SDG 3:

Hydraulic Design

Chapter 3

Tennessee Department of Transportation March 7, 2024

Table of Contents

Table of Figures

Section 1 General Responsibilities

Any structure constructed or modified on a waterway with a Q50 (50 year flood flow) of 500 cubic feet per second (cfs) or greater requires a detailed hydraulic design to be performed by a qualified hydraulic engineer. The Hydraulic Design Section performs hydraulic studies for all internally designed projects and reviews studies completed by outside consultants for TDOT projects.

For structures with a Q50 > 500 cfs, the responsibilities of the Hydraulic Design Section include:

- Sizing structure openings.
- Determining scour susceptibility and potential scour depths for structures as well as design of countermeasures, if necessary.
- Designing stormwater drainage on bridge decks and at the end of bridges including both hydraulic and grade crossings.
- Ensuring Departmental compliance with floodplain regulations of the Federal Emergency Management Agency (FEMA).
- Coordinating navigation horizontal and vertical clearance requirements with all applicable agencies.
- Supporting departmental activities related to hydraulics (detention, energy dissipators, emergency operations, etc.)
- Investigating flood complaints or issues caused by TDOT facilities at the discretion of the Director.

Section 2 Grade Approval

Hydraulic grade approvals are received as part of the initial studies activity, and requirements for submittal can be found in the TDOT Roadway Design Guidelines and Survey Standards Manual. During the grade approval process, the hydraulic engineer collects all relevant data on the proposed structure location and evaluates it to obtain a preliminary size for the proposed structure. The hydraulic engineer evaluates the proposed roadway grade and alignment to determine the appropriate structure size. Structures are reviewed for constructability conflicts based on the existing alignment, and a structural engineer may be consulted. Changes to grade or alignment may be required in some cases.

Information gathered for grade approval includes, but is not limited to:

- Proposed roadway plans and survey information
- Existing roadway and structure plans

- LiDAR data from the statewide LiDAR program
- Biannual inspection reports, including field observations and pictures
- FEMA flood insurance studies (FIS)
- Drainage area and flows
- Previously conducted hydraulic studies by TDOT and outside agencies (Tennessee Valley Authority (TVA), US Army Corps of Engineers, FEMA, other state or local agencies)
- Navigation requirements from the US Coast Guard, US Army Corps of Engineers, or TVA
- Field observations from local residences and TDOT Operations personnel.

Structure size provided at the grade approval stage is not based on hydraulic modeling. Structure sizes and details shall be considered PRELIMINARY until the final hydraulic design is completed.

Section 3 Final Hydraulic Design

The hydraulic design process requires building a detailed hydraulic model of the proposed structure location. The hydraulic model shall be constructed using HEC-RAS for one-dimensional modeling or SMS-SRH for two-dimensional modeling unless an alternate program is approved by the Hydraulic Design Section. Use of one-dimensional versus two-dimensional analysis shall be determined based on the significance and complexity of the structure, the route and the waterway being crossed, and shall be done with the approval of the Hydraulic Design Section.

The detailed hydraulic design shall include an evaluation of structure performance during a minimum of the 2, 10, 50, 100, and 500 year floods, as well as the overtopping flood if determined to be less than the 100 year flood. The extent of the model shall be sufficient to show the effects of the existing and proposed structures and shall include any nearby drainage structures on the same waterway or sharing the same floodplain that may be affected. Existing, proposed, and "no structure" conditions shall be included. The purpose of the "no structure" condition is to have a baseline for determining effects of the existing and proposed structures. Only the structure or structures proposed to be replaced shall be removed, and any other structures included in the existing conditions model shall remain in place.

Structures determined to be susceptible to scour shall include a scour analysis based on the Federal Highway Administration's (FHWA) HEC-18. Calculations shall be made using the FHWA Hydraulic Toolbox software. Scour calculations in HEC-RAS will NOT be accepted. Other methods may be acceptable with prior approval of the Hydraulic Design Section.

