146 Dascomb Road
Andover, MA 01810
978.794.1792
TheEngineeringCorp.com
Create | Design | Innovate

MEMORANDUM

TO: Ross Povenmire
Boxford Conservation Commission
7A Spofford Road
Boxford, MA 01921

DATE: October 5, 2020

FROM: Peter Ellison, P.E.

PROJECT NO.: T0998.00

RE: Response to Comments
DEP # 114-1301 – Willow Road Culvert Replacement
Boxford, MA

This memorandum is in response to comments by MassDEP regarding the NOI Submission for the proposed culvert replacement on Willow Road in Boxford, Massachusetts. DEP comments are listed below in ***bold italics.*** TEC responses are shown in *italics.*

DEP: Stream crossing culvert replacement projects should be filed under 310 CMR 10.53(8) instead of 10.53(3)(i). Therefore, the criteria in 10.53(8) should be addressed.
TEC: TEC agrees that the criteria in 10.53(8) are applicable. These criteria were considered heavily in the development of the culvert design. Full detail related to each criteria are addressed below:

(a) If the project includes replacement of an existing non-tidal crossing, the applicant demonstrates to the satisfaction of the Issuing Authority that the crossing complies with the Massachusetts Stream Crossing Standards to the maximum extent practicable."

A detailed description of how the project meets the Stream Crossing Standards is included in the Notice of Intent Narrative section and below. The culvert replacement was designed to meet these standards.

1. "The Potential for downstream flooding"

The larger opening should not cause additional flooding. The discharge rates match the existing culvert, but the upstream and downstream velocities are significantly decreased compared to existing conditions. Along with this, the surface elevation of the water will differ by less than a foot during 2-100 year storm events within the stream (see page 4, Table 2 of hydraulic report). This is a significant improvement from the existing culvert, which reaches elevations capable of flooding the roadway during a 50-100 year storm event.

2. "Upstream and downstream habitat (in-stream habitat, wetlands)"

The culverts widened opening will help connect the upstream and downstream habitat. Under existing conditions, there is no connection between upstream and downstream habitat. The culvert provides a stream depth that allows fish and other aquatic wildlife to pass up and downstream. It also provides a 1.29' wide bench on each side of the stream to allow dry passage for wildlife through the culvert.

The 24" rockfill and crushed stone stream bed will prevent erosion during major storm events. During these storm events, the increased stream velocities could partially or totally erode the top substrate layer, and without the rockfill and crushed stone the stream bed's elevation could drastically change. Soil analysis of the upstream section was conducted and is detailed in the attached Hydrologic Report on pages 40-42. The substrate proposed within the culvert will match the soils analyzed by reusing soil from both up and downstream sections of the culvert.

3. "Potential for erosion and head cutting"

The water level and water velocity in the proposed condition are lower than the existing condition. Therefore, no head cutting or erosion is anticipated.

4. "Stream stability"

Steam stability will increase because the water level and water velocity are lower in the proposed condition.

5. "Habitat fragmentation caused by the crossing;"

The culvert will provide a stable crossing for a previously fragmented habitat for dry passage wildlife, fish, and other aquatic wildlife. The previous drainage pipe did not supply adequate space for several types of wildlife, and the box culvert should significantly improve this aspect of wildlife movement.

6. "The amount of stream mileage made accessible by the improvements;"

The improved access will increase stream mileage for all prior mentioned wildlife by providing the larger opening that creates access to both up and downstream sections of the stream.

7. "Storm flow conveyance;"

Storm flow conveyance will also be drastically improved by the larger opening, preventing flooding of the roadway during major storm events (2-100 year storms).

8. "Engineering design constraints specific to the crossing;

For engineering design and hydraulic constraints, the culvert is the best practicable solution to create an opening that emulates the natural stream flow while also providing enough space to prevent flooding of the existing roadway.

9. Hydrologic constraints specific to the crossing;"

For engineering design and hydraulic constraints, the culvert is the best practicable solution to create an opening that emulates the natural stream flow while also providing enough space to prevent flooding of the existing roadway.

10. "Impacts to wetlands that would occur by improving the crossing;"

Impacts to the wetlands will be minimized by minimizing the overall limit of work, use of erosion control, and an upstream cofferdam during construction. All of these methods will prevent unwanted sediment flow into undisturbed wetlands.

11. "Potential to affect property and infrastructure; and"

If the project is not undertaken, the current 24" pipe and stone headwall will likely catastrophically fail with time, causing flooding of the roadway and disrupting the natural streamflow downstream. The culvert will greatly extend this section of Willow Road's service life, improving the roadway/waterway's safety and access, and preventing the flooding of abutting property.

12. "Cost of replacement."

The cost of replacement now is lower than if the existing pipe was left alone. This is due to the potential cost of replacing/repairing the existing pipe and roadway after failure of the pipe has occurred.

DEP: The plans should be revised to clearly show all wetland boundaries with the proposed culvert. Sheet 1 is hard to read. An enlarged plan should be provided to show where all temporary and permanent wetland resource areas alterations are occurring.
TEC: The enlarged Sheet 1 can be seen in the attached Additional Plan 1 at the end of the plan set. Both Additional Plans (1 & 2) clearly show all wetland boundaries as requested.

DEP: Pls explain how the larger opening will not cause downstream flooding downstream flooding, upstream and downstream habitat (in-stream habitat, wetlands), potential for erosion and head cutting, and stream stability. Pls explain why a layer of 24" rockfill and crushed stone is proposed to stabilize the streambed. The existing streambed substrate in the upstream and downstream reaches should be examined to determine the appropriate substrate to be placed in the culvert.
TEC: As previously noted, the larger opening should not cause additional flooding. The discharge rates match the existing culvert, but the upstream and downstream velocities are significantly decreased compared to existing conditions. Along with this, the surface elevation of the water will differ by less than a foot during 2-100 year storm events within the stream (see page 4, Table 2 of hydrologic report). This is a significant improvement from the existing culvert, which reaches elevations capable of flooding the roadway during a 50-100 year storm event.

DEP: Restoration to Bank should be revised to include appropriate sized coir logs secured by wooden stakes, and planted with live stakes and/or tubelings. A planting plans should be provided that describes how the BVW areas will be restored. The planting plan should include the species, quantity and height along with a seed mix.
TEC: The coir logs, and their associated details, have been added to the plan set and can be seen on Sheets 1, 3, 4, 7, 8 and Additional Plans 1 & 2. A Restoration Plan has been added at the end of the plan set (Additional Plan 2) and includes the plantings requested.

DEP: The riprap embankment should be replaced with loam and seed stabilized with an erosion control blanket.

TEC: The proposed downstream section of the riprap embankment will be replaced with loam and seed stabilized with an erosion control blanket as requested. TEC is hesitant to replace the upstream riprap embankment due to erosion concerns. This can be seen on Sheets 1, 3, 4, 7, 8 and Additional Plans 1 & 2.

DEP: A stream bypass should be shown on the plan.
TEC: A stream bypass is shown on the Control of Water Plan.

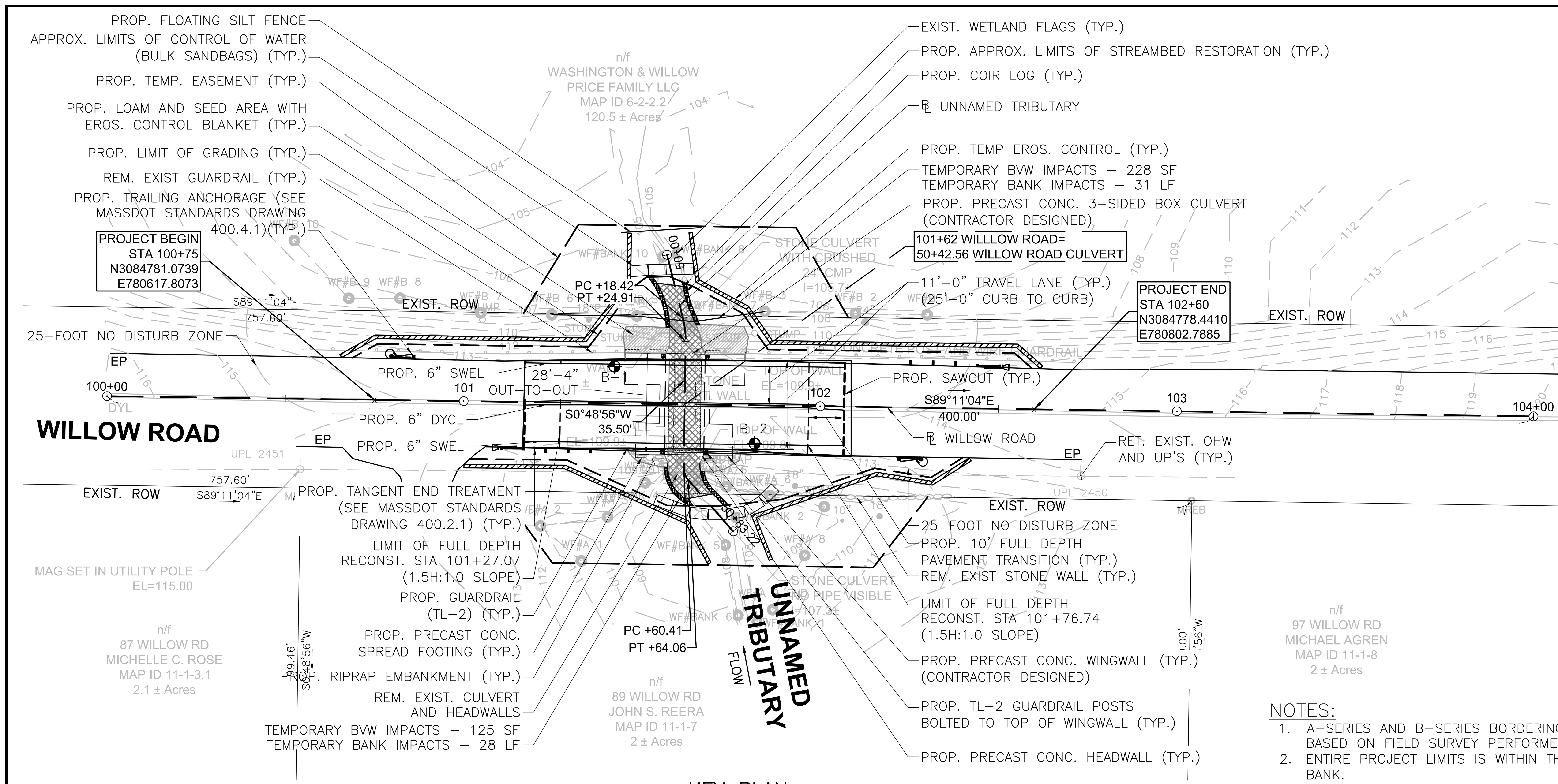
Please do not hesitate to contact me directly if you have any questions concerning the project at 978-794-1792.Thank you.

Sincerely,
TEC, Inc.
*"**T**he **E**ngineering **C**orporation"*

Peter Ellison, P.E.
Director of Strategic Land Planning

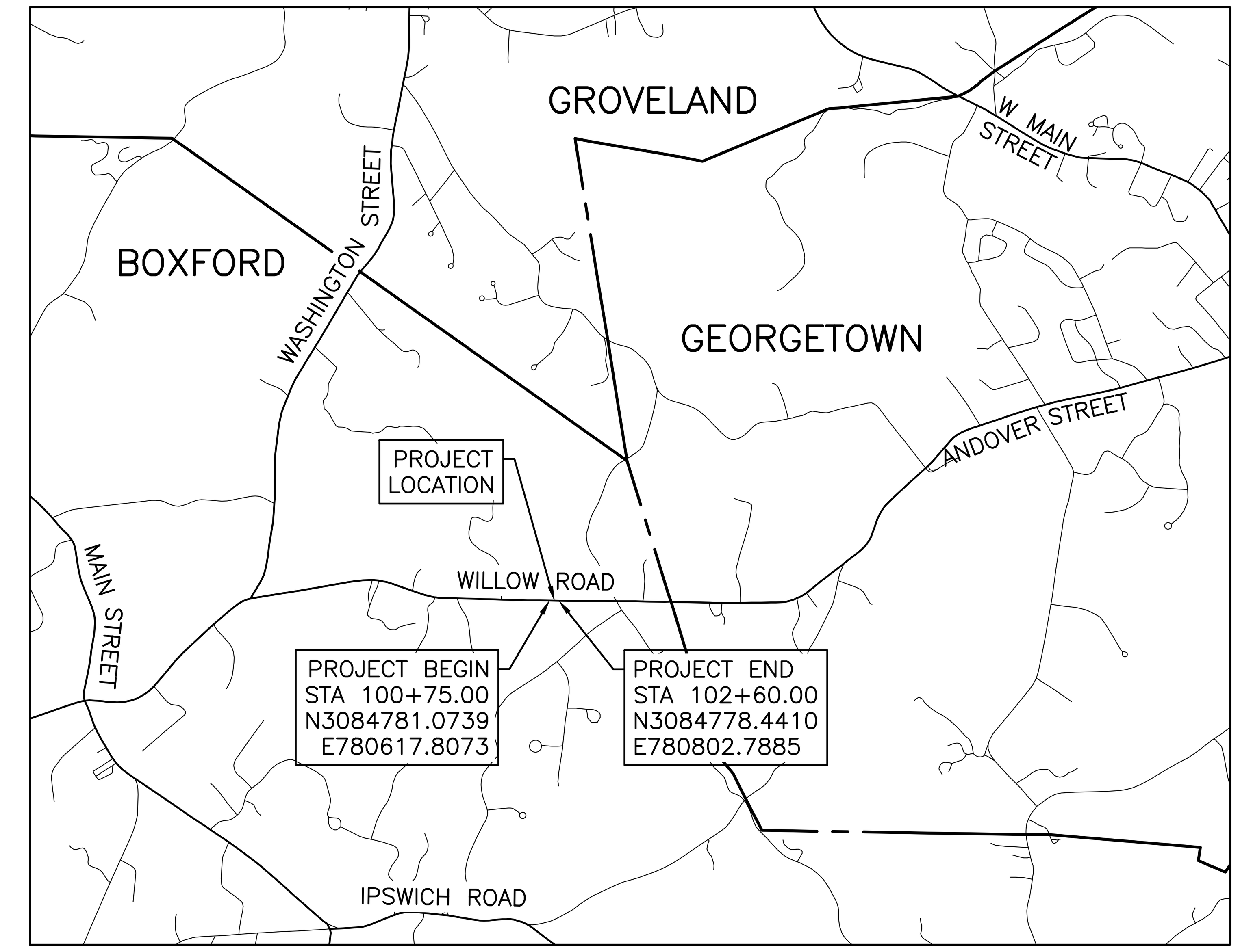
Attachment A
Revised Culvert Plans

BOXFORD, MA
WILLOW ROAD
KEY PLAN AND PROFILE
SHEET 1 OF 10



KEY PLAN

SCALE: 1" = 20'



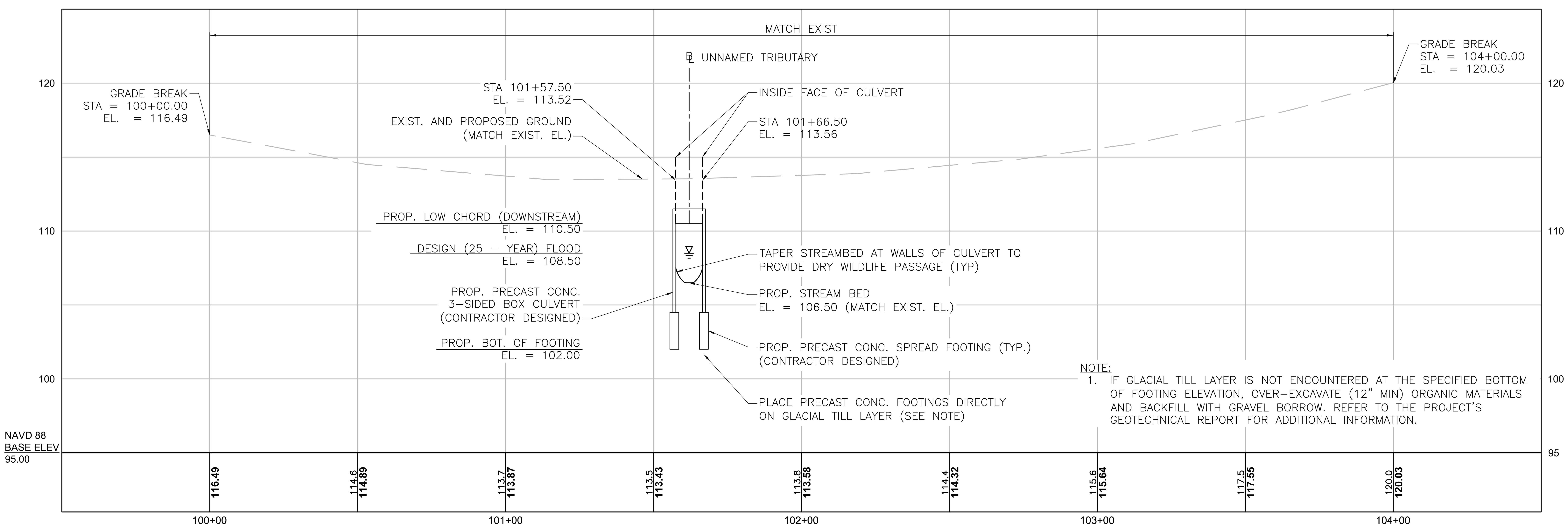
LOCUS MAP

SCALE: 1" = 2000'

NOTES:

1. A-SERIES AND B-SERIES BORDERING VEGETATIVE WETLANDS FLAGGING ARE SHOWN BASED ON FIELD SURVEY PERFORMED BY BAY COLONY GROUP ON AUGUST 12, 2020.
2. ENTIRE PROJECT LIMITS IS WITHIN THE 100-FOOT BUFFER ZONE TO BVW/INLAND BANK.

INDEX



WILLOW ROAD PROFILE

VERTICAL SCALE: 1" = 4'
HORIZONTAL SCALE: 1" = 20'

10/5/20	DEP COMMENTS	
8/12/20	UPDATED WETLAND FLAGS	
8/6/20	NOI SUBMITTAL	-
7/31/20	100% DESIGN SUBMITTAL	-
DATE	DESCRIPTION	REV #

TEC
The Engineering Corp

146 Dascomb Road, Andover, MA 01810, 978-794-1792
311 Main Street, 2nd Floor, Worcester, MA 01608, 508-868-5104
169 Ocean Blvd, Unit 3, PO Box 249, Hampton, NH 03842, 603-601-8154
www.TheEngineeringCorp.com

RECOMMENDED FOR APPROVAL

CHIEF ENGINEER | DATE

APPROVED

HIGHWAY ADMINISTRATOR | DATE

T0998_(TITLE).DWG Plotted on 5-Oct-2020 11:20 AM

BORING B-1

EXIST GROUND SURFACE
EL = 113.0±

GROUNDWATER (6/17/20)
EL = 106.0±

PROP. BOT. OF FOOTING
EL = 101.20

TEST BORING LOG

MILLER ENGINEERING & TESTING, INC.
100 Sheffield Road - Manchester, NH 03103
Ph. (603) 668-6016 - Fax: (603) 668-8641

Project: Willow Rd. Culvert Replacement, Boxford, MA
Project No: 20.097.NH
Date Start: 06-17-20
Date End: 06-17-20
Sheet 1 **of** 1
Boring No: B-1
Location: See Plan
Approx. Surface Elev:

	CASING	SAMPLER	GROUNDWATER OBSERVATIONS: Date	Depth	Casing At	Stabilization Period
Type	HSA	SS	06-17-20	7'	26'	Upon Completion
Size	2-1/4" ID	1-3/8" ID				
Hammer		140 lbs.				
Fall		30"				

Depth/ Elev.	Cas bl/ft	Sample No.	Depth Range	Pen.	Rec.	Blows 0-6"	Blows 6-12"	Blows 12-18"	Blows 18-24"	Strata Change	Sample Description	Notes
0		-	0.0-1.2	14							-: 14" Asphalt	
		S-1	1.2-2.5	16	9	7/4"	13	13			S-1: Brown, fine to coarse sand, some gravel, little silt	
		S-1A	2.5-3.0	6	4				12		S-1A: Brown, fine to coarse sand, some silt, some gravel (FILL)	
5		S-2	4.0-6.0	24	14	7	4	3	2		S-2: Brown, fine to coarse sand, some silt, little gravel (FILL)	
		S-3	6.0-8.0	24	9	2	4	4	2		S-3: Brown, fine to coarse sand, some silt, little gravel (organic roots in sample) (FILL)	
		S-4	8.0-10.0	24	4	2	2	2	3		S-4: Brown, fine to coarse sand, some silt, little gravel (FILL)	
10		S-5	10.0-11.0	12	10	6	12				S-5: Dark brown/black, peat, wet	
		S-5A	11.0-12.0	12	8			11	11		S-5A: Brown, fine sand, little silt, trace gravel, wet	(1)
15		S-6	14.0-16.0	24	14	10	17	15	21		S-6: Olive/Orange, fine to coarse sand, some silt and gravel	
20		S-7	19.0-20.5	18	13	22	34	54			S-7: Gray, silt, little clay	
25		S-8	24.0-25.3	16	13	31	47	50/4"			S-8: Gray, fine to coarse sand, some silt and angular gravel Auger Refusal at 26'	(2)
30											BORING TERMINATED AT 26 ft	

Driller: R. Marcoux
Helper: J. Donahue
Inspector: T. Young

COHESIVE CONSISTENCY (Blows/Foot): 0-2 VERY SOFT; 2-4 SOFT; 4-8 MEDIUM STIFF; 8-15 STIFF; 15-30 HARD

COHESIONLESS (Blows/Foot): 0-4 VERY LOOSE; 4-10 LOOSE; 10-30 MEDIUM DENSE; 30-50 DENSE; 50+ VERY DENSE

PROPORTIONS USED: TRACE: 0-10%; LITTLE: 10-20%; SOME: 20-35%; AND: 35-50%

NOTES: (1) A large piece of gravel was at the transition from peat to naturally occuring sand.
(2) Rock in tip of split-spoon.

REMARKS: THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES. TRANSITION MAY BE GRADUAL.
WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS.
FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

BORING B-2

EXIST GROUND SURFACE
EL = 113.1±

GROUNDWATER (6/17/20)
EL = 107.6±

PROP. BOT. OF FOOTING
EL = 102.80

TEST BORING LOG

MILLER ENGINEERING & TESTING, INC.
100 Sheffield Road - Manchester, NH 03103
Ph. (603) 668-6016 - Fax: (603) 668-8641

Project: Willow Rd. Culvert Replacement, Boxford, MA
Project No: 20.097.NH
Date Start: 06-17-20
Date End: 06-17-20
Sheet 1 **of** 1
Boring No: B-2
Location: See Plan
Approx. Surface Elev:

	CASING	SAMPLER	GROUNDWATER OBSERVATIONS: Date	Depth	Casing At	Stabilization Period
Type	HSA	SS	06-17-20	5.5'	27.5'	Upon Completion
Size	2-1/4" ID	1-3/8" ID				
Hammer		140 lbs.				
Fall		30"				

Depth/ Elev.	Cas bl/ft	Sample No.	Depth Range	Pen.	Rec.	Blows 0-6"	Blows 6-12"	Blows 12-18"	Blows 18-24"	Strata Change	Sample Description	Notes
0		-	0.0-1.2	14							-: 14" Asphalt	
		S-1	1.2-3.0	22	8	21/4"	31	17	30		S-1: Brown/Orange, fine to medium sand, some silt and gravel (FILL)	
5		S-2	4.0-6.0	24	10	7	17	13	6		S-2: Brown/Orange, fine to medium sand, some silt and gravel (FILL)	
		S-3	6.0-7.0	12	7	7	11				S-3: Brown/Orange, fine to medium sand, some silt and gravel, wet (FILL)	
		S-3A	7.0-8.0	12	8			14	5		S-3A: Dark brown/black, peat, wet	
		S-4	8.0-9.5	18	9	1	2	10			S-4: Dark brown/black, peat, wet	
10		S-4A S-5	9.5-10.0 10.0-12.0	6 24	2 13	21	25	31	15 29		S-4A: Olive/Orange (mottled), fine sand, little silt, little gravel, wet S-5: Olive/Orange (mottled), fine sand, little silt, little gravel, wet	
15		S-6	14.0-16.0	24	2	27	25	23	25		S-6: Brown, fine sand, little silt, wet	
20		S-7	19.0-21.0	24	14	22	26	21	37		S-7: Gray, fine to coarse sand, some silt and angular gravel	
25		S-8	24.0-26.0	24	12	15	15	16	26		S-8: Gray, fine to coarse sand, some silt and angular gravel Aguer Refual at 27.5	
30											BORING TERMINATED AT 27.5 ft	

Driller: R. Marcoux
Helper: J. Donahue
Inspector: T. Young

COHESIVE CONSISTENCY (Blows/Foot): 0-2 VERY SOFT; 2-4 SOFT; 4-8 MEDIUM STIFF; 8-15 STIFF; 15-30 HARD

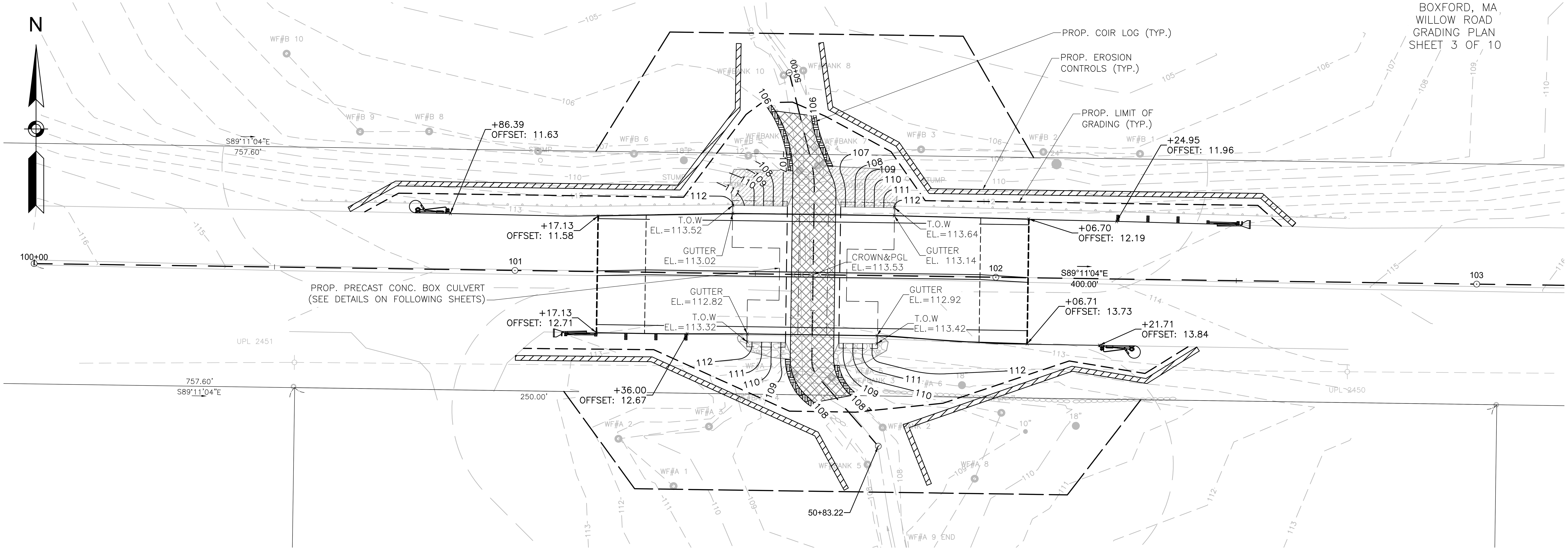
COHESIONLESS (Blows/Foot): 0-4 VERY LOOSE; 4-10 LOOSE; 10-30 MEDIUM DENSE; 30-50 DENSE; 50+ VERY DENSE

PROPORTIONS USED: TRACE: 0-10%; LITTLE: 10-20%; SOME: 20-35%; AND: 35-50%

NOTES:

REMARKS: THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES. TRANSITION MAY BE GRADUAL.
WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS.
FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

T0998_(GRADING).DWG Plotted on 30-Sep-2020 3:15 PM



GRADING PLAN

SCALE: 1" = 10'

GENERAL NOTES

DESIGN:
IN ACCORDANCE WITH THE 2017 AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS LRFD BRIDGE DESIGN SPECIFICATIONS WITH CURRENT INTERIM SPECIFICATIONS THROUGH 2019 FOR HL-93 LOADING.

BENCHMARKS:

MAG NAIL SET 1' UP	500	501	502
IN POLE 180/82	N: 3084761.976	N: 3084804.870	N: 3084792.046
EL = 115.00 (NAVD88)	E: 780674.338	E: 780247.102	E: 780914.956
	EL: 112.470	EL: 122.830	EL: 117.958

ELEVATIONS ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988.

SCALES:
SCALES NOTED ON THE PLANS ARE NOT APPLICABLE TO REDUCED SIZE PRINTS. DIVIDE SCALES BY TWO FOR HALF-SIZE PRINTS (A3).

UNSUITABLE MATERIAL:
ALL UNSUITABLE MATERIAL SHALL BE REMOVED WITHIN THE LIMITS OF THE FOUNDATIONS OF THE STRUCTURE, AS DIRECTED BY THE ENGINEER.

REINFORCEMENT:
REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M 31 GRADE 60 EPOXY COATED. UNLESS OTHERWISE NOTED ON THE CONSTRUCTION DRAWINGS, ALL BARS SHALL BE LAPPED AS FOLLOWS:

MODIFICATION CONDITION	#4 BARS	#5 BARS
1. NONE	21"	26"
2. 12" OF CONCRETE BELOW BARS	29"	36"
3. COATED BARS, COVER<3db, OR CLEAR SPACING<6db	31"	39"
4. COATED BARS, ALL OTHER CASES	25"	31"
5. CONDITION 2. AND 3.	35"	44"
6. CONDITION 2. AND 4.	34"	43"

IF THE ABOVE BARS ARE SPACED 6" OR MORE ON CENTER, THE LAP LENGTH SHALL BE 80% OF THE LAP LENGTH GIVEN ABOVE. ALL OTHER BARS SHALL BE LAPPED AS SHOWN ON THE CONSTRUCTION DRAWINGS.

PRECAST ELEMENTS:
THE FABRICATOR IS RESPONSIBLE FOR THE DESIGN AND INSTALLATION OF LIFT HOOKS FOR ALL PRECAST ELEMENTS. UNDER NO CIRCUMSTANCES WILL THE REBAR ELEMENTS SHOWN ON THE PLANS BE USED TO LIFT THE PRECAST ELEMENTS. FOR ADDITIONAL REQUIREMENTS, REFER TO THE "PRECAST CONCRETE ELEMENTS" PORTION OF ITEM 995.1 IN THE SPECIAL PROVISIONS.

PRECAST CONCRETE:
5000 PSI, 3/4 IN, 685 HP: CULVERT, HEADWALL, AND FOOTINGS.

TRAFFIC:
THE BRIDGE WILL BE CLOSED TO VEHICULAR TRAFFIC DURING ALL PHASES OF DEMOLITION AND CONSTRUCTION. VEHICULAR TRAFFIC WILL BE DETOURED AS SHOWN ON THE PLANS.

