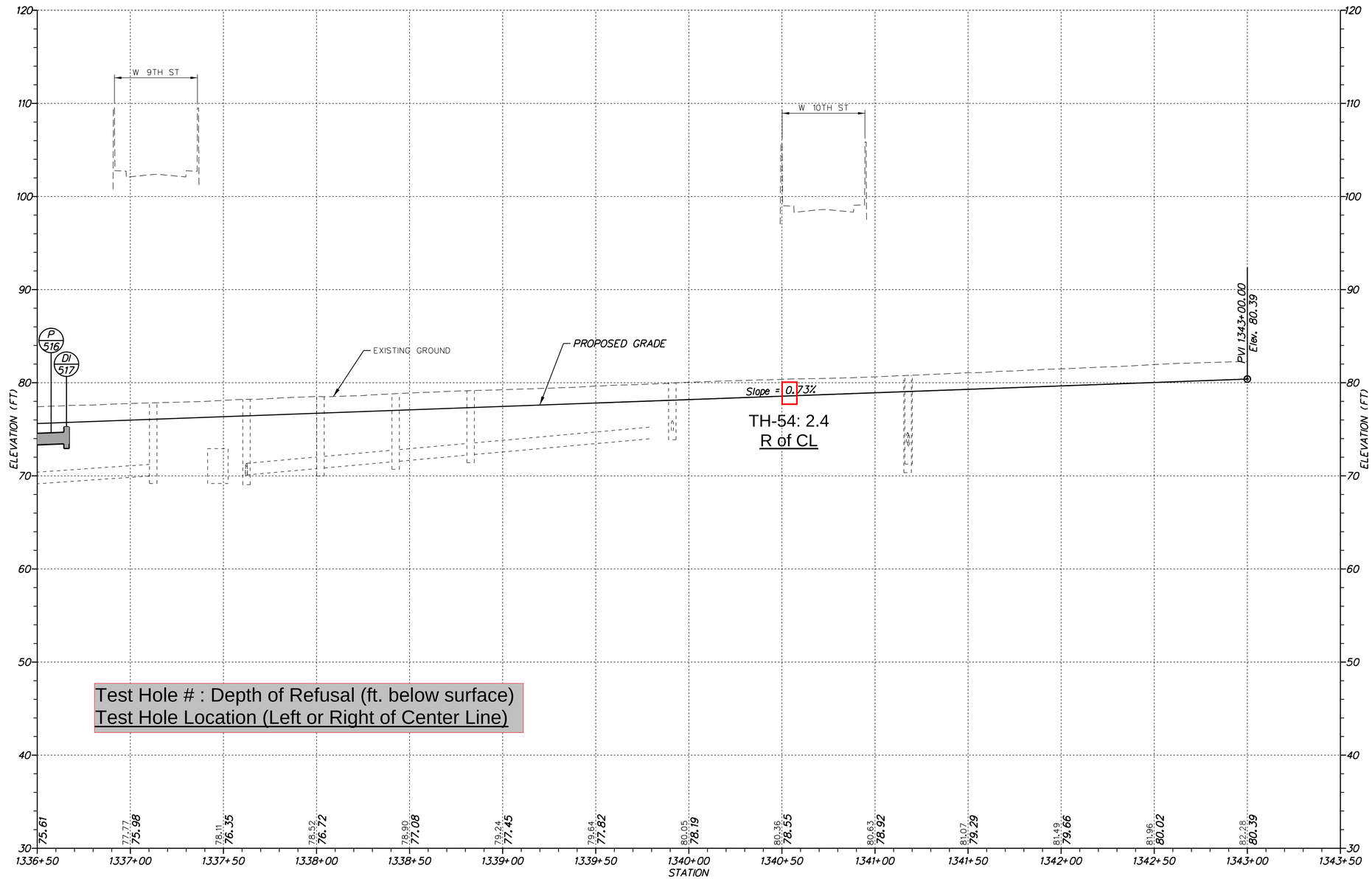
DELAWARE DEPARTMENT OF TRANSPORTATION	ADDENDUMS / REVISIONS	SCALE 0 30 60 90 FEET	REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE	CONTRACT T201407404	BRIDGE NO. 1–752, 1–753	PROFILE	SHEET NO. 1-97
				COUNTY NEW CASTLE	DESIGNED BY: JAD		TOTAL SHTS. 1 - 178
					CHECKED BY: BRT		



I–95 SOUTHBOUND

PROJECT CENTER LINE
Developed 11/2018

VERTICAL SCALE FEET 18 12 6 0

PF–09

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS	

SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–754, 1–755
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

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TOTAL SHTS.
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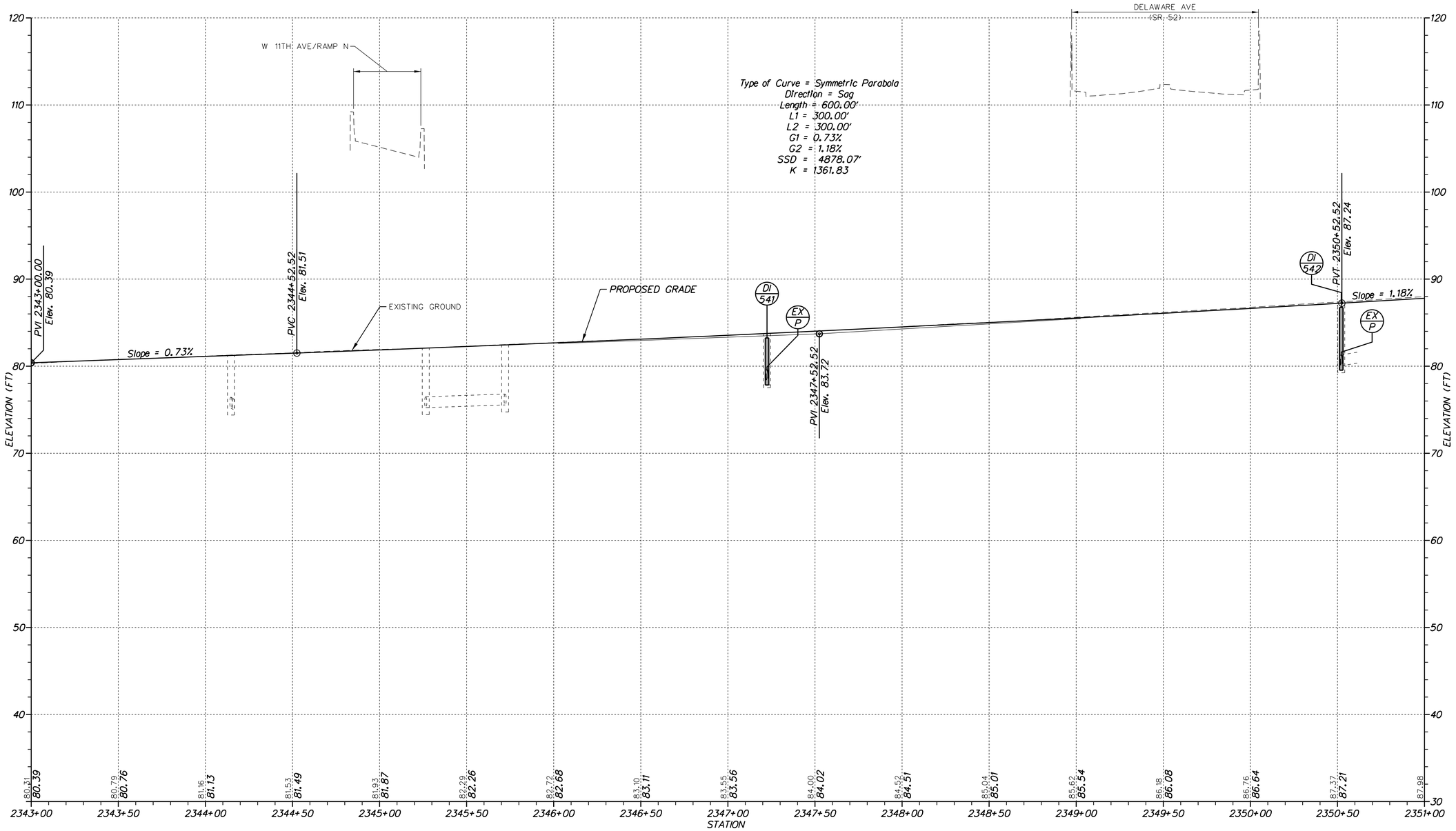