Upon completion of the hydraulic design, hydraulic and layout data shall be provided to the structural and roadway designers. Bridges shall include a sealed hydraulic layout (see Appendix A). Culverts shall include the hydraulic data below, which shall be included in the roadway plans. The hydraulic design shall also provide the station, skew, invert elevations, and standard drawing number. Riprap details at culverts shall be in accordance with STD-17-10 unless otherwise indicated. Deck drain locations and guidance on the use of end of bridge flumes shall also be provided. The final hydraulic report shall be reviewed and sealed by a licensed engineer with relevant experience in hydraulic design.

Example hydraulic data block for culverts (to be included on roadway plans):

Station 12+18	3@12'x10', 90° skew, RCB
Drainage Area	5.2 mi^2
Design Discharge (100 YR)	38.7 cfs
100 YR Backwater	0.28 ft at El. 122.63
100 YR Velocity	1.02 ft/sec
500 YR Discharge	46.2 cfs at El. 122.87
Inlet Invert Elevation	119.2
Outlet Invert Elevation	118.9
Approach Overtopping El.	124.2
Standard Drawing Number	STD-17-100

For bridges, the hydraulic data block included on the hydraulic layout shall also be included on the final bridge layout. See TDOT Design Procedures for Hydraulic Structures for additional guidance.

Section 4 Hydraulic Drawings

Culvert and riprap layout details shall be shown on the roadway plans. The hydraulic designer may provide a rough sketch of riprap details at the culvert inlet and outlet to the roadway designer if necessary. If a sketch is not provided, then all riprap at culvert outlets shall be as shown on STD-17-10.

A draft hydraulic layout shall be provided at the grade approval stage. The draft hydraulic layout shall include bridge location information as well as plan and elevation views to scale. This drawing shall show basic horizontal and vertical alignment data as well as substructure stations and span lengths. Draft hydraulic layouts shall not be sealed and shall be considered preliminary.

A hydraulic layout shall be drawn to scale, sealed by a professional engineer, and include these details:

- Basic project and bridge identifying information
- Plan view showing approximate channel banks, skew, abutment and pier locations and skews, existing bridge location (including piers), deck drain and flume locations, riprap size and limits
- Elevation view showing groundline, design flood elevation, 100 year flood elevation, 500 year flood elevation, reservoir data (if applicable), low girder elevation, datum elevation, any excavation under bridge
- Horizontal and vertical curve data
- Superelevation transition data if applicable
- Hydraulic data
- Navigation clearances (if applicable)
- Hydraulic designer, hydraulic supervisor, detailer
- General notes shall include specifications for design, parapet or bridge rail, deck drains, end of bridge flumes, riprap, type of pier, bridge beam type.

The general notes may change, but all other details shall be included on all future versions of the bridge layout.

Section 5 FEMA Compliance

Projects shall be in compliance with FEMA National Flood Insurance Program (NFIP) regulations to the extent possible. All projects in a Zone AE designated floodplain shall have a no-rise certification for the 100 year flood or Conditional Letter of Map Revision/Letter of Map Revision. Projects in a Zone A floodplain shall have a no-rise certification if possible.

Projects with lateral encroachments into FEMA designated Zone AE or Zone A floodplains shall be reviewed by the Hydraulic Design Section regardless of the presence of structures. These encroachments may require hydraulic modeling to ensure compliance with FEMA regulations.

FEMA compliance shall be coordinated with the Hydraulic Design Section on all projects.

Section 6 Consultant Designs

The Structures Division does not provide hydraulic grade approval for consultant hydraulic designs. However, all consultant hydraulic designs for structures meeting the minimum flow designated in Section 1 shall be reviewed and approved by the Structures Division. Upon

completion of the hydraulic design, the consultant shall provide roadway design plans, a hydraulic layout, digital hydraulic modeling files, and a report which includes hydrology calculations, scour analysis, deck drain analysis, site photographs, and other relevant data. The Hydraulic Design Section may review prior to completion if requested but approval will not be considered final until the hydraulic design is sealed by a professional engineer.

The Hydraulic Design Section shall review and approve the scope and type (1D, 2D) of the hydraulic modeling. All questions shall be directed to the Hydraulic Design Section.