UTILITIES:
DURING CONSTRUCTION, THE CONTRACTOR SHALL LOCATE AND PROTECT FROM DAMAGE ALL UTILITIES THAT ARE TO REMAIN. ALL EXISTING UTILITY POLES AND OVERHEAD WIRES SHALL BE LEFT IN PLACE DURING CONSTRUCTION.

COIR LOGS:
WHILE GRADING IS TAKING PLACE, NO COIR LOGS WILL BE PLACED. UPON COMPLETION OF GRADING, COIR LOGS SHALL BE PLACED AS SHOWN.

CONTROL OF WATER SYSTEM:
CONTROL OF WATER SYSTEM SHALL BE DESIGNED BY THE CONTRACTOR AND SUBMITTED TO THE ENGINEER FOR APPROVAL, PER ITEM 991.1. CONTROL OF WATER SYSTEM SHALL BE DESIGNED USING THE 2-YEAR DESIGN FLOOD EVENT ELEVATION OF 108.0. APPROXIMATE LIMITS SHOWN ON THIS PLAN ARE CONCEPTUAL AND THE FINAL LOCATION SHALL BE DETERMINED BY THE CONTRACTOR.

PAVEMENT MARKINGS:
ALL PAVEMENT MARKINGS SHALL BE THERMOPLASTIC AND SHALL SMOOTHLY TRANSITION INTO THE EXISTING PAVEMENT MARKINGS AT THE PROJECT LIMITS. A MINOR (NEGLIGIBLE) VARIATION IN THE SPECIFIED LANE WIDTHS IS PERMISSIBLE IN ORDER TO MAKE A SMOOTH TRANSITION FROM PROPOSED TO EXISTING PAVEMENT MARKINGS.

HYDRAULIC DESIGN DATA

DRAINAGE AREA:	0.19 SQUARE MILES
DESIGN FLOOD DISCHARGE:	31 CUBIC FEET PER SECOND
DESIGN FLOOD FREQUENCY:	25 YEARS
DESIGN FLOOD VELOCITY:	4.8 FEET PER SECOND
DESIGN FLOOD ELEVATION:	108.50 FEET
LOWER CHORD ELEVATION:	109.70 FEET

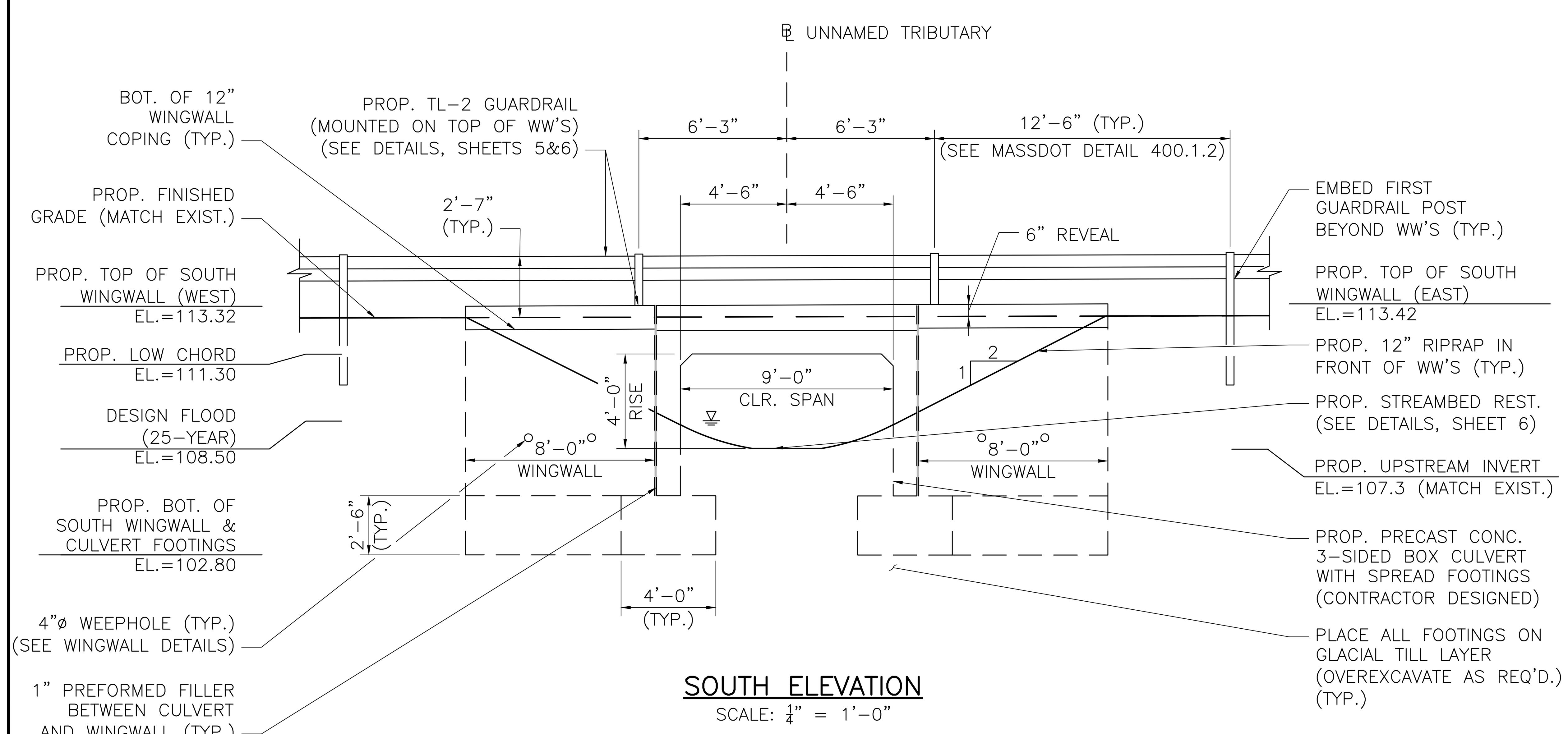
BOXFORD, MA
WILLOW ROAD
PLAN AND ELEVATIONS
SHEET 4 OF 10

BRIDGE PLAN

SCALE: 1" = 5'-0"

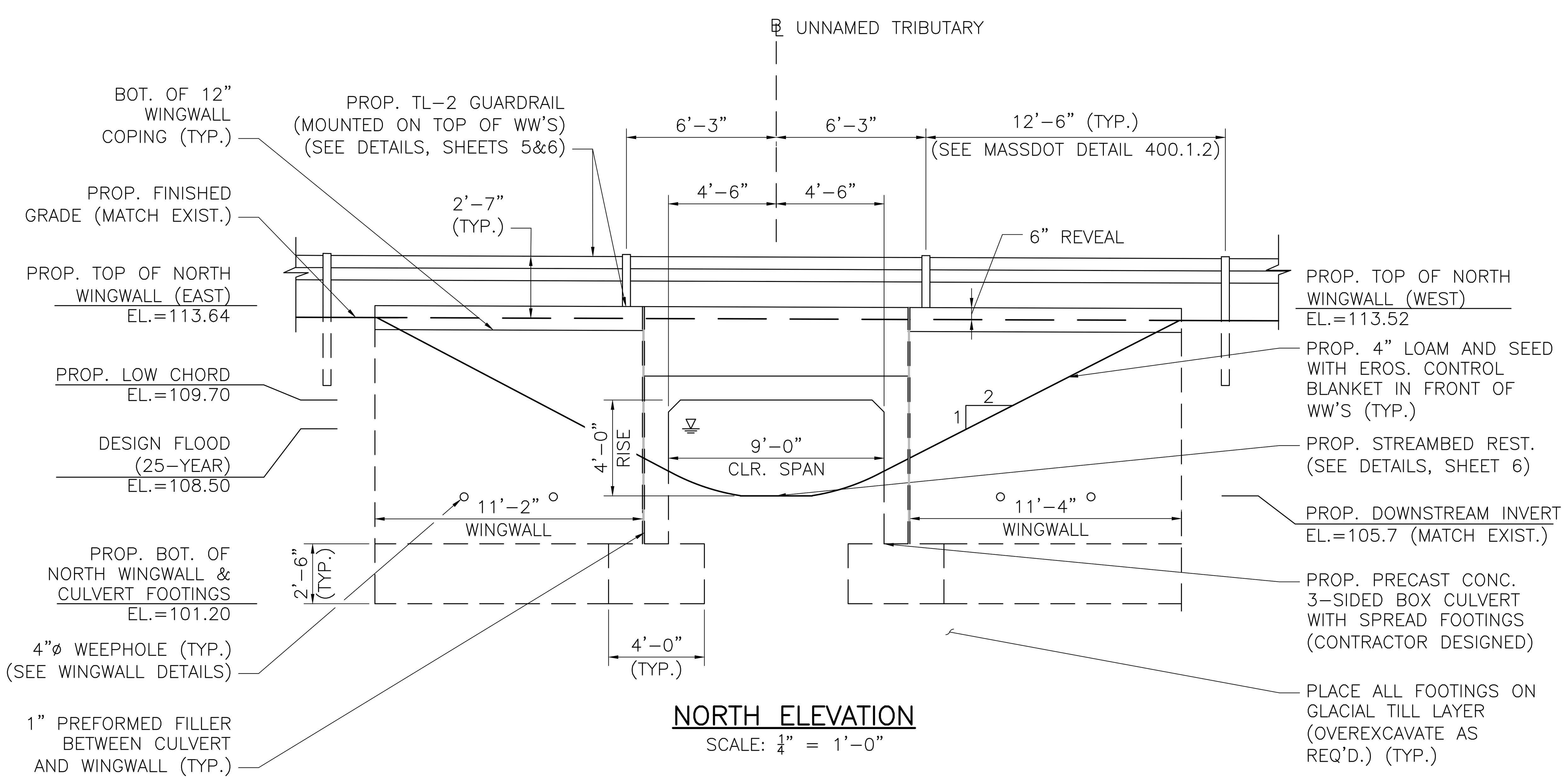
PRECAST CONCRETE CULVERT WORKING POINTS		
WORKING POINT	STATION	OFFSET (ft)
W.P.#1	STA. 101+56.50	14.17 LT
W.P.#2	STA. 101+67.50	14.17 LT
W.P.#3	STA. 101+56.50	14.17 RT
W.P.#4	STA. 101+67.50	14.17 RT

NOTE:
CULVERT FOOTING DIMENSIONS SHOWN ON THIS SHEET ARE CONCEPTUAL AND SHALL BE DESIGNED BY THE CONTRACTOR. REFER TO"PRECAST CONCRETE CULVERT NOTES" ON SHEET 5 FOR ADDITIONAL INFORMATION



SOUTH ELEVATION

SCALE: ¼" = 1'-0"



NORTH ELEVATION

SCALE: ¼" = 1'-0"

BOXFORD, MA
WILLOW ROAD
CONSTRUCTION DETAILS

TRANSVERSE SECTION NOTES:

1. EXISTING CULVERT AND HEADWALLS NOT SHOWN FOR CLARITY. CONTRACTOR IS RESPONSIBLE FOR DEMOLITION OF ALL EXISTING CULVERT INFRASTRUCTURE.
2. THE PROPOSED ROADWAY ELEVATIONS AND CROSS SLOPES ARE INTENDED TO MATCH THE EXISTING CONDITIONS. CONTRACTOR SHALL SMOOTHLY TRANSITION ALL PROPOSED ELEMENTS INTO THE EXISTING APPROACHES AND EMBANKMENT SLOPES.

PAVEMENT NOTES:

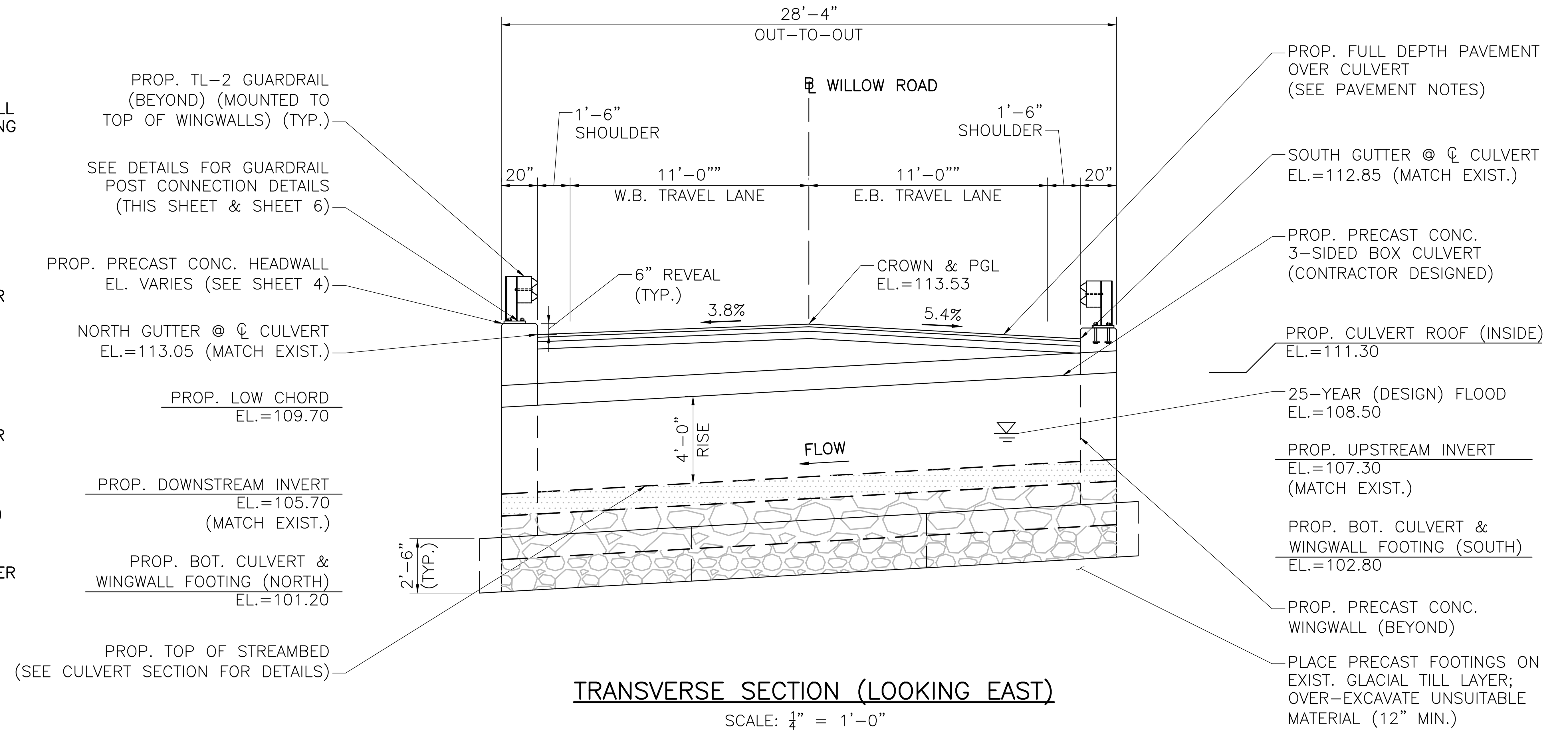
PROPOSED FULL DEPTH RECONSTRUCTION:
SURFACE: 1½" SUPERPAVE SURFACE COURSE 12.5 (SSC – 12.5) OVER
2½" SUPERPAVE INTERMEDIATE COURSE 19.0 (SIC – 19.0)

SUBBASE: 4" DENSE GRADED CRUSHED STONE OVER
8" GRAVEL BORROW, TYPE B

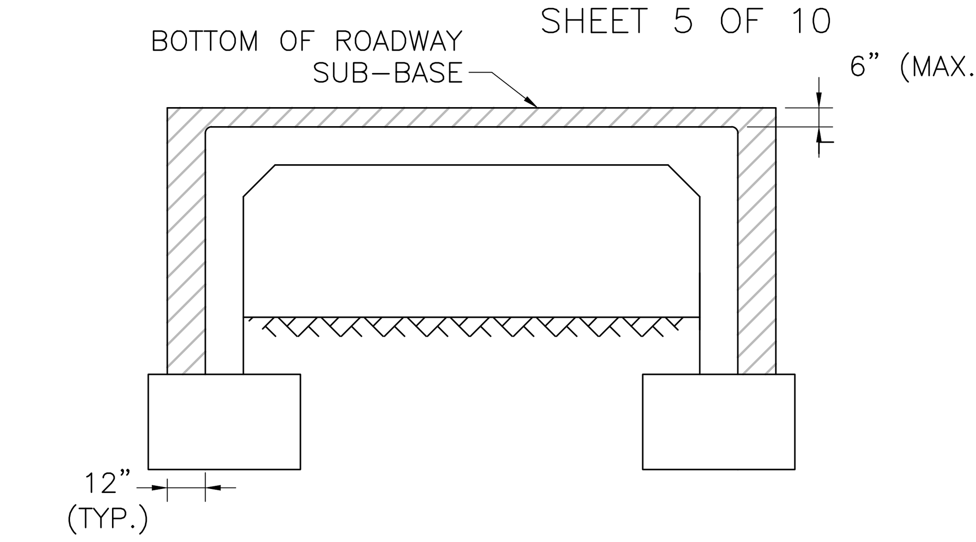
PROPOSED FULL DEPTH RECONSTRUCTION (OVER CULVERT):
SURFACE: 1½" SUPERPAVE SURFACE COURSE 12.5 (SSC – 12.5) OVER
2½" SUPERPAVE INTERMEDIATE COURSE 19.0 (SIC – 19.0)

SUBBASE: 4" DENSE GRADED CRUSHED STONE OVER
VARIABLE DEPTH GRAVEL BORROW, TYPE B (UP TO 1'-7"±)

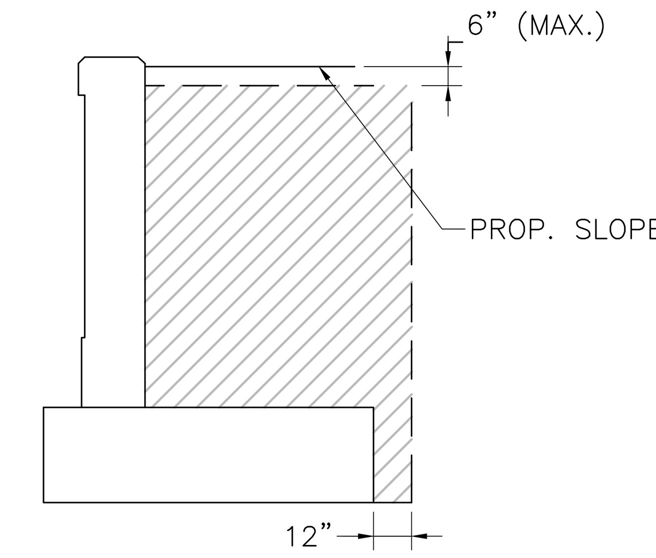
PROPOSED PAVEMENT MILLING TRANSITION:
SURFACE: 1 ½" SUPERPAVE SURFACE COURSE 12.5 (SSC – 12.5) OVER
2 ½" SUPERPAVE INTERMEDIATE COURSE 19.0 (SIC – 19.0)



TRANSVERSE SECTION (LOOKING EAST)
SCALE: ¼" = 1'-0"



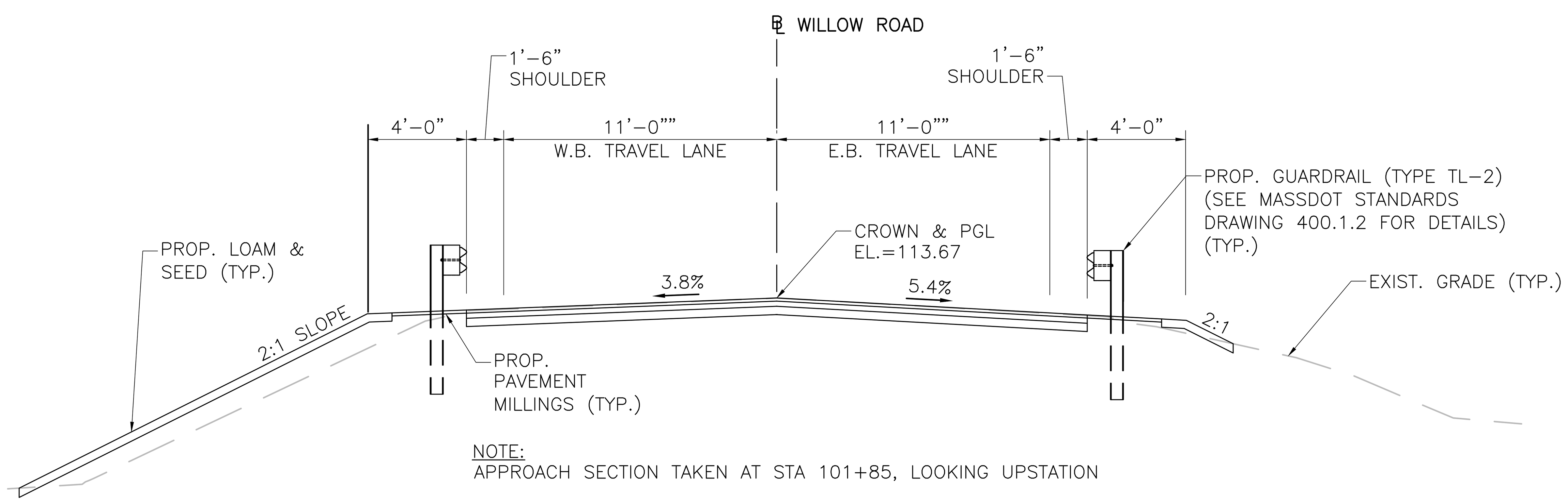
PRECAST CONCRETE BOX CULVERT



PRECAST CONCRETE WINGWALLS

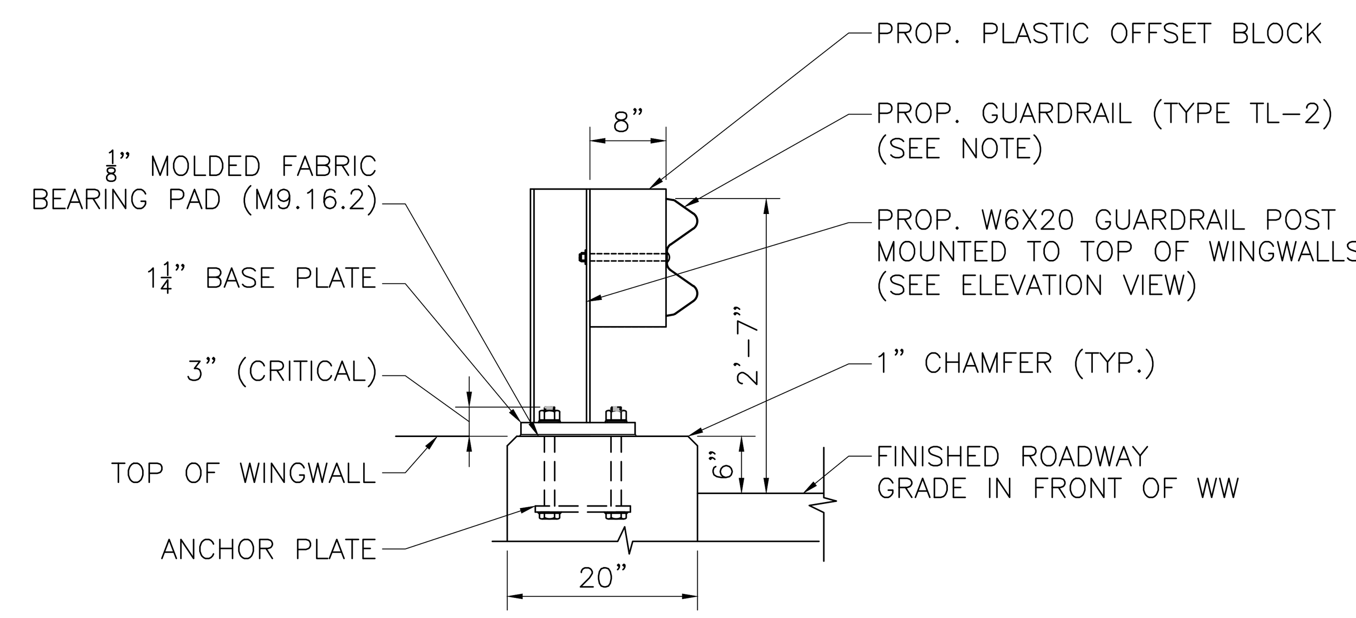
NOTES:
1. HATCHED AREAS INDICATE THE LIMIT OF GRAVEL BORROW FOR BACKFILLING STRUCTURES AND PIPES.
2. THE BACKFILL PLACED AROUND THE STRUCTURE SHALL BE DEPOSITED ON BOTH SIDES TO APPROXIMATELY THE SAME ELEVATION AT THE SAME TIME.

LIMITS OF GRAVEL BORROW FOR BACKFILLING STRUCTURES AND PIPES
SCALE: ¾" = 1'-0"



NOTE:
APPROACH SECTION TAKEN AT STA 101+85, LOOKING UPSTATION

TYPICAL APPROACH SECTION
SCALE: N.T.S.



NOTES:
1. REFER TO MASSDOT CONST. STD. DETAILS 400.1.2 AND 400.1.3 FOR ADDITIONAL INFORMATION REGARDING THE W-BEAM GUARDRAIL AND HARDWARE DETAILS.
2. SEE BASE PLATE, ANCHOR PLATE AND ANCHOR BOLT DETAILS ON SHEET 6 FOR ADDITIONAL INFORMATION.

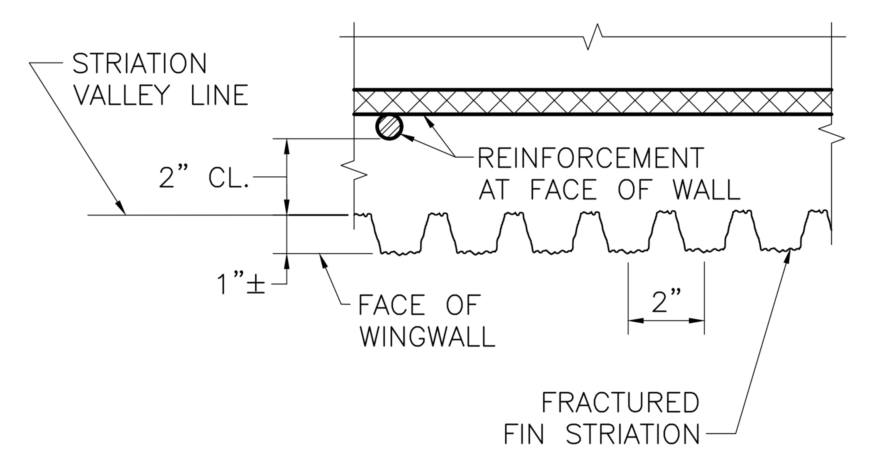
GUARDRAIL SECTION THROUGH TOP OF WINGWALL
SCALE: ¾" = 1'-0"

HANDRAIL AND GUARDRAIL NOTES:

1. ALL STEEL CONNECTING BOLTS AND FASTENERS FOR HANDRAIL POSTS, RAILINGS, NUTS AND WASHERS SHALL BE GALVANIZED IN ACCORDANCE WITH AASHTO M232.
2. GUARDRAIL BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M270 GRADE 50.
3. ANCHOR BOLTS SHALL BE SET WITH TEMPLATES. THE NUT SECURING THE POST BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AND ADDITIONAL 1/8 TURN AFTER STEEL IS IN PLACE.
4. POST FLANGE WELD DOES NOT REQUIRE MAGNETIC PARTICLE TESTING. WELD SHALL BE BACK-GOUGED ON BACK SIDE EXCEPT AT WEB. WELD IS THE SAME ON BOTH FLANGES.
5. W-BEAM DETAILS, EXCEPT ATTACHMENT TO WINGWALLS, SHALL BE STANDARD RELEVANT TO MASSDOT CONSTRUCTION STANDARDS.

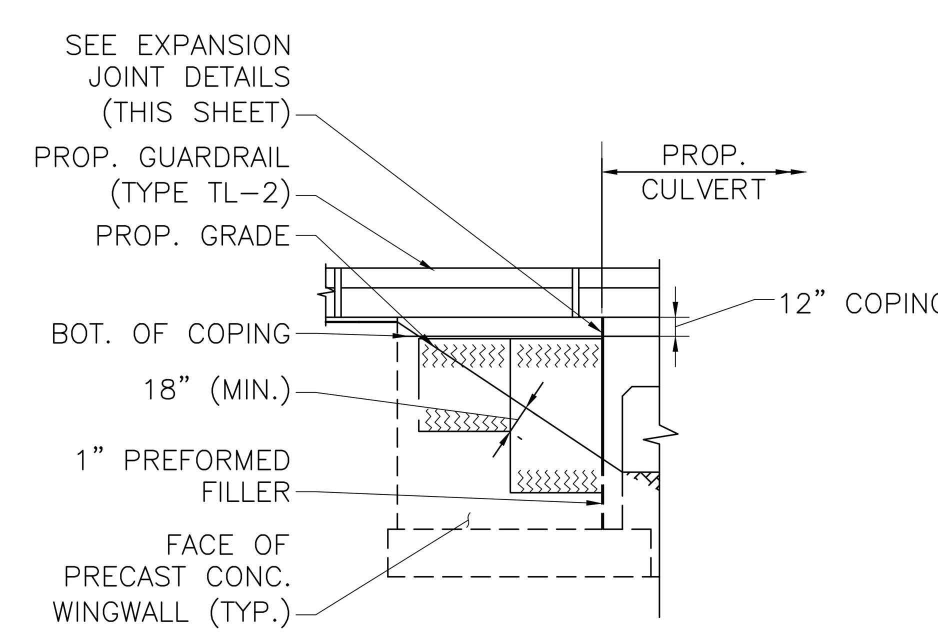
PRECAST CONCRETE CULVERT NOTES:

1. CONTRACTOR SHALL SUBMIT PRECAST CONCRETE 3-SIDED BOX CULVERT AND FOOTING DESIGN CALCULATIONS AND SHOP DRAWINGS SEALED BY A PROFESSIONAL ENGINEER REGISTERED IN THE COMMONWEALTH OF MASSACHUSETTS FOR APPROVAL PRIOR TO FABRICATION. PRESCRIBED HYDRAULIC OPENING (4'X9') SHALL BE MAINTAINED.
2. IF CLOSURE POURS ARE REQUIRED AS PART OF THE FOOTING OR CULVERT DESIGN, HIGH EARLY STRENGTH CONCRETE SHALL BE UTILIZED IN ORDER TO EXPEDITE BACKFILLING OPERATIONS. ACTUAL FOOTING DIMENSIONS SHALL BE DETERMINED BY THE CONTRACTOR. ALL OTHER CULVERT AND FOOTING CONCRETE SHALL BE 5000PSI, ¾", 685 HP CEMENT CONCRETE.
3. THE CONTRACTOR SHALL APPROVE ALL ELEVATIONS AND DIMENSIONS OF THE SHOP DRAWINGS PRIOR TO FABRICATION. SHOP DRAWINGS AND CALCUALATIONS SHALL BE SUBMITTED TO THE ENGINEER FOR REVIEW AND APPROVAL PRIOR TO FABRICATION.
4. REINFORCEMENT SHALL BE PLACED WITH A MINIMUM OF 1½" COVER. TRANSVERSE REINFORCEMENT SHALL BE PLACED NORMAL TO THE ℄ OF WILLOW ROAD.
5. ALL CULVERT REINFORCEMENT SHOWN IS CONCEPTUAL FOR BIDDING PURPOSES. THE CONTRACTOR SHALL SUBMIT DESIGN CALCULATIONS AS PART OF THE SHOP DRAWINGS.
6. DESIGN SHALL BE IN ACCORDANCE WITH THE 2017 AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS WITH CURRENT INTERIM SPECIFICATIONS THROUGH 2019 AND THE MASSDOT LRFD BRIDGE MANUAL PART 1 CHAPTER 3 FOR HL-93 LOADING.
7. A FACTORED BEARING RESISTANCE OF 5.0 KSF SHALL BE USED IN THE DESIGN OF THE CULVERT (IF PLACED DIRECTLY ON THE GLACIAL TILL LATYER, AS SPECIFIED IN THE GEOTECHNICAL REPORT). THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE SUBGRADE PREPARATION SUCH THAT THE DESIGN BEARING CAPACITY SHALL BE ACHIEVED. THE CONTRACTOR SHALL NOTIFY THE ENGINEER IF THIS BEARING CAPACITY CANNOT BE MET.
8. THE CONTRACTOR SHALL BE MADE AWARE OF THE OVERHEAD WIRES ABOVE THE SOUTH GUTTERLINE. CONTRACTOR SHALL UTILIZE CONSTRUCTION TECHNIQUES TO WORK BENEATH THESE WIRES.