I–95 SOUTHBOUND

PROJECT CENTER LINE
Developed 11/2018

VERTICAL SCALE FEET 18 12 6 0

PF–10

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

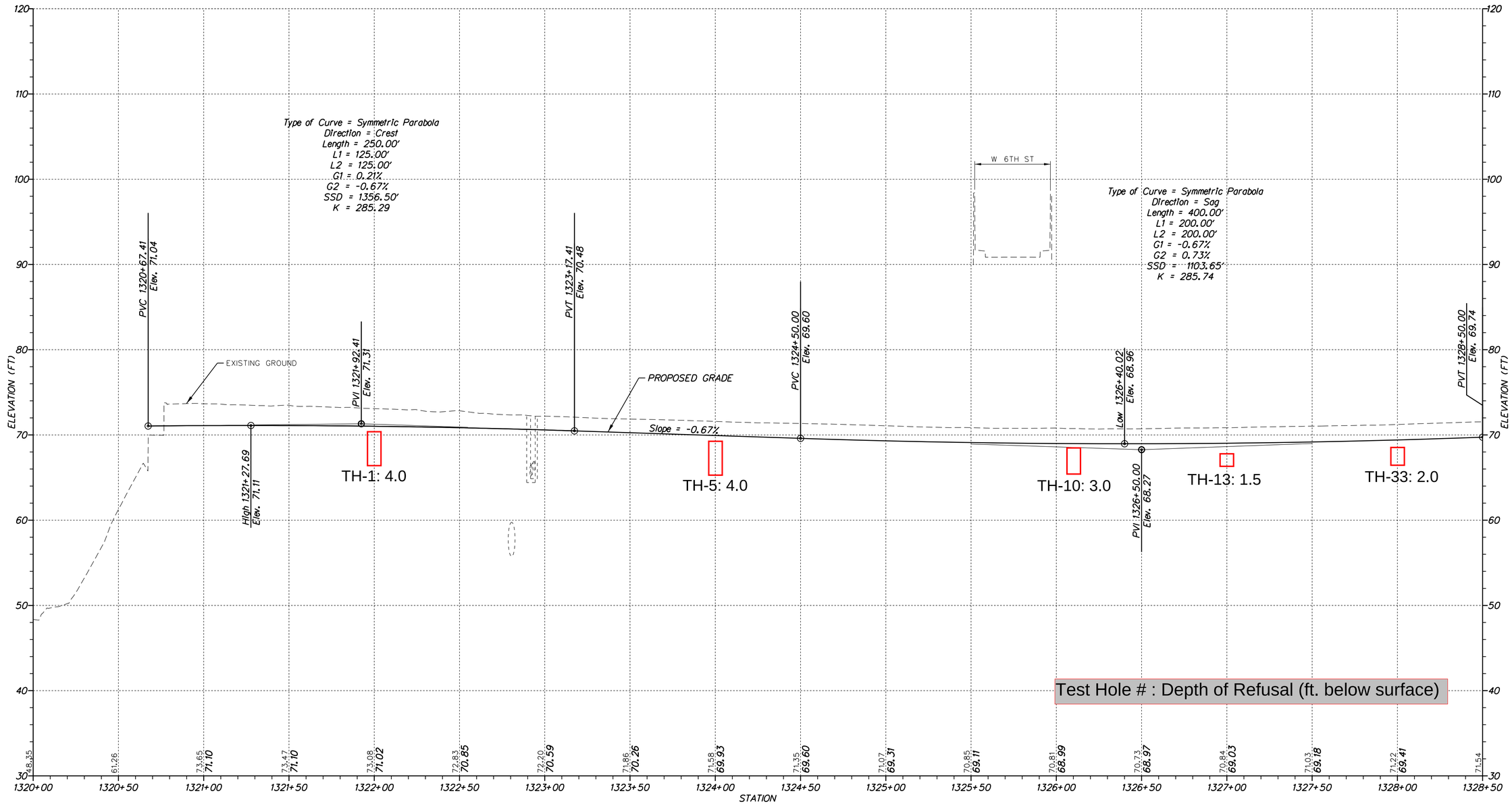
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–756, 1–757
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-99
TOTAL SHTS. 1 - 178



I–95 SOUTHBOUND

PROJECT LEFT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 0 6 12 18

PF–07

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

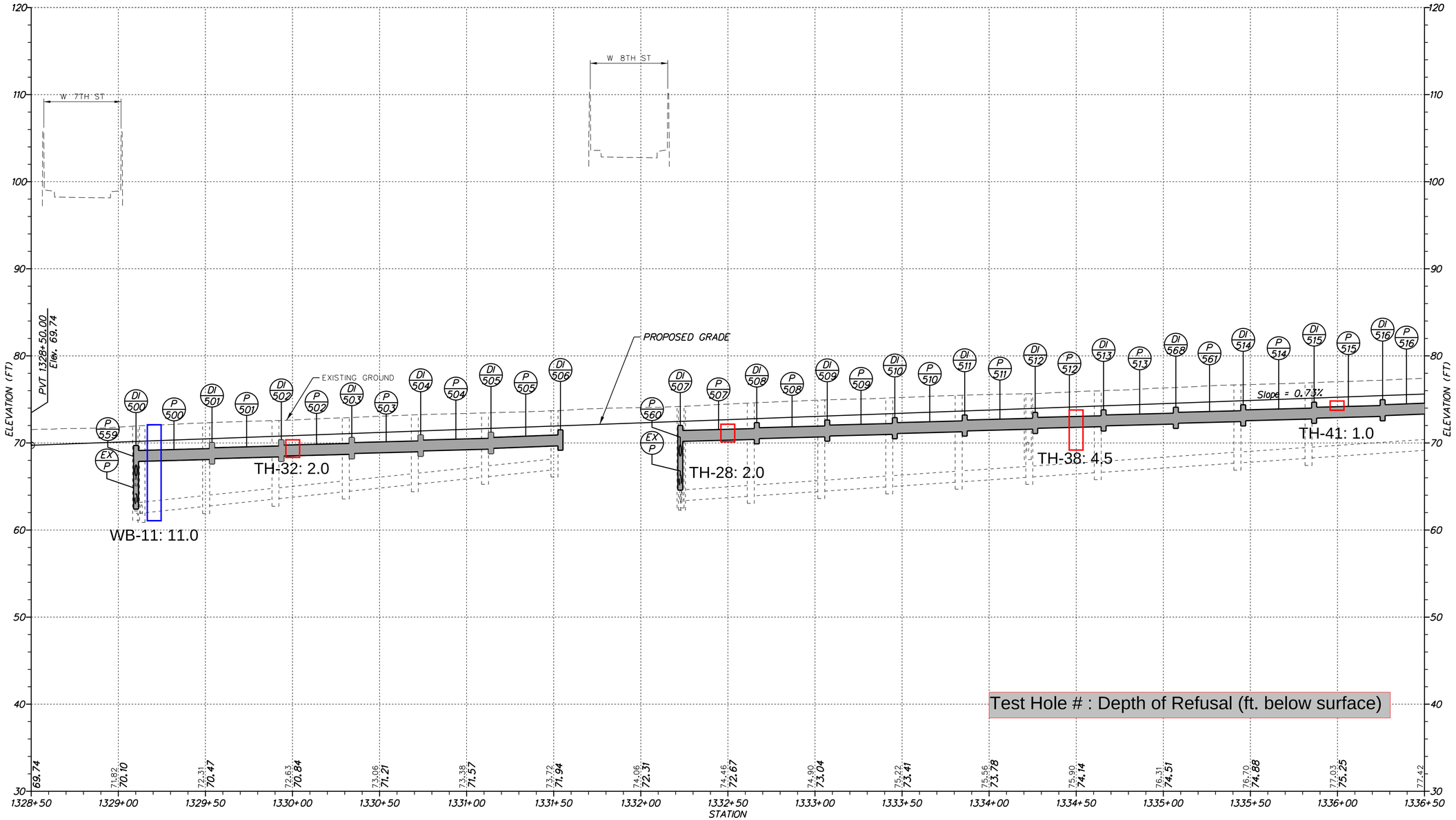
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–748, 1–751
T201407404	DESIGNED BY: JAD	
COUNTY	CHECKED BY: BRT	
NEW CASTLE		

PROFILE

SHEET NO. 1-96
TOTAL SHTS. 1 - 178



I–95 SOUTHBOUND

PROJECT LEFT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 0 6 12 18

PF–08

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

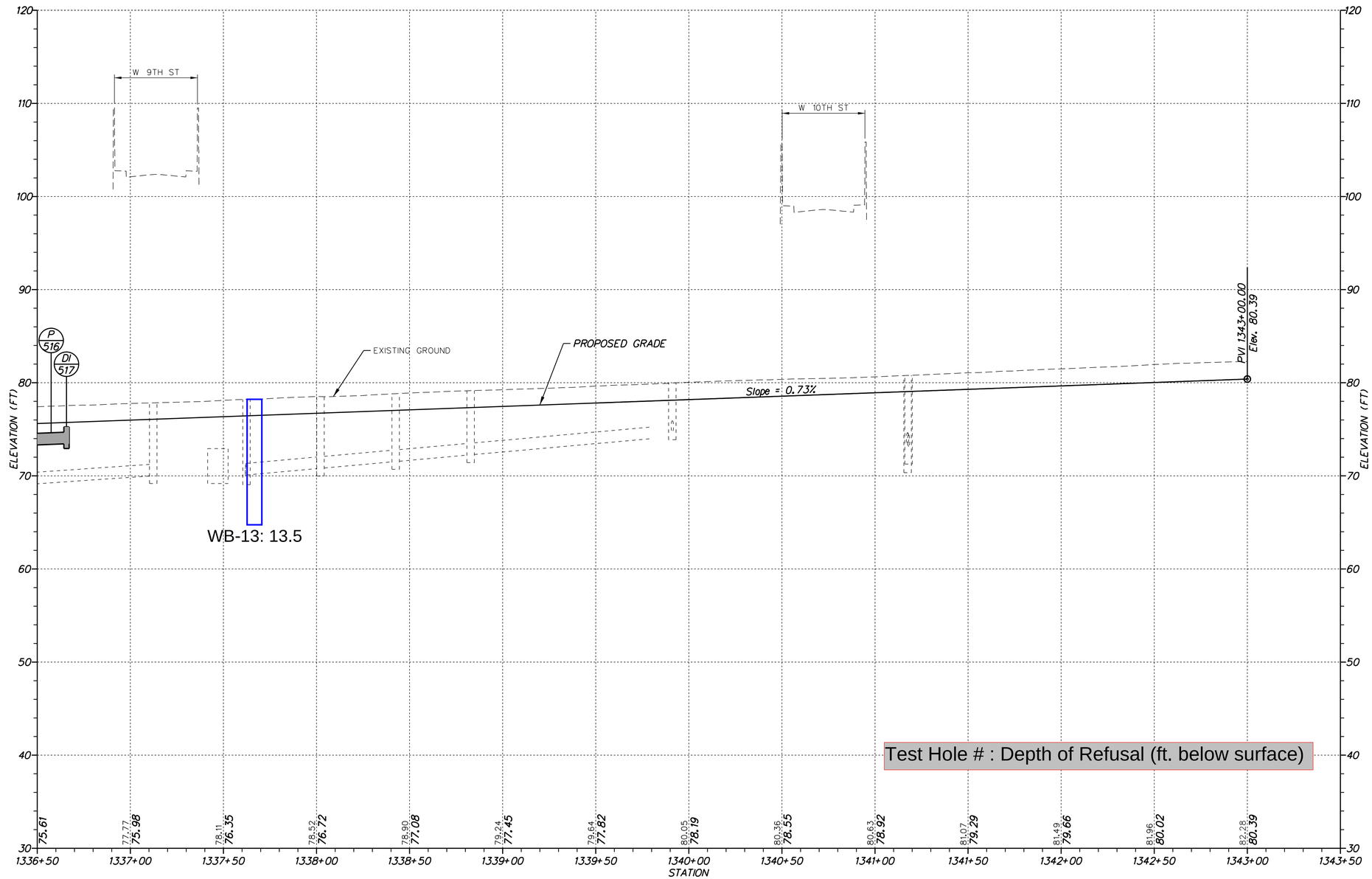
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–752, 1–753
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-97
TOTAL SHTS. 1 - 178



I–95 SOUTHBOUND

PROJECT LEFT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 18 12 6 0

PF–09

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

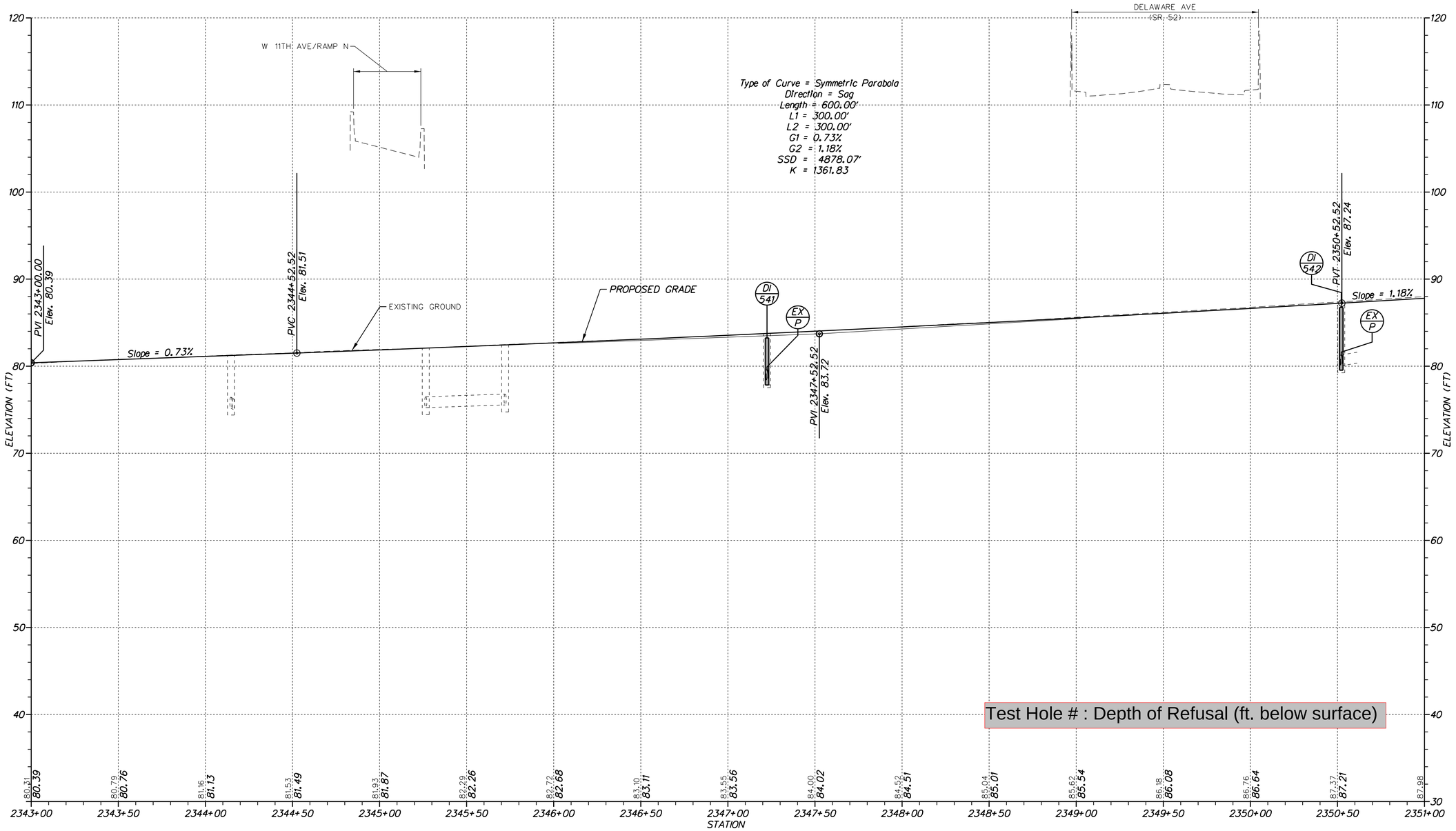
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–754, 1–755
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-98
TOTAL SHTS. 1 - 178



I–95 SOUTHBOUND

PROJECT LEFT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 18 12 6 0

PF–10

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS	

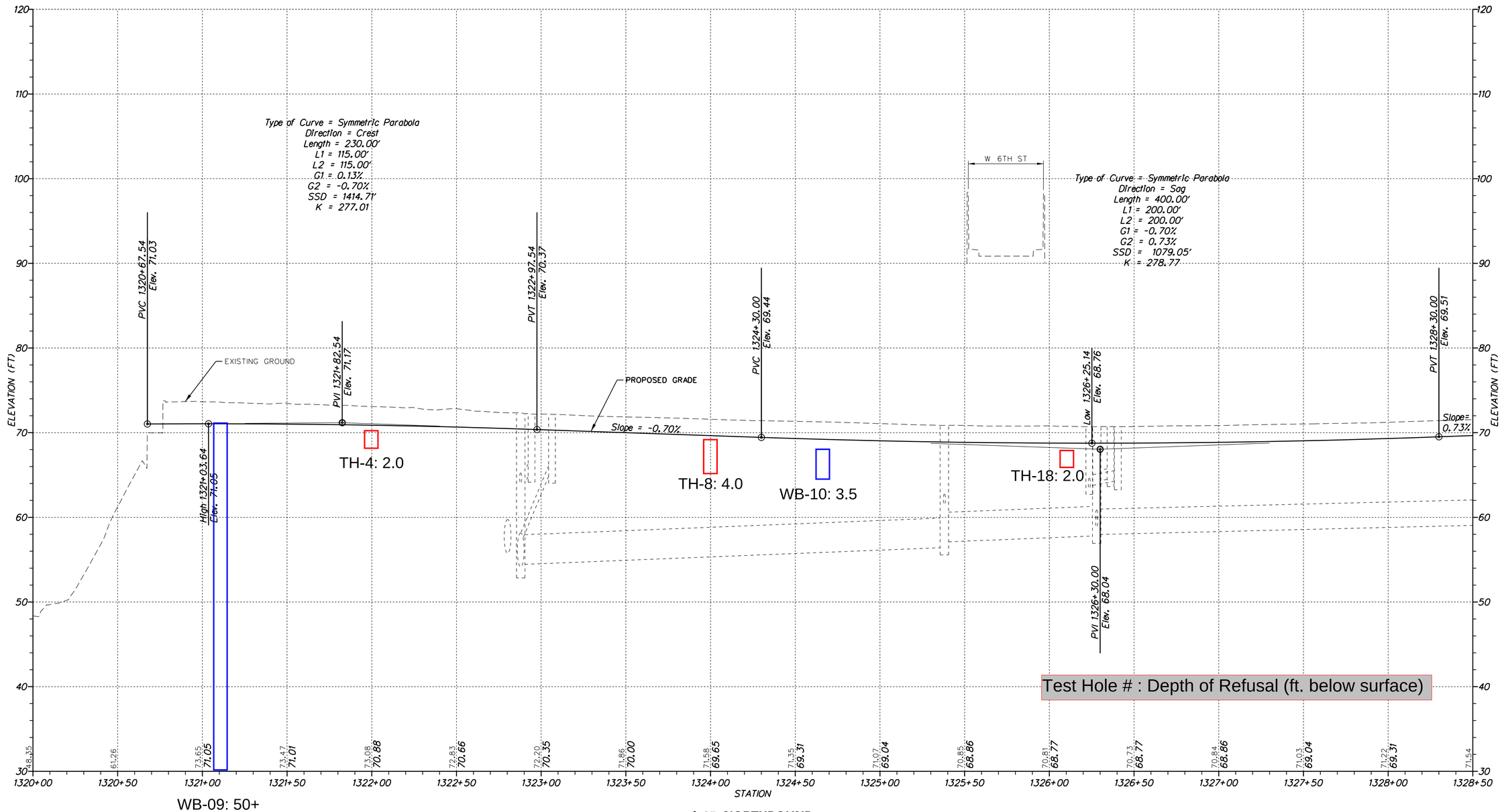
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–756, 1–757
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-99
TOTAL SHTS. 1 - 178



I–95 NORTHBOUND

PROJECT RIGHT EXTENT
Developed 11/2018

PF–01

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2/10/2018 3:49:43 PM

DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

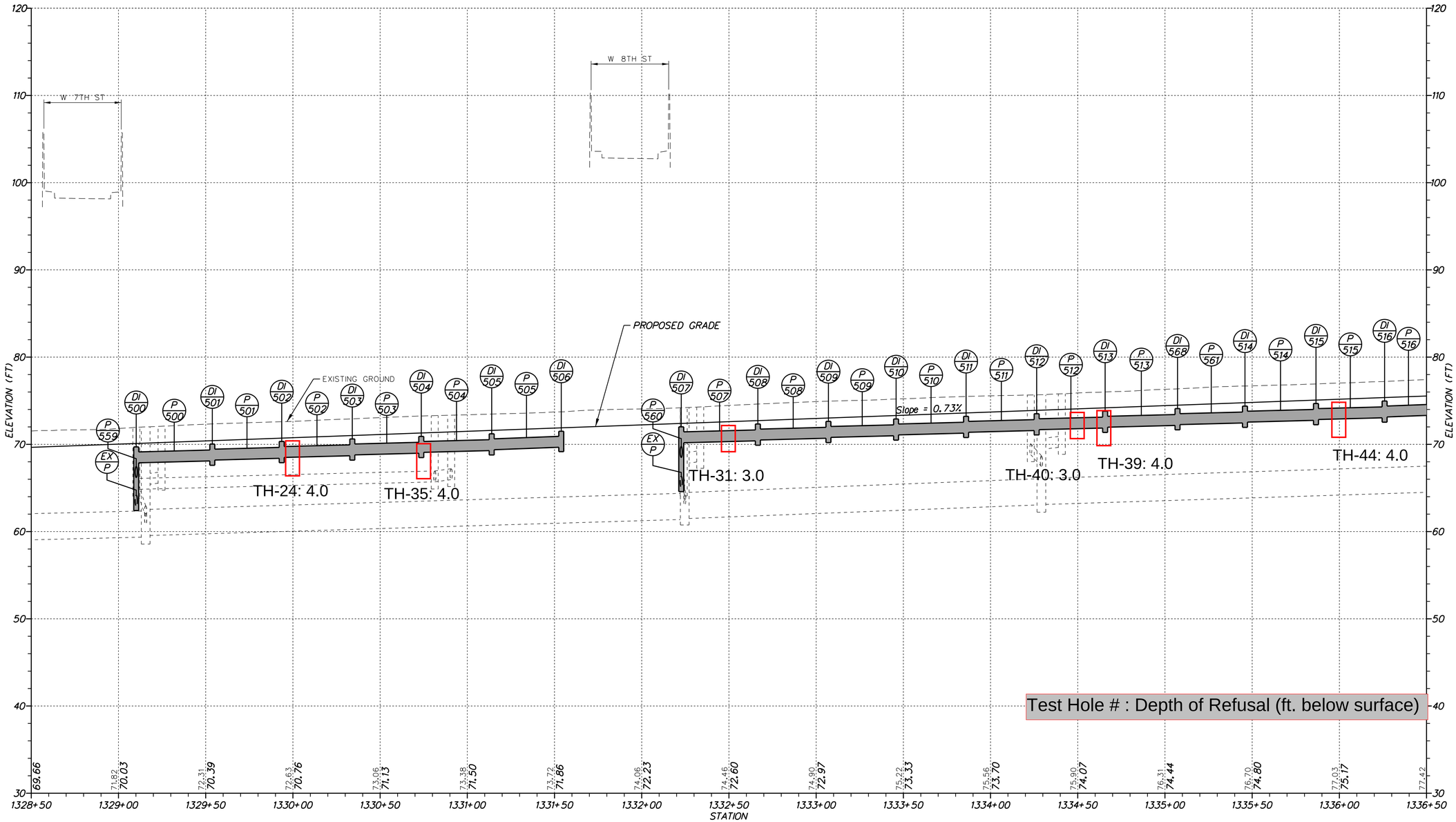
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–748, 1–751
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-90
TOTAL SHTS. 1 - 178



I–95 NORTHBOUND

PROJECT RIGHT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 0 6 12 18

PF–02

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

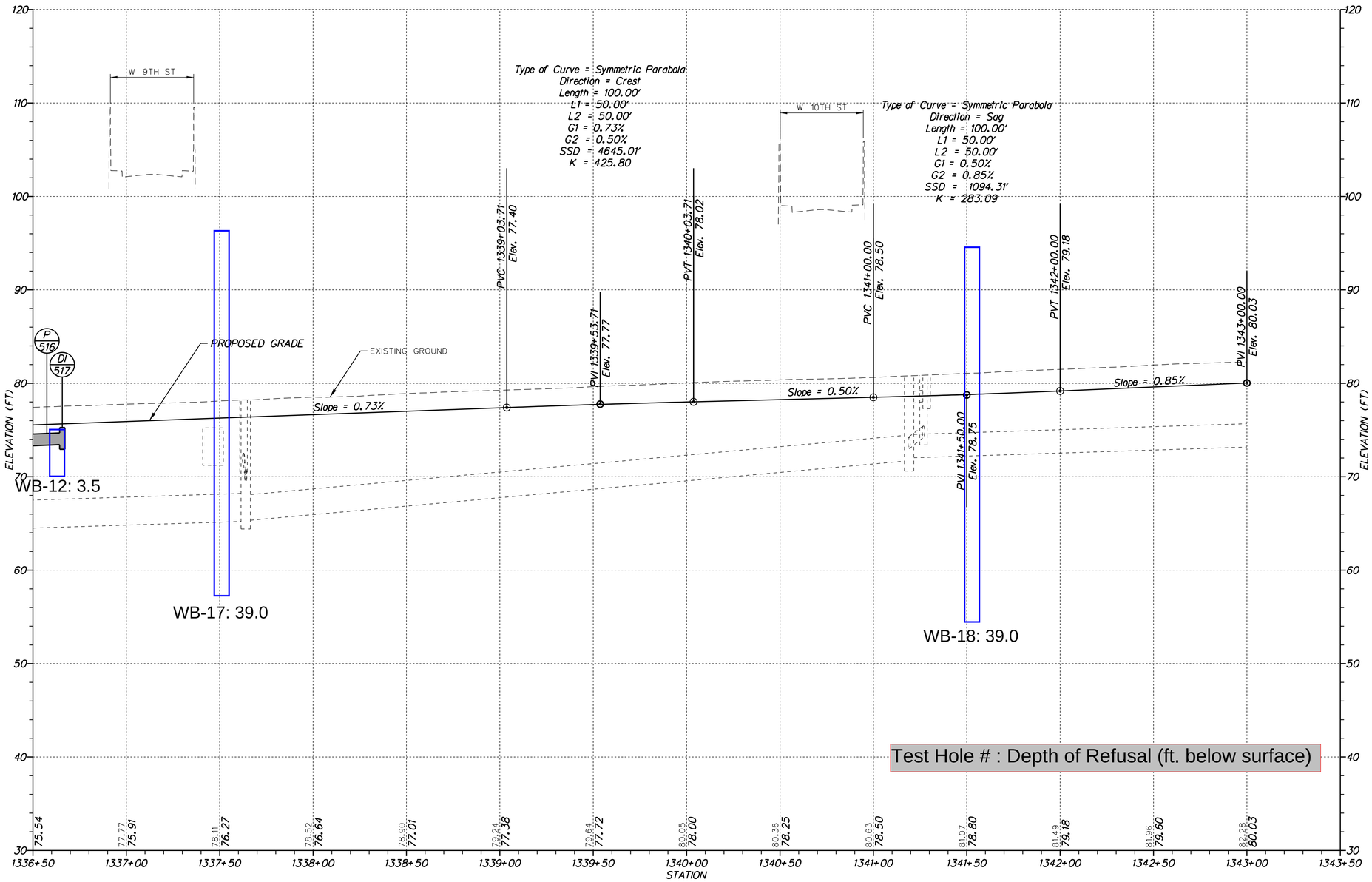
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–752, 1–753
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-91
TOTAL SHTS. 1 - 178



I–95 NORTHBOUND

PROJECT RIGHT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 18 12 6 0

PF–03

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

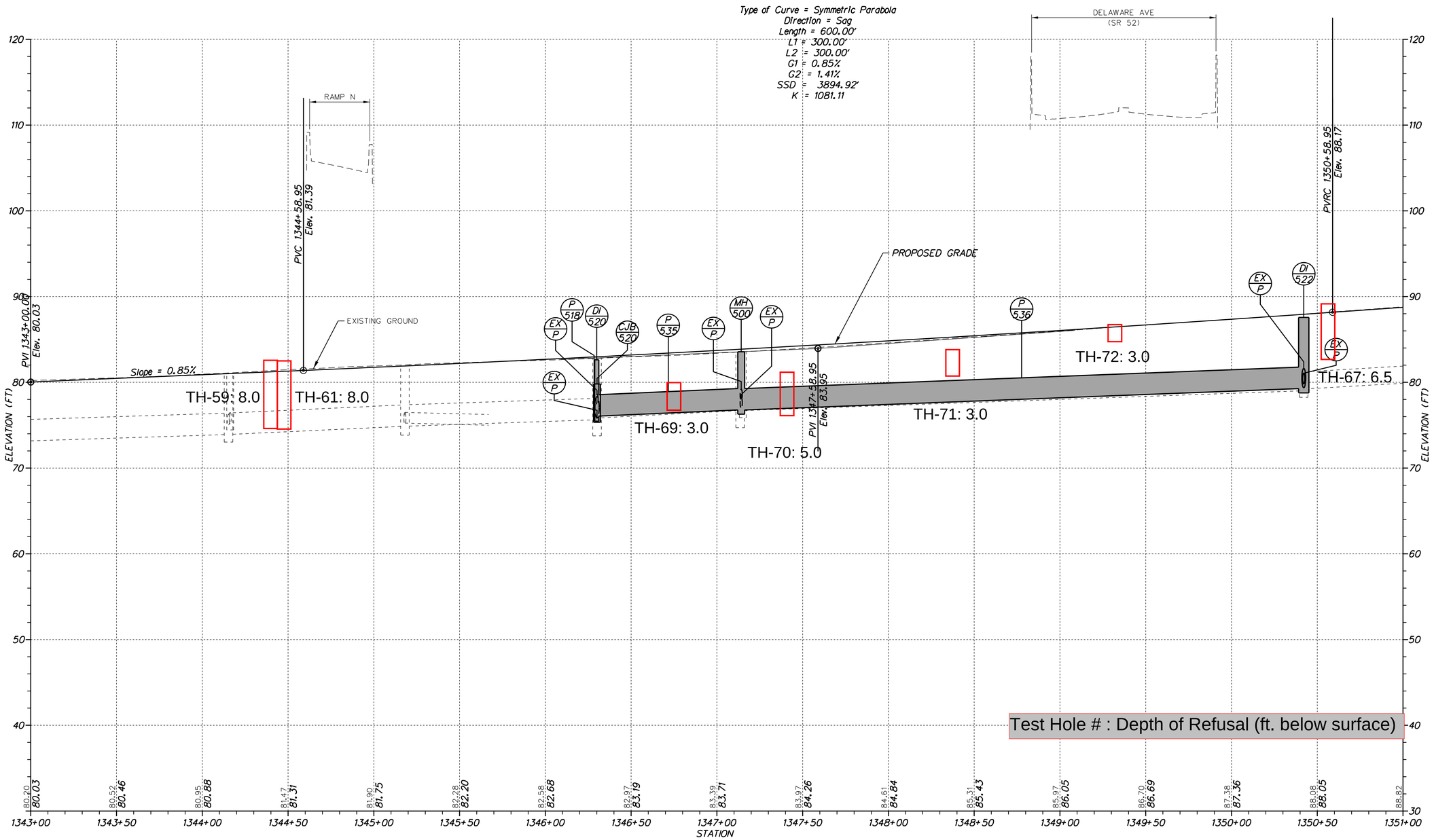
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–754, 1–755
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-92
TOTAL SHTS. 1 - 178



I–95 NORTHBOUND

PROJECT RIGHT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 0 6 12 18

PF–04

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

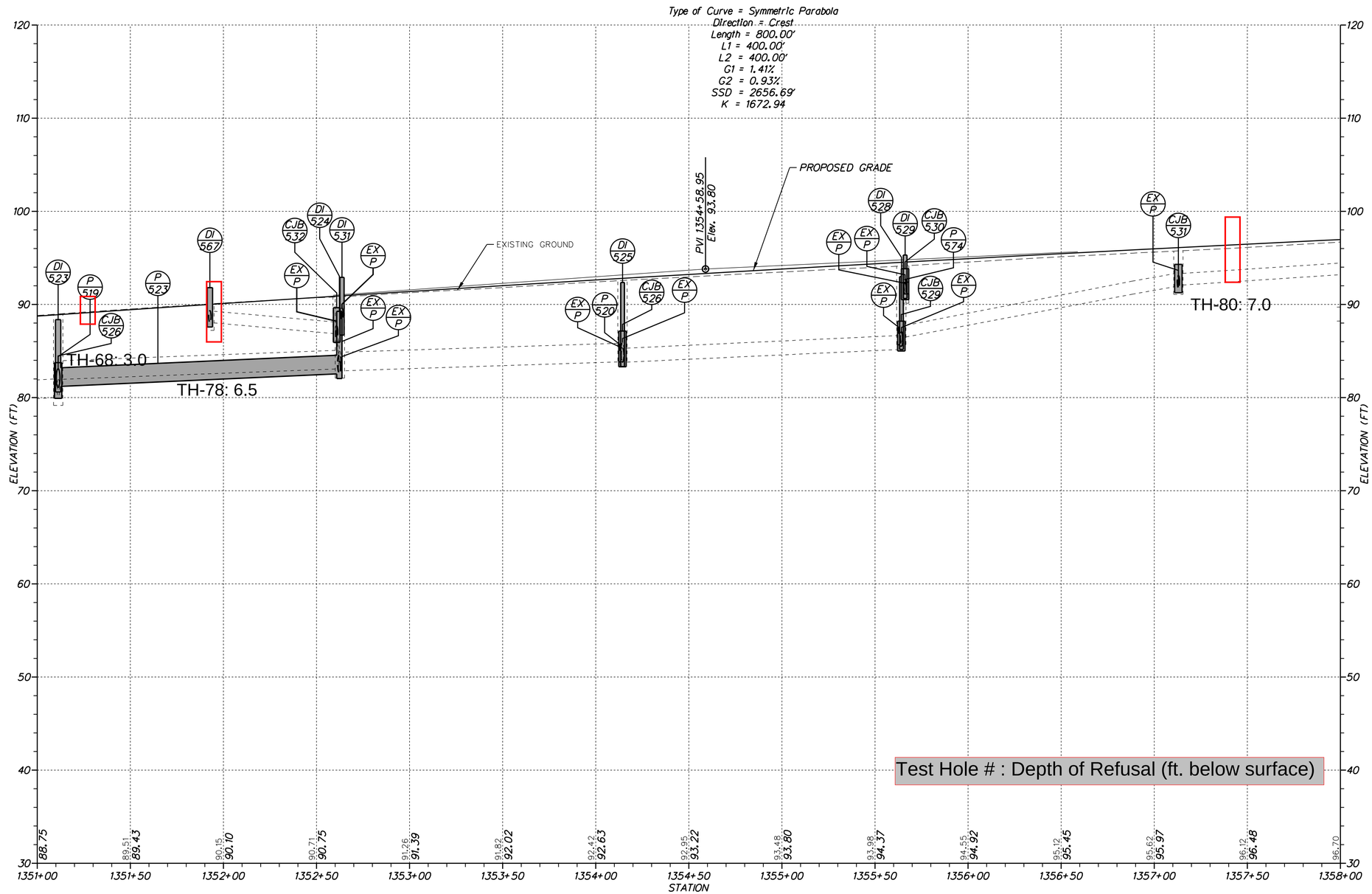
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–756, 1–757
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-93
TOTAL SHTS. 1 - 178



I–95 NORTHBOUND

PROJECT RIGHT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 0 6 12 18

PF–05

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

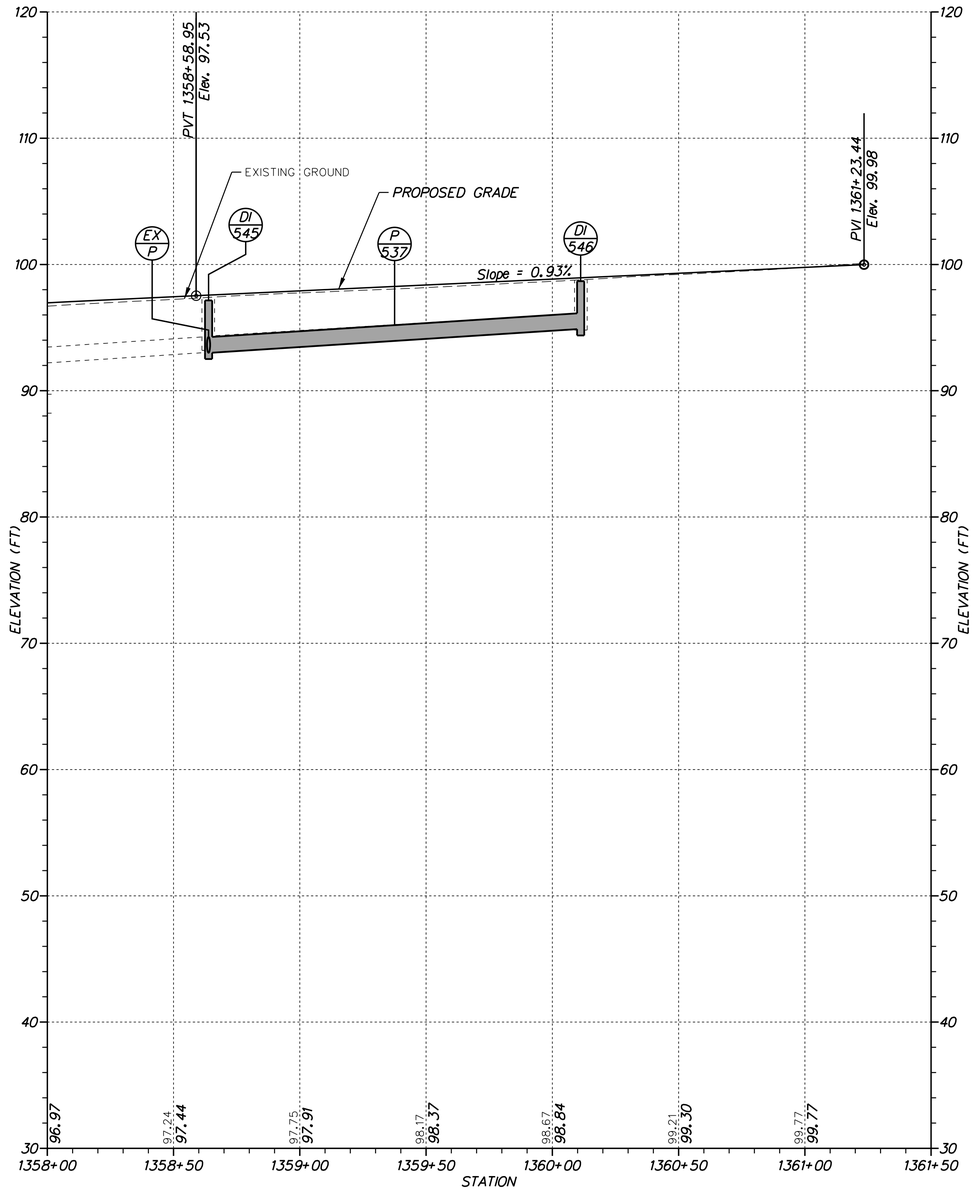
SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.
T201407404	DESIGNED BY: JAD
COUNTY	
NEW CASTLE	CHECKED BY: BRT

PROFILE

SHEET NO. 1-94
TOTAL SHTS. 1 - 178



I–95 NORTHBOUND

PROJECT RIGHT EXTENT
Developed 11/2018

VERTICAL SCALE FEET 18 12 6 0

PF–06

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DELAWARE DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

SCALE 0 30 60 90 FEET

REHABILITATION OF I–95 FROM I–495 TO NORTH OF BRANDYWINE RIVER BRIDGE

CONTRACT	BRIDGE NO.	1–759
T201407404	DESIGNED BY: JAD	
COUNTY		
NEW CASTLE	CHECKED BY: BRT	

PROFILE

SHEET NO. 1-95
TOTAL SHTS. 1 - 178

INTERNATIONAL INC.

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John M. Rogalo
Technical Adviser
Elco International, Inc
101 Van Riper Ave
Elmwood Park, NJ 07407

4 December 2018

Mr. Blake Burroughs
Geologist
Whitman, Requardt & Associates, LLP
801 South Caroline Street
Baltimore, MD 21231

Blake,

As per our conversation on 9 November 2018, I have provided an initial outline of how handheld splitters can be used for your project. I have included some of our general statistics, but I'd really like for you to wait until my end-user is finished with a similar project before you do any cost or time calculations. With this information, you'll have a much better idea of production rates for the proposed project.

Background and General Information on Elco-Darda Handheld Splitters

Elco-Darda hydraulic splitters are the ideal solution for moderately to extremely hard rock excavation when blasting is not feasible. These tools often outperform large hydraulic hammers (up to 14,000 pound-force class) in extremely hard rock with high compressive strengths and few seams. For larger projects and hard rock, the Darda C12 hydraulic splitter is the most preferred splitter.

The Darda C12 will typically engage 15-inches of rock depth per splitting cycle. However, overdrilled holes will often allow the split to extend past this 15-inch depth; it is possible to achieve splitting depths of 6 to 8 feet if holes are drilled appropriately. Therefore, it is encouraged that operators drill holes to the desired depth, plus an additional 10 inches to allow for the final splitting of rock at the bottom of the exavation, as much as possible.

The C12 exerts over 400 tons of splitting force per unit. Multiple units can be combined and run from a single Elco hydraulic power unit, delivering high force across a desired splitting plane. Increasing the number of splitters will increase production rates since the splitters will generally travel faster during their cycle (since the load is distributed across many tools and hydraulic

operating pressures will be lower). This method will also increase the precision of the tools, allowing for more accurate rock excavation, and less accidental overdig.

A key element in hydraulic splitting is the enlarging feather, which is especially useful in trenching. The initial split will yield about three-quarters of an inch (0.75”) of travel in the rock. However, this initial split will not be open enough for larger excavators to engage and rip apart the broken rock. Therefore, operators replace the normal feathers with enlarging feathers after this initial split, yielding up to one and seven-eights inches (1.875”) of travel. This method is essential for excavation when rock has little room to move, such as in trenches.

Drilling and Drill Patterns

More than half of effective splitting is drill pattern design and installation. The Darda C12 and C9 hydraulic splitters require 1-3/4 inch drill holes. Drill times with large hydraluic drill rigs are typically about 2 feet per minute. Hand drilling will typically yield 4 minutes per foot in hard rock.

Trenching in solid rock requires a very precise drilling pattern, based on the general approach for trenching and optimized for the particular rock being excavated. Therefore, I have included the general strategy, but it is essential that once splitting commenses, operators should take note of how the rock “wants” to split and take advantage of the particular grain and relief points in order to maximize production.

The general drill strategy for your particular trench will require holes installed on either side of the trench and holes drilled on the center line of the trench offset slightly from the line connecting these outer perimiter holes. Due to the project requiring a depth of 1 to 3 feet of rock excavation, the outer overdig boundaries of these lines will vary. In other words, where there is only one foot of rock to excavate, the overdig will be much less than where there is three feet of rock to excavate.

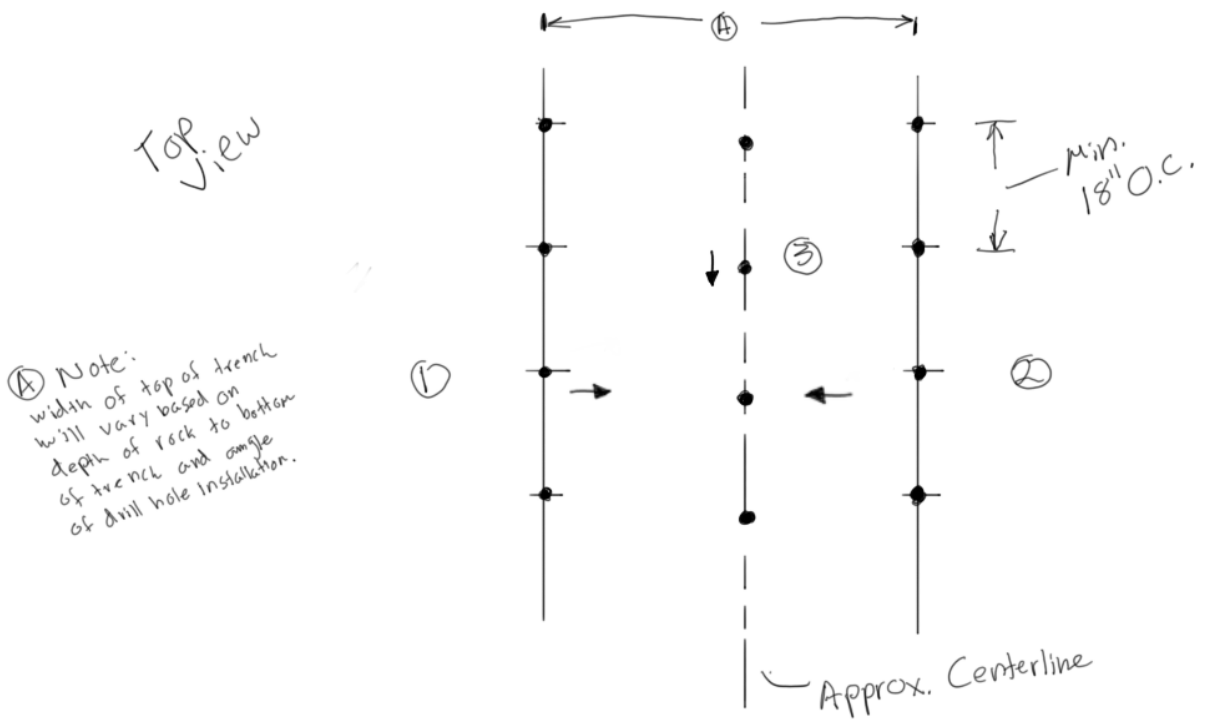
Depending on the rock structure and how it is splitting, the outer drill hole lines of the trench will require between 15 and 30 degree angles relative to vertical. This translates to the following overdig amounts in the chart below. From the sound of your project, I anticipate that you’ll probably be able to use the 20-degree from vertical drill pattern, yielding 4 to 13 inches of over-dig per side at the top of trench.

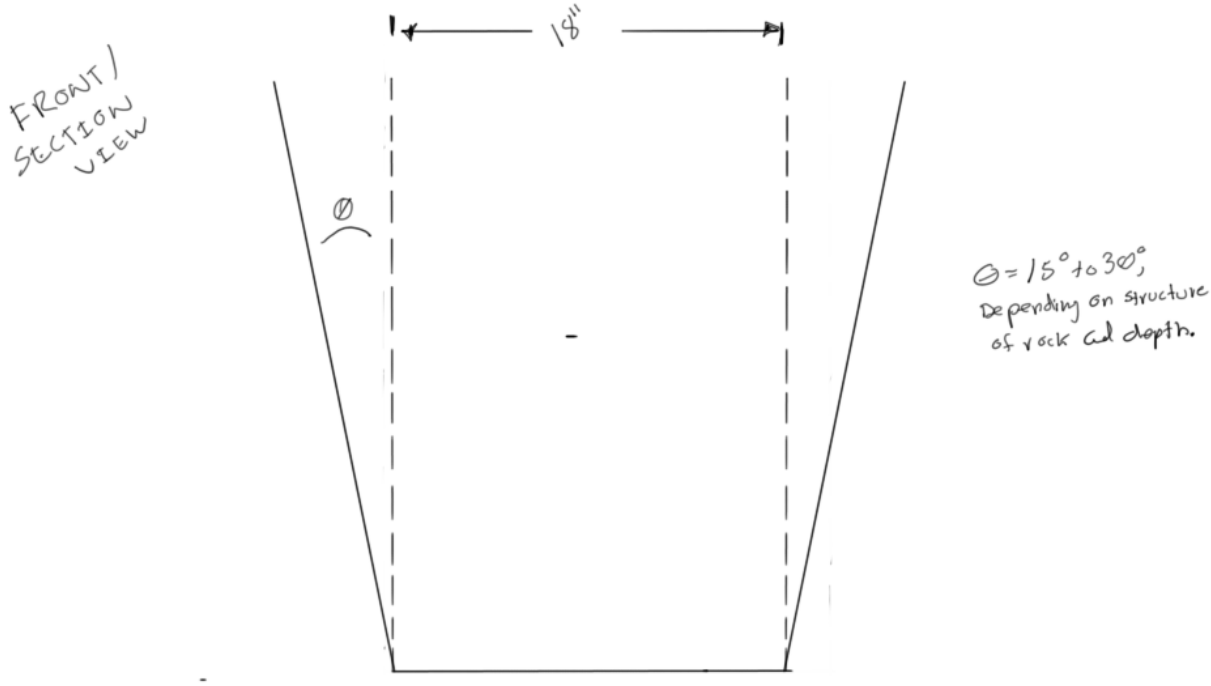
Overdig Values Based on Angles and Depth of Excavation, Inches

Depth Excavation	Angle, 15 Degrees	Angle, 20 Degrees	Angle, 30 Degrees
1 Foot	**3**	**4**	**7**
2 Feet	**6**	**9**	**14**
3 Feet	**10**	**13**	**21**

The purpose of installing drill holes on an angle is to provide a “free face” for the rock to move into. If the hole is drilled at or near perpendicular to the face of rock in a trench, then the rock will have nowhere to move towards and the tool will not perform. Placing the tool at an angle allows for the rock to split and travel in an upwards direction.

The particular project that you are working on will use the following drill pattern. All annotated holes are 1-3/4 inch diameter.





As you can see in these sketches, you will need to install 1-3/4 inch drill holes along the boundary of the trench on 18-inch centers. Then, a single drill hole (also angled at 15-30 degrees back from the free face) is installed just slightly offset (4-6 inches) from these holes on the center line. The operating strategy will be to break one side towards the centerline, then the other side, then the single hole to "kick out" the fractured block.

If increased precision is required, then 1-1/2 inch or smaller drill holes can be installed in between the 18-inch center 1-3/4 inch drill holes. These extra relief holes will actually decrease cycle times of the splitters since they will provide easy paths for the splits to travel, but may increase total project time due to the slow drilling rates. This is another factor that is site-specific and must be weighed appropriately.

Project Design

Prior to discussing project design, I have gone through some general statistics on production rates and cycle times for the two configurations that could be used on your project. Please note that all times and production rates discussed are **only for splitting**, and do not include excavation, ripping, drilling, or any other support activities required for operation.

In general, a **single C12 splitter**, with split cycle, enlarging cycle and full greasing will require 4 minutes 30 seconds to 7 minutes per hole.

A **manifold running three C12 splitters**, with split cycle, enlarging cycle on every tool, and full greasing will require 14 to 18 minutes.

General production rates, trenching, hard rock, (1) C12 vs. (3+1) C12

	(1) C12	(3 + 1) C12
Low Production (Cubic Feet / Hour)	20	50
High Production (Cubic Feet / Hour)	80	205
Linear Feet / Hour, assume 30-inch trench depth, low production	5	12
Linear Feet / Hour, assume 30-inch trench depth, high production	20	50

I believe that you're probably going to be able to produce 15 to 20 cubic yards per day (solid, in-situ) with the (3+1) C12 configuration based on what you have told me about the type of rock you're engaging. You're probably going to be on the absolute low end (5 or less cubic yards per day) with a single C12 splitter.

For your project, there are two splitter configurations that could work. The drill pattern will be the same in both applications. The two different approaches use a different number and combination of splitters to accomplish the same task (as is provided in the production rates

above). The reason for using more splitters and a flowbar manifold would be for higher production rates and increased precision. However, the end-user would have to determine the cost to production rates with the engineering firm to optimize the project.

In scenario one, a single C12 splitter is used. As per the annotations in the previous section, the C12 is first cycled on one side of the trench. The tool is retracted, greased, and placed on the opposite side of the trench. The tool is cycled. The final split for that segment occurs in the centerline hole to move the block out from the parent material. Expanding feathers will likely have to be used with every hole in this approach. This requirement can only be determined once splitting begins on the particular project. This cycle is repeated for the next segment of rock until the trench is completed.

In scenario two, a single hydraulic power unit fitted with a flowbar manifold and multiple C12 splitters (2 to 3) is used to excavate the rock. A second hydraulic power unit with an additional single C12 splitter is also used. The multiple C12 splitters are inserted every other hole (36-inches on center spacing). The tools are all cycled simultaneously. The tools are retracted, greased, and placed on the opposite side of the trench. The process is repeated. Expanding feathers may need to be used on these side splits, but this can only be determined once splitting commences on the particular project. After the multiple tools have been moved forward to the next hole series, the single C12 is used to split the centerline holes. This single tool will require the expanding feathers.

Both cases may require re-splitting of the lower portions of the trench (in areas greater than 15-inches rock excavation). In this case, either multiple or single splitters are inserted into the same drill holes and cycled. Holes must be cleared with compressed air prior to inserting the tools. If the tools cannot be inserted into these holes due to the proximity of the wall, then they can be rotated to break the rock more in-line with the trench (up to 90 degrees from the original splits). If tools still cannot be inserted, additional holes will need to be drilled.

Summary

In general, I would highly recommend using multiple splitters with a flowbar manifold. Cycle times are lower since less pressure is required in the hydraulic circuit, and much larger blocks of rock can be broken off per splitting cycle. Expanding feathers will be an absolute requirement for the project.

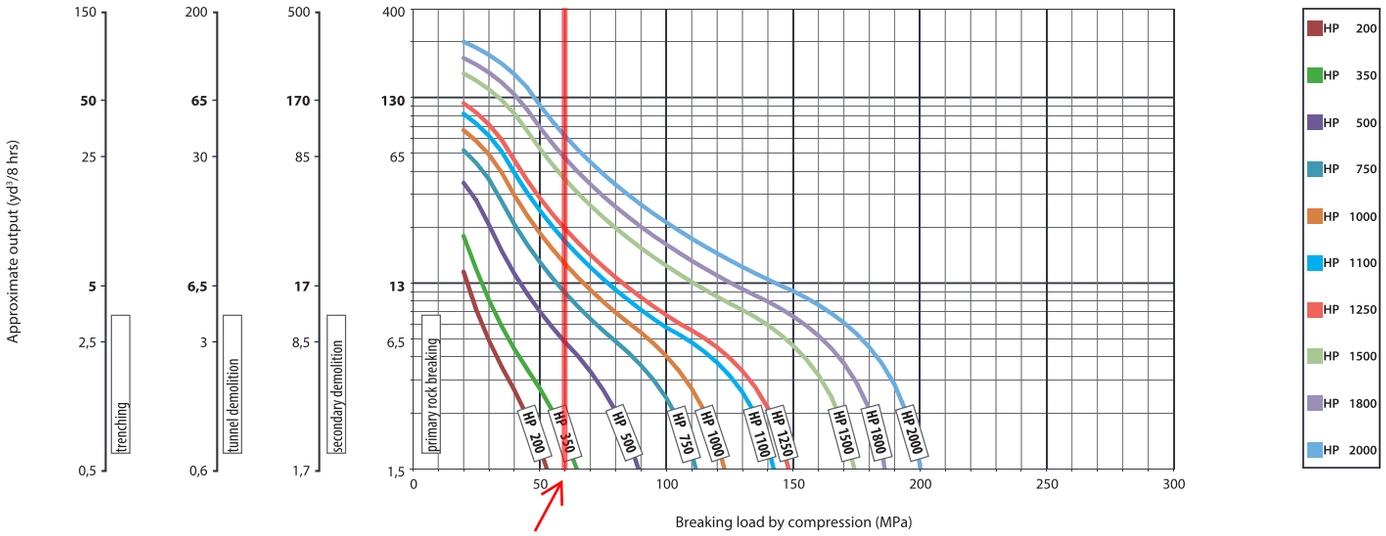
As I said before, I have an end-user who will be conducting a very similar project in the next week or so. He will be collecting production rates and drill patterns as he does the job, so I'll be able to give you those rates after he is finished.

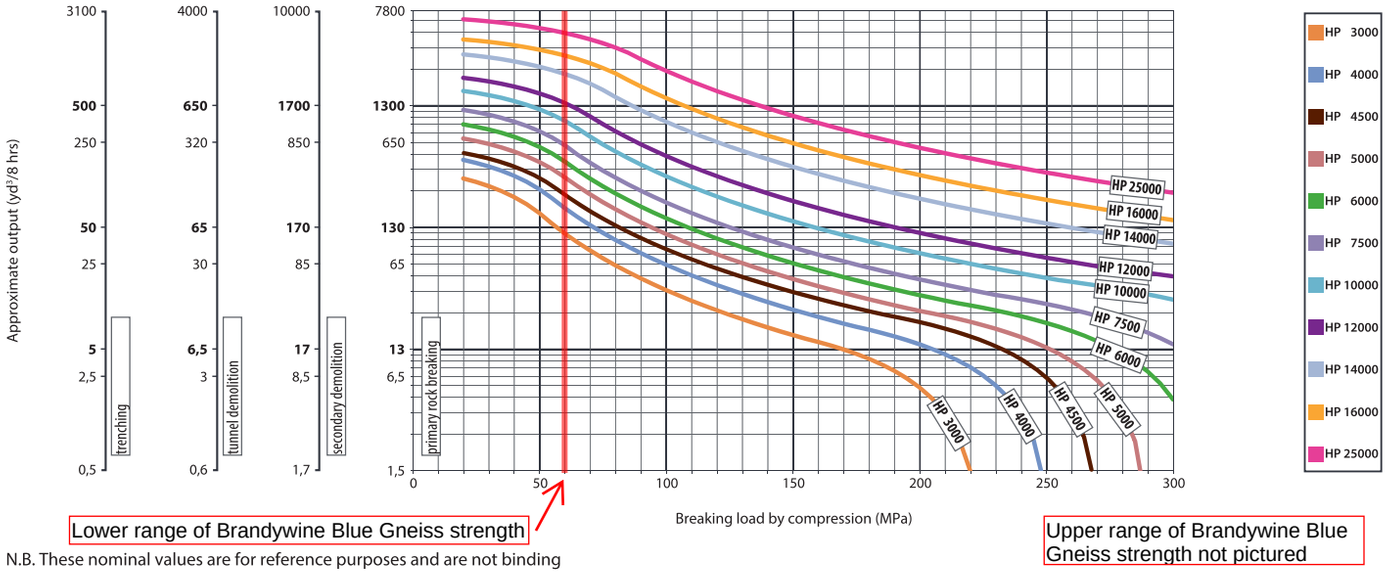
Please let me know if you have any other questions before then.

Regards,

John Rogalo

Productivity





N.B. These nominal values are for reference purposes and are not binding

Noise levels

Noise levels measured* at various distances

Distance	33 ft	50 ft	65 ft	80 ft	100 ft
All HP models	96*	92.5*	90*	88.1*	86.5*

*values expressed in dB (A)

Noise level guaranteed* by the 2006/42/CE directive

All HP models	126*

Exerpt From: Indeco HP Hydraulic Hammers Product Brochure, accessed at www.indeco-breakers.com
Edited by WRA 8.15.2018