Section 7 Coordination with Outside Agencies

Some structures may have minimum horizontal or vertical navigation clearance requirements from the US Coast Guard, US Army Corps of Engineers, TVA, or other agencies. These navigation requirements shall be coordinated by the hydraulic designer and shall be incorporated into the hydraulic layout as appropriate.

All effort shall be made to minimize fill placed inside flood control reservoirs regardless of the presence or absence of a hydraulic structure. These projects may require offset plans, and the Hydraulic Design Section will coordinate requirements with relevant agencies.

Appendix A. Example Hydraulic Layouts

Figures 1 and 2 show examples of hydraulic layouts.

PRE604.DGN

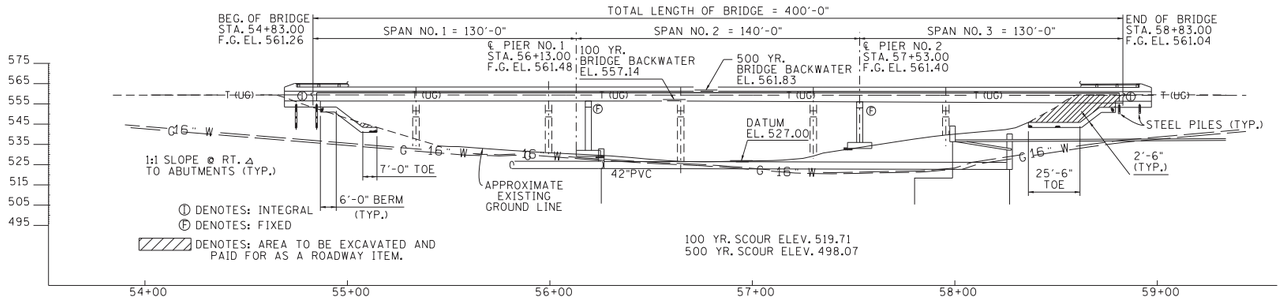
PIN NO. 115906.00

P.E. NO. 75078-1206-54

PROJECT NO.	YEAR	SHEET NO.
IM-M-268(4)	2023	

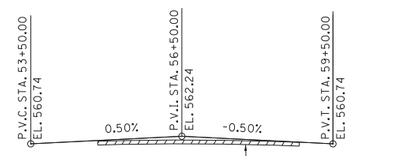
REVISIONS

NO.	DATE	BY	BRIEF DESCRIPTION



ELEVATION

SCALE: 1" = 30'-0"