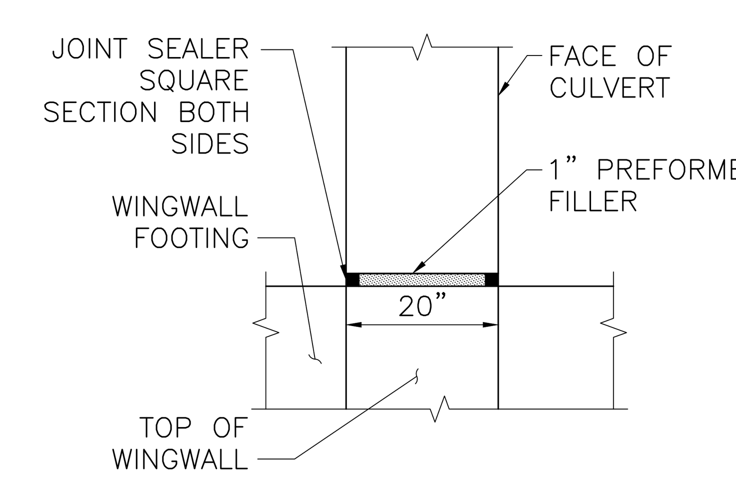


NOTES:
1. THE CONTRACTOR SHALL MAKE SURE THAT THE STRIATION FINS ARE PLUMB AND LINED UP VERTICALLY FROM PANEL TO PANEL FOR THE FULL HEIGHT OF THE WALL.
2. THE HORIZONTAL JOINT MAY BE OMITTED IF THE CONTRACTOR CAN DEMONSTRATE THAT THE FORM LINER PANELS CAN BE INSTALLED END TO END WITHOUT CREATING A VISIBLE SEAM IN THE FINAL CAST CONCRETE.
3. STRIATION DETAILS SHALL ONLY BE INCORPORATED ON THE WINGWALLS.

TYPICAL STRIATION DETAIL
SCALE: 3" = 1'-0"



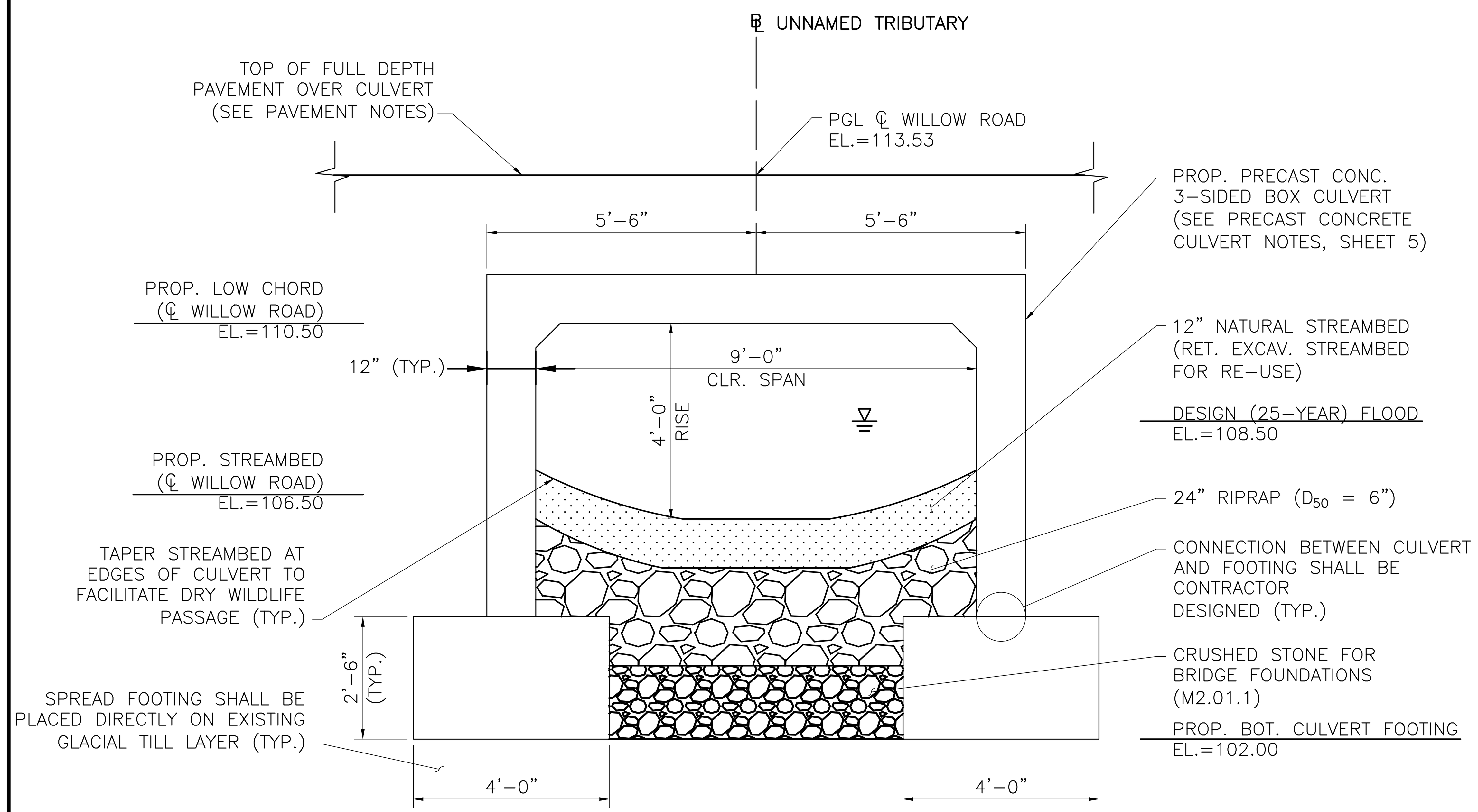
WINGWALL STRIATION – ELEVATION
SCALE: N.T.S.



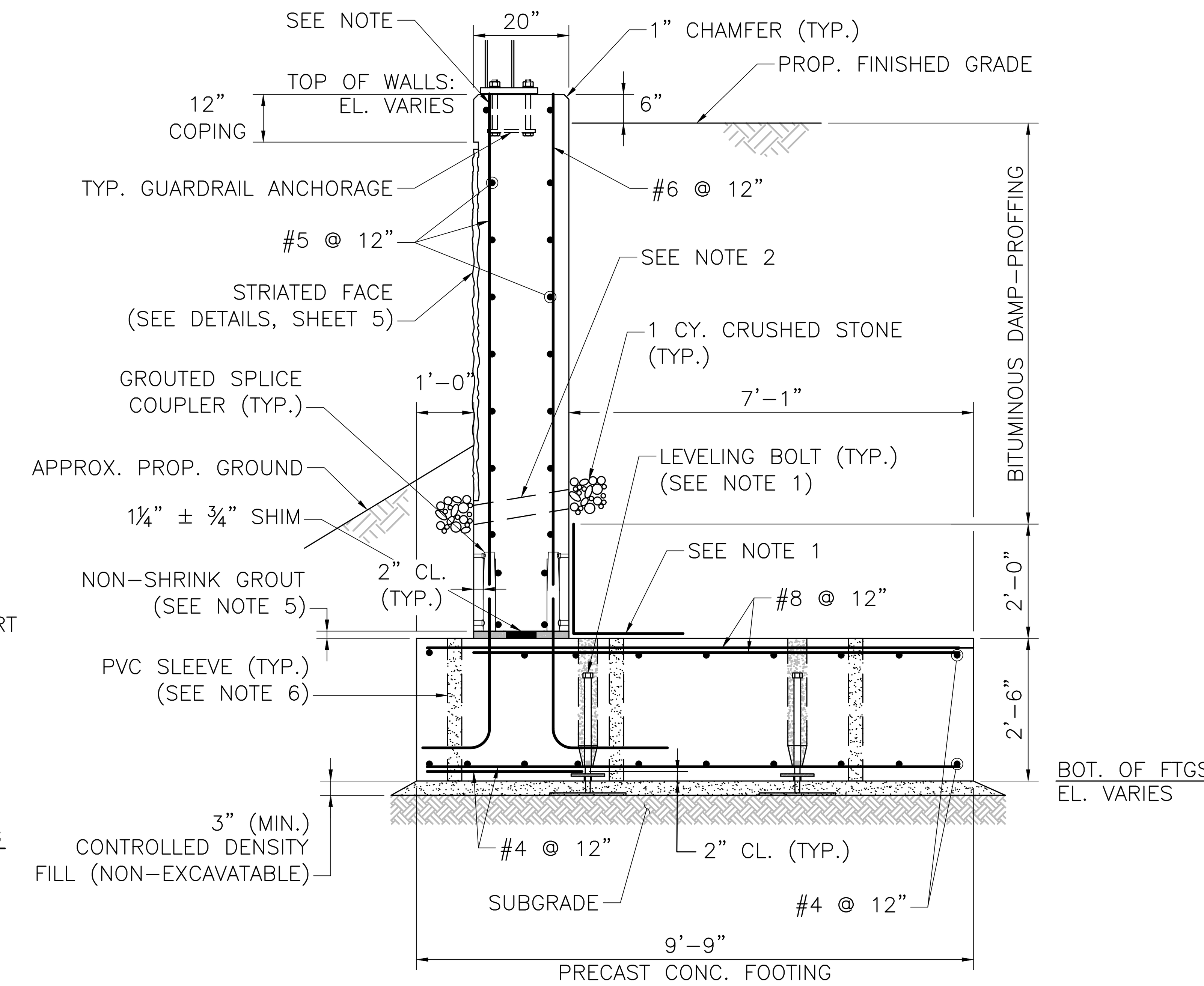
NOTE:
REINFORCEMENT NOT SHOWN FOR CLARITY.

EXPANSION JOINT DETAILS
SCALE: 1" = 1'-0"

T0996_(DETAILS).DWG Plotted on 15-Sep-2020 1:13 PM

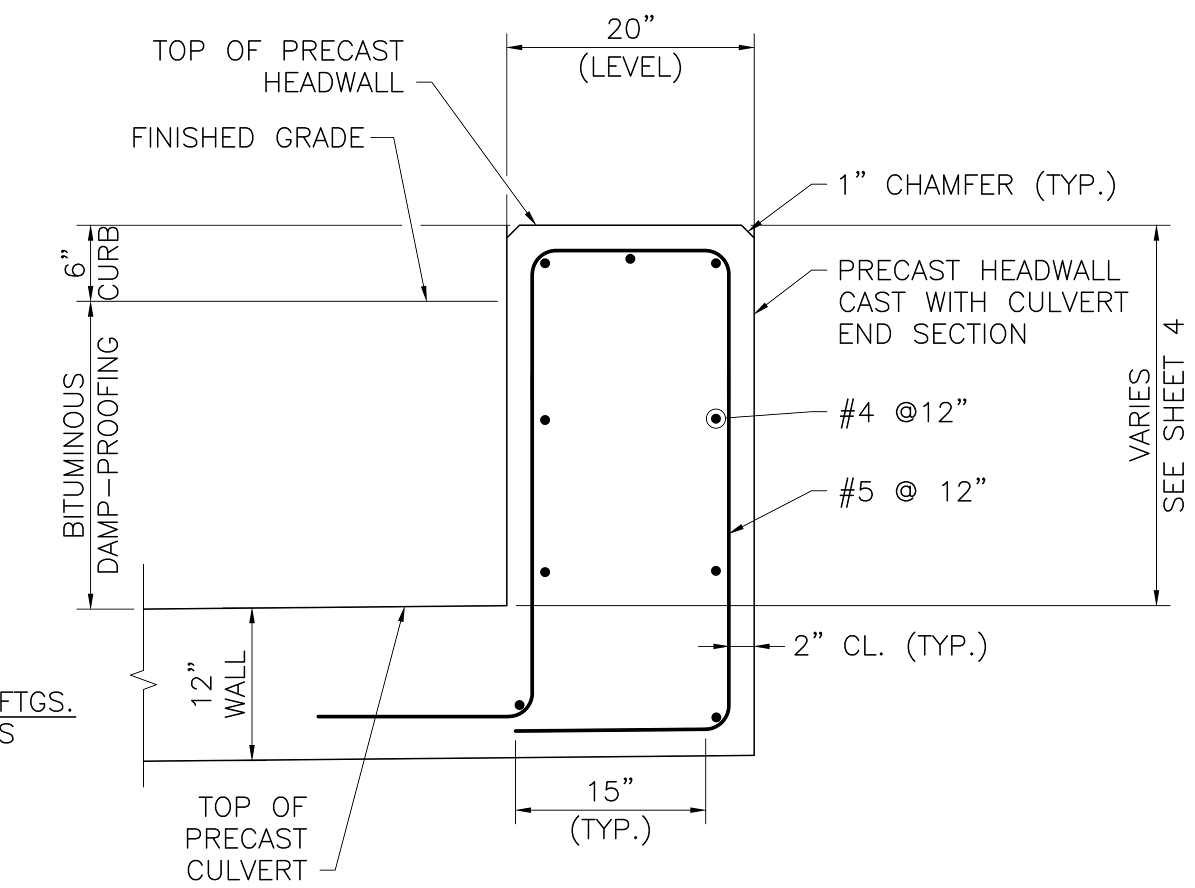


TYPICAL CULVERT SECTION (AT ℄ WILLOW ROAD)
SCALE: ½" = 1'-0"



NOTE:
PRECASTER TO COORDINATE LOCATION OF REINFORCEMENT WITH GUARDRAIL ANCHORAGE.

TYPICAL WINGWALL SECTION
SCALE: ½" = 1'-0"



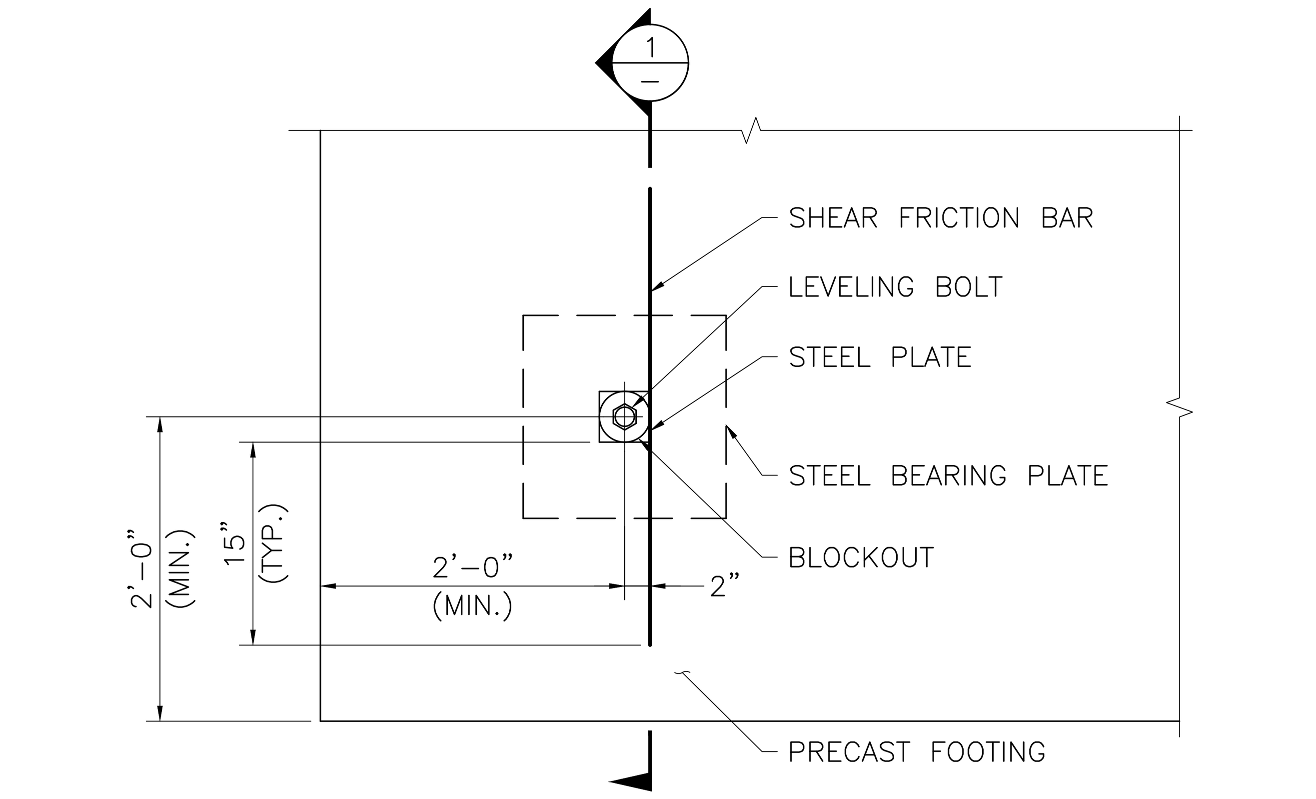
TYPICAL SECTION THROUGH PRECAST HEADWALL
SCALE: 1" = 1'-0"

WINGWALL CONSTRUCTION NOTES:

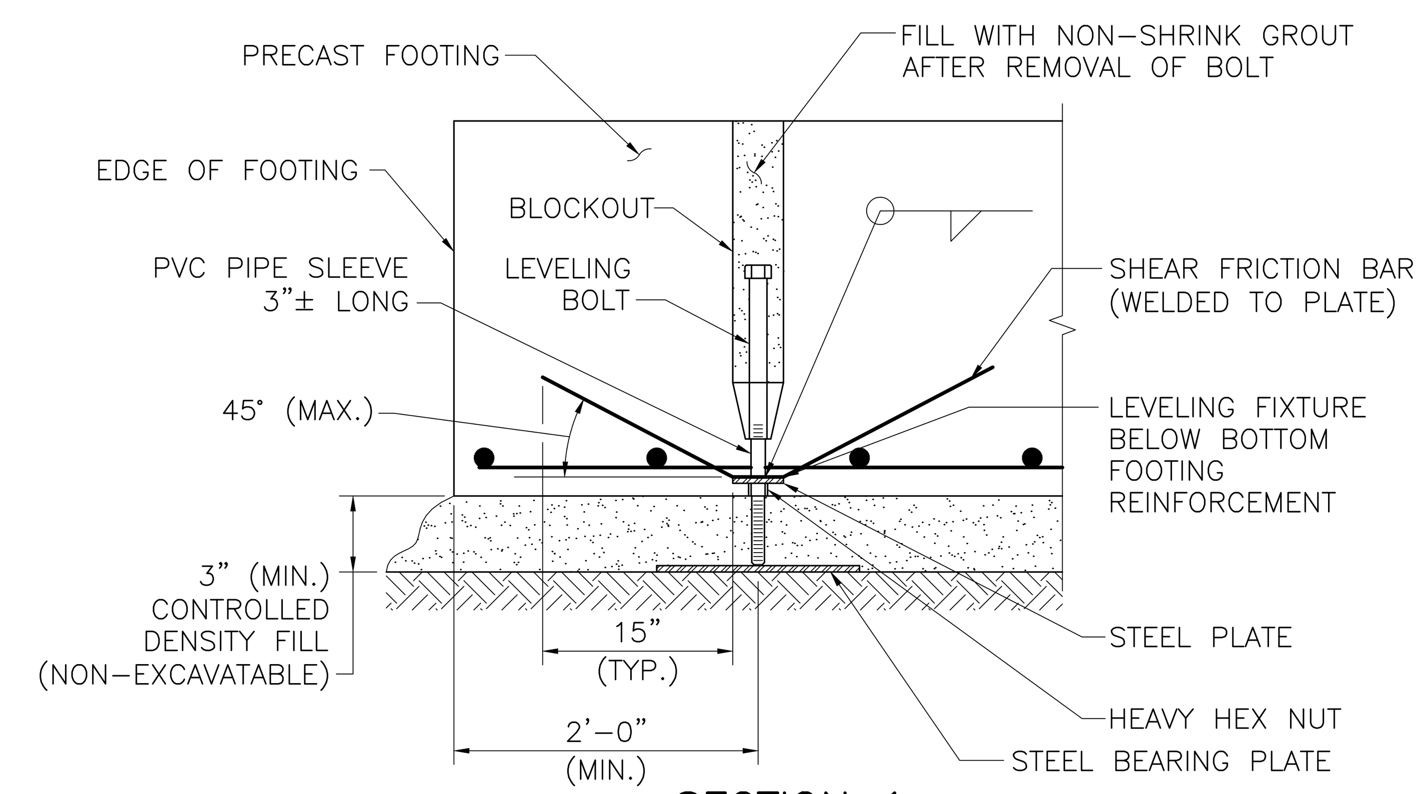
1. MEMBRANE WATERPROOFING OR OTHER WATERPROOFING PROTECTIVE COURSE, MIN. 2" THICK AS SPECIFIED IN MASSDOT STANDARD SPECIFICATIONS.
2. 4"ø WEEP HOLES AT THIRD POINTS OF WALL LENGTHS (JUST ABOVE PROTECTIVE COURSE). PROVIDE 1 CUBIC YARD OF CRUSHED STONE AT EACH END OF WEEP HOLE.
3. ALL WINGWALL CONCRETE SHALL BE 5000 PSI, ¾ IN, 685 HP CEMENT CONCRETE.
4. THE FACTORED BEARING PRESSURE = 3.75 KSF, PER AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS STRENGTH 1 LOAD COMBINATION. FACTORED BEARING RESISTANCE = 5.0 KSF. FACTORED BEARING RESISTANCE IS THE PRODUCT OF THE NOMINAL BEARING RESISTANCE AND A RESISTANCE FACTOR OF 0.45.
5. PRE-BED PRECAST ELEMENT WITH NON-SHRINK GROUT WITH THICKNESS MORE THAN SHIM STACK.
6. THE CONTRACTOR SHALL DETERMINE THE SIZE AND SPACING OF THE GROUT PORTS BASED ON THE CDF'S FLOW PROPERTIES AND THE SIZE OF THE FOOTING.

LEVELING BOLT ASSEMBLY NOTES:

1. THE LEVELING BOLT ASSEMBLY SHOWN IS SCHEMATIC. DESIGN OF THE LEVELING BOLT ASSEMBLY SHALL BE PERFORMED BY THE CONTRACTOR AND SUBMITTED WITH THE ASSEMBLY PLAN TO THE ENGINEER FOR APPROVAL.
2. BOLT SHALL BE REMOVED AFTER THE CONTROLLED DENSITY FILL (NON-EXCAVATABLE) HAS SET.
3. STEEL PLATES SHALL BE AASHTO M 270 GRADE 36 UNCOATED STEEL.
4. BOLTS SHALL BE H.S. AASHTO M 164 AND UNCOATED.
5. REINFORCEMENT SHALL BE WELDABLE LOW-ALLOW ASTM A 706 BARS.
6. GREASE OF OIL NUT AND BOLT THREADS TO FACILITATE LEVELING AND REMOVAL.

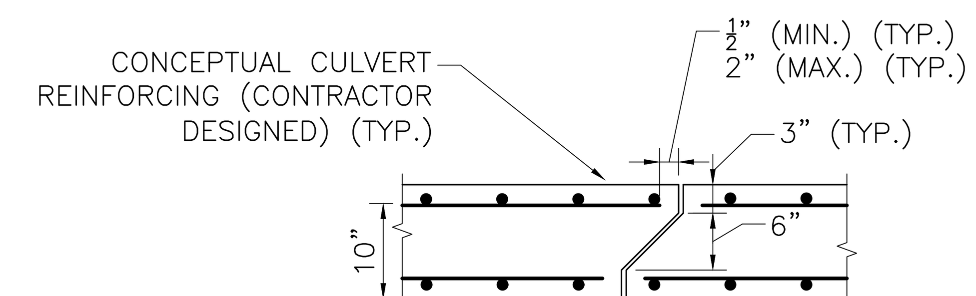


PLAN
SCALE: 1" = 1'-0"



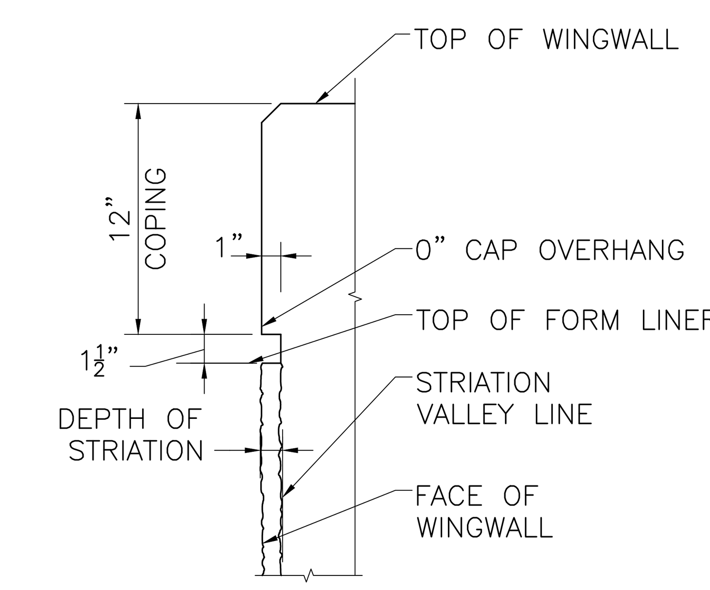
SECTION 1
SCALE: 1" = 1'-0"

LEVELING BOLT ASSEMBLY

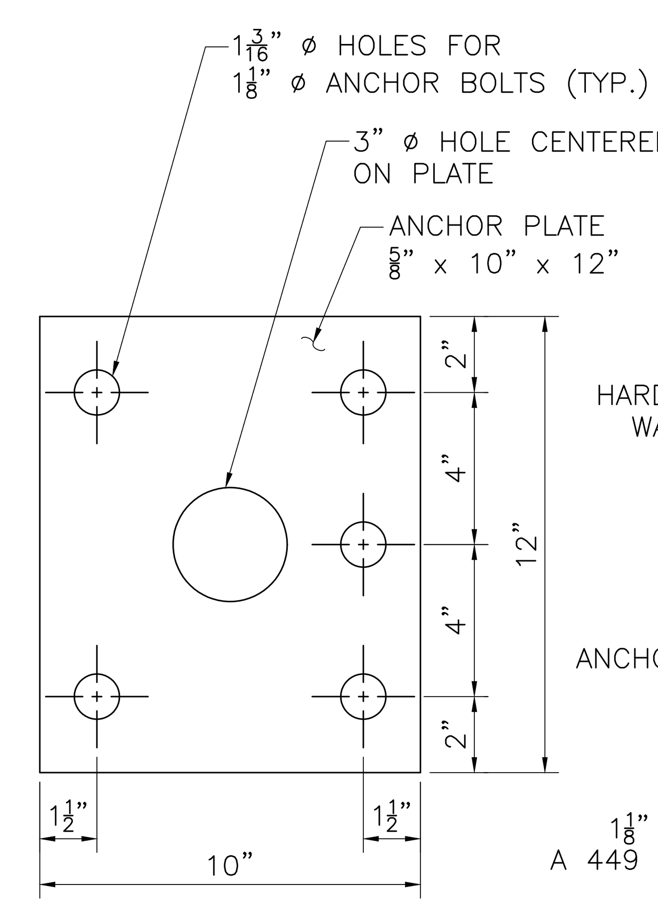


NOTE:
JOINT DIMENSIONS ARE CONCEPTUAL AND SHALL BE CONFIRMED BY THE PRECASTER.

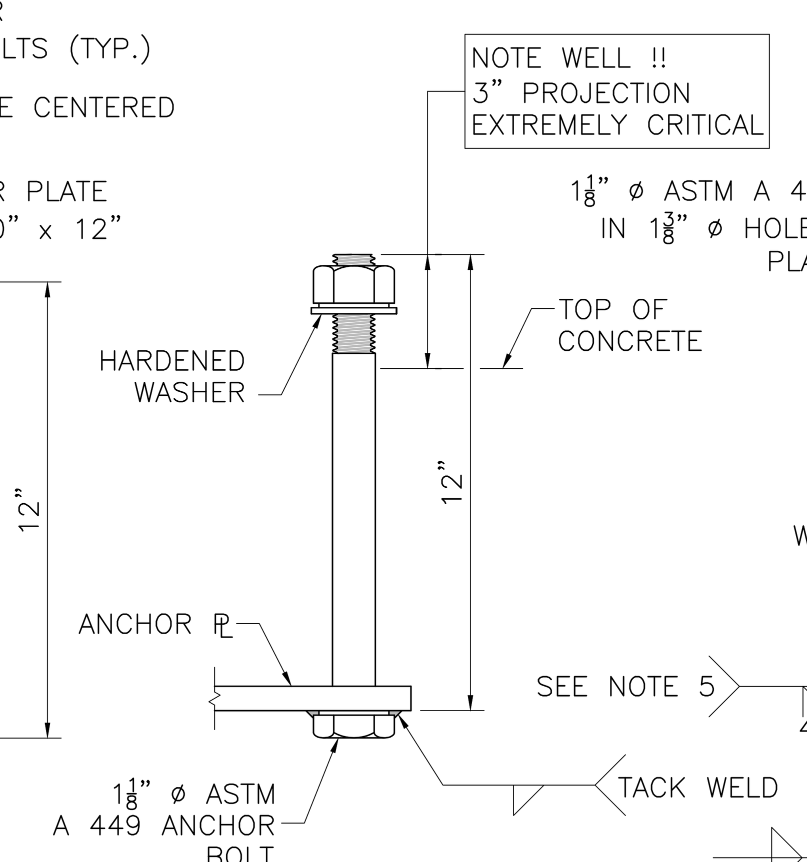
CULVERT JOINT DETAIL
SCALE: ¾" = 1'-0"



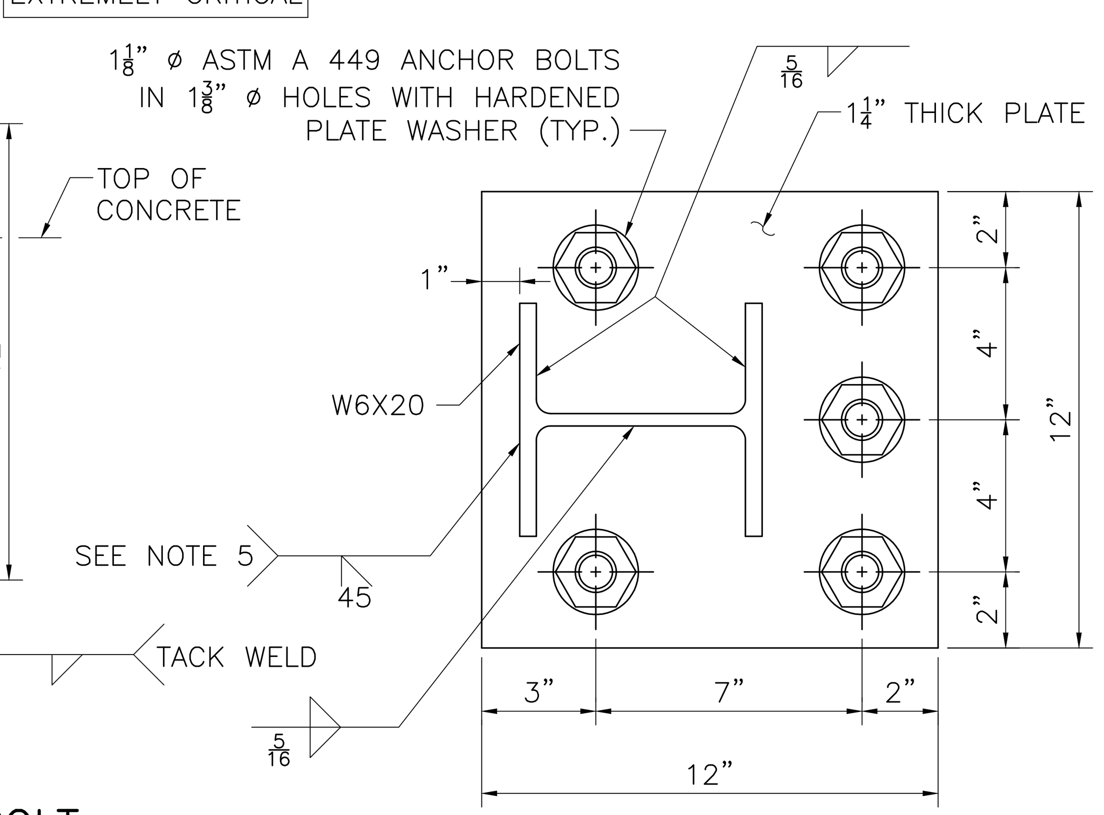
TOP OF WINGWALL DETAIL
SCALE: N.T.S.