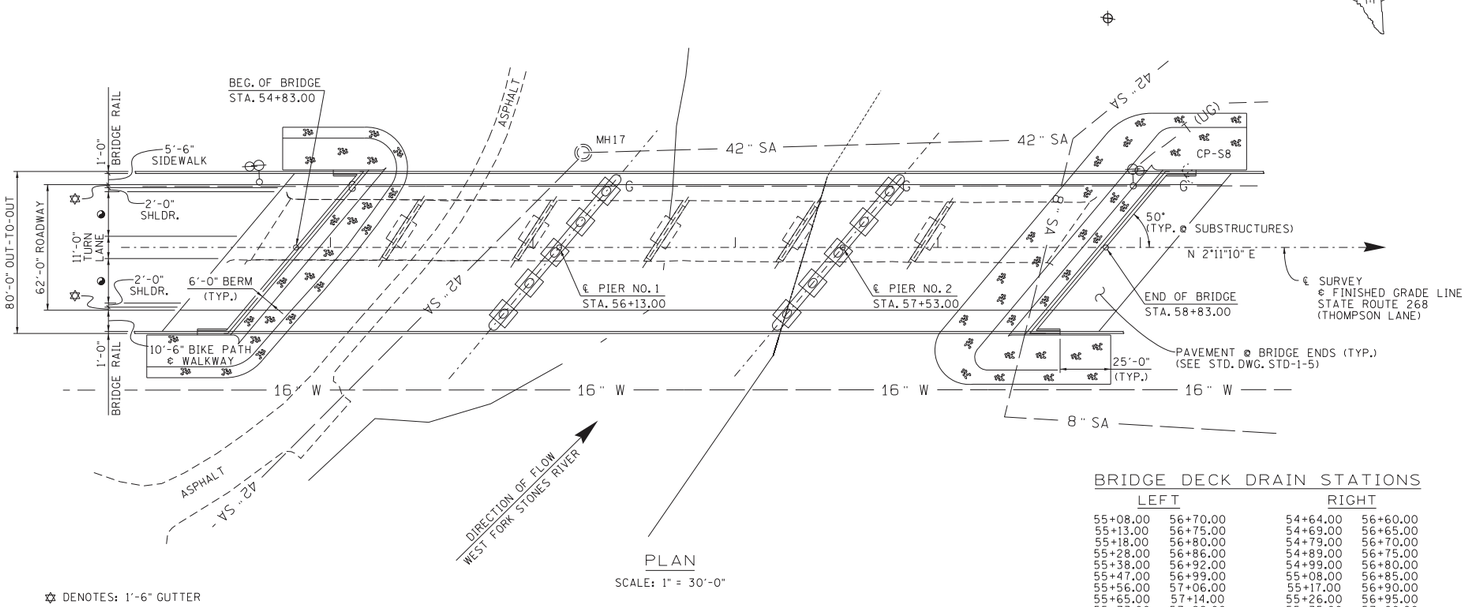


GRADE SKETCH

(STATE ROUTE 268)
(NTS)

GENERAL NOTES

1) SPECIFICATIONS: STANDARD ROAD AND BRIDGE SPECIFICATIONS OF THE TENNESSEE DEPARTMENT OF TRANSPORTATION (JANUARY 1, 2015 EDITION).
2) DESIGN SPECIFICATION: AASHTO LRFD SEVENTH EDITION, 2014, AND THE 2011 AASHTO GUIDE SPECIFICATIONS FOR LRFD SEISMIC BRIDGE DESIGN, EDITION 2 (WITH INTERIMS.)
3) LOADING: HL-93 LIVE LOADING; SEISMIC ZONE ___ WITH As=___, Sds=___, Sd1=___, (1000 YEAR RETURN PERIOD). DEAD LOAD INCLUDES 35 LB/SQ. FT. FOR FUTURE WEARING SURFACE.
4) CONCRETE: CLASS "A" F'c = 3000 PSI SLAB CONCRETE TO BE CLASS "D" F'c = 4000 PSI.
5) REINFORCING STEEL: TO BE ASTM A615 GRADE 60. (EPOXY COAT ALL SLAB STEEL.)
6) SUPERSTRUCTURE: TO CONSIST OF 3 SPANS, STEEL BEAMS.
7) USE CONCRETE PILE BENTS.
8) USE STD-11-1 BRIDGE RAIL W/STRUCTURAL TUBING AND 5'-0" SIDEWALKS.
9) BRIDGE DECK DRAINS ARE REQUIRED.
10) TEXTURE COATING: TO BE MOUNTAIN GREY (36440), EXCEPT INSIDE FACE AND TOP OF PARAPET TO BE WHITE (37886).
11) BRIDGE EXCAVATION: BASED ON FINAL PROFILE AT ABUTMENTS.
12) MACHINED RIP-RAP SHALL BE CLASS "B" IN ACCORDANCE WITH SECTION 709 OF THE STANDARD SPECIFICATIONS AND SHALL BE PAID FOR AS A ROADWAY ITEM NO. 709-05.08 - TON.
13) EXISTING BRIDGE I.D. NO. 75F00050005 AND APPROACHED TO BE REMOVED TO NATURAL GROUND BETWEEN STA. 54+69.81 AND STA. 58+63.43.
14) MAINTAIN TRAFFIC USING PHASE CONSTRUCTION.



PLAN

SCALE: 1" = 30'-0"

DENOTES: 1'-6" GUTTER

DENOTES: (2) 11'-0" LANES

DENOTES: BRIDGE DECK DRAIN (TYPE 2 GRATE) REQUIRED. SEE STD. DWG. NO. STD-1-2. FOR LOCATIONS SEE "BRIDGE DECK DRAIN STATIONS" THIS SHEET.

BRIDGE DECK DRAIN STATIONS

LEFT		RIGHT	
55+08.00	56+70.00	54+64.00	56+60.00
55+13.00	56+75.00	54+69.00	56+65.00
55+18.00	56+80.00	54+79.00	56+70.00
55+28.00	56+86.00	54+89.00	56+75.00
55+38.00	56+92.00	54+99.00	56+80.00
55+47.00	56+99.00	55+08.00	56+85.00
55+56.00	57+06.00	55+17.00	56+90.00
55+65.00	57+14.00	55+26.00	56+95.00
55+73.00	57+22.00	55+35.00	57+00.00
55+81.00	57+29.00	55+43.00	57+05.00
55+88.00	57+37.00	55+51.00	57+10.00
55+95.00	57+46.00	55+59.00	57+17.00
56+00.00	57+56.00	55+66.00	57+24.00
56+05.00	57+66.00	55+73.00	57+31.00
56+10.00	57+73.00	55+80.00	57+39.00
56+15.00	57+85.00	55+85.00	57+46.00
56+20.00	57+96.00	56+00.00	57+54.00
56+25.00	58+08.00	56+05.00	57+62.00
56+30.00	58+20.00	56+10.00	57+71.00
56+35.00	58+34.00	56+15.00	57+80.00
56+40.00	58+47.00	56+20.00	57+89.00
56+45.00	58+60.00	56+25.00	57+98.00
56+55.00	58+74.00	56+30.00	58+08.00
56+60.00	58+88.00	56+35.00	58+18.00
56+65.00	59+00.00	56+40.00	58+28.00
		56+45.00	58+38.00
		56+55.00	58+49.00
			58+58.00

NOTE: ANY WORK WITHIN THE STREAM CHANNEL AREA (E.G., FOR PIER FOOTING, RIP-RAP PLACEMENT, MULTI-BARREL CULVERT/BRIDGE CONSTRUCTION, ETC.) SHALL BE SEPARATED FROM FLOWING WATER OR EXPECTED FLOW PATH AND PERFORMED DURING LOW FLOW CONDITIONS. ALL ITEMS USED WITHIN THE STREAM CHANNEL AREA FOR DIVERSION OF FLOW (OR EXPECTED FLOW), UNLESS SPECIFIED IN THE PLANS, SHALL NOT BE PAID FOR DIRECTLY BUT SHALL BE INCLUDED IN THE COST OF OTHER ITEMS. THIS NOTE EXCLUDES ANY ITEMS SPECIFIED IN THE PLANS FOR THE TEMPORARY DIVERSION CHANNELS, EC-STR-31 AND TEMPORARY DIVERSION CULVERTS, EC-STR-32 FOR SINGLE BARREL CULVERT CONSTRUCTION.

HYDRAULIC DATA

DRAINAGE AREA = 152.38 MI²
DESIGN DISCHARGE (100 YR.) = 49.332 CFS
WATER AREA PROVIDED BELOW EL. 554.64 FT² = 7,826.77
100 YR. VELOCITY = 6.30 FPS
100 YR. BRIDGE BACKWATER = 0.40 FT @ EL. 557.14
ROADWAY OVERTOPPING EL. 560.01 FT.
100 YEAR DISCHARGE 49,332 CFS @ EL. 554.64
500 YEAR DISCHARGE 69,087 CFS @ EL. 561.47

Spinks David
2023.12.05
08:42:34
-06'00'

2040 ADT = 24,920
ROADWAY WIDTH = 62'-0" WITH
5'-6" AND 10'-6" SIDEWALKS AND
STD-11-1 BRIDGE RAIL W/STRUCTURAL TUBING
DESIGN SPEED = 50 MPH