ANCHOR PLATE
SCALE: 3" = 1'-0"



ANCHOR BOLT
SCALE: 3" = 1'-0"



BASE PLATE
SCALE: 3" = 1'-0"

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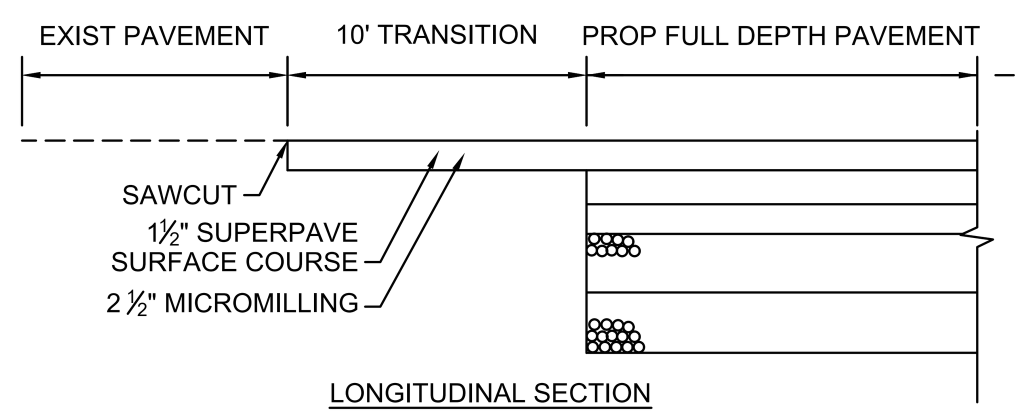
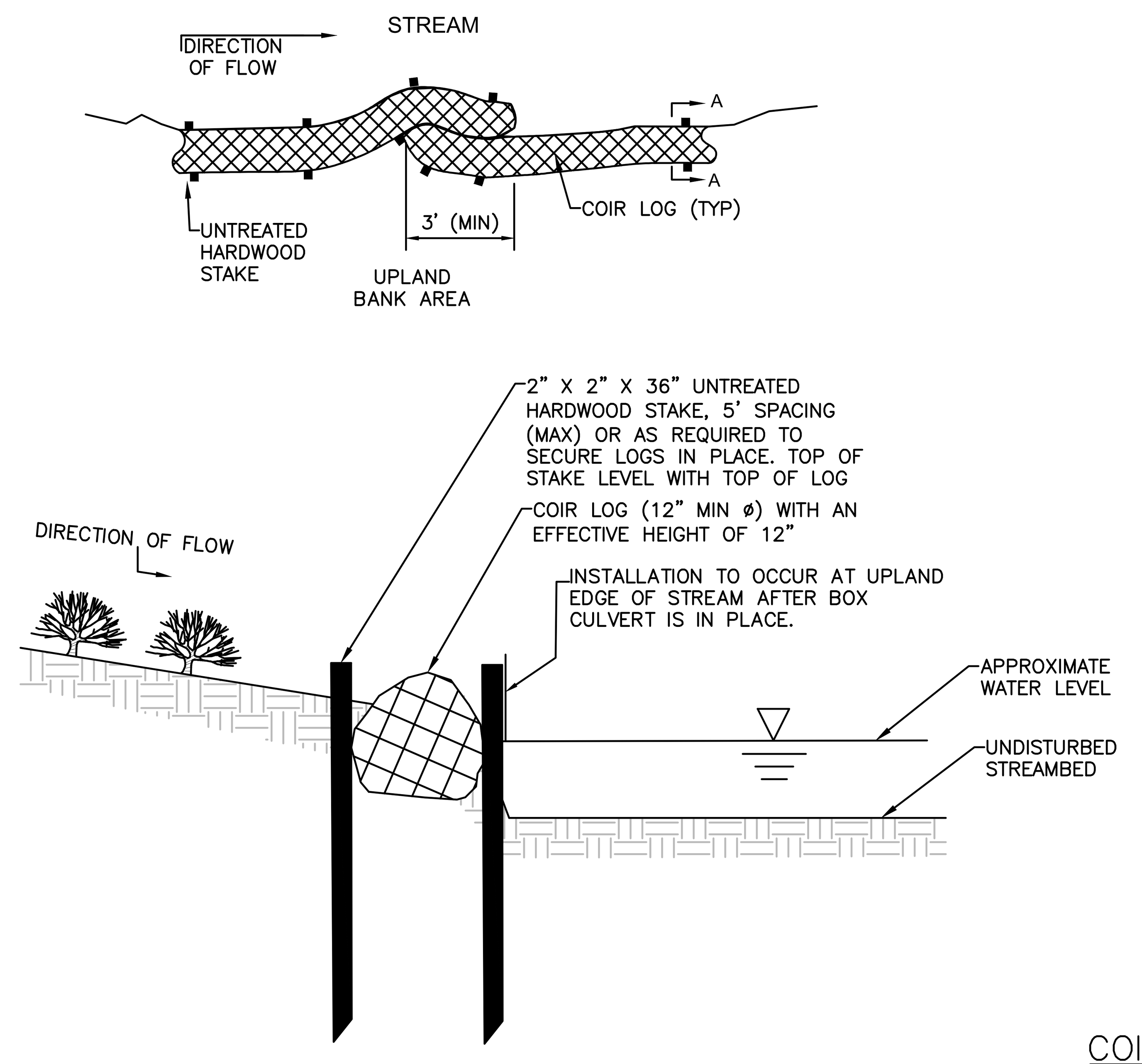
T0998_(DETAILS).DWG Plotted on 1-Oct-2020 12:10 PM



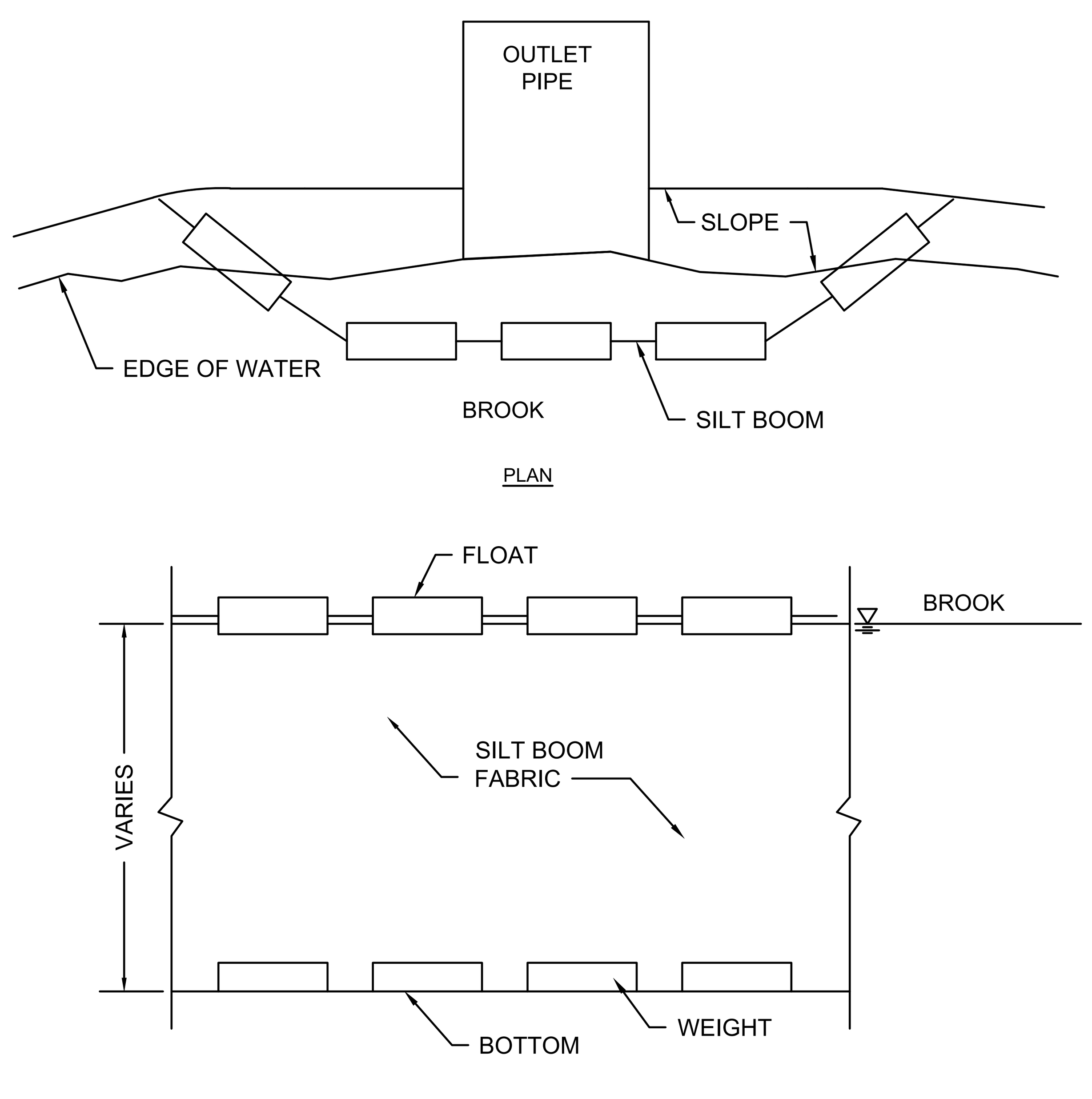
FULL DEPTH PAVEMENT TRANSITION
N.T.S.



NOTES:

1. PROVIDE A MINIMUM TUBE DIAMETER OF 12" FOR SLOPES UP TO 50 FEET IN LENGTH WITH A SLOPE RATIO OF 3H:1V OR STEEPER. LONGER SLOPES OF 3H:1V MAY REQUIRE LARGER TUBE DIAMETER OR ADDITIONAL COURSING OF FILTER TUBES TO CREATE A FILTER BERM. REFER TO MANUFACTURER'S RECOMMENDATIONS FOR SITUATIONS WITH LONGER OR STEEPER SLOPES.
2. INSTALL LOGS ALONG CONTOURS AND AT EDGE OF STREAM.
3. CONFIGURE LOGS AROUND EXISTING SITE FEATURES TO MINIMIZE SITE DISTURBANCE AND MAXIMIZE CAPTURE AREA OF STORMWATER RUN-OFF.
4. TUBES FOR COIR LOGS SHALL BE JUTE MESH OR APPROVED BIODEGRADABLE MATERIAL. ADDITIONAL LOGS SHALL BE USED AT THE DIRECTION OF THE ENGINEER.
5. TAMP COIR LOGS IN PLACE TO ENSURE GOOD CONTACT WITH SOIL SURFACE. IT IS NOT NECESSARY TO TRENCH LOGS INTO EXISTING GRADE.
6. WHEN STAKING IS NOT POSSIBLE, SUCH AS WHEN TUBES MUST BE PLACED ON A ROCKY SURFACE, HEAVY CONCRETE OR CINDER BLOCKS CAN BE USED BEHIND LOGS UP TO 5 FT. APART OR AS REQUIRED TO SECURE TUBES IN PLACE. DO NOT PUNCTURE LOGS WITH STAKES.
7. PROVIDE A 3' MINIMUM OVERLAP AT ENDS OF LOGS TO JOIN IN A CONTINUOUS BARRIER AND MINIMIZE UNIMPEDED FLOW. STAKE JOINING LOGS SNUGLY AGAINST EACH OTHER TO PREVENT UNFILTERED FLOW BETWEEN THEM.
8. SECURE ENDS OF LOGS WITH STAKES SPACED 18" APART. DO NOT PUNCTURE LOGS WITH STAKES.
9. UPON COMPLETION OF PROJECT, ALL LOGS SHALL STAY IN PLACE AND NATURALLY BIODEGRADE OVERTIME.

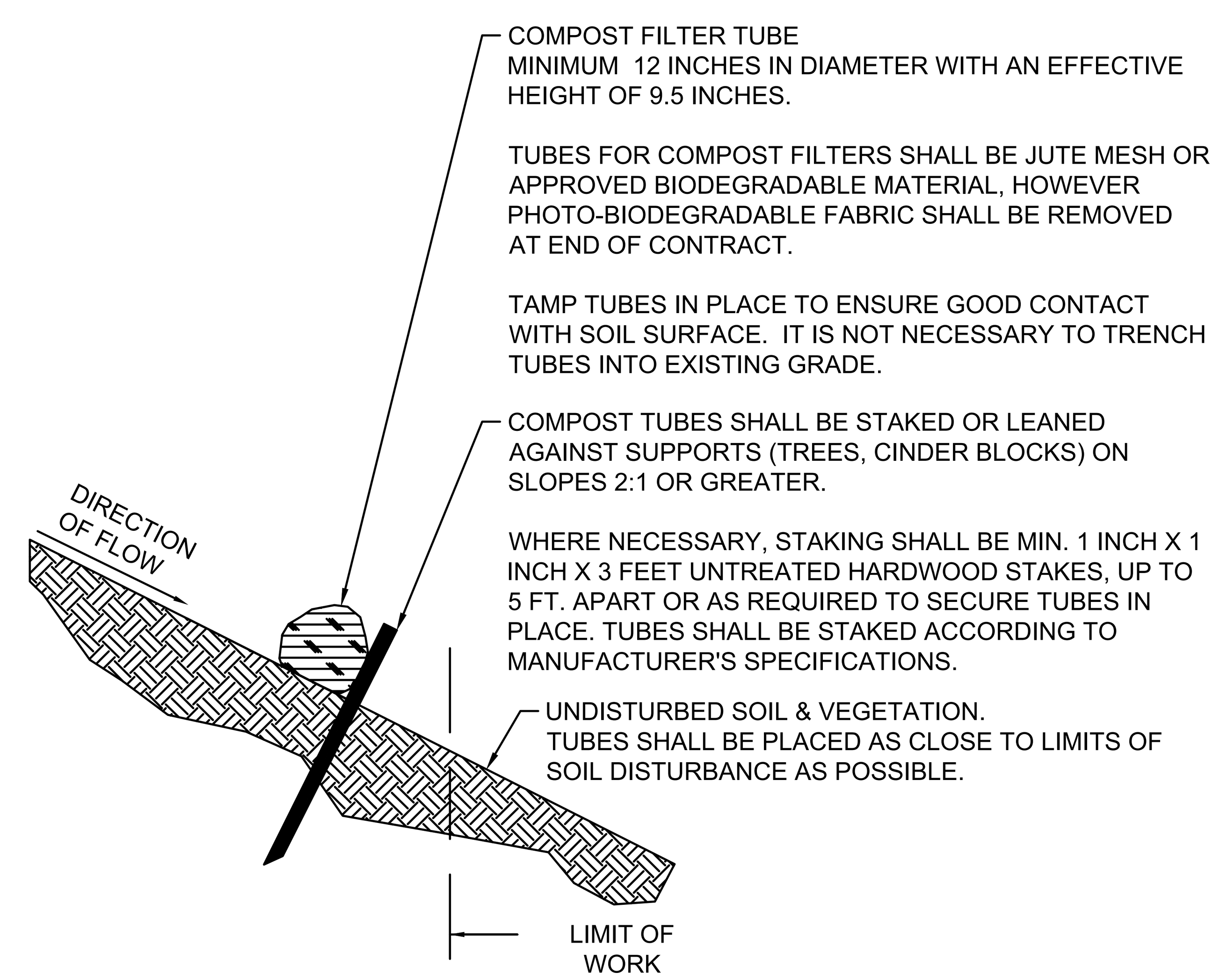
COIR LOG
N.T.S.

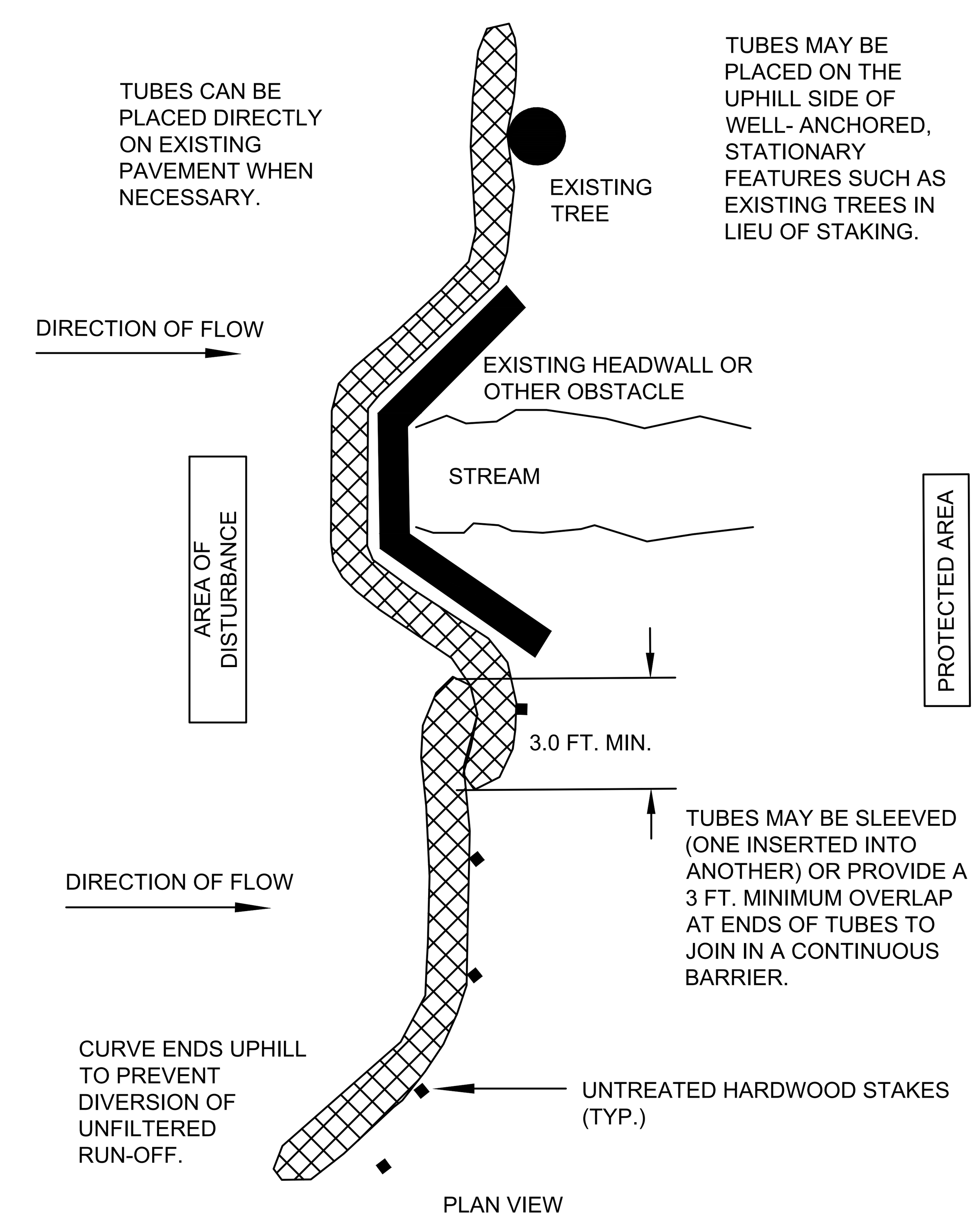


SILT BOOM FENCE
N.T.S.

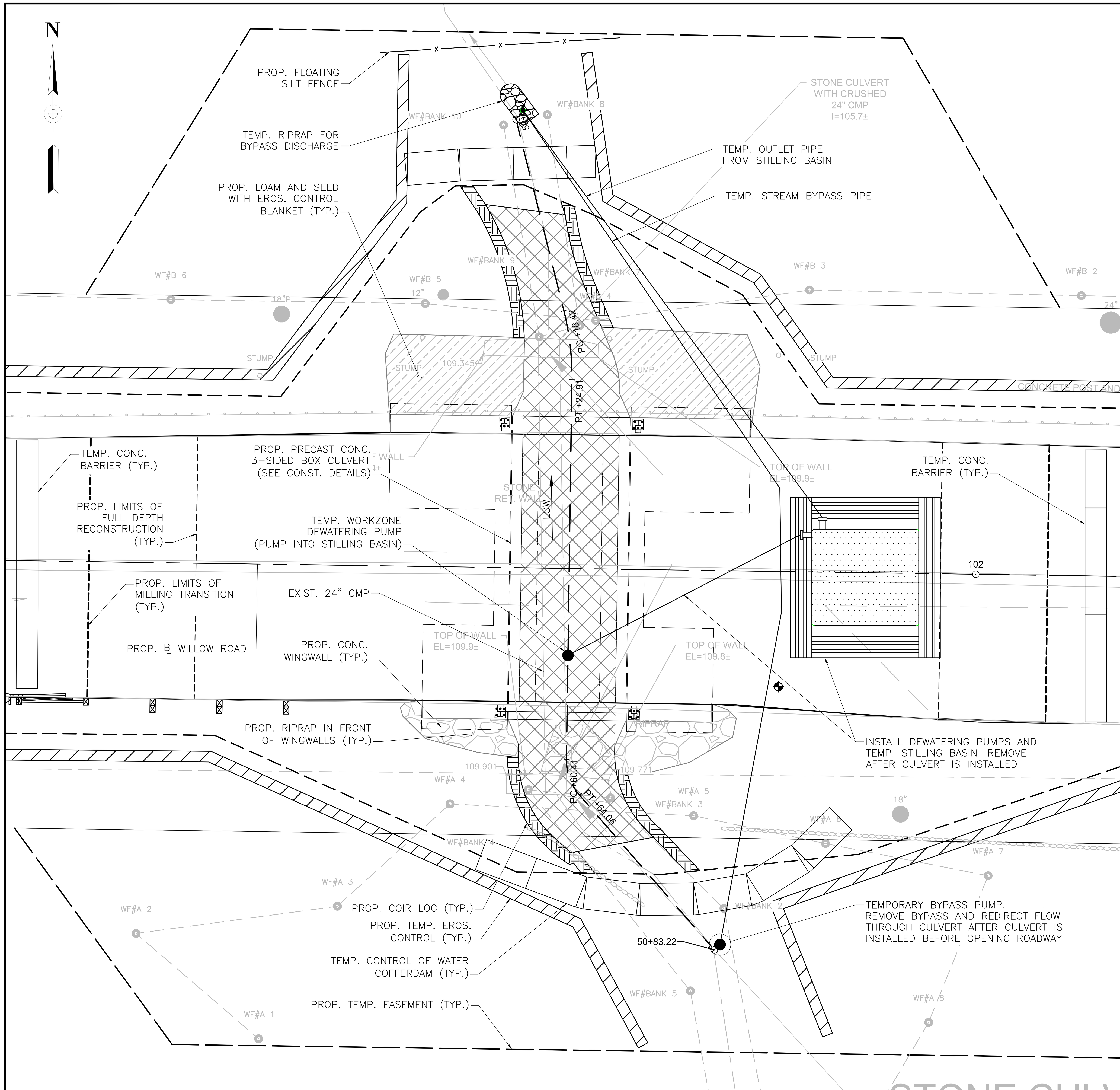
NOTES:

1. PROVIDE A MINIMUM TUBE DIAMETER OF 12 INCHES FOR SLOPES UP TO 50 FEET IN LENGTH WITH A SLOPE RATIO OF 3H:1V OR STEEPER. LONGER SLOPES OF 3H:1V MAY REQUIRE LARGER TUBE DIAMETER OR ADDITIONAL COURSING OF FILTER TUBES TO CREATE A FILTER BERM. REFER TO MANUFACTURER'S RECOMMENDATIONS FOR SITUATIONS WITH LONGER OR STEEPER SLOPES.
2. INSTALL TUBES ALONG CONTOURS AND PERPENDICULAR TO SHEET OR CONCENTRATED FLOW.
3. TUBE LOCATION MAY BE SHIFTED TO ADJUST TO LANDSCAPE FEATURES, BUT SHALL PROTECT UNDISTURBED AREA AND VEGETATION TO MAXIMUM EXTENT POSSIBLE.
4. DO NOT INSTALL IN PERENNIAL, EPHEMERAL OR INTERMITTENT STREAMS.
5. ADDITIONAL TUBES SHALL BE USED AT THE DIRECTION OF THE ENGINEER.
6. ADDITIONAL STAKING SHALL BE USED AT THE DIRECTION OF THE ENGINEER.





COMPOST FILTER TUBE
N.T.S.



CONTROL OF WATER PLAN
SCALE: 1" = 5'

CONTROL OF WATER NOTES

1. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN OF THE CONTROL OF WATER (C.O.W.) SYSTEM AND SHALL SUBMIT A C.O.W. PLAN TO THE ENGINEER FOR APPROVAL. THE C.O.W. SYSTEM SHOWN IS CONCEPTUAL ONLY. THE C.O.W. SYSTEM SHALL BE DESIGNED TO WITHSTAND THE 2-YEAR FLOOD ELEVATION OF 108.0 (NAVD).
2. WILLOW ROAD SHALL BE CLOSED TO VEHICULAR AND PEDESTRIAN TRAFFIC AT THE BRIDGE CROSSING PRIOR TO BEGINNING EXCAVATION. DETOUR SIGNAGE WILL BE INSTALLED IN ACCORDANCE WITH THE MUTCD AND THE TEMPORARY TRAFFIC CONTROL PLANS INCLUDED IN THESE CONSTRUCTION DRAWINGS.
3. C.O.W. SYSTEM SHALL BE INSPECTED DAILY FOR WATER LEAKS OR EROSION AND REPAIRS PROCEDURES SHALL BE IMPLEMENTED ACCORDINGLY.
4. THE CONSTRUCTION SEQUENCE WITH REGARDS TO THE C.O.W. SYSTEM SHALL BE AS FOLLOWS:

4.1. CLOSE THE ROADWAY TO VEHICULAR AND PEDESTRIAN TRAFFIC AT THE BRIDGE CROSSING.

4.2. INSTALL EROSION CONTROLS: TEMPORARY EROSION CONTROL AROUND PROJECT LIMITS TO PROTECT THE UNNAMED TRIBUTARY FROM WORK ZONE SEDIMENT; FLOATING SILT FENCE IN THE UNNAMED TRIBUTARY DOWNSTREAM OF THE PROJECT LIMITS TO TRAP ANY FLOATING DEBRIS/SILT THAT MAY ENTER THE TRIBUTARY.

4.3. INSTALL C.O.W. COFFERDAMS, BYPASS PUMPS, DEWATERING PUMPS, AND TEMPORARY STILLING BASIN.

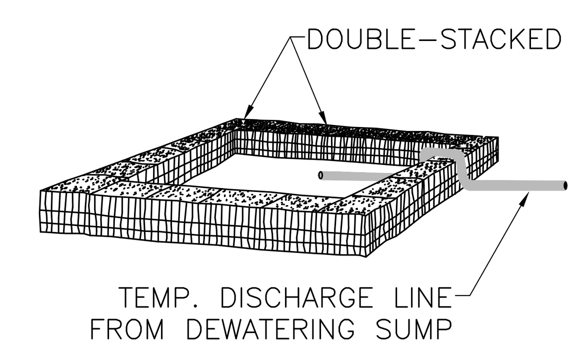
4.4. PLACE TEMPORARY RIPRAP AT OUTLET FOR BYPASS DISCHARGE.

4.5. DEWATER THE WORK AREA PRIOR TO (AND THROUGHOUT) EXCAVATION TO FACILITATE INSTALLING THE CULVERT, AND WINGWALLS IN THE DRY CONDITION. ALL DEWATERING FLOW SHALL PASS THROUGH THE STILLING BASIN TO REMOVE SEDIMENT PRIOR TO DEPOSITING BACK INTO THE STREAM.

4.6. INSTALL THE THREE-SIDED BOX CULVERT AND WINGWALLS. RESTORE THE STREAMBED IN ACCORDANCE WITH THESE PLANS. INSTALL RIPRAP EMBANKMENT AND LOAM AND SEED WITH EROSION CONTROL BLANKET IN FRONT OF THE WINGWALLS. INSTALL COIR LOGS ALONG UPLAND SIDES OF STREAMBED.

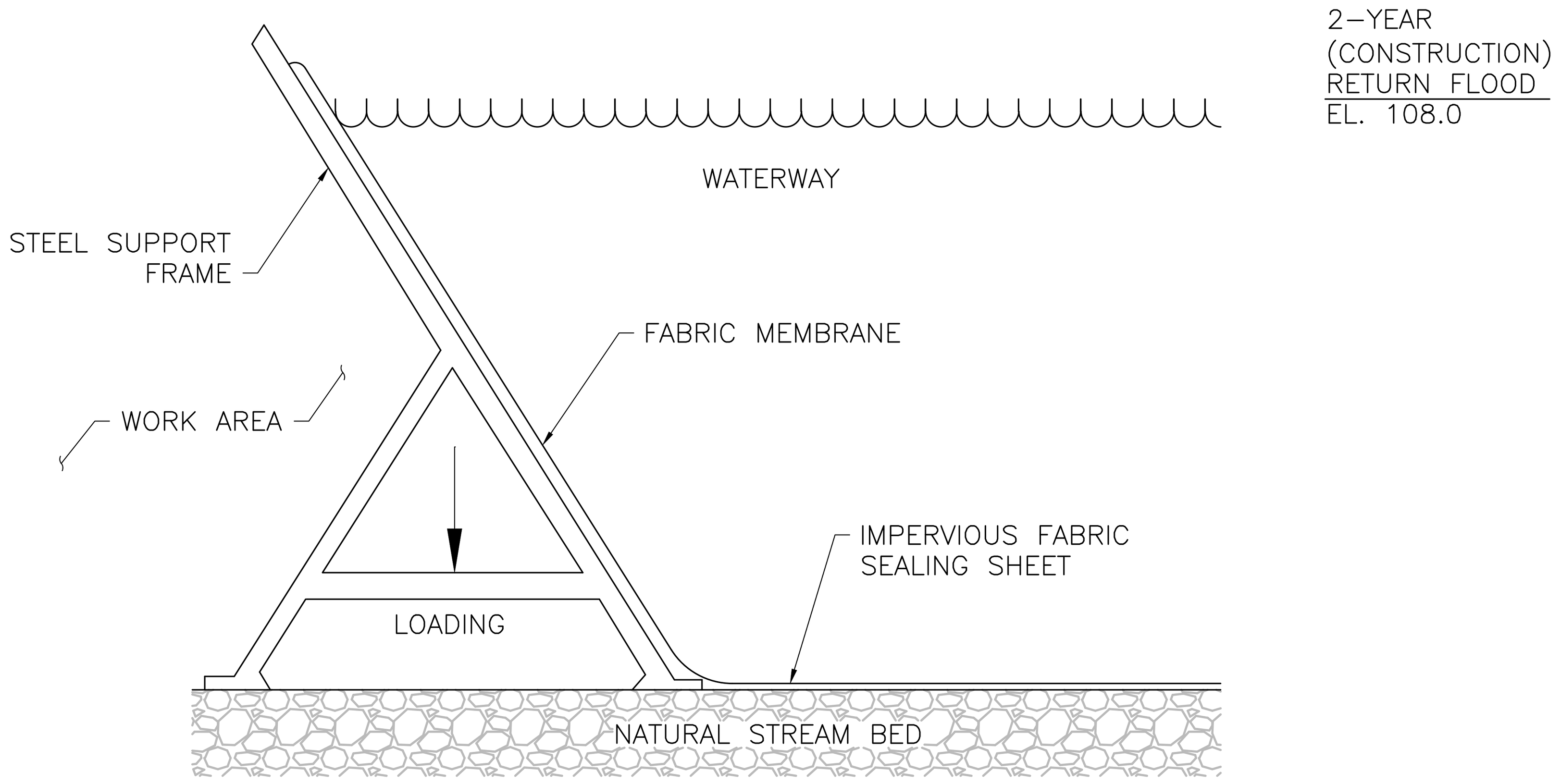
4.7. REDIRECT STREAM FLOW THROUGH THE CULVERT.

4.8. REMOVE THE C.O.W. COFFERDAMS BYPASS PUMPS AND TEMPORARY STILLING BASIN.



NOTES:
DISCHARGE TO SEDIMENTATION BASIN (AS SHOWN) OR TO SILTATION/ DEWATERING BAG SUCH AS FLOGARD DEWATERING BAG MODEL SC-DW1215Z, OR APPROVED EQUAL BY BOXFORD CONSERVATION COMMISSION. SYSTEM SHOWN IS CONCEPTUAL ONLY AND IS TO BE DESIGNED BY CONTRACTOR.

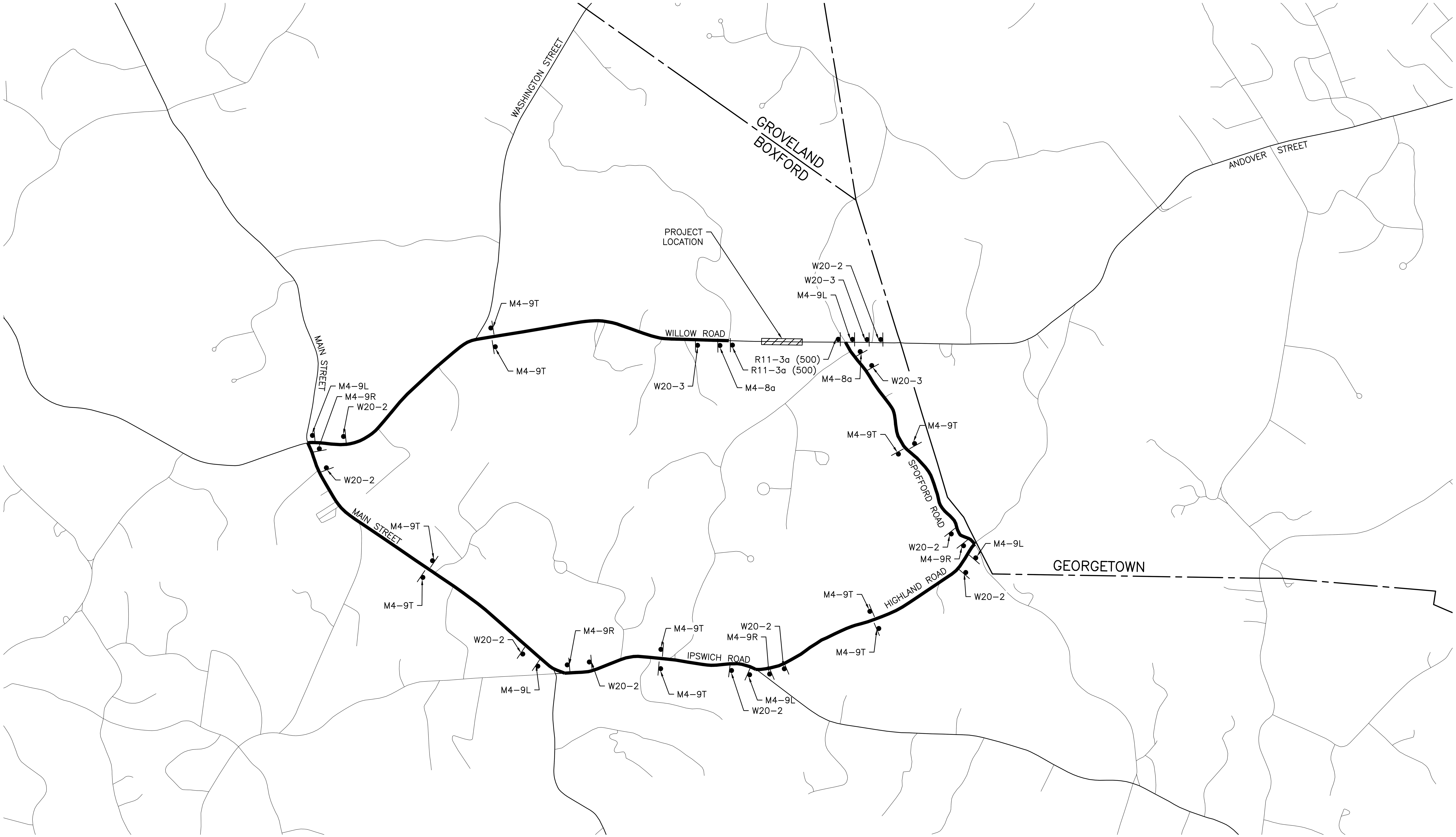
TEMPORARY STILLING AREA
SCALE: N.T.S.



TEMPORARY COATED FABRIC STEEL FRAME COFERDAM
SCALE: N.T.S.

NOTES:
THE STEEL FRAME COFFERDAM SHOWN ABOVE IS FOR CONCEPTUAL ONLY. THE CONTRACTOR SHALL DETERMINE THE APPROPRIATE SYSTEM FOR CONTROLLING THE WATER (I.E. BULK SANDBAGS). THE CONTRACTOR SHALL SUBMIT THEIR PROPOSED CONTROL OF WATER DESIGN TO THE ENGINEER FOR REVIEW AND APPROVAL.

T0998_C.O.W. PLAN.DWG Plotted on 1-Oct-2020 12:14 PM



BRIDGE CLOSURE DETOUR PLAN
SCALE: 1" = 750'

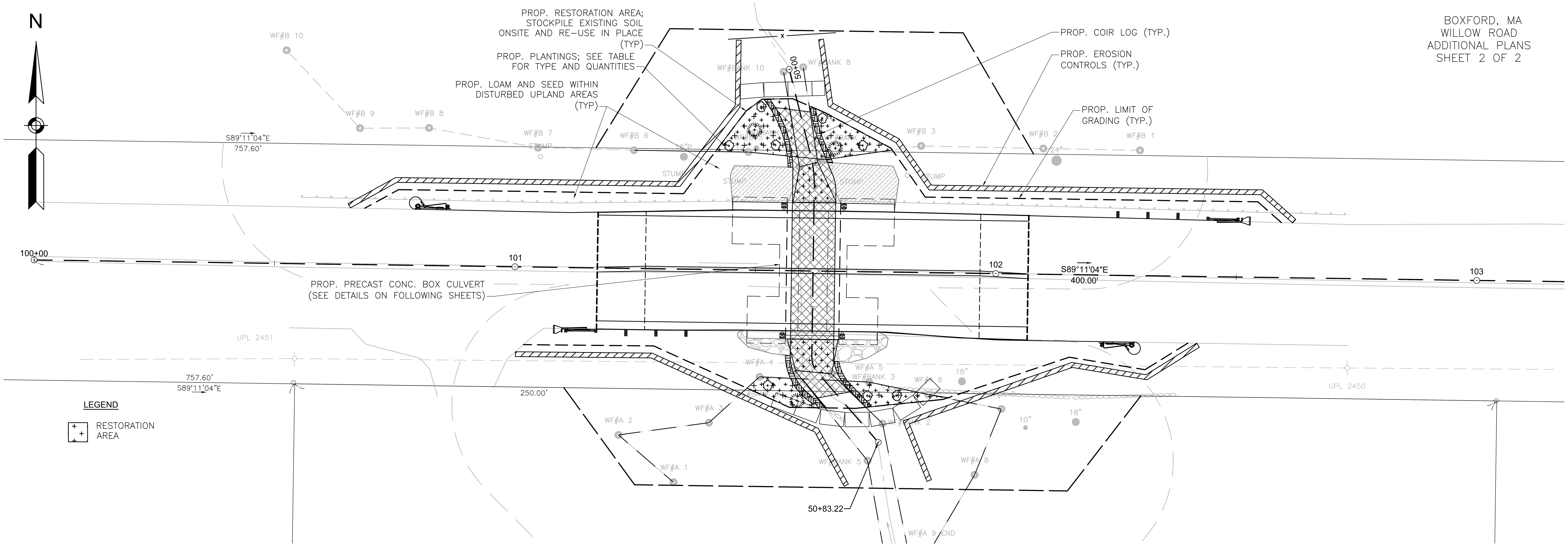
TRAFFIC SIGN SUMMARY

TEMPORARY TRAFFIC SIGN SUMMARY												
IDENTIFICATION NUMBER	SIZE OF SIGN (in)			TEXT DIMENSIONS (in)			NUMBER OF SIGNS REQUIRED	COLOR			UNIT AREA (SF)	TOTAL AREA (SF)
	WIDTH	HEIGHT	LEGEND	LETTER HEIGHT	VERTICAL SPACING	ARROW RTE. MKR		BACK-GROUND	LEGEND	BORDER		
M4-8a	24	18	END DETOUR	SEE 2009 MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES FOR STREETS AND HIGHWAYS			2	ORANGE	BLACK	BLACK	3.00	6.00
M4-9L	30	24	DETOUR ←				5	ORANGE	BLACK	BLACK	5.00	25.00
M4-9R	30	24	DETOUR →				4	ORANGE	BLACK	BLACK	5.00	20.00
M4-9T	30	24	DETOUR ↑				10	ORANGE	BLACK	BLACK	5.00	50.00
R11-3a	60	30	ROAD CLOSED 500 FT AHEAD LOCAL TRAFFIC ONLY				2	ORANGE	BLACK	BLACK	12.50	25.00
W20-2	36	36	DETOUR AHEAD				10	ORANGE	BLACK	BLACK	9.00	90.00
W20-3	37	37	ROAD CLOSED AHEAD				3	ORANGE	BLACK	BLACK	9.51	28.52

T0996_(TTCP).DWG Plotted on 15-Sep-2020 1:14 PM

T0998_(TITLE - SHEET 1 ENLARGED).DWG Plotted on 5-Oct-2020 10:10 AM

BOXFORD, MA
WILLOW ROAD
ADDITIONAL PLANS
SHEET 2 OF 2



RESTORATION PLAN

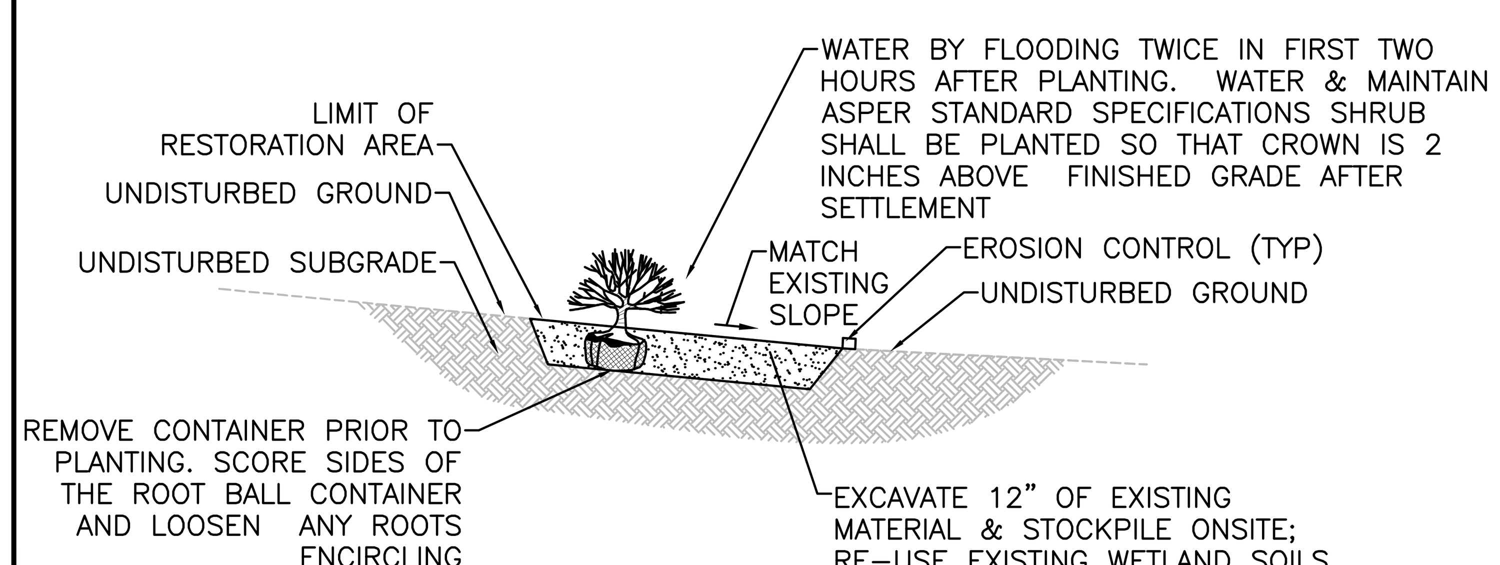
SCALE: 1" = 10'

SCALE: 1" = 10'

PROPOSED PLANTING SUMMARY TABLE					
SYMBOL	QTY	BOTANICAL NAME	COMMON NAME	SIZE	COMMENTS
⊙	3	SYMPLOCARPUS FOETIDUS	SKUNK CABBAGE	6" – 24"	CONTAINER
⊙	8	OSMUNDA CINNAMOMEA	CINNAMON FERN	6" – 24"	CONTAINER

PLANTING NOTES:

1. CONTRACTOR SHALL HAVE ALL SUBSURFACE UTILITIES MARKED PRIOR TO THE START OF WORK.
2. FINAL LOCATION OF ALL PLANT MATERIAL WILL BE APPROVED BY THE RESIDENT ENGINEER PRIOR TO PLANTING.
3. ALL PLANT MATERIAL WILL HAVE TAGS INDICATING COMMON NAME, BOTANICAL NAME & SIZE.
4. ALL PLANTS WILL BE MULCHED PER THE PLANTING SPECIFICATIONS AND DETAILS.
5. WETLAND SOIL OR LOAM SHALL BE APPLIED TO ALL DISTURBED AREAS AND SEEDED WITH THE CORRESPONDING SEED MIX PER THE APPLICABLE DETAIL.
6. WETLAND SEED MIX SHALL BE IN ACCORDANCE WITH MASSDOT STANDARDS. SEED MIX SHALL BE SITE SPECIFIC THAT IS NATIVE TO THE TOWN OF BOXFORD.



NOTES:

1. RESTORATION AREAS TO BE SEEDED WITH WETLAND MIX – OBLIGATE (ITEM 765.552).

RESTORATION AREA

N.T.S.

WETLAND RESTORATION SPECIFICATIONS & GENERAL NOTES:

RESTORATION SITE SELECTION

THE RESTORATION AREA IS LOCATED WITHIN THE EXISTING WETLAND AREA THAT WILL BE TEMPORARILY ALTERED IN ORDER TO CONSTRUCT THE NEW CULVERT. THE RESTORATION AREA WITHIN THE WETLAND WILL CONSIST OF WETLAND SHRUBS AND WETLAND SEED MIX AS SHOWN IN THE ATTACHED TABLE. RESTORATION SHALL BE SUPERVISED BY A PROFESSIONAL WETLAND SCIENTIST. THE RESTORED WETLAND ONCE ESTABLISHED WITH NATIVE PLANTINGS WILL PROVIDE SIGNIFICANTLY IMPROVED HABITAT FUNCTION FROM THE IMPACTED WETLAND.

HYDROLOGY

WETLAND HYDROLOGY WITHIN THE RESTORATION AREA WILL BE ACHIEVED BY ESTABLISHING AN UNRESTRICTED HYDRAULIC CONNECTION BETWEEN THE RESTORED WETLAND AND THE EXISTING WETLAND, AND BY INTERCEPTING THE SEASONAL HIGH GROUNDWATER TABLE. FINISHED GRADES OF THE RESTORATION AREA SHALL BE CONSTRUCTED TO MATCH EXISTING GRADES PRIOR TO START OF WORK. THE HYDRAULIC CONNECTION THAT EXISTS TODAY WILL REMAIN IN PLACE POST CONSTRUCTION.

SOILS

SOIL TRANSLOCATION FROM THE IMPACTED WETLAND IS THE PREFERRED METHODOLOGY FOR RESTORATION SOILS. SOILS WITHIN THE RESTORATION SHALL BE EXCAVATED AND STORED ONSITE FOR RE-USE. THERE ARE FOUR DISTINCT RESTORATION AREAS AS PART OF THE PROJECT. STOCKPILES FOR EACH RESTORATION AREA SHALL BE KEPT ONSITE AND CLEARLY LABELED FOR RE-USE IN EACH AREA. SUBGRADE OF EACH RESTORATION AREA SHOULD BE ESTABLISHED AND THEN 12-INCHES (MINIMUM) OF EXISTING WETLAND SOIL SHOULD BE PLACED IN EACH RESTORATION AREA. EXISTING WETLAND SOILS SHOULD BE KEPT WET AND NOT BE ALLOWED TO DRY OUT.

IT IS ESTIMATED THAT ADDITIONAL, IMPORTED SOILS MAY BE REQUIRED IN ORDER TO ESTABLISH THE RESTORATION AREAS AND RESTORED STREAMBED. IMPORTED SOIL SHALL CONSIST OF EQUAL PARTS ORGANIC MATTER (LEAF COMPOST IS PREFERRED) AND CLEAN LOAM OR ORGANIC RICH LOAM WITH A MINIMUM 20% ORGANIC CARBON BY DRY WEIGHT. IMPORTED SOIL WILL BE APPROVED BY A WETLAND SCIENTIST PRIOR TO PLACEMENT IN THE WETLAND RESTORATION AREA AND SHALL BE INSTALLED TO A MINIMUM DEPTH OF 12 INCHES. SURVEYING OF SUBGRADES AND FINISHED ELEVATIONS SHOULD BE CONDUCTED FREQUENTLY DURING CONSTRUCTION. SOILS TO BE USED AT THE MITIGATION SITE SHOULD BE USED IMMEDIATELY IF POSSIBLE AND STOCKPILED FOR AS LITTLE TIME AS POSSIBLE. WHILE STOCKPILED THE SOILS SHOULD BE KEPT WET AND NOT BE ALLOWED TO DRY OUT. CONTAMINATION OF THESE SOILS SHOULD BE PREVENTED. THEY SHOULD BE TRANSPORTED IN VEHICLES THAT HAVE BEEN WASHED SO THAT NO EXOTIC/INVASIVE SEEDS FROM OTHER SITES GET MIXED IN WITH THEM.

PLANTING REQUIREMENTS

SHRUBS SHOULD BE PLANTED 4–10 FEET ON CENTER IN A RANDOM PATTERN OR IN CLUSTERS TO MIMIC NATURAL CONDITIONS.

INVASIVE SPECIES

TRUCKS THAT HAVE PREVIOUSLY BEEN ON OTHER SITES SHOULD BE WASHED PRIOR TO INTRODUCTION TO THE REPLICATION SITE SO THAT MUD/DIRT WITH EXOTIC/INVASIVE SEEDS IS NOT INADVERTENTLY BROUGHT TO THE RESTORATION SITE.

TIMING OF PLANTINGS

ALL PLANTING SHOULD OCCUR AT THE BEGINNING OR END OF THE GROWING SEASON. FALL PLANTINGS SHOULD BE DONE BEFORE THE FIRST FROST, BUT NO LATER THAN NOVEMBER 15.

EROSION CONTROL

EROSION CONTROLS WILL BE PLACED ALONG THE BOUNDARY OF THE RESTORATION AREA. UPON COMPLETION OF THE RESTORATION AREA, INSTALLATION OF SILTATION FENCING AND COMPOST FILTER TUBES BETWEEN THE RESTORATION AREA AND THE ADJACENT UPLAND WILL BE PROVIDED TO PREVENT SILT FROM ENTERING THE RESTORATION AREA. PRIOR TO PERMANENT ESTABLISHMENT OF VEGETATION IN THE RESTORATION AREA, SOILS WILL BE TEMPORARILY STABILIZED TO PREVENT IMPACTS FROM EROSION BY MULCHING AND SEEDING WITH A WETLAND SEED MIXTURE UNTIL RE-ESTABLISHMENT OF WETLAND VEGETATION OCCURS. ALL EMBANKMENT SLOPES ADJACENT TO WETLAND RESTORATION AREAS SHOULD HAVE SLOPES NO GREATER THAN 2H:1V UNLESS STABILIZED BY STRUCTURAL MEANS. BIOENGINEERING STABILIZATION METHODS ARE RECOMMENDED FOR SLOPE STABILIZATION. ORGANIC SOILS AND WETLAND VEGETATION SHOULD NOT BE PLACED IN THE RESTORATION AREA UNTIL IT IS VERIFIED THAT THE FINAL EXCAVATED GRADE FOR THE RESTORATION AREA WILL ALLOW THE FINISHED GRADE OF THE RESTORATION SITE TO MEET THE DESIGN SPECIFICATIONS. FOLLOWING EXCAVATION WORK, FINAL GRADING AND LANDSCAPING SHOULD BE COMPLETED AS SOON AS POSSIBLE TO MINIMIZE EROSION. ALL EXPOSED SOIL WILL BE STABILIZED USING SEED-FREE MULCH OR OTHER APPROPRIATE EROSION CONTROL MEASURES IN THE EVENT THAT SEASONAL CONDITIONS RESULT IN A DELAY IN PLANTING. IF THE SITE IS EXCAVATED TO THE SUBGRADE IN THE FALL AND A DELAY IS INEVITABLE, CONSIDERATION SHOULD BE GIVEN TO STABILIZING THE SITE FOR WINTER, AND CONDUCTING FINAL GRADING IN THE SPRING.

T0998_(GRADING - RESTORATION AREA PLAN).DWG Plotted on 5-Oct-2020 9:52 AM

Attachment B
Hydraulic Report

Bay Colony Group, Inc. **MEMORANDUM**
Professional Civil Engineers & Land Surveyors

Four School Street
P.O. Box 9136
Foxborough, MA 02035
(508)543-3939
(508)543-8866 fax

June 23, 2020

To: Robert Niccoli, P.E. Deputy Director of Structures, The Engineering Corp.

From: William R. Buckley, Jr., P.E.

RE: Unnamed Tributary to Parker Brook at 89 Willow Road Boxboro, MA

1.0 Introduction

1.1 Purpose

The purpose of this technical report is to present the results of a study conducted at the culvert conveying an unnamed tributary to Parker Brook at 89 Willow Road Boxford, MA in order to evaluate the hydraulic performance of the existing culvert and to develop an alternative design. This report was prepared in a manner consistent with the Massachusetts Department of Transportation (MassDOT) guidelines for preparation of hydraulic studies at bridge sites modified to account for the preliminary nature of the design.

1.2 Scope

The scope of work for this investigation consisted of review of pertinent hydrologic and hydraulic data for the project site and a detailed hydraulic analysis. Data collected and hydraulic model computer outputs are presented in the appendices of this report. A narrative discussion of the problem statement, engineering methods, as well as results and conclusions of the hydraulic study follow.

1.3 Executive Summary

The Town of Boxford proposes to replace the existing 24" one-barrel culvert conveying an unnamed tributary to Parker Brook under Willow Road, which is classified as an Urban Minor Arterial street. The site does not lie within a National Flood Insurance Program (NFIP) Special Flood Hazard Area (SFHA) as shown on the currently effective National Flood Insurance Rate Map (FIRM) dated 7/3/2012 (Appendix B). Because it does not lie within a SFHA a "No-Rise" Flood Encroachment Review is not necessary for the final design.

2.0 Project Description

2.1 Existing Structure

The subject culvert is located in the Town of Boxford, MA located adjacent to 89 Willow Road. The Massachusetts State Plane Coordinates (NAD83-feet) are N 3,084,781/ E 780,703 (Appendix B). There is no culvert designation and the date of construction is unknown. The culvert consists of a single 24" crushed corrugated metal pipes that is 42' long. The unnamed tributary flows from south to north into Parker Brook about one half mile north of the site. The source of the tributary is in the Highland Road Conservation Area and its drainage basin is about 0.2 square miles.

The culvert inlets and outlets have stone headwalls that have partially collapsed. There is no evidence of scouring on the upstream or downstream end of the culvert. The culvert is partially submerged with no dry passage through it at the time of observation. The current inlet openness ratio is about 0.075.

The roadway is a two-lane urban minor arterial roadway approximately 25' wide with no curbing. There is approximate 5' of cover over the existing pipe to the crown of the roadway. The runoff from the roadway is directed off the roadway into swales or into cuts in the pavement on the south side of the road where the runoff goes into the stream just east of the outfall. The project area was marked by DIGSAFE and there are no underground utilities in the area. (Appendix B)

2.2 Proposed Action

The principal project action is to upgrade the existing culvert in order to ameliorate the flooding condition that takes place during heavy rain events. The design will be in accordance to the maximum extent practical with the MassDOT LRFD Bridge Manual and with the Massachusetts Stream Crossing Standard. The horizontal and vertical alignment for the new culvert will remain approximately the same. We are recommending that the new structure consist of a 9'wide x 4' high open bottom concrete box culvert that will have a natural bottom substrate matching the upstream and downstream condition. The design will pass the 25-year storm with about 2.8' of freeboard within the culvert and no overtopping of the roadway in accordance with the MassDOT LRFD Bridge Manual Table 1.3.4-1. The design of the structure will be in compliance with the MassDEP Stream Crossing Standards with the main limiting factor being the elevation of the roadway which limits the height of the proposed culvert. The Openness Ratio will be 0.82 where 0.82 – 1.62 are suggested. The open bottom will allow the passage of fish and wildlife while maintaining similar depths of flow and velocity of the upstream and downstream conditions. The span will be 1.29 where 1.2 is suggested and which will be obtained by creating a bench on both sides of the culvert that will allow dry passage for wildlife through the culvert during normal base flow.

3.0 Data Collection

3.1 Sources and Applications

Reference No.	Title
1	Flood Insurance Rate Map Community Panel Number 25009C0233F, effective date July 3, 2012
2	MassDOT LRFD Bridge Manual, January 2020 Revision
3	US Army Corps of Engineer (USACOE), Hydrologic Engineering Center, HEC-RAS River Analysis System, Version 5.0.7 March, 2019
4	United States Geological Survey (USGS) National Streamflow Statistics (StreamStats), Version 4.3.11
5	US Department of Transportation Federal Highway Administration Hydraulic Engineering Circular No. 18 "Evaluating Scour at Bridges", Fifth Edition, April 2012
6	MassDOT "Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams" December, 2010

4.0 Engineering Methods

4.1 Hydrologic Analysis

The peak flood discharges for the project were developed using the USGS StreamStats program (Reference 4) in accordance with Reference 2 paragraph 1.3.3.3 Hydrologic Analysis. The following is a summary of the discharges at the project site.

Table 1 – Summary of Discharges

Drainage Area (sq. miles)	2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
0.19	9.9	22.6	31	37.9	45.4

4.2 Hydraulic Analysis

The hydraulic analysis was conducted using the US Army Corps of Engineer (USACOE), Hydrologic Engineering Center, HEC-RAS River Analysis System (Reference 3). HEC-RAS is capable of calculating steady flow water surface profile computations, one- and two-dimensional unsteady flow simulation, movable boundary sediment transport computations and water quality analysis. For the purposes of this analysis we will be using the steady flow water surface profile module to calculate the water surface profiles for the existing condition and then develop a proposed upgraded design for the project site.

The existing conditions geometry was developed through a combination of field survey conducted by this office in June, 2020 and direct observation of the site. Channel and overbank roughness coefficients (Manning's "n") used in the models are 0.05 for the overbanks and 0.025 for the channel and these values were based on direct observation and Table 3-1 Manning's "n"

Values in the HEC-RAS 5.0 Reference Manual. A normal depth downstream boundary condition slope of 0.024 and upstream boundary condition slope of 0.002 was used to determine the initial condition. Though the entrance and entrance of the culvert are crushed we assumed that they are fully functional since that could be the condition with some work. There is also a gravel road about 200' upstream of the site that contains a culvert on private property where the stream passes. We have assumed that all flow within the tributary area flows directly to the culvert under Willow Road. This is a conservative assumption since the upstream culvert would in fact decrease the flow reaching the Willow Road culvert. The analysis determined that the existing culvert if returned to its full capacity could pass the design storm without overtopping the road, but it would be under pressure. Currently weir flow takes place once the roadway tops somewhere between the 25-year and 50-year event. The 50-year storm would overtop the roadway.

The developed conditions were developed using the existing conditions geometry and inserting a 9'wide x 4' high open bottom box culvert with wing walls at the same location as the existing culvert. Because the roadway is an Urban Minor Arterial Street the hydraulic design storm is the 25-year event. The analysis found that the proposed culvert could pass the 25-year event without overtopping the roadway and with 2.8' of freeboard. It will pass up to the 100-year event without overtopping the roadway. See Table 2 for a summary of the existing and proposed conditions. Detailed data is available in Appendix D.

Table 2 – Summary of Hydraulic Performance

	Return Frequency (years)	Discharge (cfs)	US Water Surface Elevation (ft)	US Velocity (fps)	DS Water Surface Elevation (ft)	DS Velocity (fps)
Existing Culvert	2	9.9	109.1	5.4	106.2	9.9
	10	22.6	110.5	7.2	106.7	12.1
	25	31	112.3	9.9	106.9	13.8
	50	37.9	113.6	11.4	107.1	14.9
	100	45.4	113.7	11.5	107.3	15.0
Proposed Open Bottom Box Culvert	2	9.9	108.0	3.3	106.1	1.3
	10	22.6	108.3	4.3	106.4	1.8
	25	31	108.5	4.8	106.6	2.1
	50	37.9	108.6	5.1	106.8	2.3
	100	45.4	108.7	5.5	106.9	2.6

In accordance with the MassDOT LRFD Bridge Manual (Reference 2) the total scour was evaluated for the 50-year frequency storm and the 100-year frequency storm check scour event. The models used are detailed in the Hydraulic Engineering Circular No. 18 (Reference 5) and include abutment scour and abutment scour. We have assumed that the streambed elevation would not measurably degrade over the life of the structure. Using the aforementioned references, we estimate that about 3.6 feet of potential scour could occur along the proposed abutments. The results are listed in Table 3 and Appendix E.

Table 3 – Summary of Calculated Scour

Scour Event	Return Frequency (years)	Discharge (cfs)	Contraction Scour (ft)	Local Abutment Scour (ft)	Total Abutment Scour (ft)
Scour Design Event	50	37.9	0.4	3.2	3.6
Scour Check Event	100	45.4	0.7	3.5	4.2

5.0 Conclusions and Recommendations

5.1 Conclusions

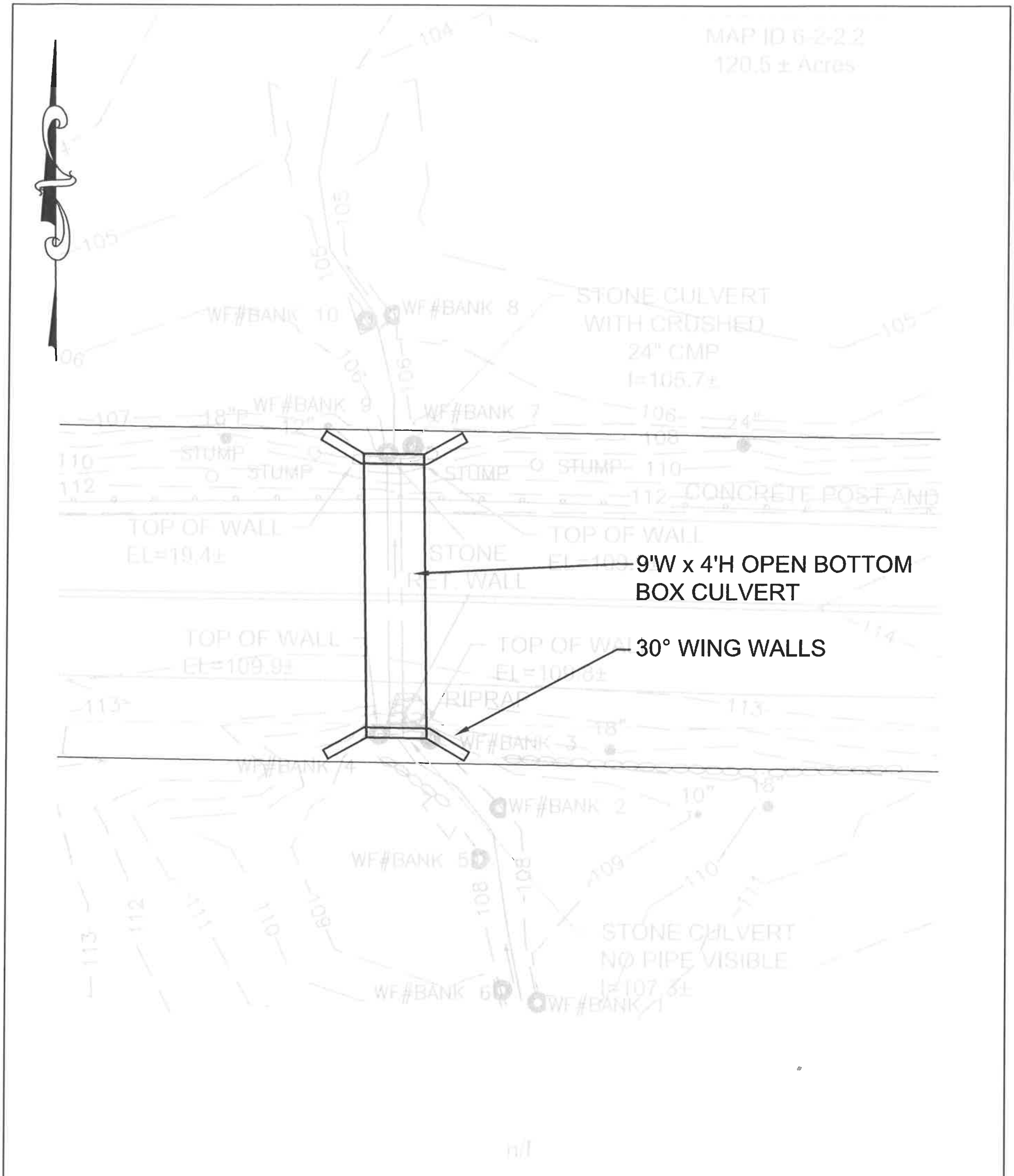
1. Simulations performed with the project hydraulic model indicate that the existing culvert if repaired to its full capacity can pass the 25-year design storm event.
2. The elevation of the existing roadway limits the ability to construct a culvert to the optimum standard as referenced in the MassDEP Stream Crossings Handbook referenced in Reference 6, but the design does meet the general standard to provide fish passage, stream continuity, most wildlife passage and is a significant improvement over the existing condition.
3. The site is not within a FEMA SFHA and so a "no-rise" analysis is not necessary but the design does result in no rise between the pre- and post-development water elevations.

5.2 Recommendations

1. The existing culvert should be removed and replaced with the 9'W x 4'H open bottom precast box culvert with new abutments that extend below the project scour depth. The new culvert should include wing walls and a headwall at the inlet.
2. The bottom of the culvert shall contain natural streambed material consistent with the material found on the site with a shelf on each side consisting of on-site material and stones that will allow dry wildlife passage.

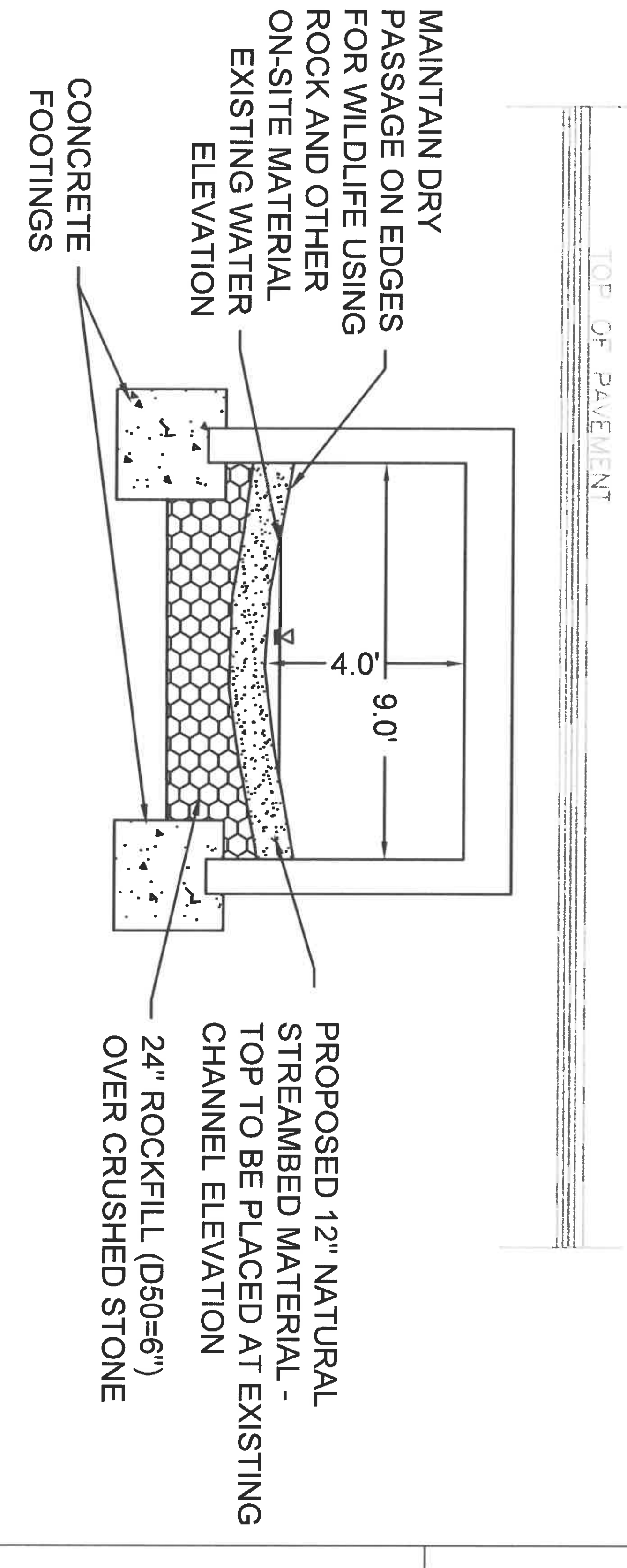
Appendices

A – Photographs
B – FEMA FIRM Community Panel No. 25009 C0233F Effective Date: July 3, 2012
USGS Quadrangle Extract
C – StreamStats Report
D – HEC-RAS Data
E – Scour Calculation Worksheets



BAY COLONY GROUP, INC.
FOUR SCHOOL STREET
FOXBOROUGH, MA 02035
(508) 543-3939

CONCEPTUAL DESIGN
WILLOW ROAD CULVERT
BOXFORD, MA
JUNE 24, 2020
SCALE: 1"= 20'



BAY COLONY GROUP, INC.
FOUR SCHOOL STREET
FOXBOROUGH, MA 02035
(508) 543-3939

CULVERT SECTION
WILLOW ROAD CULVERT
BOXFORD, MA
JUNE 24, 2020
NOT TO SCALE

Appendix A – Photographs

Upstream Channel

Upstream Culvert Entrance

Downstream Channel

Downstream Culvert Exit

Appendix B

- FEMA FIRM Community Panel No. 25009C0233F Effective Date: July 3, 2012
- USGS Extract

National Flood Hazard Layer FIRMette

FEMA

71°2'32"W 42°42'56"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Area of 1% annual chance flood with average depth less than one foot or with drainag areas of less than one square mile
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard
- Effective LOMRs
- Area of Undetermined Flood Hazard

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

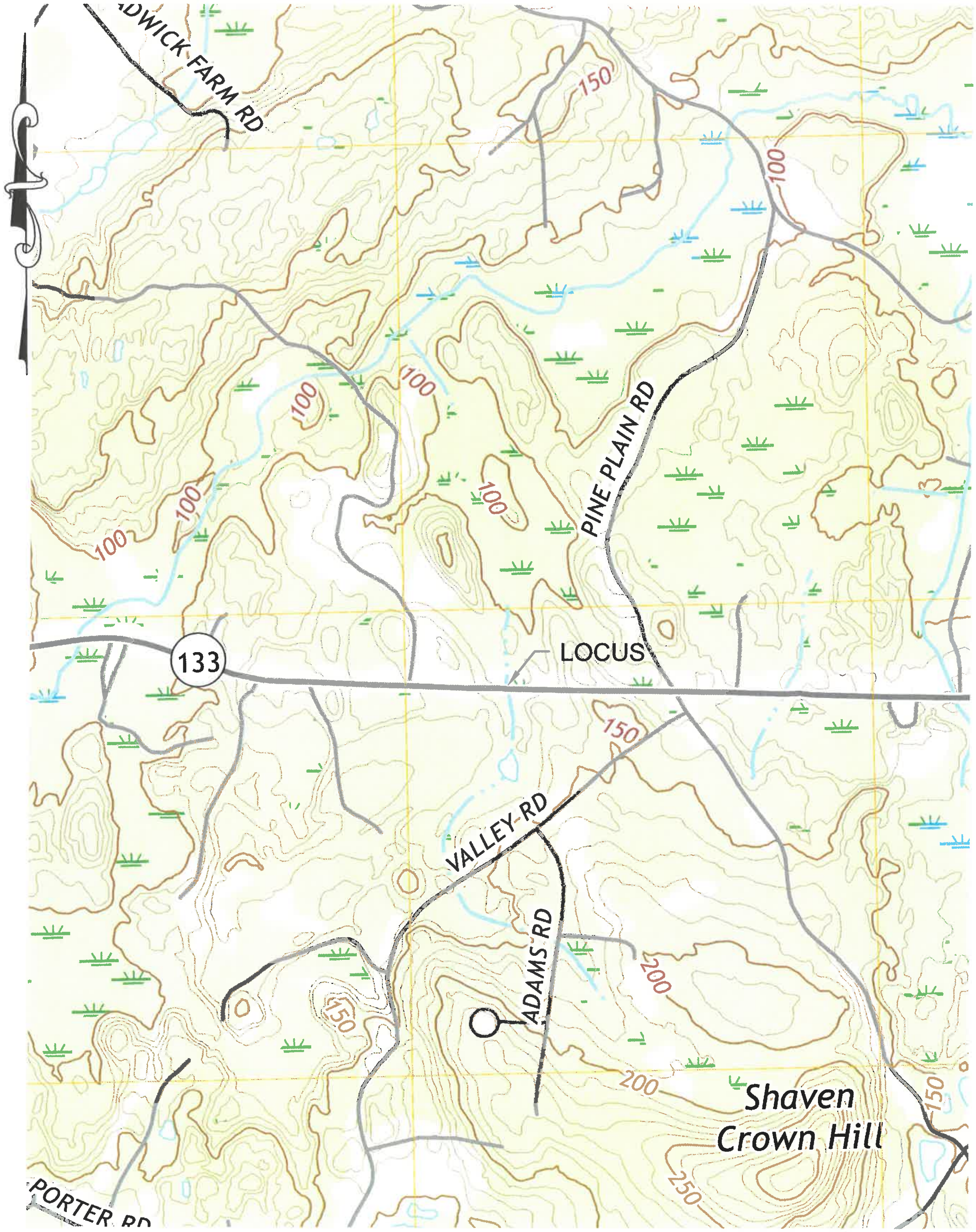
N

The pin displayed on the map is an approximate point selected by the user and does not represe an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/22/2020 at 9:55 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.



BAY COLONY GROUP, INC.
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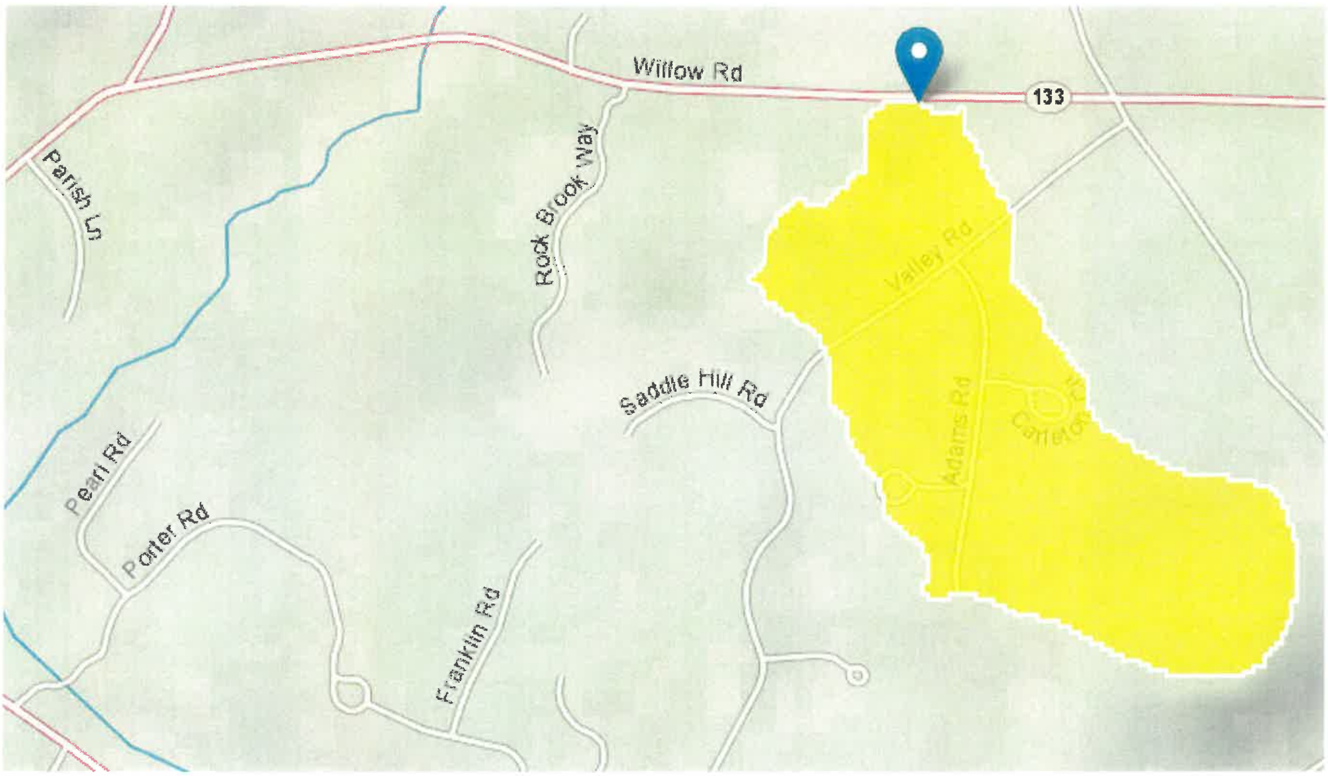
FOXBOROUGH, MA 02035
(508) 543-3939

USGS EXTRACT
WILLOW ROAD CULVERT
BOXFORD, MA
GROVELAND SOUTH QUADRANGLE
SCALE: 1"= 1,000'

Appendix C – StreamStats Report

StreamStats Report - Willow Road Culvert Boxford, MA

Region ID: MA
Workspace ID: MA20200622132328511000
Clicked Point (Latitude, Longitude): 42.71171, -71.03665
Time: 2020-06-22 09:23:45 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.19	square miles
DRFTPERSTR	Area of stratified drift per unit of stream length	0.13	square mile per mile
MAREGION	Region of Massachusetts 0 for Eastern 1 for Western	0	dimensionless
BSLDEM250	Mean basin slope computed from 1:250K DEM	3.418	percent

Parameter Code	Parameter Description	Value	Unit
PCTSNDGRV	Percentage of land surface underlain by sand and gravel deposits	40.68	percent
FOREST	Percentage of area covered by forest	63.35	percent
BSLDEM10M	Mean basin slope computed from 10 m DEM	7.935	percent
ELEV	Mean Basin Elevation	183	feet
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	7.86	percent

Flow-Duration Statistics Parameters[Statewide Low Flow WRIR00 4135]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.19	square miles	1.61	149
DRFTPERSTR	Stratified Drift per Stream Length	0.13	square mile per mile	0	1.29
MAREGION	Massachusetts Region	0	dimensionless	0	1
BSLDEM250	Mean Basin Slope from 250K DEM	3.418	percent	0.32	24.6

Flow-Duration Statistics Disclaimers[Statewide Low Flow WRIR00 4135]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Flow-Duration Statistics Flow Report[Statewide Low Flow WRIR00 4135]

Statistic	Value	Unit
50 Percent Duration	0.176	ft^3/s
60 Percent Duration	0.111	ft^3/s
70 Percent Duration	0.0608	ft^3/s
75 Percent Duration	0.0449	ft^3/s
80 Percent Duration	0.0398	ft^3/s
85 Percent Duration	0.0278	ft^3/s
90 Percent Duration	0.0209	ft^3/s

Statistic	Value	Unit
95 Percent Duration	0.0108	ft^3/s
98 Percent Duration	0.00649	ft^3/s
99 Percent Duration	0.00431	ft^3/s

Flow-Duration Statistics Citations

Ries, K.G., III,2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

Low-Flow Statistics Parameters[Statewide Low Flow WRIR00 4135]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.19	square miles	1.61	149
BSLDEM250	Mean Basin Slope from 250K DEM	3.418	percent	0.32	24.6
DRFTPERSTR	Stratified Drift per Stream Length	0.13	square mile per mile	0	1.29
MAREGION	Massachusetts Region	0	dimensionless	0	1

Low-Flow Statistics Disclaimers[Statewide Low Flow WRIR00 4135]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report[Statewide Low Flow WRIR00 4135]

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.0105	ft^3/s
7 Day 10 Year Low Flow	0.00381	ft^3/s

Low-Flow Statistics Citations

Ries, K.G., III,2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

August Flow-Duration Statistics Parameters[Statewide Low Flow WRIR00 4135]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.19	square miles	1.61	149
BSLDEM250	Mean Basin Slope from 250K DEM	3.418	percent	0.32	24.6
DRFTPERSTR	Stratified Drift per Stream Length	0.13	square mile per mile	0	1.29
MAREGION	Massachusetts Region	0	dimensionless	0	1

August Flow-Duration Statistics Disclaimers[Statewide Low Flow WRIR00 4135]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

August Flow-Duration Statistics Flow Report[Statewide Low Flow WRIR00 4135]

Statistic	Value	Unit
August 50 Percent Duration	0.0288	ft^3/s

August Flow-Duration Statistics Citations

Ries, K.G., III,2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

Probability Statistics Parameters[Perennial Flow Probability]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.19	square miles	0.01	1.99
PCTSNDGRV	Percent Underlain By Sand And Gravel	40.68	percent	0	100
FOREST	Percent Forest	63.35	percent	0	100
MAREGION	Massachusetts Region	0	dimensionless	0	1

Probability Statistics Flow Report[Perennial Flow Probability]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PC
Probability Stream Flowing Perennially	0.536	dim	71

Probability Statistics Citations

Bent, G.C., and Steeves, P.A.,2006, A revised logistic regression equation and an automated procedure for mapping the probability of a stream flowing perennially in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2006–5031, 107 p. (http://pubs.usgs.gov/sir/2006/5031/pdfs/SIR_2006-5031rev.pdf)

Bankfull Statistics Parameters[Bankfull Statewide SIR2013 5155]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.19	square miles	0.6	329
BSLDEM10M	Mean Basin Slope from 10m DEM	7.935	percent	2.2	23.9

Bankfull Statistics Disclaimers[Bankfull Statewide SIR2013 5155]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Bankfull Statistics Flow Report[Bankfull Statewide SIR2013 5155]

Statistic	Value	Unit
Bankfull Width	7.97	ft
Bankfull Depth	0.598	ft
Bankfull Area	4.68	ft^2
Bankfull Streamflow	11.5	ft^3/s

Bankfull Statistics Citations

Bent, G.C., and Waite, A.M.,2013, Equations for estimating bankfull channel geometry and discharge for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2013–5155, 62 p., (http://pubs.usgs.gov/sir/2013/5155/)

Peak-Flow Statistics Parameters[Peak Statewide 2016 5156]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.19	square miles	0.16	512
ELEV	Mean Basin Elevation	183	feet	80.6	1948
LC06STOR	Percent Storage from NLCD2006	7.86	percent	0	32.3

Peak-Flow Statistics Flow Report[Peak Statewide 2016 5156]

PIl: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	Plu	SEp
2 Year Peak Flood	9.93	ft^3/s	4.98	19.8	42.3
5 Year Peak Flood	16.9	ft^3/s	8.37	34.3	43.4
10 Year Peak Flood	22.6	ft^3/s	10.9	47	44.7
25 Year Peak Flood	31	ft^3/s	14.4	66.7	47.1
50 Year Peak Flood	37.9	ft^3/s	17	84.6	49.4
100 Year Peak Flood	45.4	ft^3/s	19.7	105	51.8
200 Year Peak Flood	53.6	ft^3/s	22.6	127	54.1
500 Year Peak Flood	65.5	ft^3/s	26.3	163	57.6

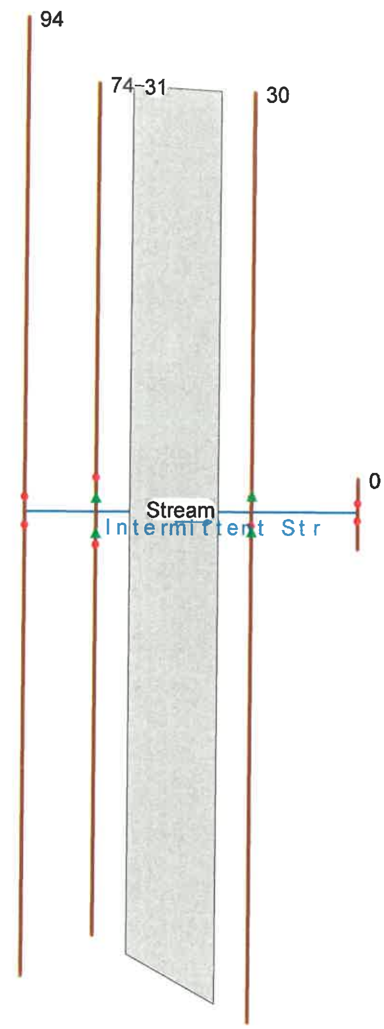
Peak-Flow Statistics Citations

Zarriello, P.J.,2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156, 99 p. (https://dx.doi.org/10.3133/sir20165156)

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Application Version: 4.3.11

Appendix D – HEC-RAS Data

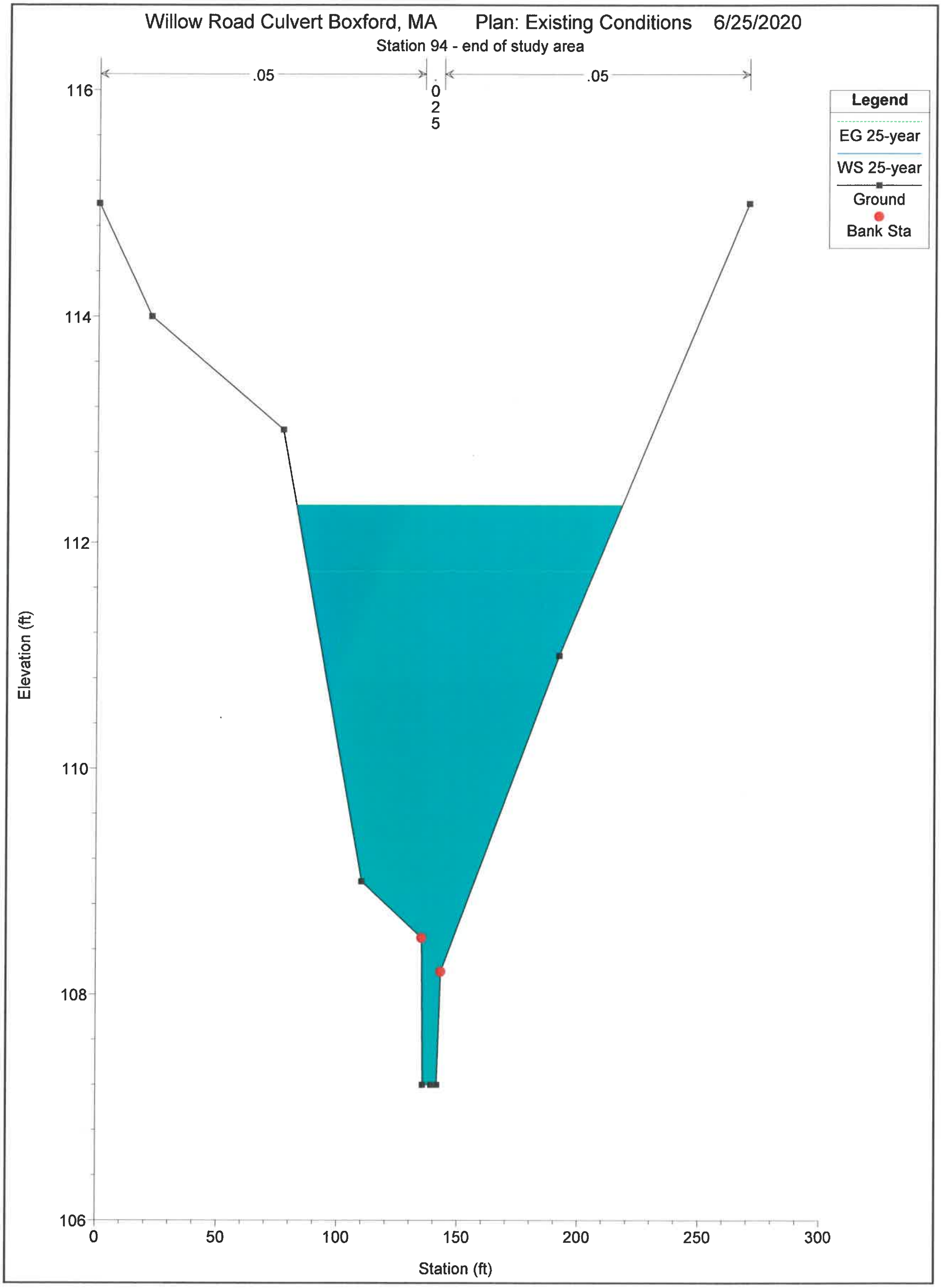

94
74-31
30
0
Stream
Intermittent Str

Existing Culvert Conditions

Station	Structure	Event	E.G. US	W.S. US	Min El. Weir Flow	Culvert Flow	Weir Flow	Culv Vel US	Culv Vel DS	E.G. DS	W.S. DS
			(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	(ft)	(ft)
31	Culvert	2-year	109.11	109.08	113.51	9.90		5.43	9.90	106.54	106.23
31	Culvert	10-year	110.60	110.54	113.51	22.60		7.19	12.14	107.20	106.69
31	Culvert	25-year	112.33	112.29	113.51	31.00		9.87	13.80	107.55	106.93
31	Culvert	50-year	113.57	113.56	113.51	35.83	2.07	11.41	14.93	107.81	107.11
31	Culvert	100-year	113.66	113.66	113.51	36.16	9.06	11.51	15.01	108.08	107.29

Existing Stream Conditions

Reach	Station	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Stream	94	2-year	10	107.2	109.12		109.12	0.00005	0.56	31	50	0.07
Stream	94	10-year	23	107.2	110.6		110.6	0.00001	0.38	133	88	0.04
Stream	94	25-year	31	107.2	112.33		112.33	0.000002	0.23	326	135	0.02
Stream	94	50-year	38	107.2	113.57		113.57	0.000001	0.2	522	196	0.01
Stream	94	100-year	45	107.2	113.66		113.66	0.000002	0.23	540	203	0.02
Stream	74	2-year	10	107.3	109.08	108.02	109.11	0.000347	1.52	7	14	0.21
Stream	74	10-year	23	107.3	110.54	108.45	110.6	0.000213	1.83	12	33	0.18
Stream	74	25-year	31	107.3	112.29	108.68	112.32	0.00009	1.6	19	106	0.13
Stream	74	50-year	38	107.3	113.56	108.86	113.57	0.000001	0.19	360	189	0.01
Stream	74	100-year	45	107.3	113.66	109.04	113.66	0.000002	0.22	378	194	0.02
Stream	31		Culvert									
Stream	30	2-year	10	105.4	106.23	106.23	106.54	0.012254	4.46	2	5	1
Stream	30	10-year	23	105.4	106.69	106.69	107.2	0.011024	5.68	4	6	1
Stream	30	25-year	31	105.4	106.93	106.93	107.55	0.010487	6.31	5	7	1
Stream	30	50-year	38	105.4	107.11	107.11	107.81	0.009933	6.73	6	7	1
Stream	30	100-year	45	105.4	107.29	107.29	108.08	0.009528	7.14	6	7	1
Stream	0	2-year	10	104.7	105.33	105.33	105.56	0.010869	3.87	3	7	0.94
Stream	0	10-year	23	104.7	105.74	105.74	105.94	0.005628	3.97	8	20	0.73
Stream	0	25-year	31	104.7	105.85	105.85	106.07	0.005809	4.35	10	20	0.76
Stream	0	50-year	38	104.7	105.91	105.91	106.17	0.006343	4.73	11	20	0.8
Stream	0	100-year	45	104.7	105.98	105.98	106.27	0.006582	5.03	13	20	0.83


Willow Road Culvert Boxford, MA Plan: Existing Conditions 6/25/2020
Station 94 - end of study area
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Legend
EG 25-year
WS 25-year
Ground
Bank Sta
Elevation (ft)
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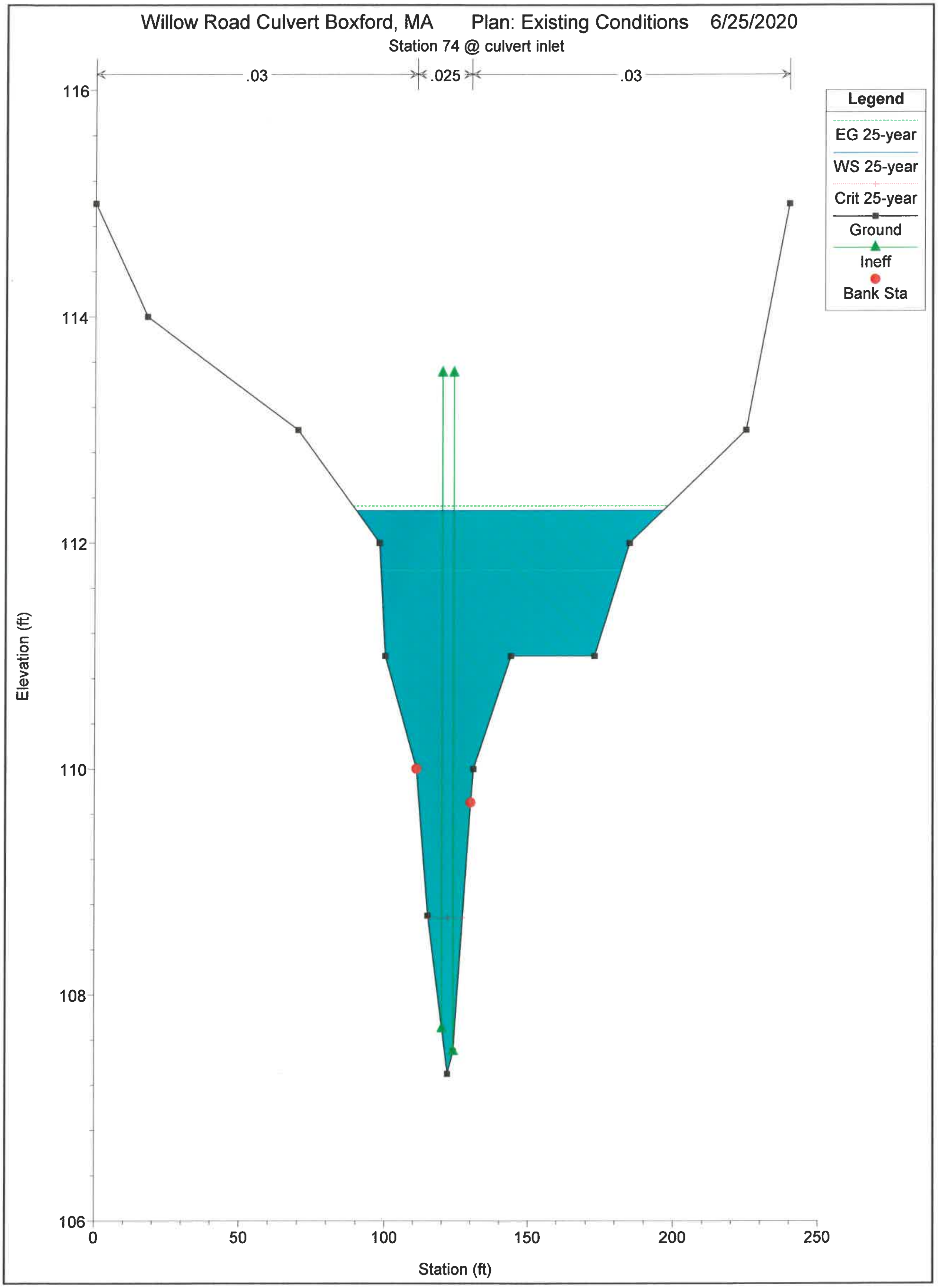
Station (ft)


Willow Road Culvert Boxford, MA Plan: Existing Conditions 6/25/2020
Station 74 @ culvert inlet
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EG 25-year
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Elevation (ft)
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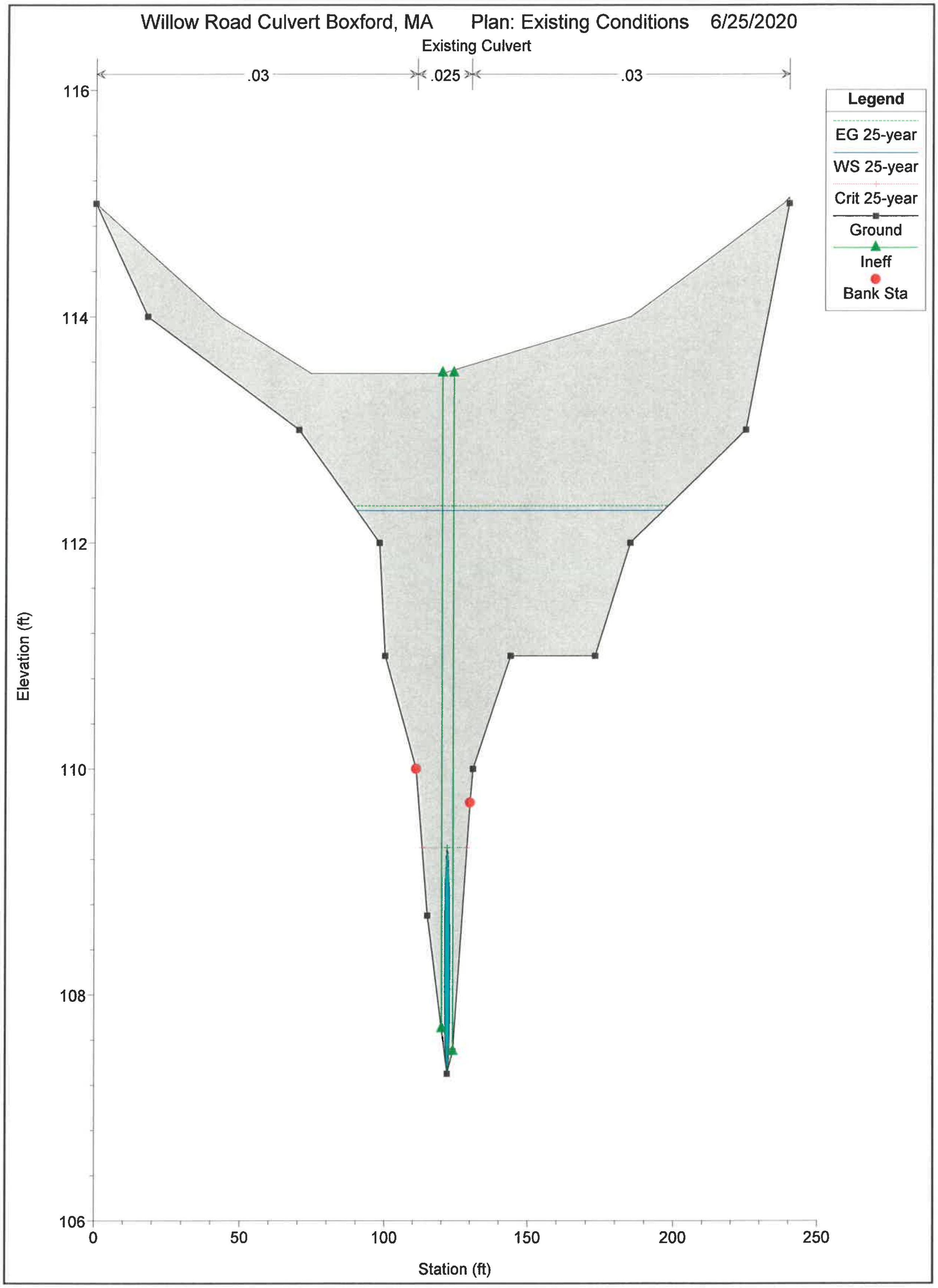

Willow Road Culvert Boxford, MA Plan: Existing Conditions 6/25/2020
Existing Culvert
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Elevation (ft)
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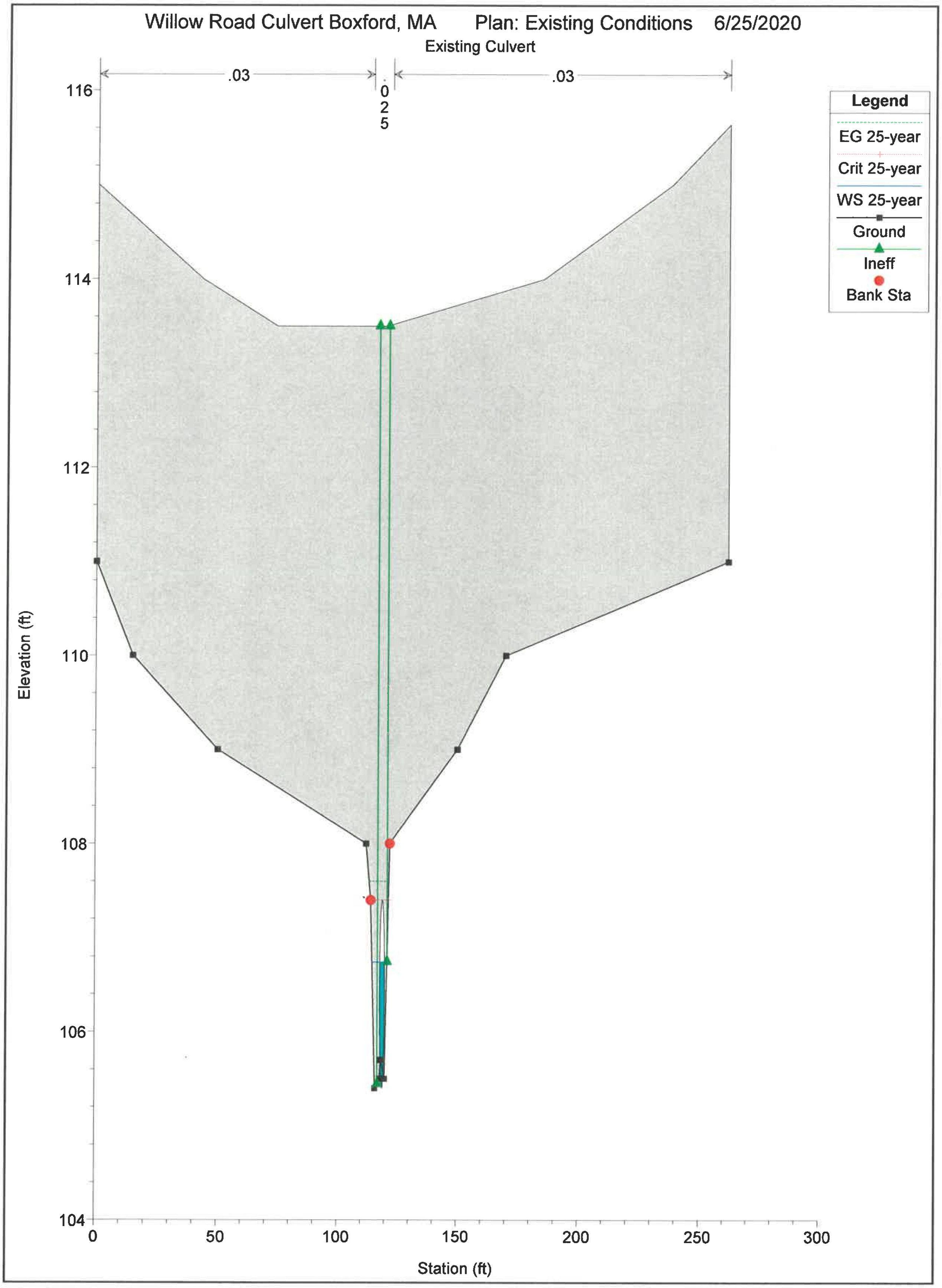

Willow Road Culvert Boxford, MA Plan: Existing Conditions 6/25/2020
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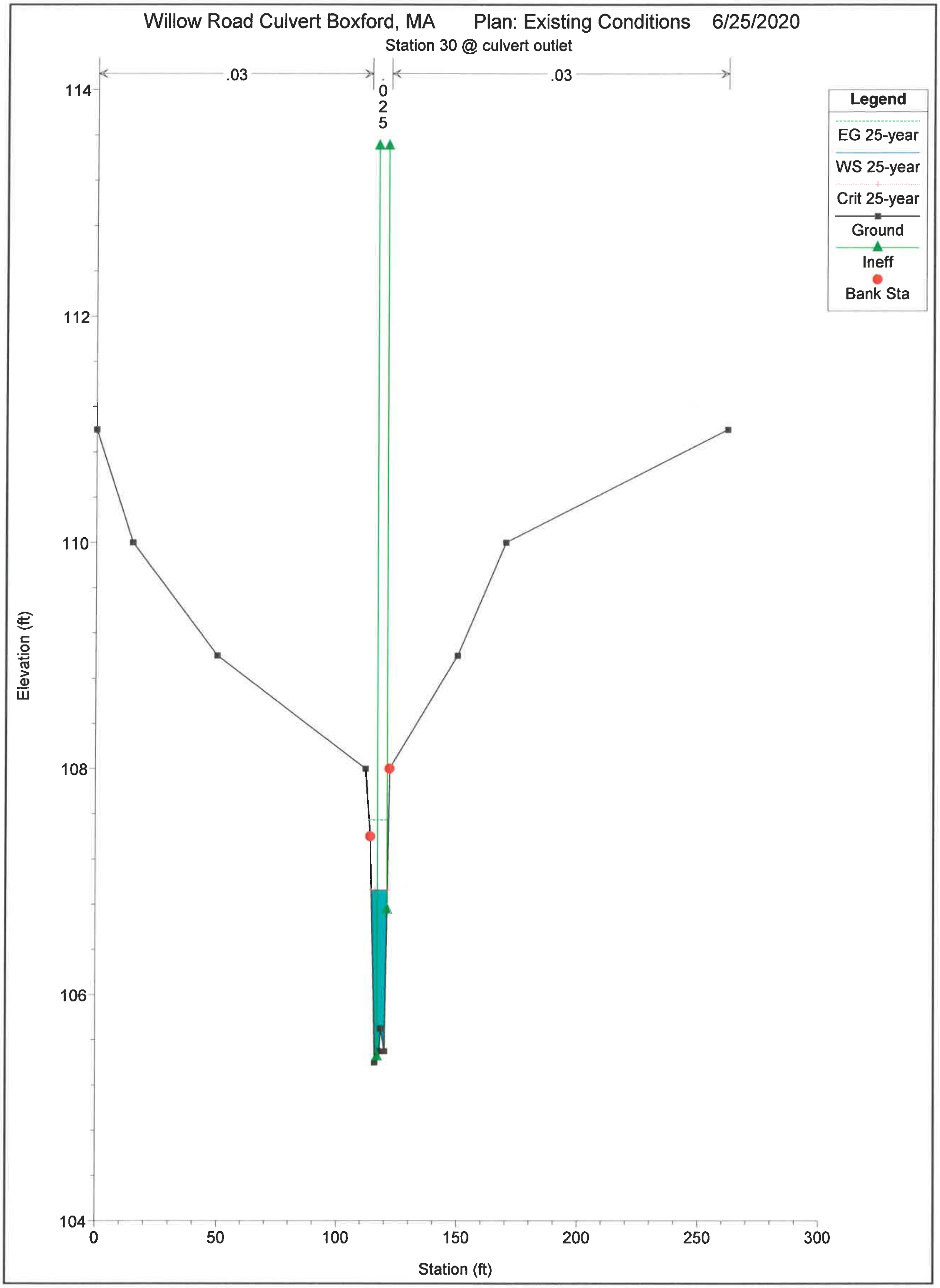

Willow Road Culvert Boxford, MA Plan: Existing Conditions 6/25/2020
Station 30 @ culvert outlet
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Legend
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Elevation (ft)
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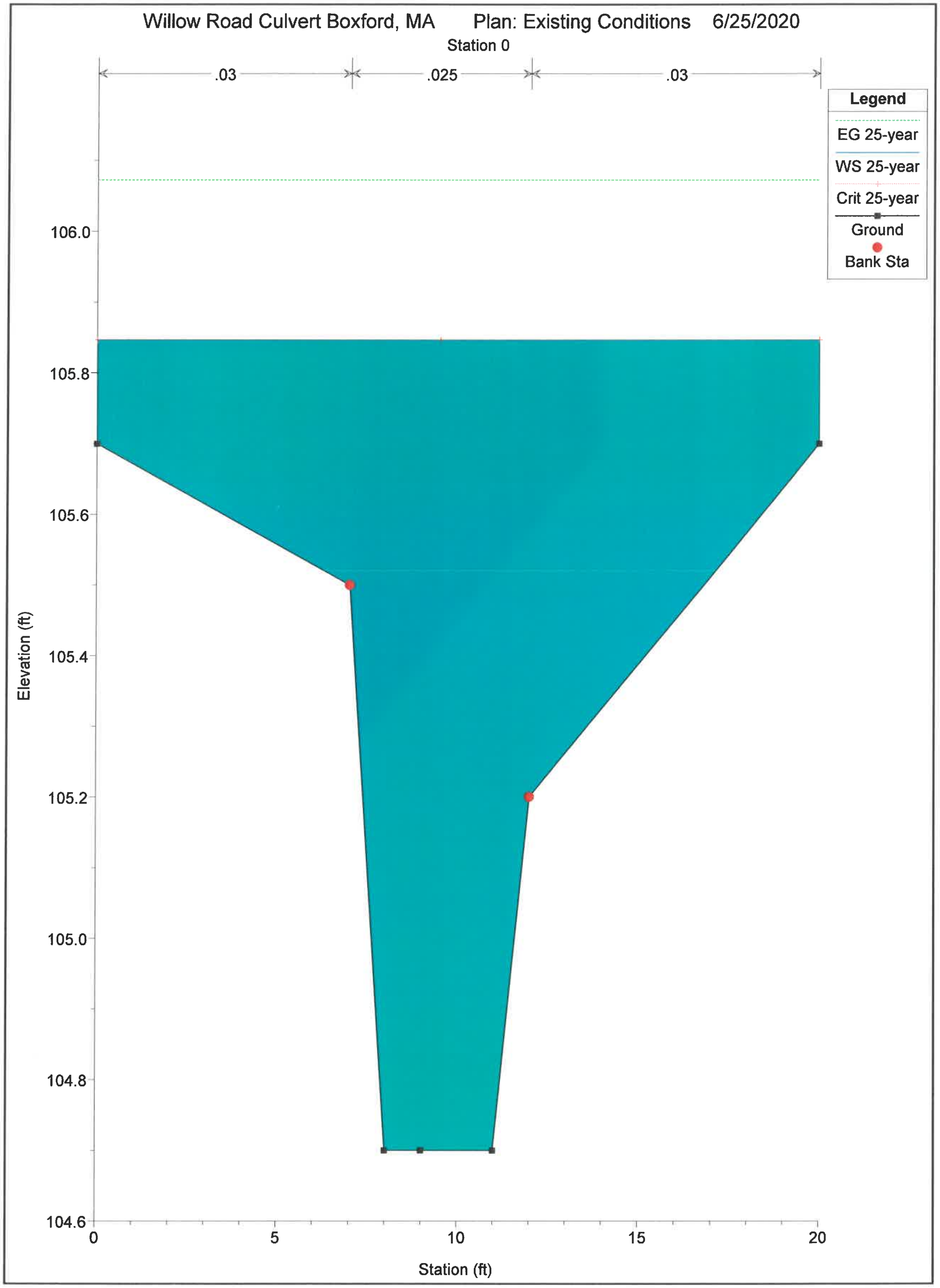
Station (ft)


Willow Road Culvert Boxford, MA Plan: Existing Conditions 6/25/2020
Station 0
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Legend
EG 25-year
WS 25-year
Crit 25-year
Ground
Bank Sta
Elevation (ft)
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104.6
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5
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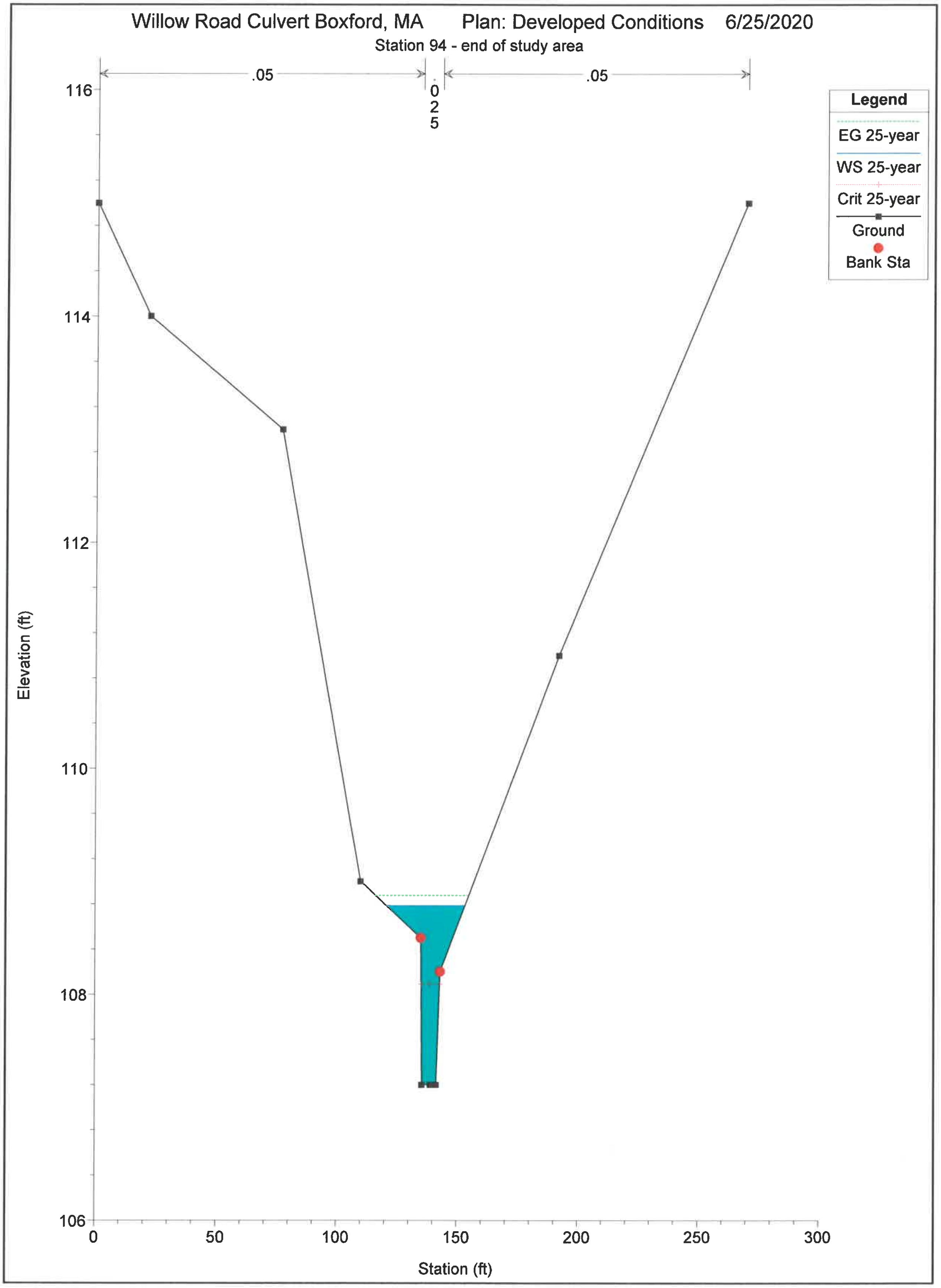
15
20
Station (ft)

Developed Culvert Conditions

Station	Structure	Event	E.G. US	W.S. US	Min El. Weir Flow	Culvert Flow	Weir Flow	Culv Vel US	Culv Vel DS	E.G. DS	W.S. DS
			(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	(ft)	(ft)
31	9'X4' Culvert	2-year	107.73	108.00	113.51	9.90		3.28	1.25	106.31	106.06
31	9'X4' Culvert	10-year	108.11	108.31	113.51	22.60		4.32	1.83	106.82	106.43
31	9'X4' Culvert	25-year	108.33	108.45	113.51	31.00		4.80	2.13	107.09	106.63
31	9'X4' Culvert	50-year	108.49	108.56	113.51	37.90		5.14	2.34	107.29	106.77
31	9'X4' Culvert	100-year	108.66	108.66	113.51	45.40		5.45	2.55	107.48	106.92

Developed Stream Conditions

Reach	Station	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Stream	94	2-year	10	107.2	108.22	107.63	108.25	0.000731	1.39	7	8	0.26
Stream	94	10-year	23	107.2	108.60	107.93	108.67	0.001184	2.18	12	20	0.34
Stream	94	25-year	31	107.2	108.79	108.09	108.88	0.001288	2.49	17	33	0.36
Stream	94	50-year	38	107.2	108.93	108.21	109.03	0.001269	2.63	22	42	0.37
Stream	94	100-year	45	107.2	109.08	108.34	109.17	0.001161	2.68	29	49	0.36
Stream	74	2-year	10	107.3	108.00	108.00	108.20	0.012975	3.62	3	7	1.01
Stream	74	10-year	23	107.3	108.31	108.31	108.60	0.011345	4.29	5	9	1
Stream	74	25-year	31	107.3	108.45	108.45	108.79	0.010799	4.71	7	10	1
Stream	74	50-year	38	107.3	108.56	108.56	108.94	0.010178	4.95	8	11	0.99
Stream	74	100-year	45	107.3	108.66	108.66	109.09	0.009863	5.25	9	12	1
Stream	31		Culvert									
Stream	30	2-year	10	105.4	106.06	106.06	106.31	0.013384	3.96	2	5	1
Stream	30	10-year	23	105.4	106.43	106.43	106.82	0.012051	5.01	5	6	1
Stream	30	25-year	31	105.4	106.63	106.63	107.09	0.01157	5.44	6	6	1
Stream	30	50-year	38	105.4	106.77	106.77	107.29	0.011473	5.77	7	6	1
Stream	30	100-year	45	105.4	106.92	106.92	107.48	0.011252	6.04	8	7	1
Stream	0	2-year	10	104.7	105.18	105.33	105.65	0.032179	5.52	2	5	1.55
Stream	0	10-year	23	104.7	105.45	105.74	106.18	0.028879	7.02	4	9	1.57
Stream	0	25-year	31	104.7	105.55	105.85	106.44	0.029926	7.86	5	12	1.63
Stream	0	50-year	38	104.7	105.62	105.91	106.61	0.030922	8.47	6	16	1.68
Stream	0	100-year	45	104.7	105.67	105.98	106.79	0.032558	9.1	7	19	1.75



Willow Road Culvert Boxford, MA Plan: Developed Conditions 6/25/2020
Station 94 - end of study area
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Legend
EG 25-year
WS 25-year
Crit 25-year
Ground
Bank Sta
Elevation (ft)
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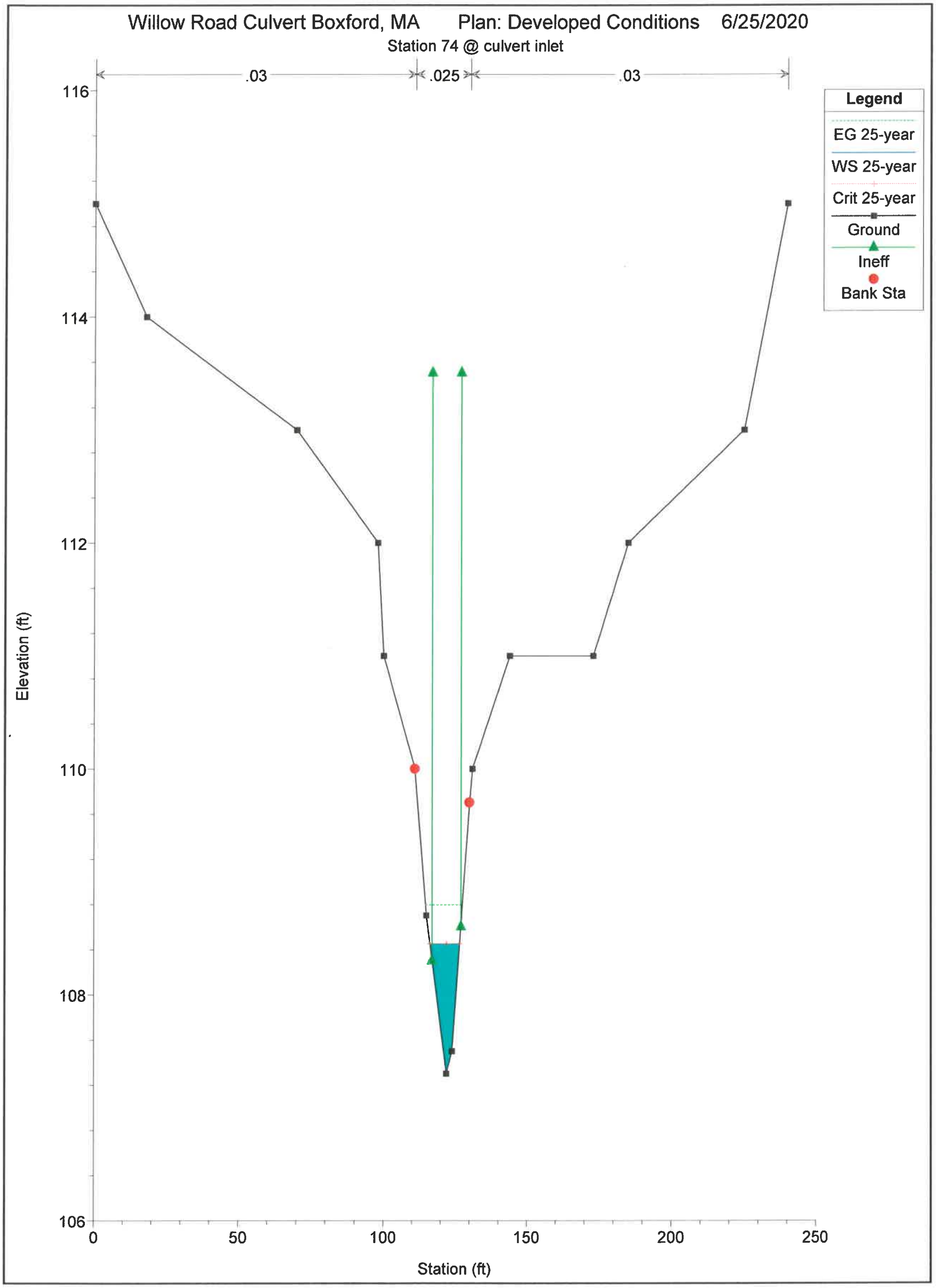
Station (ft)


Willow Road Culvert Boxford, MA
Plan: Developed Conditions
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Station 74 @ culvert inlet
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EG 25-year
WS 25-year
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Station (ft)
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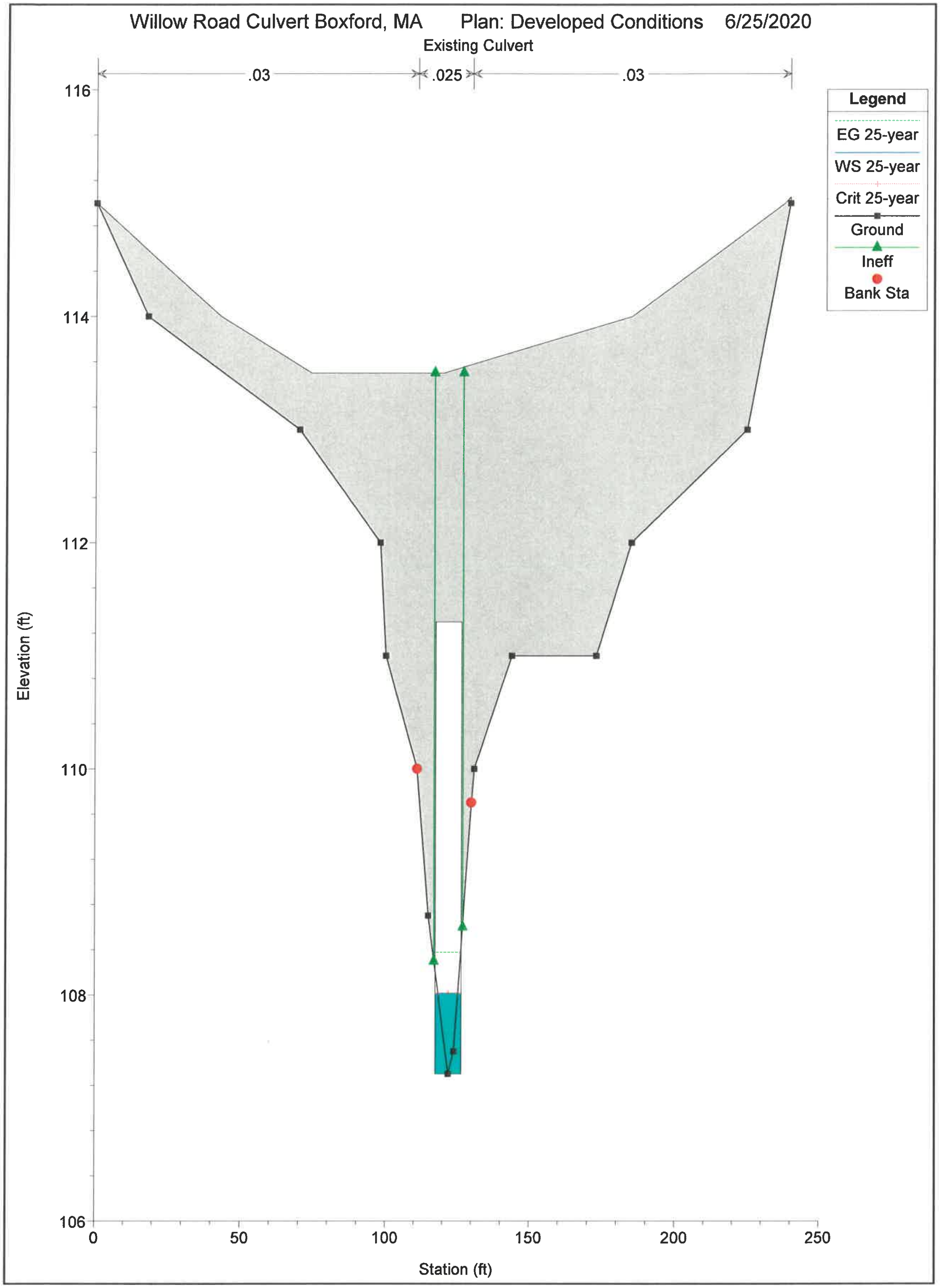
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Existing Culvert
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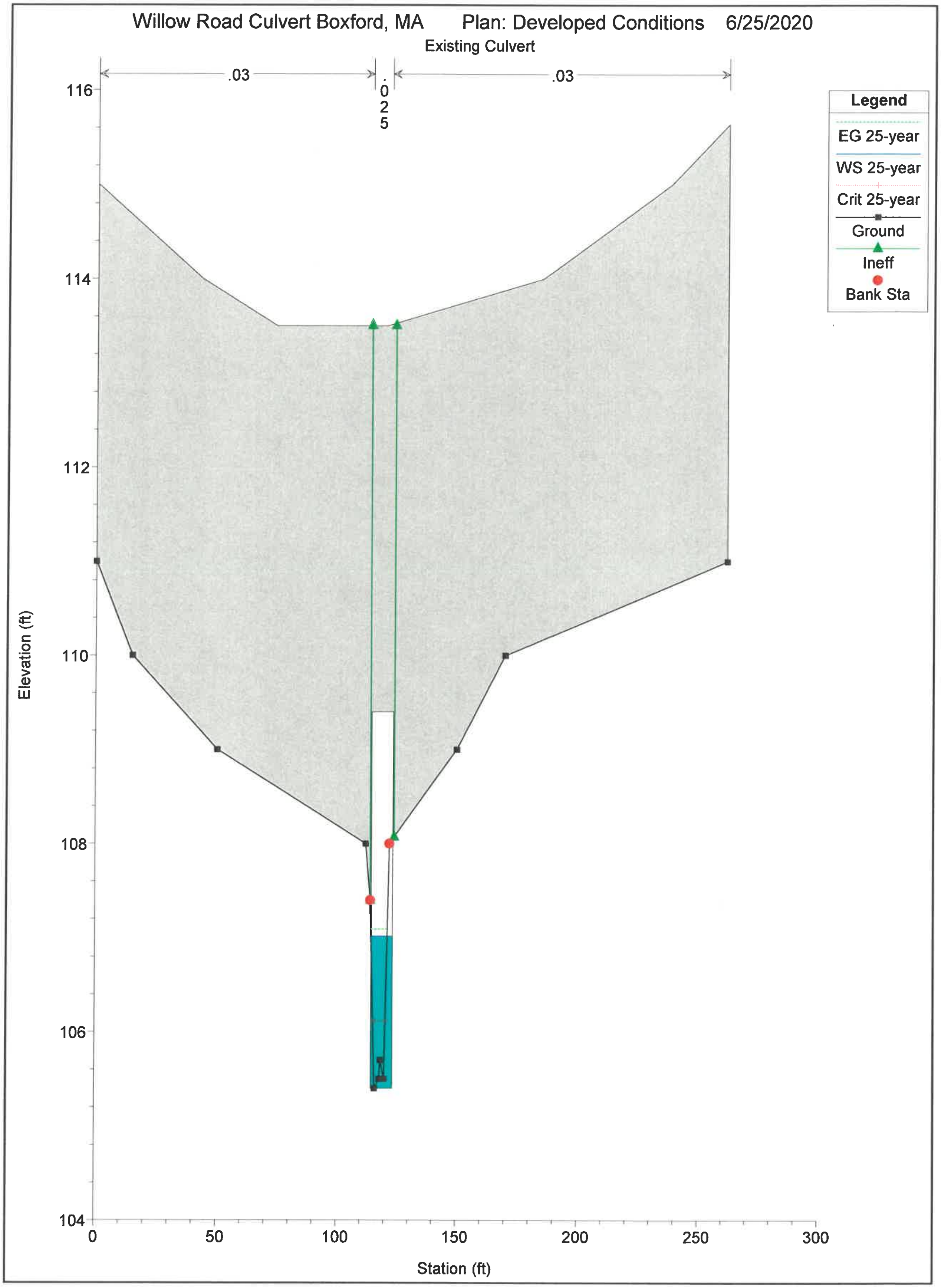
Station (ft)



Willow Road Culvert Boxford, MA Plan: Developed Conditions 6/25/2020
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Elevation (ft)
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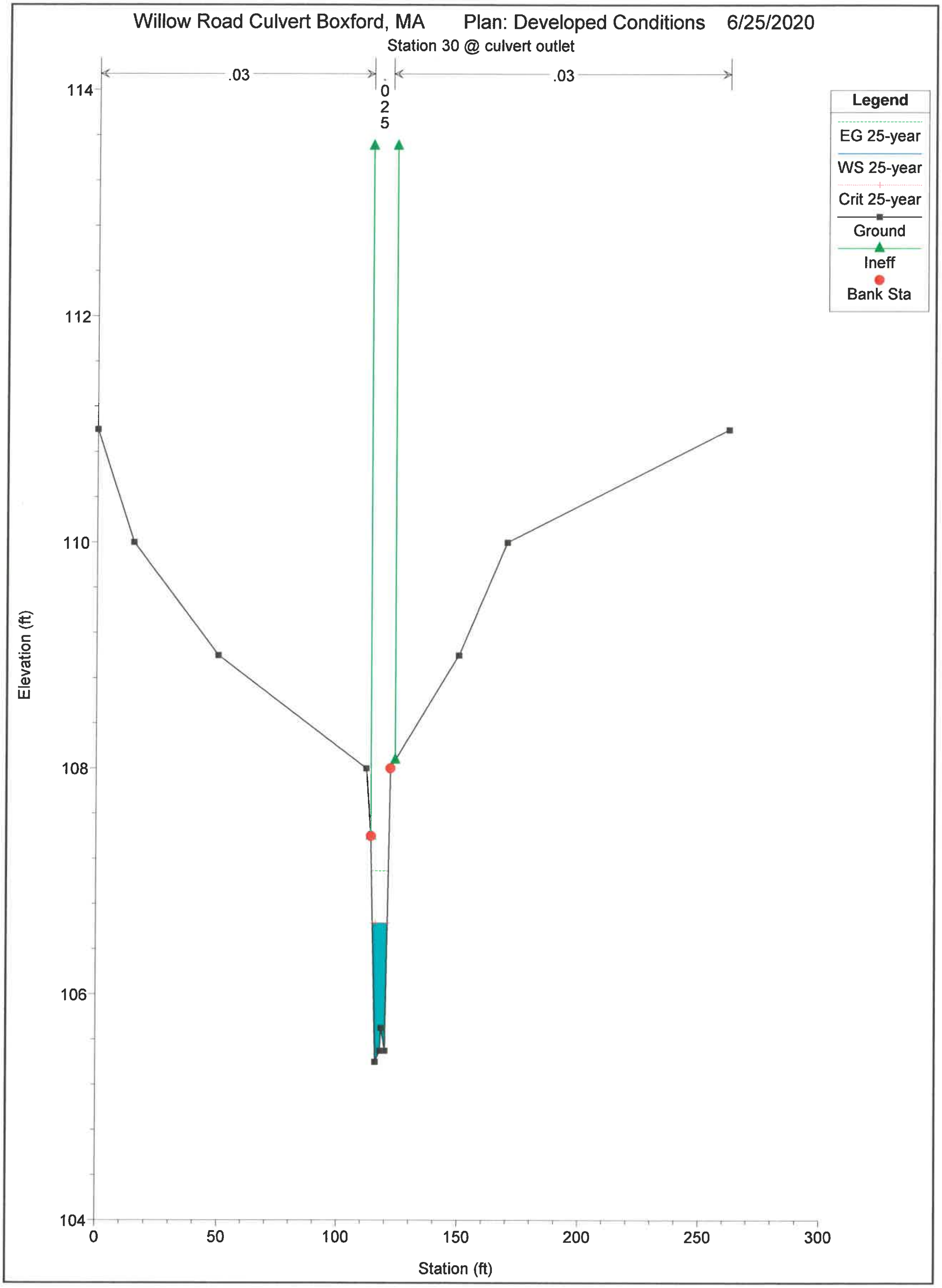
Station (ft)


Willow Road Culvert Boxford, MA   Plan: Developed Conditions   6/25/2020
Station 30 @ culvert outlet
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EG 25-year
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Crit 25-year
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Elevation (ft)
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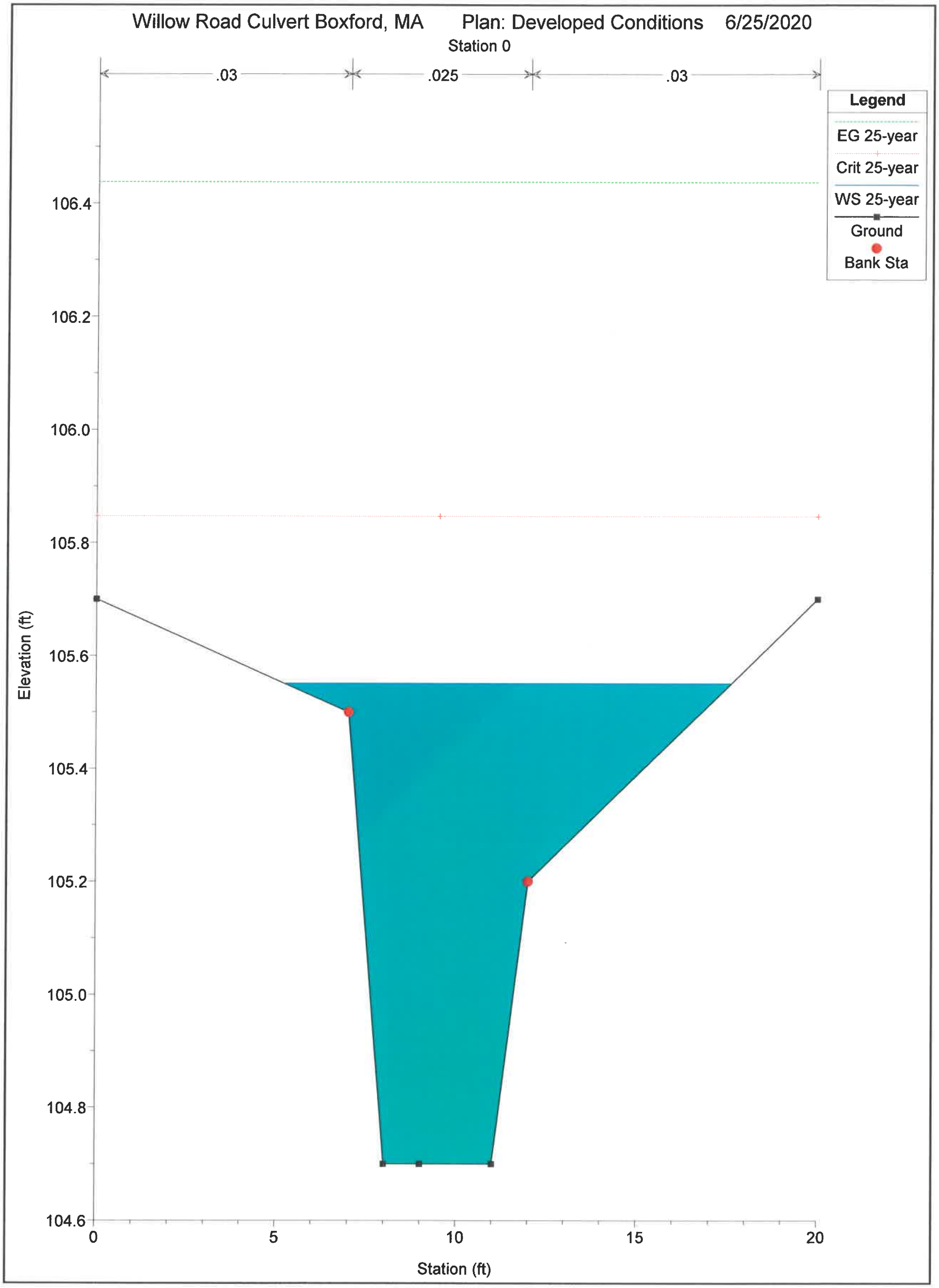
Station (ft)


Willow Road Culvert Boxford, MA
Plan: Developed Conditions
6/25/2020
Station 0
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Legend
EG 25-year
Crit 25-year
WS 25-year
Ground
Bank Sta
Elevation (ft)
106.4
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105.6
105.4
105.2
105.0
104.8
104.6
0
5
10
15
20
Station (ft)

Appendix E – Scour Calculation Worksheets

Professional Service Industries, Inc.
480 Neponset Street, Suite 9C
Canton, MA 02021

Phone: (781) 821-2355
Fax: (781) 821-6276

Material Test Report

Report No: MAT:0446516-33-S1
Issue No: 1

These test results apply only to the specific locations and materials noted and may not represent any other locations or elevations. This report may not be reproduced, except in full, without written permission by Professional Service Industries, Inc. If a non-compliance appears on this report, to the extent that the reported non-compliance impacts the project, the resolution is outside the PSI scope of engagement.

Client: BAY COLONY GROUP
4 SCHOOL ST., P.O. BOX 9136
FOXBORO, MA 02035

CC:

Project: BAY COLONY GROUP - LAB TESTING
CANTON, MA

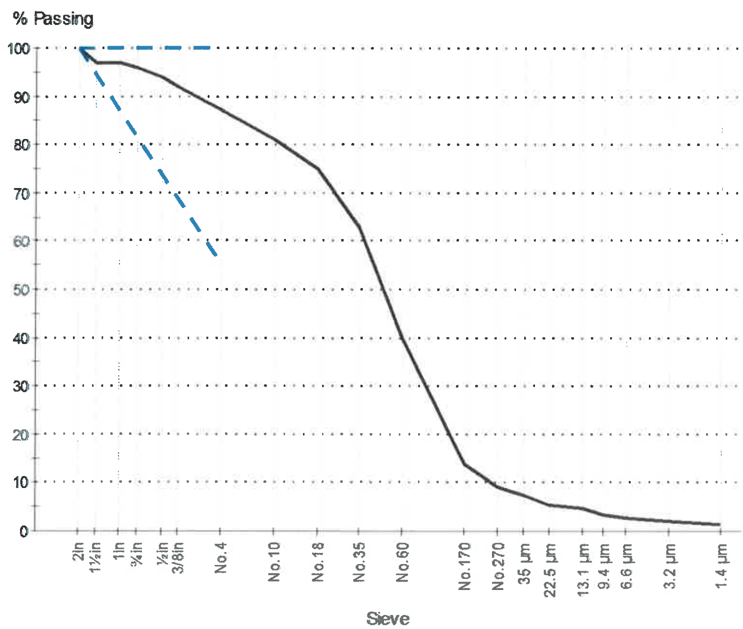
Approved Signatory: Yannick Lastennet (Department Manager)
Date of Issue: 6/22/2020

Sample Details

Sample ID:	0446516-33-S1
Client Sample ID:	
Date Sampled:	06/11/20
Sampled By:	Client
Specification:	Title V Hydrometer
Supplier:	
Source:	
Material:	Sandy Gravel with Organics
Sampling Method:	
General Location:	89 Willow Rd, Boxford MA - Upstream Bed

Sample Description:

Particle Size Distribution



COBBLES	GRAVEL		SAND			FINES	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
(0.0%)	(4.1%)	(9.1%)	(6.2%)	(24.6%)	(44.3%)	(9.2%)	(2.5%)

Grading: ASTM D 422

Date Tested: 6/22/2020
Tested By: Gary Brooks

Sieve Size	% Passing	Limits
2in (50.0mm)	100	100
1½in (37.5mm)	97	
1in (25.0mm)	97	
¾in (19.0mm)	96	
½in (12.5mm)	94	
3/8in (9.5mm)	92	
No.4 (4.75mm)	87	55 to 100
No.10 (2.0mm)	81	
No.18 (1.0mm)	75	
No.35 (500µm)	63	
No.60 (250µm)	40	
No.170 (90µm)	14	
No.270 (53µm)	9	
35.0 µm	7.6	
22.5 µm	5.5	
13.1 µm	4.8	
9.4 µm	3.5	
6.6 µm	2.8	
3.2 µm	2.1	
1.4 µm	1.4	

D85: 3.5602 **D60:** 0.4568 **D50:** 0.3379
D30: 0.1688 **D15:** 0.0936 **D10:** 0.0589
Cu: 7.75 **Cc:** 1.06

Professional Service Industries, Inc.
480 Neponset Street, Suite 9C
Canton, MA 02021

Phone: (781) 821-2355
Fax: (781) 821-6276

Material Test Report

Report No: MAT:0446516-33-S1
Issue No: 1

Approved Signatory: Yannick Lastennet (Department Manager)
Date of Issue: 6/22/2020

Client: BAY COLONY GROUP
4 SCHOOL ST., P.O. BOX 9136
FOXBORO, MA 02035

CC:

Project: BAY COLONY GROUP - LAB TESTING
CANTON, MA

Sample Details

Sample ID: 0446516-33-S1
Client Sample ID:
Date Sampled: 06/11/20
Sampled By: Client
Specification: Title V Hydrometer
Supplier:
Source:
Material: Sandy Gravel with Organics
Sampling Method:
General Location: 89 Willow Rd, Boxford MA - Upstream Bed

Other Test Results

Description	Method	Result	Limits
Dispersion device	ASTM D 422		
Dispersion time (min)		1	
Shape			
Hardness			

Comments

N/A

Professional Service Industries, Inc.
480 Neponset Street, Suite 9C
Canton, MA 02021

Phone: (781) 821-2355
Fax: (781) 821-6276

Report No: DFR:0446516-33/1
Issue No: 1

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Daily Field Report

Client: BAY COLONY GROUP
4 SCHOOL ST.
P.O. BOX 9136
FOXBORO, MA 02035

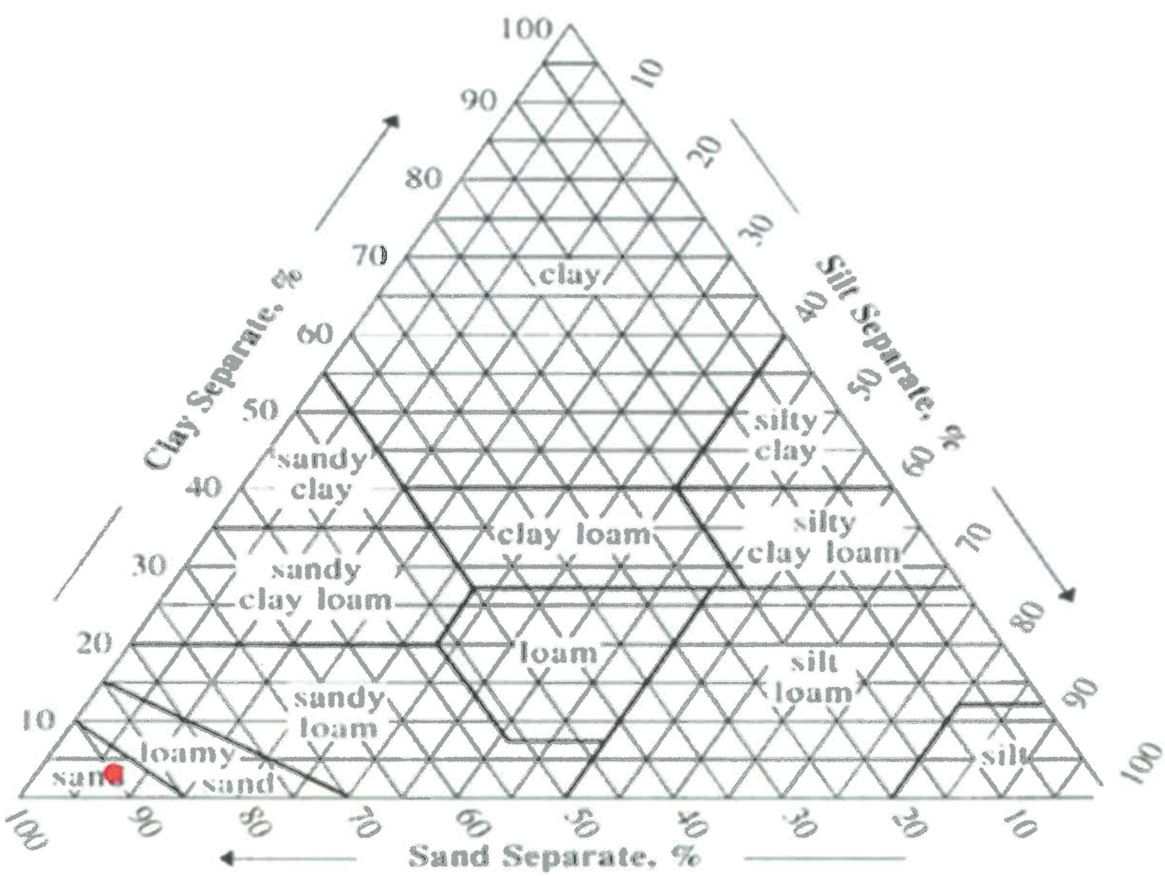
CC:

Project: BAY COLONY GROUP - LAB TESTIN
CANTON, MA

Approved Signatory: Yannick Lastennet (Department Manager)
Date of Issue: 6/22/2020

Date: 6/22/2020 **Technician:**

Soil Texture Triangle



SOIL DATA						
	Source	Sample No.	Percentages From Material Passing a #10 Sieve			Classification
			Sand	Silt	Clay	
●	89 Willow Rd. Boxford MA - Upstream Bed	S1	89.66	7.47	2.87	Sand

Project Name:	Willow Road Boxford, MA
Project Location:	89 Willow Road Boxford, MA
Project Job Number:	20-0148

MassDOT Modified Froehlich Equation for Abutment Scour

$Y_s/Y_a = 2.27\ K_1 K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}$

K_1 = coefficient for abutment shape

K_2 = coefficient for angle of embankment to flow

L' = length of abutment projected normal to flow, ft

Y_a = average depth of flow in the floodplain, ft

A_e = the flow area of the approach cross section obstructed by the embankment, ft^2

Fr = Froude Number

$V_e = Q_e / A_e$, ft/sec

Q_e = the flow obstructed by the abutment and approach embankments, ft^3/sec

Y_s = scour depth, ft

Data Input

Abutment Location:	50-yr Frequency Left	50-yr Frequency Right	100-yr Frequency Left	100-yr Frequency Right
Y_a = average depth of flow in the floodplain, ft	1.3	1.3	1.6	1.6
K_1 = coefficient for abutment shape	0.82	0.82	0.82	0.82
K_2 = coefficient for angle of embankment to flow	1.0	1.0	1.0	1.0
L' = length of abutment projected normal to flow, ft	10.0	4.0	10.0	4.0
Q_e = the flow obstructed by the abutment and approach embankments, ft^3/sec	1.8	2.5	4.0	4.0
A_e = the flow area of the approach cross section obstructed by the embankment, ft^2	9.0	13.0	14.5	14.5
$V_e = Q_e / A_e$, ft/sec	0.2	0.2	0.3	0.3
Fr = Froude Number	0.370	0.370	0.360	0.360

Data Output

	50-yr Left	50-yr Right	100-yr Left	100-yr Right	
Ys =	3.2	2.1	3.5	2.4	ft

Bay Colony Group, Inc.
4 School Street
Foxborough, MA 02035

Project Name:	Willow Road Boxford, MA
Project Location:	89 Willow Road Boxford, MA
Project Job Number:	20-0148
Frequency Event:	50-year

Determine Critical Velocity

$V_c = K_u y^{1/6} D^{1/3}$

V_c = Critical velocity above which bed material of D and smaller will be transported, ft/s

y = Average depth of flow upstream of the bridge, ft

D = Particle size for V_c, ft

D_{50} = Particle size in a mixture of which 50% are smaller, ft

K_u = 11.17

Data Input

y =	1.3	ft
D =	0.3379	ft
K_u =	11.17	

Velocity Upstream of Bridge = 5.0 ft/sec

Data Output

V_c = 8.1 ft/sec

Critical velocity V_C is greather than mean velocity V therefore clear water condition

HEC - 18 Scour Equation for Open Bottom Cluverts (Clear Water Condition w/Wing Wall)

$y_{max} = (K_u\, Q_{BI}^{0.28})\ (Q/(W_C D_{50}^{1/3})^{0.26}$

	Data Input
y_{max} = Flow depth at culvert entrance corner including contraction and local scour, ft	1.7
Q_{BI} = Discharge blocked by road embankment on one side of culvert, ft^3/sec	3
Q = Discharge through the culvert, ft^3/sec	38
W_C = width of the culvert, ft	9.0
D_{50} = Median diameter of bed material, ft	0.337900
y_s = Scour at the culvert entrance corner, ft	0.4
y_o = Average existing depth in the contracted section, ft	1.3
K_u = 0.84	0.84

Data Output

y_{max} = 1.7 ft

$y_s = y_{max} - y_0$ = 0.4 ft

Project Name:	Willow Road Boxford, MA
Project Location:	89 Willow Road Boxford, MA
Project Job Number:	20-0148
Frequency Event:	100-year

Determine Critical Velocity

$V_c = K_u y^{1/6} D^{1/3}$

V_c = Critical velocity above which bed material of D and smaller will be transported, ft/s

y = Average depth of flow upstream of the bridge, ft

D = Particle size for V_c, ft

D_{50} = Particle size in a mixture of which 50% are smaller, ft

K_u = 11.17

Data Input

y =	1.4	ft
D =	0.3379	ft
K_u =	11.17	

Velocity Upstream of Bridge = 5.3 ft/sec

Data Output

V_c = **8.2 ft/sec**

Critical velocity V_C is greather than mean velocity V therefore clear water condition

HEC - 18 Scour Equation for Open Bottom Cluverts (Clear Water Condition w/Wing Wall)

$y_{max} = (K_u Q_{BI}^{0.28})\ (Q/(W_C D_{50}^{1/3}))^{0.26}$

	Data Input
y_{max} = Flow depth at culvert entrance corner including contraction and local scour, ft	2.1
Q_{BI} = Discharge blocked by road embankment on one side of culvert, ft^3/sec	4
Q = Discharge through the culvert, ft^3/sec	45
W_C = width of the culvert, ft	9.0
D_{50} = Median diameter of bed material, ft	0.337900
y_s = Scour at the culvert entrance corner, ft	0.7
y_o = Average existing depth in the contracted section, ft	1.4
K_u = 0.84	0.84

Data Output

y_{max} = 2.1 ft

$y_s = y_{max} - y_0$ = 0.7 ft

Project Name:	Willow Road Boxford, MA
Project Location:	89 Willow Road Boxford, MA
Project Job Number:	20-0148
Frequency Event:	100-year

Given

D = Culvert dimensions	9' x 4'
A = Culvert area (sf)	36
Pw = Culvert wetted perimeter (ft)	26
S = Culvert slope	0.038
H_d = Height of outlet above bed in pipe diameters	0
Q = Peak discharge (peak flow duration assumed to be 30 minutes)	45.4
D_{84} = Grain size distribution	3.5602
D_{16} = Grain size distribution	0.0936

Calculate Hydraulic Radius (R_c)

R_c = Area/Wetted Perimeter 1.385

Coefficents of Scour Obtained from Tables 5.1, 5.2 and 5.3 are:

	α	β	θ	C_s	C_h
Depth of scour	2.27	0.39	0.06	1.03	1.00
Width of scour	6.94	0.53	0.08	1.28	1.00
Length of scour	17.10	0.47	0.10	1.17	1.00
Volume of scour	127.08	1.24	0.18	1.30	1.00

Material Standard Deviation

$\sigma = (D_{84}/D_{16})^{0.5}$ 6.17

HEC - 14 Estimating Scour Hole Geometry in a Cohesionless Soil

h_s = Depth of scour (ft)	2.5
W_s = Width of scour (ft)	10.9
L_s = Length of scour (ft)	21.8
V_s = Volume of scour (ft^3)	756.8
L_m=Location of maximum scour downstream of culvert (ft)	8.7