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
HYDRAULIC PRELIMINARY
STATE ROUTE 268
(THOMPSON LANE)
OVER
WEST FORK STONES RIVER
BRIDGE I.D. NO. 75F00050005
STATION 56+83.00
LOG MILE 0.00
RUTHERFORD COUNTY
2023

DESIGNED BY JIMMY SCALES DATE 08-23
DRAWN BY TLW (C.A. BERNATEK) DATE 08-23 (4-17)
SUPERVISED BY S.S./DJ. WISEMAN DATE 08-23
CHECKED BY JIMMY SCALES DATE 08-23

CORRECT Ted A Kniazewycz
ENGINEER OF STRUCTURES

1 OF 1

12-05-23

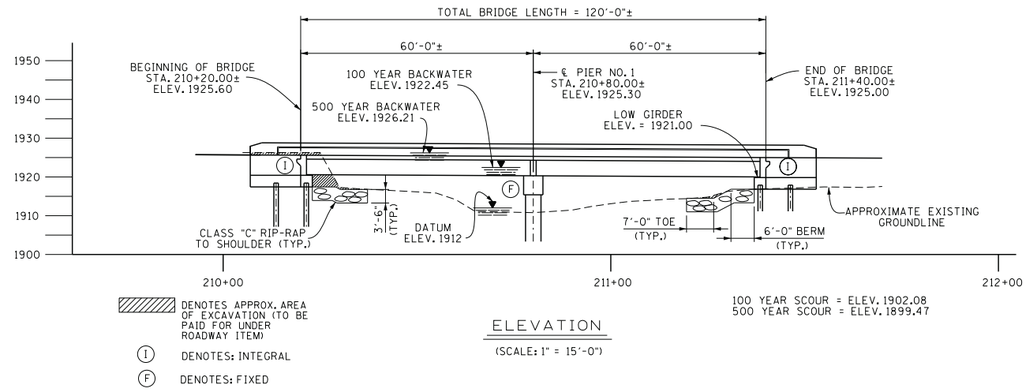
CLASS "B" RIP-RAP = 729 TONS

12/5/2023 7:46:40 AM
C:\Users\DJ3254\OneDrive - Tennessee\Desktop\D Drive\dgn\MCROSTATION\Projects\pre604.dgn

FIGURE 1: EXAMPLE HYDRAULIC LAYOUT 1

PREL307.DGN

PIN NO. 124631.00



ELEVATION

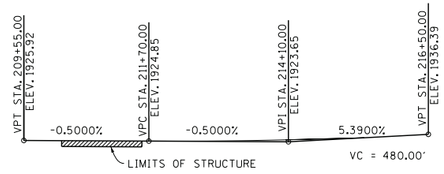
(SCALE: 1" = 15'-0")

P.E. NO. 86006-1235-94

PROJECT NO.	YEAR	SHEET NO.
BR-STP-107(28)	2020	

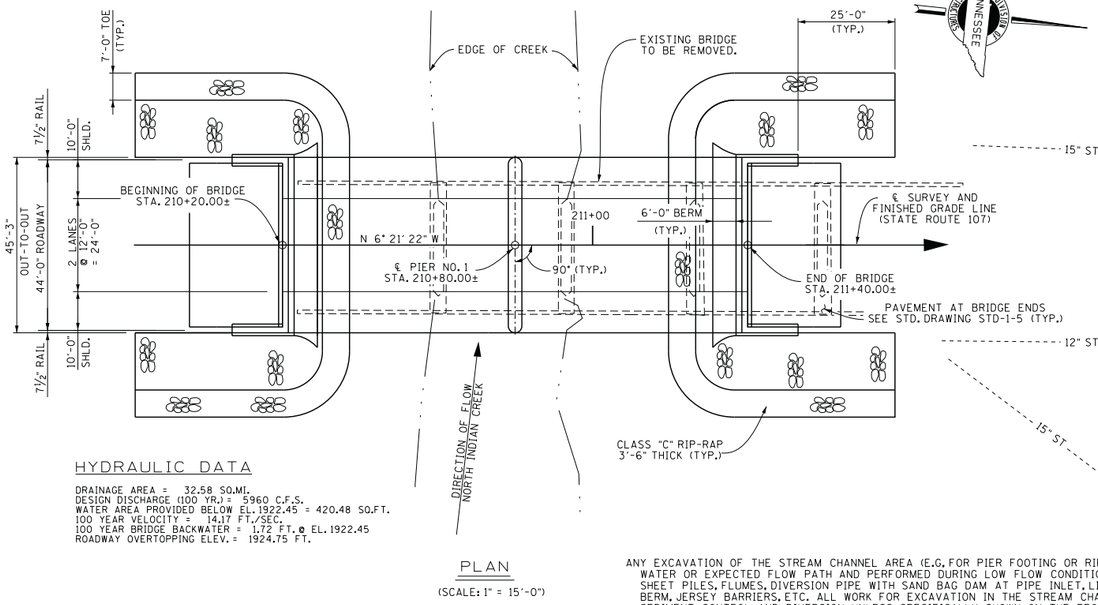
REVISIONS

NO.	DATE	BY	BRIEF DESCRIPTION



GRADE SKETCH

(STATE ROUTE 107)



PLAN

(SCALE: 1" = 15'-0")

HYDRAULIC DATA

DRAINAGE AREA = 32.58 SQ.MI.
DESIGN DISCHARGE (100 YR.) = 5960 C.F.S.
WATER AREA PROVIDED BELOW EL. 1922.45 = 420.48 SQ.FT.
100 YEAR VELOCITY = 14.17 FT./SEC.
100 YEAR BRIDGE BACKWATER = 1.72 FT. @ EL. 1922.45
ROADWAY OVERTOPPING ELEV. = 1924.75 FT.

GENERAL NOTES

1) SPECIFICATIONS: STANDARD ROAD AND BRIDGE SPECIFICATIONS OF THE TENNESSEE DEPARTMENT OF TRANSPORTATION. (JAN. 1, 2015 EDITION).
2) LOADING: HL-93 LIVE LOADING; SEISMIC CATEGORY " " WITH As= ,
Sds = , Sd1 = (1000 YEAR RETURN PERIOD).
(DEAD LOAD TO INCLUDE 35 LB/SQ. FT. FOR FUTURE WEARING SURFACE.
3) DESIGN SPECIFICATIONS: AASHTO LRFD EIGHTH EDITION 2017 WITH INTERIMS, AND THE 2011 AASHTO GUIDE SPECIFICATIONS FOR LRFD SEISMIC BRIDGE DESIGN, SECOND EDITION WITH INTERIMS.
4) CONCRETE: CLASS "A" f'c = 3000 PSI, EXCEPT AS NOTED OTHERWISE.
5) CLASS " " CONCRETE (f'c = PSI) FOR BRIDGE DECKS SHALL BE IN ACCORDANCE WITH SECTION 604 OF THE STANDARD SPECIFICATIONS.
6) BRIDGE DECK SURFACE FINISH : TO BE IN ACCORDANCE WITH METHOD " " IN ARTICLE 604.22 OF THE STANDARD SPECIFICATIONS.
7) REINFORCING STEEL: TO BE ASTM A615 GRADE 60 UNLESS NOTED OTHERWISE. SEE SECTION 604 AND 907 OF THE STANDARD SPECIFICATIONS. EPOXY COAT ALL SLAB STEEL.
8) SUPERSTRUCTURE: TO CONSIST OF 2 SPANS, CONTINUOUS 33" PRESTRESSED BOX BEAMS WITH COMPOSITE CONCRETE DECK SLAB.
9) BRIDGE RAIL SYSTEM: BUILD BRIDGE RAILINGS ACCORDING TO STANDARD DRAWING STD-1-1SS.
10) TEXTURE COATING: TO BE MOUNTAIN GRAY (36440) EXCEPT ENTIRE PARAPET TO BE WHITE (37886).
11) BRIDGE DECK DRAINS ARE NOT REQUIRED.
12) MAINTAIN TRAFFIC BY STAGE CONSTRUCTION.
13) TYPE OF PIER IS DESIGNER'S CHOICE.
14) MACHINED RIP-RAP SHALL BE CLASS "C" IN ACCORDANCE WITH SECTION 709 OF THE STANDARD SPECIFICATIONS AND SHALL BE PAID FOR UNER ITEM 709-05.09.
15) REMOVE EXISTING BRIDGE.

ANY EXCAVATION OF THE STREAM CHANNEL AREA (E.G. FOR PIER FOOTING OR RIP-RAP PLACEMENT) SHALL BE SEPARATED FROM FLOWING WATER OR EXPECTED FLOW PATH AND PERFORMED DURING LOW FLOW CONDITIONS. THIS SHALL BE ACCOMPLISHED BY THE USE OF SHEET PILES, FLUMES, DIVERSION PIPE WITH SAND BAG DAM AT PIPE INLET, LINED DIVERSION CHANNEL WITH SAND BAG OR CLEAN ROCK BERM, JERSEY BARRIERS, ETC. ALL WORK FOR EXCAVATION IN THE STREAM CHANNEL AREA INCLUDING EROSION PREVENTION AND SEDIMENT CONTROL AND DIVERSION, UNLESS SPECIFICALLY SHOWN ON THE EROSION PREVENTION AND SEDIMENT CONTROL PLAN, SHALL BE PAID FOR UNDER ITEM NO. 209-65.2X, SEQUENCING FOR CONSTRUCTION IN THE DRY (DESCRIPTION), LS. THIS ITEM SHALL INCLUDE ALL COSTS FOR MATERIALS, LABOR, MAINTENANCE, REMOVAL, SITE RESTORATION, AND OTHER MISCELLANEOUS ITEMS. ADDITIONALLY, ANY EXCAVATION NOT DESIGNATED AS BRIDGE EXCAVATION 204-XX IS TO BE INCLUDED IN THIS ITEM AND FOOTNOTED "EXCAVATION INCLUDED IN THIS ITEM IS UNSUITABLE FOR ROADWAY FILL MATERIAL".

WESLEY PECK
REGISTERED ENGINEER
AGRICULTURE
No. 106034
STATE OF TENNESSEE

Digitally signed by Wesley Peck
Date: 2020.06.15 10:01:06 -05'00'

2020 ADT = 3950
44'-0" ROADWAY WITH STD-1-1SS PARAPET
DESIGN SPEED = 45 MPH

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
BRIDGE NO. 1
HYDRAULIC LAYOUT
STATE ROUTE 107
(UNICOI DRIVE)
OVER
NORTH INDIAN CREEK
BRIDGE ID. NO. 86SR1070007
STATE 210+80.00
UNICOI COUNTY
2020

Jed A. Kniginsky
ENGINEER OF STRUCTURES

DESIGNED BY J. RANDOLPH DATE 10/18
DRAWN BY DEANNA EASTERLY/JRC DATE 10/18
SUPERVISED BY DYE/ DATE 10/18
CHECKED BY DATE

6/8/2020
P:\Cadd User Group Regions I and 2\backup\prelims\PREL307.dgn

FIGURE 2: EXAMPLE HYDRAULIC LAYOUT 2

Works Cited

1. TDOT Roadway Design Guidelines - https://www.tn.gov/tdot/roadway-design/design-standards/design-guidelines.html
2. TDOT Drainage Manual – https://www.tn.gov/tdot/roadway-design/design-standards/drainage-manual.html
3. TDOT Survey Standards Manual – https://www.tn.gov/content/dam/tn/tdot/roadway-design/documents/tdot-documents/survey-documents/TDOT%20Survey%20Standards%20Manual.pdf
4. TDOT Standard Specifications for Road and Bridge Construction - https://www.tn.gov/tdot/tdot-construction-division/transportation-construction-division-resources/2021-standard-specifications.html
5. TDOT Design Procedures for Hydraulic Structures - https://www.tn.gov/content/dam/tn/tdot/structures/hydraulic-design/thmall.pdf
6. FHWA Hydraulic Engineering Circular 18, “Evaluating Scour at Bridges” - https://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm