JACOBS ch2m

ADDENDUM NO. 2

TO THE CONTRACT DOCUMENTS

Date: September 18, 2018
CH2M HILL Project No.: 691267

for the
Brooks Bridge Water Main Replacement for the Okaloosa Island Water Supply Project

To All Plan Holders:

The following changes, additions, and/or deletions are hereby made part of the Contract Documents for the Brooks Bridge Water Main Replacement Project, dated August 2018, as fully and completely as if the same set forth fully therein:

Specifications

A. OCWS Contractor Procurement Front End

SECTION C-451, Qualifications Statement

1. Page 6, REPLACE in its entirety with the attached revised page 6 of the Qualifications Statement.

SECTION C-520, Agreement

2. Page 2, Section 4.02 CHANGE "…within 45 days after the date when the Contract Times commence to run." TO "…within 225 days after the date when the Contract Time commence to run."

B. TECHNICAL SPECIFICATIONS

SECTION 01 29 00, Payment Procedures

1. Page 2, Section 1.05 A CHANGE "No partial payments based upon percentage of completion or stored materials will be awarded." TO "If requested by the Contractor, partial payments will be awarded for mobilization. Contractor to submit invoices for bonds and insurance certificates with pay application. No partial payments based upon percentage of completion or stored materials will be awarded for the 20-in Diameter HDPE Directional Drill and Erosion Control Measures line items as shown on the Bid Sheet."

SECTION 01 50 00, Temporary Facilities and Controls

1. Page 3, Section 3.01 C.1 CHANGE "Hydrant Water" TO "Hydrant Water: Okaloosa Island"
2. Page 3, ADD Section 3.01 C.2 and C.3

   "2. Hydrant Water: Ft. Walton Beach

a. Hydrant water is available for construction purposes for all activities located on the Ft. Walton Beach side of the project from the City of Ft. Walton Beach, Fl.

b. Contractor to submit a meter order form to the City of Ft. Walton Beach prior to beginning construction and will be responsible for all costs associated with utilizing water from the City.

3. Water Processing and Disposal

a. Contractor is responsible for obtaining, handling and disposal of all water used onsite for all construction activities including pipe flushing and pressure testing. Contractor shall obtain any required permits and shall be responsible for adhering to all local, state, and federal rules that pertain to the disposal of the water."

3. Page 7, Section 3.03 B CHANGE "Noise Ordinance Control: City of Ft. Walton Beach" TO "Noise Ordinance Control: City of Ft. Walton Beach and Okaloosa County, FL"

4. Page 10, CHANGE Section 3.08 to Section 3.09 and ADD Section 3.08:

"SITE RESTORATION

a. All disturbed areas of the project site shall be returned to their preconstruction conditions, including, but not limited to, driveways and grassed areas. If disturbed during construction the property bordering the Okaloosa Island Fire Station shall be returned to preconstruction site conditions including replacing existing sod with the same sod type and condition; as well as irrigation systems, etc.

b. OCWS will be responsible for the removal and replacement of fencing and retaining walls within the County-owned property boundaries on the Okaloosa Island portion of the project. Contractor to inform the OCWS the extent of fencing that needs removal prior to construction. "

SECTION 33 05 01, High-Density Polyethelyne (HDPE) Pressure Pipe and Fittings

1. Page 9, Section 3.03 ADD the following paragraph: "C. Disinfection of new pipe to be performed by OCWS."

SECTION 33 05 23, Utility Horizontal Directional Drilling

1. Page 3, Section 3.04 D CHANGE "A single stage pull should be performed but no more than a 2-stage pull or one intermediate weld will be permitted while pulling pipe." TO "Contractor shall limit the number of individual pullbacks based on available area for pipe string staging, but no more than 4 pullbacks, or the number that the Contractor deems technically feasible without compromising the pullback, whichever is less."

2. Page 3, Section 3.04 E DELETE "Staging of pipe on the Okaloosa Island side, as shown on the drawings, is an available option."

3. Page 4, Section 3.11: DELETE Supplement A.2 and REPLACE with the attached HDD Report.

B. PART 4 – DRAWINGS

1. DELETE drawing sheets C-01, C-02, C-03, and C-04 and REPLACE with the drawings attached.

Questions Received during Advertisement for Bid Period

1. What is the project budget?
    a. The construction estimate is $460,000.

Attachments

1. Qualifications Statement
2. Revised Contract Drawings C-01, C-02, C-03, and C-04
3. Mandatory Pre-Bid Meeting Minutes
4. CH2M HDD Report dated June 2017

All Bidders shall acknowledge receipt of this Addendum.

Name of Contractor's Safety Officer:_____

Include the following as attachments:

Provide as an Attachment Contractor's (and Contractor's proposed Subcontractors and Suppliers furnishing or performing Work having a value in excess of 10 percent of the total amount of the Bid) OSHA No. 300- Log & Summary of Occupational Injuries & Illnesses for the past 5 years.

Provide as an Attachment Contractor's (and Contractor's proposed Subcontractors and Suppliers furnishing or performing Work having a value in excess of 10 percent of the total amount of the Bid) list of all OSHA Citations & Notifications of Penalty (monetary or other) received within the last 5 years (indicate disposition as applicable) - IF NONE SO STATE.

Provide as an Attachment Contractor's (and Contractor's proposed Subcontractors and Suppliers furnishing or performing Work having a value in excess of 10 percent of the total amount of the Bid) list of all safety citations or violations under any state all received within the last 5 years (indicate disposition as applicable) - IF NONE SO STATE.

Provide the following for the firm listed in Section V (and for each proposed Subcontractor furnishing or performing Work having a value in excess of 10 percent of the total amount of the Bid) the following (attach additional sheets as necessary):

Workers' compensation Experience Modification Rate (EMR) for the last 5 years:

YEAR	_____	EMR	_____
YEAR	_____	EMR	_____
YEAR	_____	EMR	_____
YEAR	_____	EMR	_____
YEAR	_____	EMR	_____

Total Recordable Frequency Rate (TRFR) for the last 5 years:

YEAR	_____	TRFR	_____
YEAR	_____	TRFR	_____
YEAR	_____	TRFR	_____
YEAR	_____	TRFR	_____
YEAR	_____	TRFR	_____

13. EQUIPMENT:

MAJOR EQUIPMENT:

List on **Schedule C** all pieces of major equipment available for use on Owner's Project.

NOTES:

1. FUSED PIPE STAGING ALIGNMENT OPTION IS SHOWN. CONTRACTOR TO SUBMIT PROPOSED STAGING PLAN ALONG WITH TRAFFIC CONTROL PLAN. CONTRACTOR TO PROVIDE TRAFFIC CONTROL AND TEMPORARY ACCESS WHILE STAGING FOR FUSED PIPE. PROVIDE MEANS OF INGRESS AND EGRESS TO ALL RESIDENCES AND BUSINESSES DURING CONSTRUCTION.
2. SEE SHEET C-03 AND C-04 FOR LIMITS OF WORK AND CONTRACTOR RESPONSIBILITY.
3. SEE GENERAL CONSTRUCTION NOTES ON SHEET G-02.

CONTROL POINTS

RSM CONTROL POINT #104158
NAIL & DISC LS #5791 (SET)
NORTHING: 514938.5940'
EASTING: 1306262.4610'
ELEVATION: 2.91'

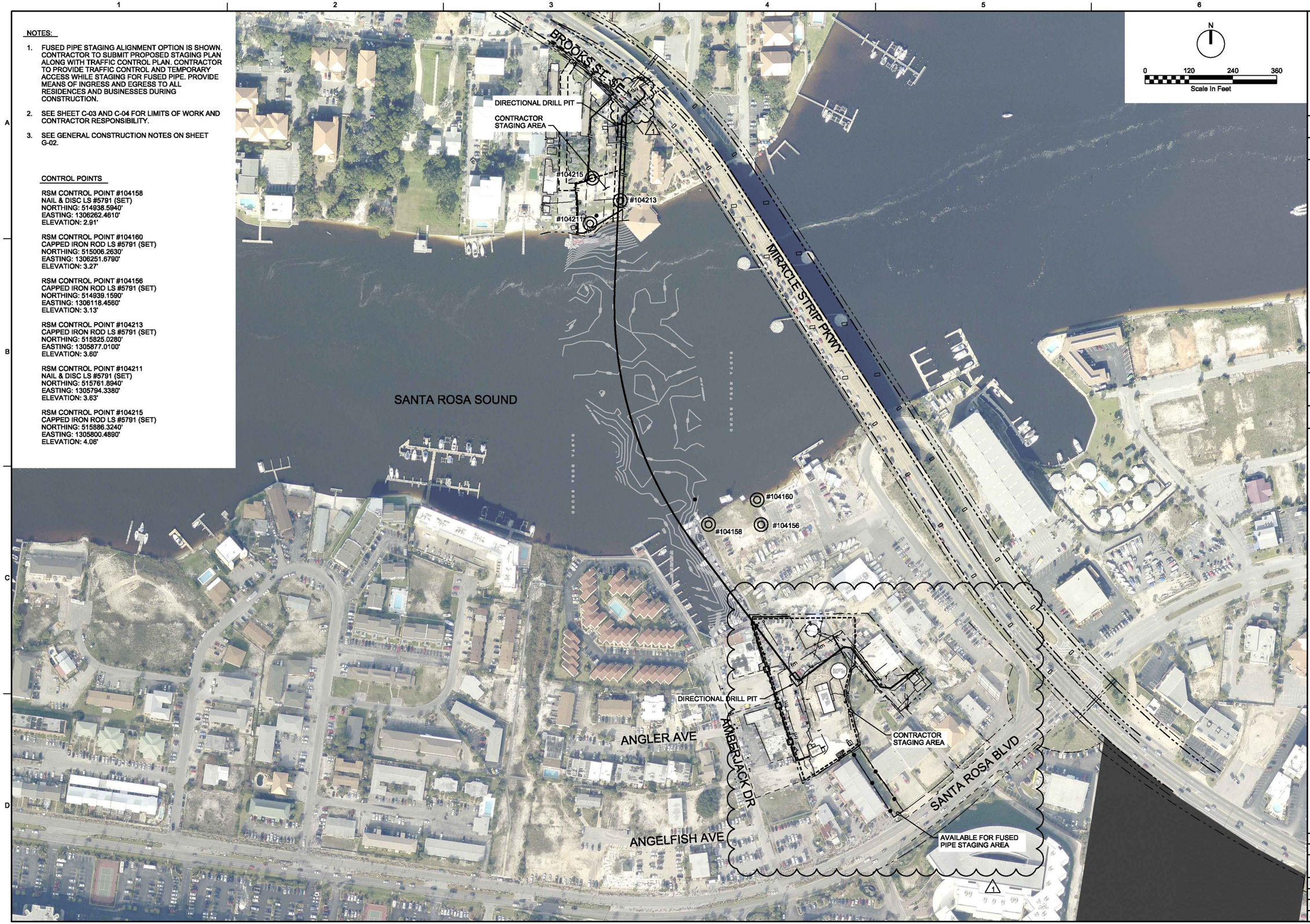
RSM CONTROL POINT #104160
CAPPED IRON ROD LS #5791 (SET)
NORTHING: 515006.2630'
EASTING: 1306251.6790'
ELEVATION: 3.27'

RSM CONTROL POINT #104156
CAPPED IRON ROD LS #5791 (SET)
NORTHING: 514939.1590'
EASTING: 1306118.4560'
ELEVATION: 3.13'

RSM CONTROL POINT #104213
CAPPED IRON ROD LS #5791 (SET)
NORTHING: 515825.0280'
EASTING: 1305877.0100'
ELEVATION: 3.60'

RSM CONTROL POINT #104211
NAIL & DISC LS #5791 (SET)
NORTHING: 515761.8940'
EASTING: 1305794.3380'
ELEVATION: 3.63'

RSM CONTROL POINT #104215
CAPPED IRON ROD LS #5791 (SET)
NORTHING: 515886.3240'
EASTING: 1305800.4890'
ELEVATION: 4.06'



NO.	DATE	REVISION	BY	APVD
1	09/17/2018	ADDENDUM #2	KW	

DSGN K WADDELL | DR C CHILDRESS | CHK M STICKLEY | APVD J KLAUS

25 W CEDAR STREET, SUITE 350
PENSACOLA, FL 32502
KEVIN WADDELL PE 83025

BROOKS BRIDGE WATER MAIN REPLACEMENT
FOR THE
OKALOOSA ISLAND WATER SUPPLY PROJECT
OKALOOSA COUNTY, FL

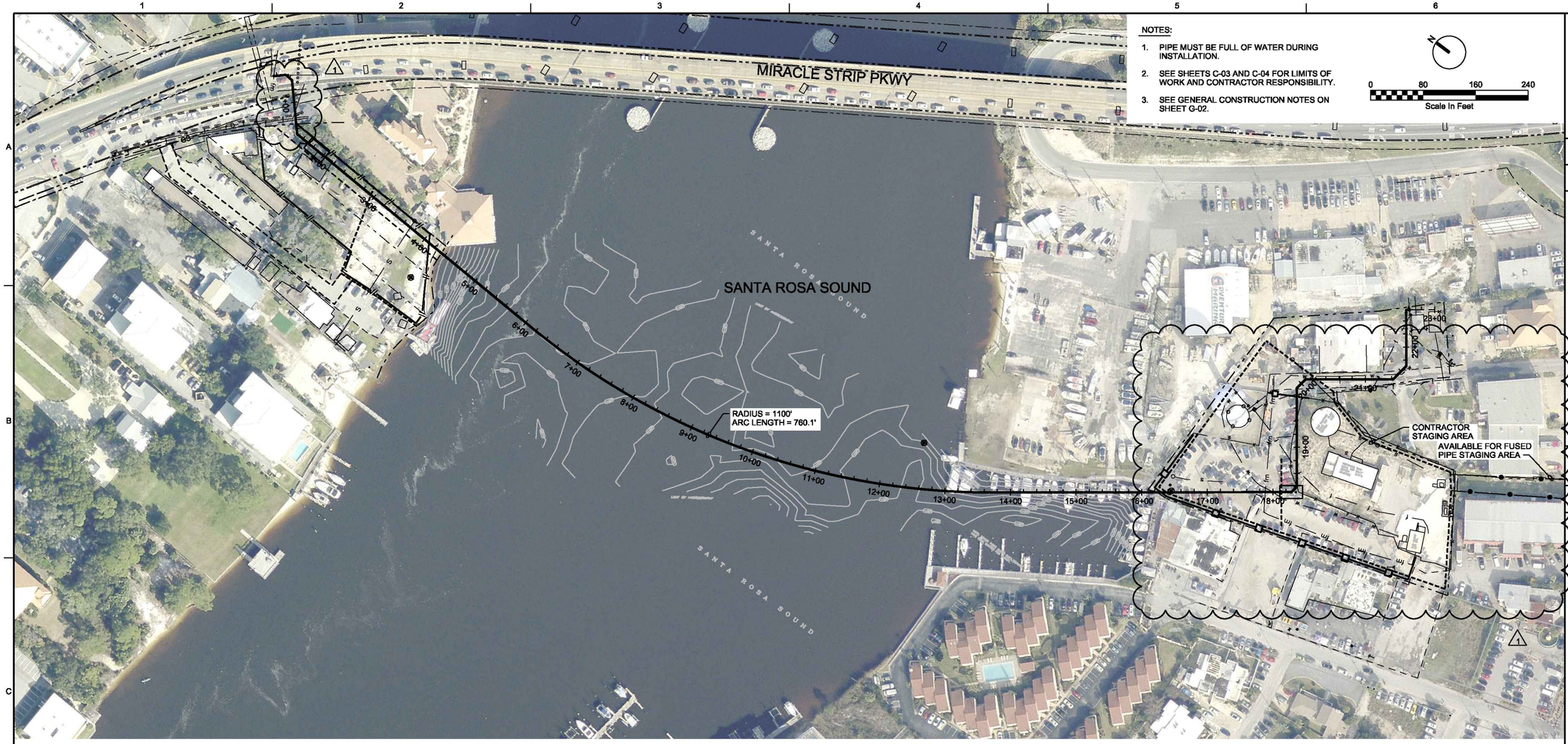
CIVIL

OVERALL SITE PLAN AND SURVEY CONTROL

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	AUGUST 2018
PROJ	691267
DWG	C-01
SHEET	of

BID DOCUMENTS

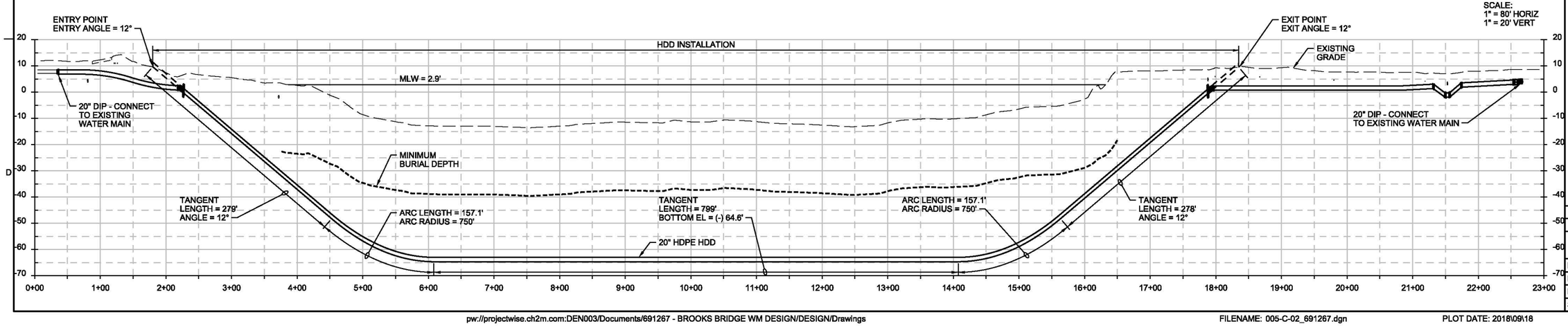


NOTES:

1. PIPE MUST BE FULL OF WATER DURING INSTALLATION.
2. SEE SHEETS C-03 AND C-04 FOR LIMITS OF WORK AND CONTRACTOR RESPONSIBILITY.
3. SEE GENERAL CONSTRUCTION NOTES ON SHEET G-02.

N

0 80 160 240
Scale In Feet



SCALE:
1" = 80' HORIZ
1" = 20' VERT

NO.	DATE	REVISION	CHK	APVD
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ch2m:

CIVIL
WATER MAIN
OVERALL PLAN AND PROFILE

VERIFY SCALE
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DATE	AUGUST 2018
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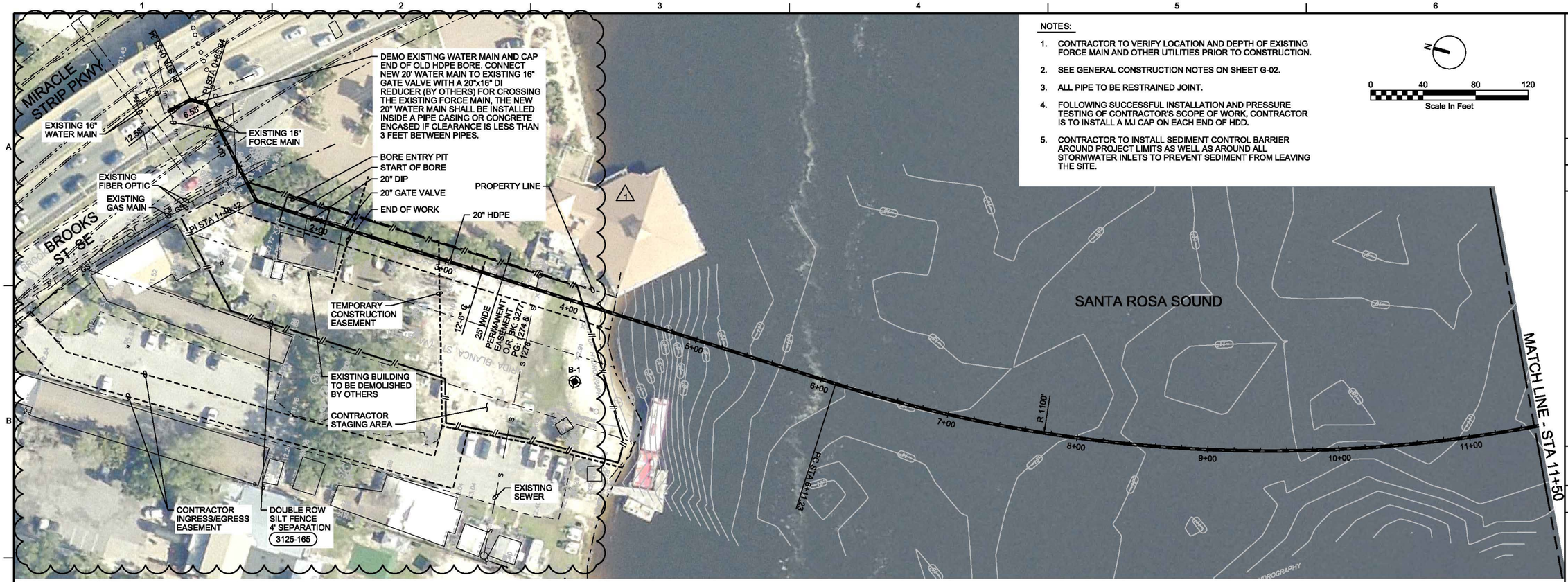

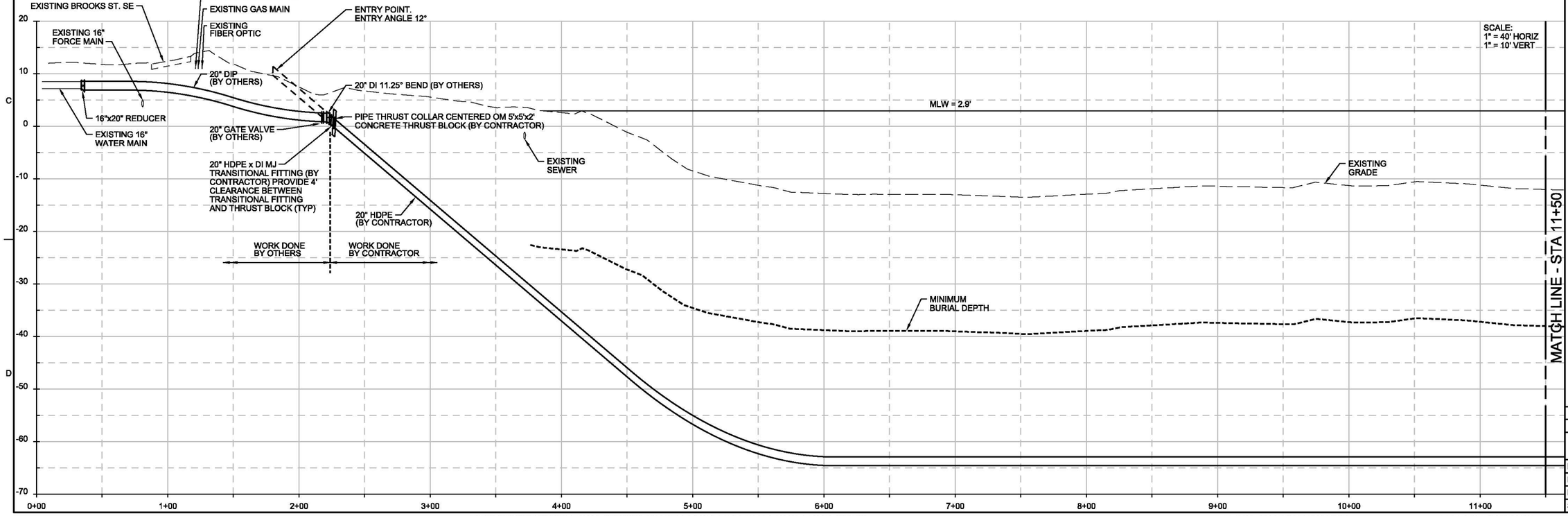

pw://projectwise.ch2m.com:DEN003/Documents/691267 - BROOKS BRIDGE WM DESIGN/DESIGN/Drawings

FILENAME: 005-C-03_691267.dgn PLOT DATE: 2018\09\18 PLOT TIME: 8:15:46 AM

NO.	DATE	REVISION	BY	APVD
1	09/17/2018	ADDENDUM #2	KW	

DSGN K WADDELL DR C CHILDRESS CHK M STICKLEY APVD J KLAUS

25 W CEDAR STREET, SUITE 350
PENSACOLA, FL 32502
KEVIN WADDELL PE 83025

BROOKS BRIDGE WATER MAIN REPLACEMENT
FOR THE
OKALOOSA ISLAND WATER SUPPLY PROJECT
OKALOOSA COUNTY, FL

CIVIL
WATER MAIN
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PLAN AND PROFILE

VERIFY SCALE
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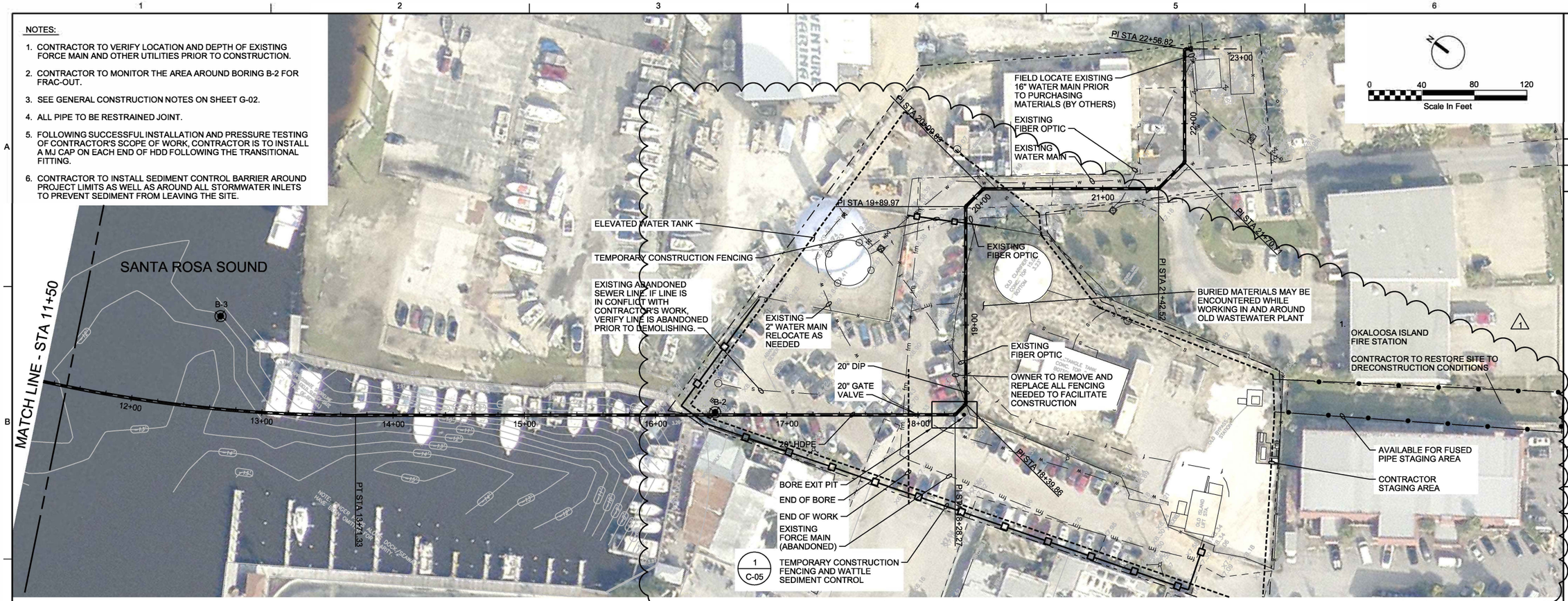
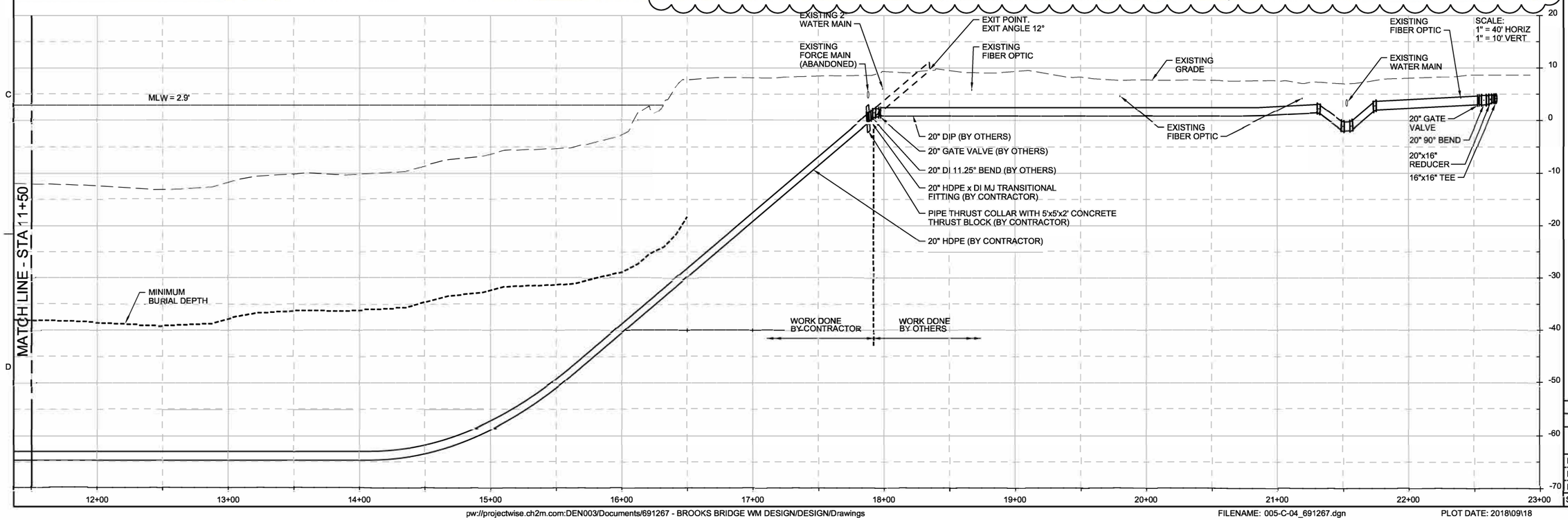
DATE	AUGUST 2018
PROJ	691267
DWG	C-03
SHEET	of

BID DOCUMENTS

NOTES:

1. CONTRACTOR TO VERIFY LOCATION AND DEPTH OF EXISTING FORCE MAIN AND OTHER UTILITIES PRIOR TO CONSTRUCTION.
2. CONTRACTOR TO MONITOR THE AREA AROUND BORING B-2 FOR FRAC-OUT.
3. SEE GENERAL CONSTRUCTION NOTES ON SHEET G-02.
4. ALL PIPE TO BE RESTRAINED JOINT.
5. FOLLOWING SUCCESSFUL INSTALLATION AND PRESSURE TESTING OF CONTRACTOR'S SCOPE OF WORK, CONTRACTOR IS TO INSTALL A MJ CAP ON EACH END OF HDD FOLLOWING THE TRANSITIONAL FITTING.
6. CONTRACTOR TO INSTALL SEDIMENT CONTROL BARRIER AROUND PROJECT LIMITS AS WELL AS AROUND ALL STORMWATER INLETS TO PREVENT SEDIMENT FROM LEAVING THE SITE.





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BROOKS BRIDGE WATER MAIN REPLACEMENT
FOR THE
OKALOOSA ISLAND WATER SUPPLY PROJECT
OKALOOSA COUNTY, FL

CIVIL

WATER MAIN STA 11+50 TO 24+00 PLAN AND PROFILE

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
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DATE	AUGUST 2018
PROJ	691267
DWG	C-04
SHEET	of

BID DOCUMENTS

MEETING SUMMARY

Brooks Bridge Water Main Replacement Project

Mandatory Pre-Bid Meeting

PREPARED BY: Jacobs

PROJECT: Brooks Bridge WM Replacement

MEETING DATE: September 13, 2018

MEETING TIME: 10:00 AM

LOCATION: OCWS Board Conference Room

ATTENDEES: See attached Sign-In sheet

1. **Attendee Sign-In and Introductions**
2. **Project Scope**
3. **Project Task Overview**
    a. Contractor's Responsibilities:
        i. A new 20" HDPE watermain across Santa Rosa Sound via HDD – fusible PVC will be accepted.
        ii. Installation of transitional fittings and caps on pipe ends
        iii. Pressure testing of Contractor installed pipe
        iv. Erosion and sediment control
        v. Traffic control for pipe fusing staging
        vi. Site restoration to pre-construction conditions
    b. Owner's Responsibilities
        i. Demo of existing structure on mainland side of bore
        ii. Direct-buried pipe installation from transitional fittings to connection points
        iii. Pressure testing of Owner installed pipe
        iv. Disinfection and bacteriological testing of all new pipe
4. **Response Requirements**
    a. Provide one (1) original and two (2) copies of their ITB response
    b. Portrait orientation, unbound, and 8 ½" x 11" where practical
    c. All originals must have original signatures in blue ink
    d. Submission must comply with all requirements of the ITB
    e. Bid Opening Location:
        i. Conference and Training Room #305
        ii. 302 N Wilson St., Crestview, Fl 32536
    f. Submission Dates:

i. **Bid Opening: September 26, 2018 at 3:00 PM CT**

ii. **Last Day for Questions: September 17, 2018 at 3:00 PM CT**

5. Addenda

a. Addendum #1 – Contract Dates

b. Contact: DeRita Mason (dmason@myokaloosa.com)

c. At least one more addendum will be issued to current plan holders, including responses to questions raised at this meeting.

6. Contract Details

a. Contract Times

i. Substantial Completion – 180 days

1. The project will be considered substantially complete when the HDD and transitional fittings are installed and capable of being put into service, as well as having been restored to the pre-construction site conditions. This includes successful pressure testing of the pipe.

ii. Final Completion – 225 days

b. FDEP Grant Funded Project

c. FDEP Environmental Resource Permit

i. Sediment and Frac-out control

d. USACE General Permit

i. The Work shall comply with the National Marine Fisheries PDC's for In-Water Activities; Sea Turtle; and Standard Manatee conditions

e. FDOT permits – OCWS has obtained permit for installation of their waterline. Contractor to obtain any additional permits that may be required.

f. Pipe fusing staging – Drawings will be updated in an addendum to show the boundaries of the county-owned property and the property next to the fire station that is available for pipe fusing staging. This area is newly sodded and has a new irrigation system. The Contractor will be required to restore the site to pre-construction conditions.

i. Contractor may contact adjacent property owner for permission to use their property for pipe staging. Contact info is as follows.

Owner, Cohen Investments LLC-(Barry Cohen)
Ph. # 781-330-9527
Plat BK. 2 PG. 84A
Block 1 Lots 2 ,11 & 12

g. Staging Area – Contractor may use the County owned property on the Island, as well as the easement on the Playground Inn property as shown on the drawings.

h. Basis of Award – Lowest responsive, responsible bidder for total base bid price.

7. Questions and General Discussion

a. Pipe flushing and pressure testing –

i. Contractor is responsible for obtaining, handling and properly disposing of water used to facilitate construction activities. Contractor to obtain any permits

that may be required. Water can be obtained from the County on Okaloosa Island, but will need to be obtained from the City of Ft. Walton Beach on the mainland side. The City's meter order form is attached to these meeting notes.

ii. Pressure testing to be performed with water. Pneumatic air pressure testing will not be allowed.

b. Drilling methods – Contractor may provide an alternative method to a wire line as long as a good as-builts can be provided with X,Y, and Z coordinates.

8. Site Visit

a. A site visit was conducted with attendees immediately following the meeting.

METER ORDER FOR FIRE HYDRANT

Today's Date: _____
Company Name: _____
Mailing/Billing Address: _____
_____
Contact Person's Name: _____
Contact Person's Phone Number:_____
Location of hydrant (& hydrant # if known): _____
Date Meter requested to be installed:_____
Size meter requested (2" or 3" if available):_____
Customer Signature: _____

OFFICE USE ONLY

Meter Number: _____
Reading Out: _____Date: _____ By: _____
Reading In: _____ Date: _____ By: _____

Actual Usage: _____

Deposit Required 401-0000-220-1100	$ 1,000.00	Date Paid_____
Account Receivable (Usage) 401-1310-343-3100		
10% Utility Tax 001-0500-314-3000		
Installation Charge 401-1310-343-3200	$ 50.00	
Direct Pay to Reimburse		DP Date_____

Usage will be based on the In and Out Reading above, and
the costs will be calculated using the following block rates:

Base Rate 0-2000 gallons	2" Mtr $25.26 or 3" Mtr $38.49
Block 1 2001-4000 gallons	$3.26 per 1,000 gallons
Block 2 4001-8000 gallons	$3.99 per 1,000 gallons
Block 3 8001 + gallons	$5.98 per 1,000 gallons

Rates effective 10/1/17 thru 9/30/18, and until all new rates are established

Meter # and Size

Meter #1 - 3 inch
Meter #2 - 2 inch
Meter #3 - 2 inch
Meter #4 - 3 inch
Meter #5 - 2 inch

3" meter has 4" register (written 3-4)

Horizontal Directional Drill Design

Brooks Bridge WM

Prepared for

Okaloosa County Water and Sewer Department

June 8, 2017
Project: 691267

Prepared by

ch2m

25 W Cedar St, Suite 350
Pensacola, FL, USA 32502

Contents

1. Introduction

Okaloosa County Water and Sewer Department (OCWS) determined that the appropriate alternative for providing a long-term, reliable source of potable water and fire protection to Okaloosa Island is to replace the existing water main with a new subaqueous pipe. The new water main will be located roughly 400 feet west of the existing main to minimize the potential for impacts to the new main in the event Brooks Bridge is replaced. The new main will be a 20-inch DR11 high-density polyethylene (HDPE) pipe installed by horizontal directional drilling (HDD) under the Sound. It will be the responsibility of the contractor to install the HDD pipe segment along with the piping at the entry and exit bore pits. OCWS will be responsible for constructing the remaining direct-buried pipe segments between the entry and exit bore pits to the connection points with the existing distribution system.

The following report outlines the crossing profile, design philosophy, stress analyses, and drill fluid pressure checks for the HDD crossing.

2. Geotechnical Data

CH2M has reviewed boring logs and geologic information provided by Larry M Jacobs Associates, Inc. to evaluate the subsurface conditions. Boring logs from the original bridge construction project were also reviewed. The soil properties provided by or derived from these data are summarized in Table 1.

In general, a fairly uniform surface layer of medium dense sand is approximately 25 feet thick under the seabed. The upper layer is underlain by a transition layer approximately 5 to 10 feet thick, comprised of loose to very loose sand, medium dense silty sand, and soft lean clay. The lower soil layer below the transition zone is very dense sand.

2.1 Assumed Soil Profile

The geotechnical data reviewed indicated the Brooks Bridge HDD crossing will launch and exit in the upper medium dense sand layer. The alignment will pass through the transition layer of silty sand, loose sand, and clay, and complete the vertical and horizontal curves within the lower very dense sand layer.

The soil properties for this evaluation were derived from the boring log data and geologic data available, the draft geotechnical data report (LMJ, 2017), and estimated using industry standards and accepted correlations.

The subsurface profile and the soil properties assumed for the HDD design are presented in Figure 1 and Table 1.

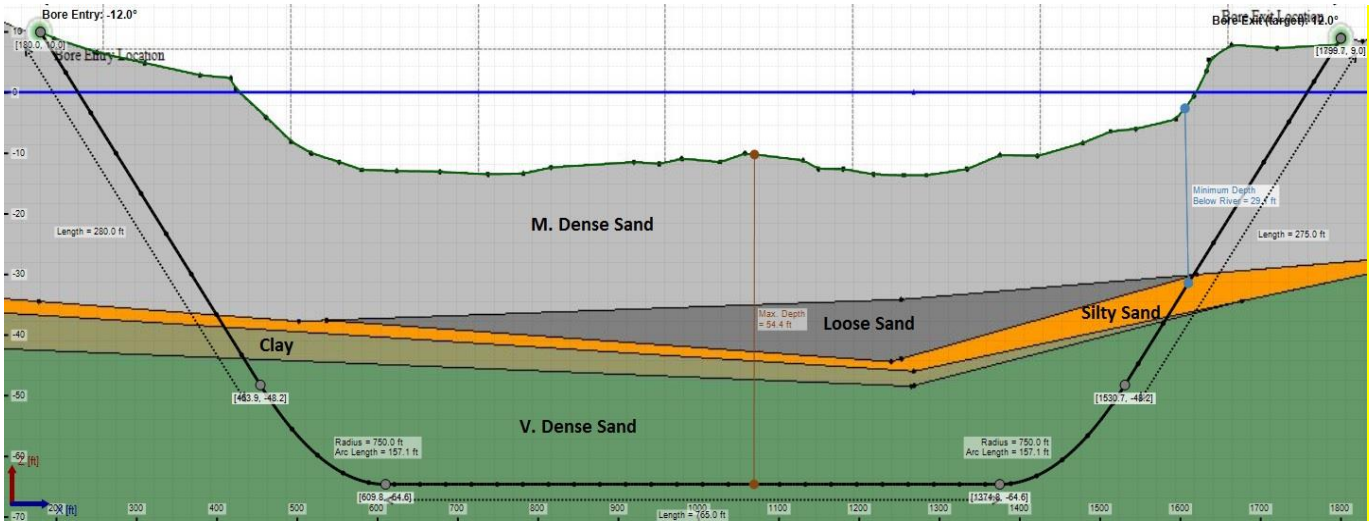


FIGURE 1

Subsurface Profile Assumed in the Brooks Bridge Water Main Crossing HDD Analysis
Distance and elevation shown in feet. See Table 1 for material descriptions and properties

TABLE 1
Soil Properties for Brooks Bridge Water Main Crossing HDD Analysis

Soil Properties	Medium Dense Sand	Loose Sand	Silty Sand	Clay	Very Dense Sand
Dry Unit Weight (pcf)	105	100	90	85	110
Saturated Unit Weight (pcf)	129	125	113	110	135
Friction Angle (degrees)	32	28	28	0	42
Shear Modulus (tsf)	160	35	30	12	250
Cohesion (psf)	0	0	50	250	0

2.2 Identified Geotechnical Risks

The following geotechnical risks were identified in the geotechnical assessment.

1. Reaming of the hole within the overburden. *Risk:* Past experience indicates that attempts to ream a directionally drilled borehole too rapidly can result in incomplete clearance of cuttings from the hole which, in turn, can lead to a pipeline drag section becoming stuck. Reaming in a single pass increases the risk of inadvertent fluid returns. *Mitigation:* It is expected that at least two and possibly three reaming passes will be required in order to reach the required borehole diameter.
2. Inadvertent fluid returns in overburden. *Risk:* Borehole pressures in the shallow overburden may cause inadvertent fluid returns in shallow overburden, especially as the pilot bore nears the exit point. *Mitigation:* To mitigate this risk, the pilot borehole diameter should be a minimum of 10 inches and the mud weight should be maintained under 9.2 ppg (68 lb/ft^3). The mud flow rate should also be maintained under 150 gallons/minute. A frac-out contingency plan should address personnel and equipment to be on-site at all times during drilling.
3. Presence of underground utilities. *Risk:* Underground utilities are present along the crossing alignment. If steering is not controlled, the pilot bore or reaming passes may damage the existing utilities. *Mitigation:* The contractor is advised to locate and obtain clearance of these underground utilities prior to the commencement of any HDD work, and steering should be controlled within specified tolerances.

3. Horizontal Drill Profile Design

The Brooks Bridge water main HDD profile (See Appendix A) was prepared with the following design parameters:

3.1 Pipe Specifications

The following outline the design specifications of horizontal directional drill pipe.

Pipe Type:	HDPE
Pipe Specification:	DR 11 DIPS PE 4710
Average Pipe Outside Diameter:	21.6 in
Minimum Wall Thickness:	1.96 in
Design Maximum Operating Pressure:	200 psi
Mainline Test Pressure:	150 psi

The intended maximum operating pressure for the project is 65 psi, relative to the connection points to the existing main. To ensure conservative design for the HDD, DR11 rated HDPE is recommended which has a design pressure rating of 200 psi. This is greater than the project overall design pressure or 95 psi (based on the low point elevation pressure) for additional safety factor allowing flexibility in design depths and construction (actual install) tolerances. The test pressure of 150 psi is the maximum test pressures the HDD will experience during the mainline test. This is determined by the static pressure profile for the test section, and elevation difference between the critical low and HDD low point.

3.2 Drill Requirements

The crossing alignment is designed based on two primary criteria. The first criteria is that the main must stay within the OCWS 25-foot wide easement on the Fort Walton Beach side of the crossing. The second criteria is that the main must stay within the OCWS 25-foot property line bordering the Sound. OCWS will be responsible for removing an existing structure on the mainland side to provide sufficient space for drilling operations. The exit pit will be located on the island side within the OCWS property boundaries, with sufficient space for drilling operations and pipe string staging. The contractor will need to provide a traffic control plan and provide temporary access routes for access during construction. The exit point is positioned such that the bore will be able to pass underneath the existing 16-inch diameter sewer force main. Contractor should locate and expose top of pipe during drilling operations to keep adequate clearance from this force main. The bore depth on the island side needs to be followed at a minimum as to avoid dock piles present in the marina inlet.

3.3 Entry and Exit Angles

A current entry and exit angle of 12 degrees has been designed for the crossing. It should be noted that these angles are measured from horizontal, not from the existing ground surface. This exit angle may require additional breakover support.

An approximately 150 ft x 200 ft workspace will be required at the drill entrance to provide adequate space for the drilling equipment and casing requirements. For the drill exit, it is recommended that the entire pipe string be assembled prior to pullback. The pipe layout and exit area should be at least 30 ft wide and as long as the pipe string plus approximately 15 ft. The total length of the pipe string should include an additional length, which is a minimum of 4 percent of the total borepath length. This additional length mitigates the risk that the elastic rebound of the HDPE pipe pulls the pipe ends underground following pullback. The Contractor should notify the Owner/Engineer if the available space does not meet these requirements.

3.4 Design Bend Radius

The industry standard HDD minimum bend radius for HDPE pipe is 25 times the outside diameter of the pipe. Assuming a pipe diameter of 21.6 in (1.8 ft), this results in a minimum bend radius of 45 ft. However, the minimum design radius for HDPE is typically determined by the bend radius of the steel drill rods. The anticipated drill rod diameter for an HDD crossing of this size is 5 in. The industry standard minimum bend radius for steel pipe is 100 times the outside diameter of the pipe, which results in a minimum design radius of 500 ft.

The current design vertical bend radii are 750 ft for the entry and exit sides of the borepath, and the design horizontal bend radius at the center of the bore is 1,000 ft. The pilot hole should be installed at the minimum design bend radius with the following steering tolerances:

- Single-joint radius not less than 200 ft.
- Three-joint radius not less than 300 ft.
- Ten-joint radius not less than 450 ft.

4. Load and Stress Analysis

The Brooks Bridge water main has been analyzed using the method employed by the BoreAid software Version 5.0.14. The BoreAid Summary Reports are included in Appendix C. The BoreAid software calculates the pulling loads

and installation and operating stresses, as well as frac-out risk (inadvertent loss of drilling fluid to the ground surface). The pullback forces calculated with BoreAid have been checked using the ASCE/PRCI guidelines.

4.1 Pullback Buoyancy Control

A check of pipe stresses was performed and the resulting pipe stresses are within the allowable ranges, with the use of buoyancy control measures during the pullback. The design calculations contained in Appendix C utilize buoyancy control of filling the pipe full with water during pullback. If buoyancy control is not considered in the calculations, the factor of safety for unconstrained collapse during installation falls below the industry-recommended standard. Accordingly, buoyancy control measures must be used during construction. If the pipe is not filled with water during pullback, the pipe may collapse during installation.

4.2 Pulling Load Calculations

Pulling loads were analyzed using the BoreAid software. The results are found in the attached BoreAid Summary Reports in Appendix C. BoreAid calculates pulling force, stress and strain along the pipeline. The maximum pullback force with and without a factor of safety and the maximum stress developed during pullback from the BoreAid analysis are summarized in Table 2. Pullback forces applied during construction are limited to the Maximum Allowable Pullback Force shown in Table 2. Note that no buoyancy control was considered in this analysis, which is conservative for the pullback force. When maximum

TABLE 2
Maximum Pulling Force and Maximum Stress

Maximum Calculated Pullback Force[1] (lbs)	Maximum Allowable Pullback Force[2] (lbs)	Maximum Installation Bending Stress[3] (psi)	In-Service Deflection (%)[4]
68,000	136,000	69	4.3

[1] Assumptions: Pipe assembled prior to pullback and supported on rollers. Buoyancy control is used (pipe must be filled with water during pullback), and no safety factor has been applied. Values are rounded up.

[2] Assumptions: Pipe assembled prior to pullback and supported on rollers. Buoyancy control is used (pipe must be filled with water during pullback), and a safety factor of 2 has been applied. Values are rounded up.

[3] Tensile stress was also checked.

[4] % = percent. Maximum allowable deflection for DR 11 HDPE pipe is 5%.

4.3 Installation Stress Analysis

Installation stresses were analyzed using the BoreAid calculations. Tensile stress, unconstrained collapse stress, and pipe deflection were checked. The results are found in the attached BoreAid Summary Reports in Appendix C. The maximum stress calculated during pullback for the crossing is shown in Table 2 above.

4.4 Operating Stress Analysis

Operating stresses including pipe deflection, unconstrained collapse, and compressive wall stress were analyzed using the BoreAid calculations. The analyses show that the pipe wall thickness is adequate for the anticipated operating stresses.

4.5 Frac-Out Analysis

Risk of inadvertent fluid returns to the surface (“frac-out”) was analyzed. No casings were assumed to be used for this analysis. Drilling fluid pressure for frac-out due to “plastic zone related to soil cover” was analyzed using the BoreAid software. BoreAid utilizes the Delft geotechnics model for this analysis, using the distance from the

borehole to the ground surface as the plastic radius in the calculation, in accordance with industry guidelines. The tabulated results are presented at the end of the BoreAid Summary Reports in Appendix C.

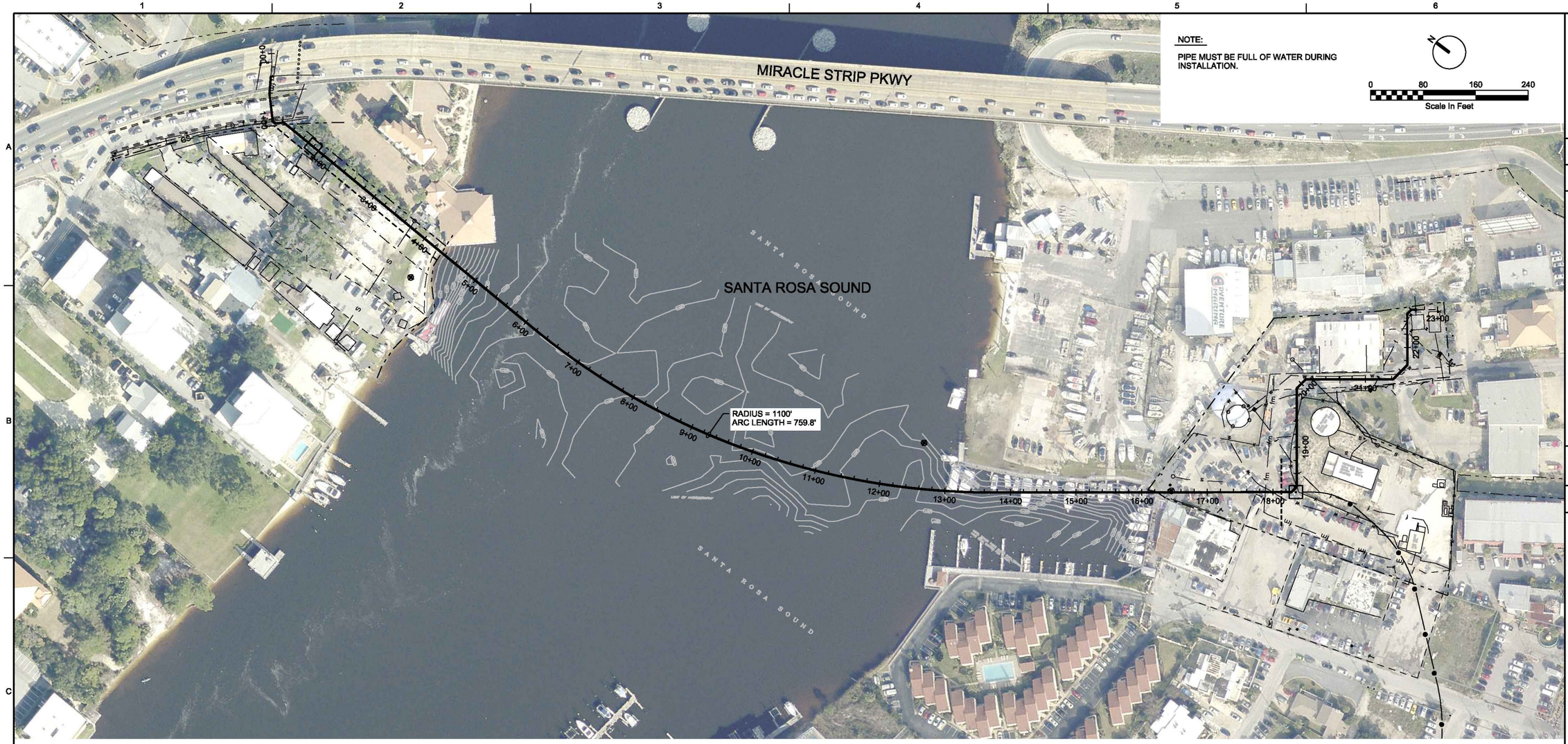
An analytic solution following the Bennett and Wallin (2008) model was perfomed using a factor of safety of 2.5 for the allowable drilling fluid pressure, in accordance with industry guidelines (Staheli et al, 2010). The tabulated results are presented in Appendix E.

Graphical results for the soil cover check and required borehole fluid pressure are presented in the annular pressure chart in Appendix D. Frac-out was considered for the pilot drilling operation, which is the stage of HDD construction when frac-out risk is highest.

5. Conclusions

CH2M has evaluated the anticipated configuration of the Brooks Bridge water main. The findings of our evaluation indicate the crossing can be completed in accordance with industry accepted guidelines provided the recommendations of this report are followed.

Appendix A
HDD Drill Plan and Profile

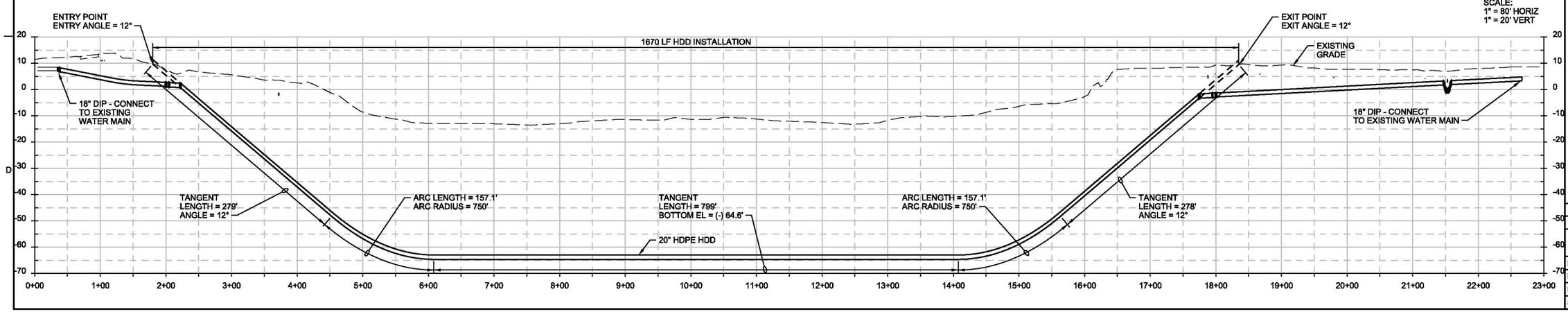


NOTE:

PIPE MUST BE FULL OF WATER DURING INSTALLATION.

0 80 160 240

Scale In Feet



NO.	DATE	REVISION	BY	APVD
DSGN	K WADDELL	DR C CHILDRESS	CHK J KLAUS	APVD J KLAUS

BROOKS BRIDGE
WATER MAIN
OKALOOSA COUNTY, FL

ch2m:

CIVIL
WATER MAIN
OVERALL PLAN AND PROFILE

60% DESIGN DOCUMENTS

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	JUNE 2017
PROJ	691267
DWG	C-02
SHEET	of

Appendix B
BoreAid Summary Report

Generated Output

WARNING: The accuracy of the data obtained by the BoreAid® system is highly dependent upon accurate data gathering, data input and proper use of the software. Vermeer is not responsible for that information. BoreAid® data is not intended to replace the need for future on-site utility locating, measuring and verification procedures, which are essential for accurate placement of new underground installations and avoidance of existing utilities.

CALL YOUR ONE-CALL SYSTEM FIRST

WARNING: Always contact your local One-Call system before the start of your digging project. The BoreAid® system is intended to be used with other utility locating methods, such as the use of the One-Call system and the exposing of existing utilities by potholing.

Locate utilities before drilling. Call 811 (U.S. only) or 1-888-258-0808 (U.S. or Canada) or local utility companies or national regulating authority.

Before you start any digging project, do not forget to call the local One-Call system in your area and any utility company that does not subscribe to the One-Call system. For areas not represented by One-Call Systems International, contact the appropriate utility companies or national regulating authority to locate and mark the underground installations. If you do not call, you may have an accident or suffer injuries; cause interruption of services; damage the environment; or experience job delays.

OSHA CFR 29 1926.651 requires that the estimated location of underground utilities be determined before beginning the excavation or underground drilling operation. When the actual excavation or bore approaches an estimated utility location, the exact location of the underground installation must be determined by a safe, acceptable and dependable method. If the utility cannot be precisely located, it must be shut off by the utility company.

Input Summary

Start Coordinate	(180.00, 0.00, 10.00) ft
End Coordinate	(1800.00, 0.00, 9.00) ft
Project Length	1620.00 ft
Pipe Type	HDPE
OD Classification	DIPS
Pipe OD	21.600 in
Pipe DR	11.0
Pipe Thickness	1.96 in
Rod Length	32.00 ft
Rod Diameter	5 in
Drill Rig Location	(0.00, 0.00, 0.00) ft

Soil Summary

Number of Layers: 5

Soil Layer #1 USCS, Sand (S), SW
From Assistant
Unit Weight: 105.0000 (dry), 129.0000 (sat) [lb/ft3]
Phi: 32.00, S.M.: 2361.11, Coh: 0.00 [psi]

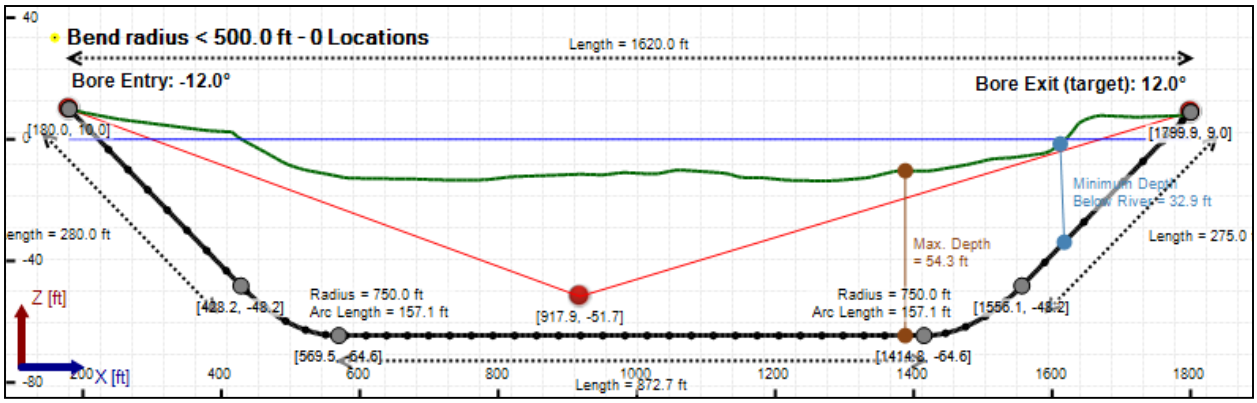
Soil Layer #2 USCS, Sand (S), SW
From Assistant
Unit Weight: 100.0000 (dry), 125.0000 (sat) [lb/ft3]
Phi: 28.00, S.M.: 486.00, Coh: 0.00 [psi]

Soil Layer #3 USCS, Silt (M), ML
From Assistant
Unit Weight: 90.0000 (dry), 113.0000 (sat) [lb/ft3]
Phi: 28.00, S.M.: 416.70, Coh: 0.35 [psi]

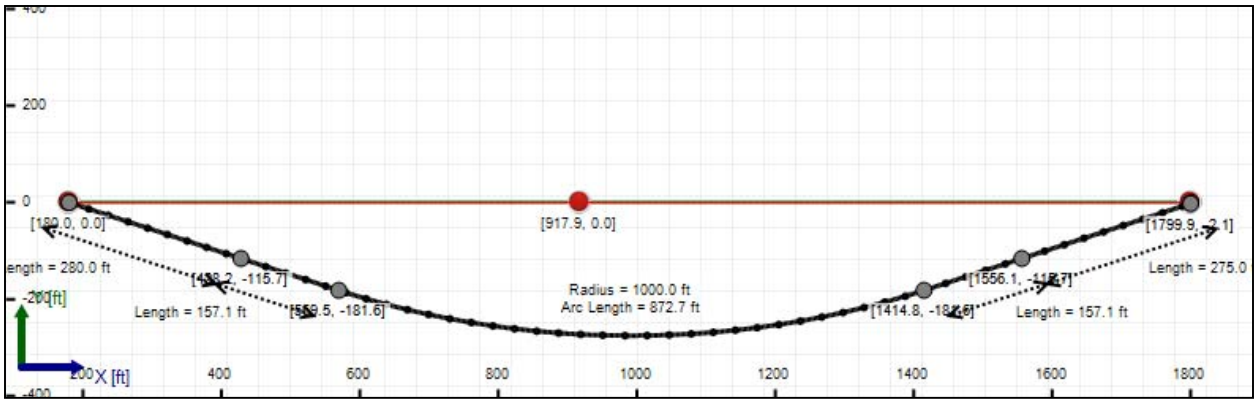
Soil Layer #4 USCS, Clay (C), CL
From Assistant
Unit Weight: 85.0000 (dry), 110.0000 (sat) [lb/ft3]
Phi: 0.00, S.M.: 166.70, Coh: 1.74 [psi]

Soil Layer #5 USCS, Sand (S), SP
From Assistant
Unit Weight: 110.0000 (dry), 135.0000 (sat) [lb/ft3]
Phi: 42.00, S.M.: 3472.20, Coh: 0.00 [psi]

Bore Cross-Section View



Bore Plan View



Load Verifier Input Summary:

Pipe Application: Water Main

Pipe Type: HDPE

Classification: DIPS

Pipe OD: 20" (21.6")

Pipe DR: 11

Pipe Length: 1759.94 ft

Internal Pressure: 200 psi

Borehole Diameter: 2.70000012715658 ft

Silo Width: 2.70000012715658 ft

Surface Surcharge: 0 psi

Short Term Modulus: 57500 psi

Long Term Modulus: 28200 psi

Short Term Poisson Ratio: 0.35

Long Term Poisson Ratio: 0.45

Pipe Unit Weight: 59.30500 lb/ft3

Allowable Tensile Stress (Short Term): 1200 psi

Allowable Tensile Stress (Long Term): 1100 psi

Allowable Compressive Stress (Short Term): 1150 psi

Allowable Compressive Stress (Long Term): 1150 psi

Surface-pipe friction coefficient at entrance: 0.1

Surface-pipe friction coefficient in borehole: 0.3

Pipe-soil friction angle: 30

Slurry Unit Weight: 93.64118 lb/ft3

Hydrokinetic Pressure: 10 psi

Ballast Unit Weight: 62.42746 lb/ft3

In-service Load Summary:

Pressure [psi]	Deformed	Collapsed
Earth Pressure	7.0	25.1
Water Pressure	28.0	28.0
Surface Surcharge	0.0	0.0
Internal Pressure	200.0	200.0
Net Pressure	-164.9	-146.9
Deflection		
Earth Load Deflection	3.758	13.407
Bouyant Deflection	0.484	0.484
Reissner Effect	0	0
Net Deflection	4.242	13.891
Compressive Stress [psi]		
Compressive Wall Stress	-807.2	-707.7

Installation Load Summary:

Forces/Stresses	@Maximum Force	Absolute Maximum
Pullback Force [lb]	67595.9	67595.9
Pullback Stress [psi]	558.0	558.0
Pullback Strain	9.705E-3	9.705E-3
Bending Stress [psi]	0.0	69.0
Bending Strain	0	1.200E-3
Tensile Stress [psi]	558.0	616.9
Tensile Strain	9.705E-3	1.193E-2

Net External Pressure = 20.7 [psi]

Bouyant Deflection = 0.2

Hydrokinetic Force = 2290.2 lb

In-service Analysis

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	4.242	5.0	1.2	OK
Unconstrained Collapse [psi]	-198.2	67.7	-	OK
Compressive Wall Stress [psi]	-807.2	1150.0	-	OK

Installation Analysis

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	0.238	5.0	21.0	OK
Unconstrained Collapse [psi]	26.7	110.9	4.2	OK
Tensile Stress [psi]	616.9	1200.0	1.9	OK

Maximum Allowable Bore Pressure Summary

Ream Number	Initial Diameter	Final Diameter	Estimated Maximum Pressure (Avg.)	Estimated Maximum Pressure (Local)
Pilot Bore	0.00 in	10.00 in	279.409 psi	379.856 psi
1	10.00 in	22.00 in	272.130 psi	366.402 psi
2	22.00 in	30.00 in	265.069 psi	353.667 psi
3	30.00 in	36.00 in	259.010 psi	342.970 psi

Note: The maximum bore pressures presented in this table are the maximum values along the length of the bore and not the maximum allowable at any point. The estimated maximum pressures should be compared to the estimated circulating pressures along the bore to determine potential locations of inadvertant returns.

Estimated Circulating Pressure Summary

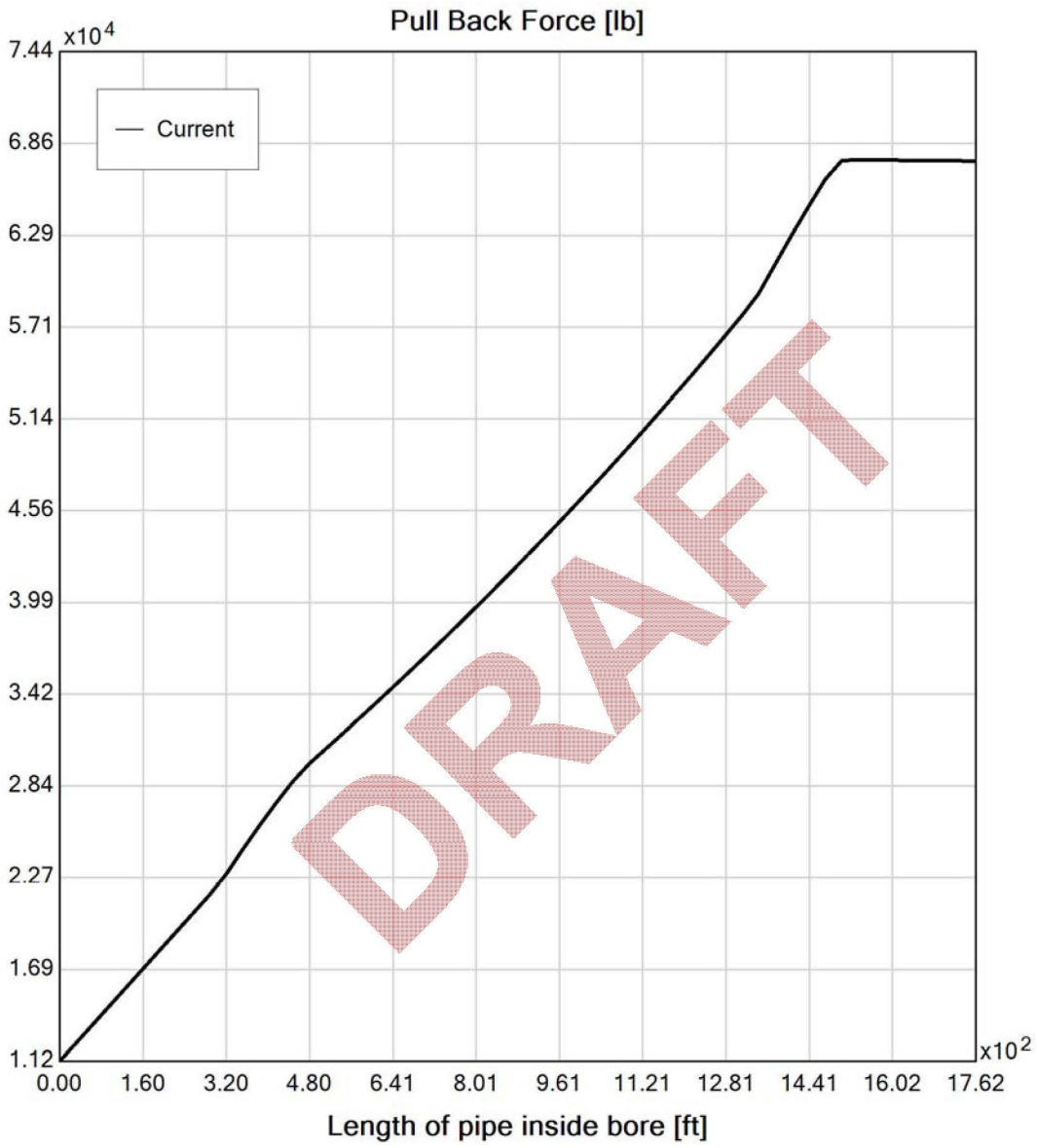
Active	Shear Rate [rpm]	Shear Stress [Fann Degrees]
No	600	37
No	300	32
No	200	29
Yes	100	25
Yes	6	17
No	3	15

Flow Rate (Q): 120.00 US (liquid) gallon/min

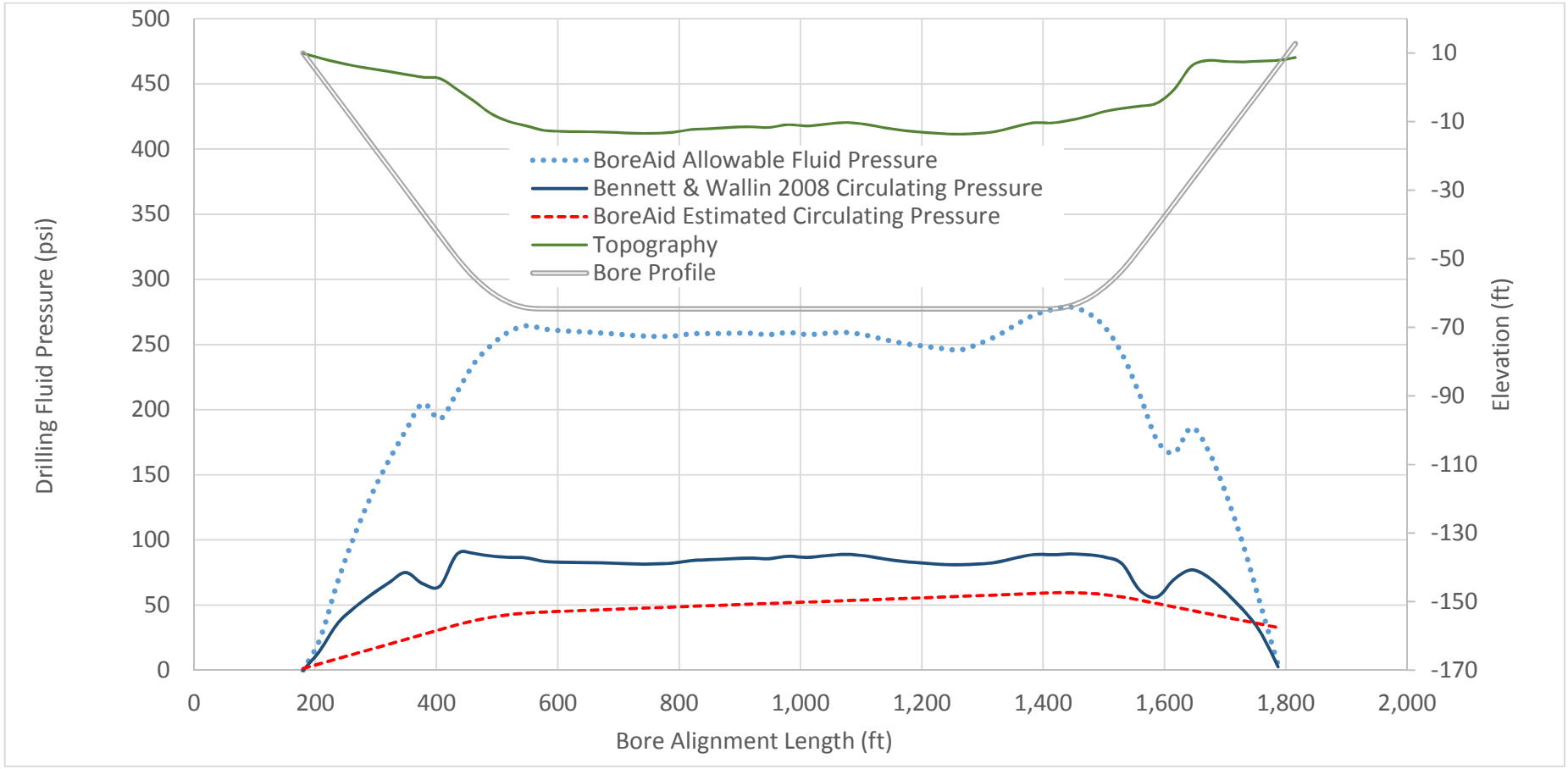
Drill Fluid Density: 68.700 lb/ft3

Rheological model: Bingham-Plastic

- Plastic Viscosity (PV): 25.53
- Yield Point (YP): 16.49
- Effective Viscosity (cP): 657.0



Appendix C
Drilling Fluid Pressure Plot


Drilling Fluid Pressure (psi)
500
450
400
350
300
250
200
150
100
50
0
Elevation (ft)
10
-10
-30
-50
-70
-90
-110
-130
-150
-170
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Bore Alignment Length (ft)
BoreAid Allowable Fluid Pressure
Bennett & Wallin 2008 Circulating Pressure
BoreAid Estimated Circulating Pressure
Topography
Bore Profile

Appendix D
Analytic Solution for Allowable Borehole Pressure with Bennett and Wallin 2008 Method

1. **Groundwater is assumed at el. 0m for the HDD profile.**

2. **Multi-layered soil profile:**
   Bennett 2008 states that effective stress σ' for each soil layer and sum them to find the effective stress at the point of interest.
   For friction angle ϕ, cohesion c, and shear modulus G, weighted average can be used.

Soil parameters:

			Saturated?									
m. dense sand	25	ft	Unit weight of m. dense SP	129	pcf	φ (deg) =	32	c =	0.01	psf	G =	320000	psf
loose sand	15	ft	Unit weight of loose SP	125	pcf	φ (deg) =	28	c =	0	psf	G =	70000	psf
silty sand	2	ft	Unit weight of SM	113	pcf	φ (deg) =	28	c =	50	psf	G =	60000	psf
						Wt avg =	30.3809524	Wt avg =	2.38690476		Wt avg =	218333.333	
clay	4	ft	Unit weight of CL	110	pcf	φ (deg) =	0.01	c =	250	psf	G =	24000	psf
						Wt avg =	27.74	Wt avg =	23.9184783		Wt avg =	201434.783	
v. dense sand	13	ft	Unit weight of v. dense SP	145	pcf	φ (deg) =	42	c =	0.01		G =	560000	psf
						Wt avg =	30.8820339	Wt avg =	18.6505085	psf	Wt avg =	280440.678	psf

Pipe info:

Pilot Bore Diameter = 10 in = 0.83333333 ft

Pilot borehole radius R_o (ft) 0.41666667

Applied factor of safety (2.5 per Staheli et al 2010) 2.5

			BoreAid Bore Path				Estimate		Bennett Wallin 2008 Eq 1													Hydrofracture Analysis by BoreAid.											
	ft (station)	M/CL-ML el (ft	Ground El. (ft)	Ground El. (ft)	Bore El. (ft	Bore El. (ft)	Water El. (m)	Water El. (ft)	h_{tot} (ft)	h_w (ft)	σ_v (lb/ft^2)	u (lb/ft^2)	σ_o' (lb/ft^2)	$R_{p,max}$ (ft)	sinϕ	1+sinϕ	c*cosϕ	c*cotϕ	$(R_o/R_{pmax})^2$	σ_o'*sinϕ+c*cosϕ/G	-sinϕ/1+sinϕ	Pmax (lb/ft^2)	Pmax (psi)	X-Location	Y-Location	Z-Location	Length	Depth	Qmud	RhoMud	Limiting	Static	Friction	Circulating
m. dense sand	180.0000	10.0000	9.9107	9.9107	10.0000	10.0000	0.0000	0.0000	-0.0893	0	-11.5144	0	-11.5143852	-0.0892588	0.5299	1.52991926	0.0085	0.0160	21.7909131	0.0000	-0.34637074	-2.42646012	-0.01685042	180.0000	0.0000	10.0000	0.0000	-0.0893	100.0000	68.6700	0.0000	1.3058	0.0000	1.3058
x loose sand	208.2040	3.3468	8.5129	8.5129	3.3468	3.3468	0.0000	0.0000	5.16609	0	666.4256	0	666.42561	5.16609	0.5299	1.52991926	0.0085	0.0160	0.00650509	0.0011	-0.34637074	2209.7392	15.3454111	208.2040	-13.5738	3.3468	32.0000	5.1661	100.0000	68.6700	24.4146	4.4785	0.5570	5.0355
378 silty sand	236.4090	-3.3064	7.2920	7.2920	-3.3064	-3.3064	0.0000	0.0000	10.5983	3.30635	1367.1807	206.31624	1160.86446	10.5983	0.5299	1.52991926	0.0085	0.0160	0.00154563	0.0019	-0.34637074	5135.6298	35.6640958	236.4090	-27.1477	-3.3064	64.0000	10.5983	100.0000	68.6700	66.9974	7.6512	1.1140	8.7652
390 clay	264.6130	-9.9595	6.2499	6.2499	-9.9595	-9.9595	0.0000	0.0000	16.2094	9.95952	2091.0126	621.474048	1469.53855	16.2094	0.5299	1.52991926	0.0085	0.0160	0.00066076	0.0024	-0.34637074	6902.97058	47.9372957	264.6130	-40.7215	-9.9595	96.0000	16.2094	100.0000	68.6700	103.2800	10.8239	1.6711	12.4950
411 v. dense sand	292.8170	-16.6127	5.4267	5.4267	-16.6127	-16.6127	0.0000	0.0000	22.0394	16.6127	2843.0826	1036.63248	1806.45012	22.0394	0.5299	1.52991926	0.0085	0.0160	0.00035742	0.0030	-0.34637074	8373.65108	58.1503547	292.8170	-54.2954	-16.6127	128.0000	22.0394	100.0000	68.6700	134.5030	13.9967	2.2281	16.2247
1548 silty sand	321.0220	-23.2659	4.6029	4.6029	-23.2659	-23.2659	0.0000	0.0000	27.8688	23.2659	3595.0752	1451.79216	2143.28304	27.8688	0.5299	1.52991926	0.0085	0.0160	0.00022353	0.0035	-0.34637074	9641.84949	66.9572881	321.0220	-67.8692	-23.2659	160.0000	27.8688	100.0000	68.6700	160.6720	17.1694	2.7851	19.9545
1594 n. dense sand	349.2260	-29.9190	3.7779	3.7779	-29.9190	-29.9190	0.0000	0.0000	33.6969	29.919	4346.9001	1866.9456	2479.9545	33.6969	0.5299	1.52991926	0.0085	0.0160	0.0001529	0.0041	-0.34637074	10799.5936	74.997178	349.2260	-81.4431	-29.9190	192.0000	33.6969	100.0000	68.6700	183.7810	20.3421	3.3421	23.6842
	377.4310	-36.5722	2.9592	2.9592	-36.5722	-36.5722	0.0000	0.0000	39.5314	36.5722	4867.0482	2282.10528	2584.94292	39.5314	0.5057	1.505747	2.0591	4.0715	0.00011109	0.0060	-0.33587781	9553.07036	66.3407664	377.4310	-95.0169	-36.5722	224.0000	39.5314	100.0000	68.6700	204.7690	23.5149	3.8991	27.4140
	405.6350	-43.2254	2.5675	2.5675	-43.2254	-43.2254	0.0000	0.0000	45.7929	43.2254	5518.2190	2697.26496	2820.95404	45.7929	0.4655	1.46546005	21.1695	45.4808	8.2791E-05	0.0066	-0.31762043	9296.95147	64.562163	405.6350	-108.5910	-43.2254	256.0000	45.7929	100.0000	68.6700	192.7560	26.6876	4.4561	31.1437
	433.8470	-49.8368	-0.6018	-0.6018	-49.8368	-49.8368	0.0000	0.0000	49.235	49.8368	6535.0750	3109.81632	3425.25868	49.235	0.5133	1.51327217	16.0063	31.1849	7.1619E-05	0.0063	-0.33918034	12839.5111	89.1632717	433.8470	-122.1680	-49.8368	288.0000	49.2350	100.0000	68.6700	213.4800	29.8404	5.0131	34.8535
	462.2270	-55.4847	-4.0937	-4.0937	-55.4847	-55.4847	0.0000	0.0000	51.391	55.4847	6847.6950	3462.24528	3385.44972	51.391	0.5133	1.51327217	16.0063	31.1849	6.5736E-05	0.0063	-0.33918034	12895.0887	89.5492272	462.2270	-135.8270	-55.4847	319.9980	51.3910	100.0000	68.6700	235.7010	32.5338	5.5686	38.1024
	490.7970	-59.7840	-7.7708	-7.7708	-59.7840	-59.7840	0.0000	0.0000	52.0132	59.784	6937.9140	3730.5216	3207.3924	52.0132	0.5133	1.51327217	16.0063	31.1849	6.4173E-05	0.0059	-0.33918034	12600.8118	87.5056373	490.7970	-149.5770	-59.7840	351.9950	52.0132	100.0000	68.6700	249.6910	34.5840	6.1222	40.7062
	519.5080	-62.7271	-9.9835	-9.9835	-62.7271	-62.7271	0.0000	0.0000	52.7436	62.7271	7043.8220	3914.17104	3129.65096	52.7436	0.5133	1.51327217	16.0063	31.1849	6.2408E-05	0.0058	-0.33918034	12497.2761	86.7866399	519.5080	-163.3940	-62.7271	383.9930	52.7436	100.0000	68.6700	259.7090	35.9875	6.6739	42.6613
	548.3050	-64.3084	-11.2454	-11.2454	-64.3084	-64.3084	0.0000	0.0000	53.063	64.3084	7090.1350	4012.84416	3077.29084	53.063	0.5133	1.51327217	16.0063	31.1849	6.1659E-05	0.0057	-0.33918034	12416.4234	86.2251623	548.3050	-177.2530	-64.3084	415.9910	53.0630	100.0000	68.6700	264.3950	36.7415	7.2236	43.9651
	577.1620	-64.6046	-12.5607	-12.5607	-64.6046	-64.6046	0.0000	0.0000	52.0439	64.6046	6942.3655	4031.32704	2911.03846	52.0439	0.5133	1.51327217	16.0063	31.1849	6.4097E-05	0.0054	-0.33918034	12033.9891	83.5693687	577.1620	-191.0750	-64.6046	447.9880	52.0439	100.0000	68.6700	261.8770	36.8828	7.7714	44.6542
	606.3590	-64.6046	-12.8393	-12.8393	-64.6046	-64.6046	0.0000	0.0000	51.7653	64.6046	6901.9685	4031.32704	2870.64146	51.7653	0.5133	1.51327217	16.0063	31.1849	6.4789E-05	0.0053	-0.33918034	11938.0736	82.9032886	606.3590	-204.1710	-64.6046	479.9870	51.7653	100.0000	68.6700	260.5710	36.8828	8.3188	45.2016
	635.9590	-64.6046	-12.9277	-12.9277	-64.6046	-64.6046	0.0000	0.0000	51.6769	64.6046	6889.1505	4031.32704	2857.82346	51.6769	0.5133	1.51327217	16.0063	31.1849	6.5011E-05	0.0053	-0.33918034	11907.5426	82.6912677	635.9590	-216.3250	-64.6046	511.9850	51.6769	100.0000	68.6700	259.7880	36.8828	8.8662	45.7490
	665.9330	-64.6047	-13.0064	-13.0064	-64.6047	-64.6047	0.0000	0.0000	51.5983	64.6047	6877.7535	4031.33328	2846.42022	51.5983	0.5133	1.51327217	16.0063	31.1849	6.5209E-05	0.0053	-0.33918034	11880.3443	82.5023906	665.9330	-227.5260	-64.6047	543.9840	51.5983	100.0000	68.6700	259.0230	36.8828	9.4136	46.2965
	696.2500	-64.6047	-13.1692	-13.1692	-64.6047	-64.6047	0.0000	0.0000	51.4355	64.6047	6854.1475	4031.33328	2822.81422	51.4355	0.5133	1.51327217	16.0063	31.1849	6.5622E-05	0.0052	-0.33918034	11823.9158	82.1105265	696.2500	-237.7630	-64.6047	575.9830	51.4355	100.0000	68.6700	258.0130	36.8829	9.9610	46.8439
	726.8790	-64.6047	-13.3952	-13.3952	-64.6047	-64.6047	0.0000	0.0000	51.2095	64.6047	6821.3775	4031.33328	2790.04422	51.2095	0.5133	1.51327217	16.0063	31.1849	6.6203E-05	0.0052	-0.33918034	11745.3114	81.5646622	726.8790	-247.0240	-64.6047	607.9810	51.2095	100.0000	68.6700	256.8150	36.8829	10.5084	47.3913
	757.7890	-64.6047	-13.4137	-13.4137	-64.6047	-64.6047	0.0000	0.0000	51.191	64.6047	6818.6950	4031.33328	2787.36172	51.191	0.5133	1.51327217	16.0063	31.1849	6.6251E-05	0.0052	-0.33918034	11738.8629	81.5198812	757.7890	-255.3010	-64.6047	639.9800	51.1910	100.0000	68.6700	256.1960	36.8829	11.0558	47.9387
	788.9470	-64.6048	-13.1358	-13.1358	-64.6048	-64.6048	0.0000	0.0000	51.469	64.6048	6859.0050	4031.33952	2827.66548	51.469	0.5133	1.51327217	16.0063	31.1849	6.5537E-05	0.0052	-0.33918034	11835.5282	82.191168	788.9470	-262.5840	-64.6048	671.9790	51.4690	100.0000	68.6700	256.4110	36.8829	11.6032	48.4861
	820.3230	-64.6048	-12.3113	-12.3113	-64.6048	-64.6048	0.0000	0.0000	52.2935	64.6048	6978.5575	4031.33952	2947.21798	52.2935	0.5133	1.51327217	16.0063	31.1849	6.3487E-05	0.0055	-0.33918034	12119.5078	84.1632486	820.3230	-268.8670	-64.6048	703.9770	52.2935	100.0000	68.6700	258.1650	36.8829	12.1506	49.0336
	851.8840	-64.6048	-12.0255	-12.0255	-64.6048	-64.6048	0.0000	0.0000	52.5793	64.6048	7019.9985	4031.33952	2988.65898	52.5793	0.5133	1.51327217	16.0063	31.1849	6.2798E-05	0.0055	-0.33918034	12217.0147	84.8403797	851.8840	-274.1430	-64.6048	735.9760	52.5793	100.0000	68.6700	258.3920	36.8829	12.6981	49.5810
	883.5970	-64.6049	-11.7592	-11.7592	-64.6049	-64.6049	0.0000	0.0000	52.8457	64.6049	7058.6265	4031.34576	3027.28074	52.8457	0.5133	1.51327217	16.0063	31.1849	6.2167E-05	0.0056	-0.33918034	12307.4726	85.4685597	883.5970	-278.4060	-64.6049	767.9750	52.8457	100.0000	68.6700	258.5610	36.8829	13.2455	50.1284
	915.4310	-64.6049	-11.4947	-11.4947	-64.6049	-64.6049	0.0000	0.0000	53.1102	64.6049	7096.9790	4031.34576	3065.63324	53.1102	0.5133	1.51327217	16.0063	31.1849	6.1549E-05	0.0057	-0.33918034	12396.9052	86.0896194	915.4310	-281.6520	-64.6049	799.9730	53.1102	100.0000	68.6700	258.7210	36.8830	13.7929	50.6758
	947.3520	-64.6049	-11.6991	-11.6991	-64.6049	-64.6049	0.0000	0.0000	52.9058	64.6049	7067.3410	4031.34576	3035.99524	52.9058	0.5133	1.51327217	16.0063	31.1849	6.2026E-05	0.0056	-0.33918034	12327.8276	85.6099142	947.3520	-283.8790	-64.6049	831.9720	52.9058	100.0000	68.6700	257.5580	36.8830	14.3403	51.2232
	979.3280	-64.6049	-10.9117	-10.9117	-64.6049	-64.6049	0.0000	0.0000	53.6932	64.6049	7181.5140	4031.34576	3150.16824	53.6932	0.5133	1.51327217	16.0063	31.1849	6.022E-05	0.0058	-0.33918034	12592.6814	87.4491767	979.3280	-285.0820	-64.6049	863.9700	53.6932	100.0000	68.6700	259.1870	36.8830	14.8877	51.7707
	1011.3300	-64.6050	-11.2590	-11.2590	-64.6050	-64.6050	0.0000	0.0000	53.346	64.605	7131.1700	4031.352	3099.818	53.346	0.5133	1.51327217	16.0063	31.1849	6.1006E-05	0.0057	-0.33918034	12476.2978	86.6409568	1011.3300	-285.2630	-64.6050	895.9690	53.3460	100.0000	68.6700	257.6200	36.8830	15.4351	52.3181
	1043.3100	-64.6050	-10.7062	-10.7062	-64.6050	-64.6050	0.0000	0.0000	53.8988	64.605	7211.3260	4031.352	3179.974	53.8988	0.5133	1.51327217	16.0063	31.1849	5.9761E-05	0.0059	-0.33918034	12661.2794	87.9255515	1043.3100	-284.4190	-64.6050	927.9680	53.8988	100.0000	68.6700	258.5870	36.8830	15.9825	52.8655
	1075.2600	-64.6050	-10.2771	-10.2771	-64.6050	-64.6050	0.0000	0.0000	54.3279	64.605	7273.5455	4031.352	3242.1935	54.3279	0.5133	1.51327217	16.0063	31.1849	5.8821E-05	0.0060	-0.33918034	12803.7641	88.9152083	1075.2600	-282.5520	-64.6050	959.9660	54.3279	100.0000	68.6700	259.2040	36.8830	16.5299	53.4129
	1107.1300	-64.6051	-10.7849	-10.7849	-64.6051	-64.6051	0.0000	0.0000	53.8202	64.6051	7199.9290	4031.35824	3168.57076	53.8202	0.5133	1.51327217	16.0063	31.1849	5.9936E-05	0.0059	-0.33918034	12635.0646	87.7435043	1107.1300	-279.6640	-64.6051	991.9650	53.8202	100.0000	68.6700	257.1850	36.8830	17.0773	53.9603
	1138.8900	-64.6051	-11.7926	-11.7926	-64.6051	-64.6051	0.0000	0.0000	52.8125	64.6051	7053.8125	4031.35824	3022.45426	52.8125	0.5133	1.51327217	16.0063	31.1849	6.2245E-05	0.0056	-0.33918034	12296.1955	85.3902466	1138.8900	-275.7580	-64.6051	1023.9600	52.8125	100.0000	68.6700	253.7330	36.8830	17.6247	54.5078
	1170.5000	-64.6051	-12.6100	-12.6100	-64.6051	-64.6051	0.0000	0.0000	51.9951	64.6051	6935.2895	4031.35824	2903.93126	51.9951	0.5133	1.51327217	16.0063	31.1849	6.4217E-05	0.0054	-0.33918034	12017.1605	83.4525036	1170.5000	-270.8380	-64.6051	1055.9600	51.9951	100.0000	68.6700	250.7990	36.8831	18.1721	55.0552
	1201.9500	-64.6051	-13.0967	-13.0967	-64.6051	-64.6051	0.0000	0.0000	51.5084	64.6051	6864.7180	4031.35824	2833.35976	51.5084	0.5133	1.51327217	16.0063	31.1849	6.5437E-05	0.0052	-0.33918034	11849.1544	82.2857947	1201.9500	-264.9090	-64.6051	1087.9600	51.5084	100.0000	68.6700	248.8000	36.8831	18.7195	55.6026
	1233.1900	-64.6052	-13.5345	-13.5345	-64.6052	-64.6052	0.0000	0.0000	51.0707	64.6052	6801.2515	4031.36448	2769.88702	51.0707	0.5133	1.51327217	16.0063	31.1849	6.6563E-05	0.0051	-0.33918034	11696.8158	81.2278873	1233.1900	-257.9770	-64.6052	1119.9600	51.0707	100.0000	68.6700	246.9320	36.8831	19.2669	56.1500
	1264.1900	-64.6052	-13.6200	-13.6200	-64.6052	-64.6052	0.0000	0.0000	50.9852	64.6052	6788.8540	4031.36448	2757.48952	50.9852	0.5133	1.51327217	16.0063	31.1849	6.6787E-05	0.0051	-0.33918034	11666.9207	81.0202828	1264.1900	-250.0490	-64.6052	1151.9600	50.9852	100.0000	68.6700	245.8950	36.8831	19.8144	56.6974
	1294.9200	-64.6052	-13.4094	-13.4094	-64.6052	-64.6052	0.0000	0.0000	51.1958	64.6052	6819.3910	4031.36448	2788.02652	51.1958	0.5133	1.51327217	16.0063	31.1849	6.6238E-05	0.0052	-0.33918034	11740.474	81.5310698	1294.9200	-241.1330	-64.6052	1183.9600	51.1958	100.0000	68.6700	250.6820	36.8831	20.3618	57.2449
	1325.3500	-64.6052	-12.7973	-12.7973	-64.6052	-64.6052	0.0000	0.0000	51.8079	64.6052	6908.1455	4031.36448	2876.78102	51.8079	0.5133	1.51327217	16.0063	31.1849	6.4682E-05	0.0053	-0.33918034	11952.6961	83.0048338	1325.3500	-231.2390	-64.6052	1215.9600	51.8079	100.0000	68.6700	256.9300	36.8831	20.9092	57.7923
	1355.4500	-64.6053	-11.4331	-11.4331	-64.6053	-64.6053	0.0000	0.0000	53.1722	64.6053	7105.9690	4031.37072	3074.59828	53.1722	0.5133	1.51327217	16.0063	31.1849	6.1406E-05	0.0057	-0.33918034	12417.765	86.2344792	1355.4500	-220.3750	-64.6053	1247.9500	53.1722	100.0000	68.6700	265.1920	36.8831	21.4566	58.3397
	1385.1800	-64.6053	-10.3289	-10.3289	-64.6053	-64.6053	0.0000	0.0000	54.2764	64.6053	7266.0780	4031.37072	3234.70728	54.2764	0.5133	1.51327217	16.0063	31.1849	5.8933E-05	0.0060	-0.33918034	12786.6781	88.7963759	1385.1800	-208.5550	-64.6053	1279.9500	54.2764	100.0000	68.6700	272.6000	36.8831	22.0040	58.8871
	1414.5300	-64.6019	-10.4161	-10.4161	-64.6019	-64.6019	0.0000	0.0000	54.1858	64.6019	7252.9410	4031.15856	3221.78244	54.1858	0.5133	1.51327217	16.0063	31.1849	5.9136E-05	0.0060	-0.33918034	12757.0474	88.5906067	1414.5300	-195.7910	-64.6019	1311.9500	54.1858	100.0000	68.6700	276.7040	36.8815	22.5514	59.4329
	1443.6800	-63.8232	-9.6280	-9.6280	-63.8232	-63.8232	0.0000	0.0000	54.1952	63.8232	7254.3040	3982.56768	3271.73632	54.1952	0.5133	1.51327217	16.0063	31.1849	5.9109E-05	0.0060	-0.33918034	12851.1193	89.2438843	1443.6800	-182.6280	-63.8232	1343.9500	54.1952	100.0000	68.6700	278.8720	36.5102	23.0976	59.6078
	1472.7800	-61.6807	-8.5102	-8.5102	-61.6807	-61.6807	0.0000	0.0000	53.1705	61.6807	7105.7225	3848.87568	3256.84682	53.1705	0.5133	1.51327217	16.0063	31.1849	6.141E-05	0.0060	-0.33918034	12762.4328	88.6280057	1472.7800	-169.4900	-61.6807	1375.9500	53.1705	100.0000	68.6700	274.4060	35.4885	23.6419	59.1304
	1501.7600	-58.1785	-7.0319	-7.0319	-58.1785	-58.1785	0.0000	0.0000	51.1466	58.1785	6812.2570	3630.3384	3181.9186	51.1466	0.5133	1.51327217	16.0063	31.1849	6.6366E-05	0.0059	-0.33918034	12501.1531	86.8135633	1501.7600	-156.4020	-58.1785	1407.9400	51.1466	100.0000	68.6700	263.2460	33.8183	24.1842	58.0025
	1530.5900	-53.3228	-6.1566	-6.1566	-53.3228	-53.3228	0.0000	0.0000	47.1662	53.3228	6235.0990	3327.34272	2907.75628	47.1662	0.5133	1.51327217	16.0063	31.1849	7.804E-05	0.0054	-0.33918034	11735.6127	81.4973107	1530.5900	-143.3870	-53.3228	1439.9400	47.1662	100.0000	68.6700	242.2890	31.5028	24.7245	56.2273
	1559.2000	-47.1400	-5.5084	-5.5084	-47.1400	-47.1400	0.0000	0.0000	41.6316	47.14	5104.3708	2941.536	2162.8348	41.6316	0.5057	1.505747	2.0591	4.0715	0.00010017	0.0050	-0.33587781	8849.82484	61.457117	1559.2000	-130.4670	-47.1400	1471.9400	41.6316	100.0000	68.6700	211.5950	28.5544	25.2628	53.8172
	1587.7300	-40.4868	-4.6049	-4.6049	-40.4868	-40.4868	0.0000	0.0000	35.8819	40.4868	4454.6547	2526.37632	1928.27838	35.8819	0.5057	1.505747	2.0591	4.0715	0.00013484	0.0045	-0.33587781	8097.82753	56.2349134	1587.7300	-117.5870	-40.4868	1503.9400	35.8819	100.0000	68.6700	176.7400	25.3817	25.8005	51.1821
	1616.2600	-33.8337	-0.5837	-0.5837	-33.8337	-33.8337	0.0000	0.0000	33.25	33.8337	4289.2500	2111.22288	2178.02712	33.25	0.5299	1.52991926	0.0085	0.0160	0.00015703	0.0036	-0.34637074	10060.0965	69.8617809	1616.2600	-104.7060	-33.8337	1535.9400	33.2500	100.0000	68.6700	166.7970	22.2090	26.3382	48.5471
	1644.7900	-27.1806	6.2297	6.2297	-27.1806	-27.1806	0.0000	0.0000	33.4103	27.1806	4309.9287	1696.06944	2613.85926	33.4103	0.5299	1.52991926	0.0085	0.0160	0.00015553	0.0043	-0.34637074	11087.3072	76.9951892	1644.7900	-91.8254	-27.1806	1567.9400	33.4103	100.0000	68.6700	186.1580	19.0362	26.8758	45.9121
	1673.3100	-20.5275	7.8263	7.8263	-20.5275	-20.5275	0.0000	0.0000	28.3538	20.5275	3657.6402	1280.916	2376.7242	28.3538	0.5299	1.52991926	0.0085	0.0160	0.00021595	0.0039	-0.34637074	10232.722	71.0605694	1673.3100	-78.9447	-20.5275	1599.9400	28.3538	100.0000	68.6700	167.7300	15.8635	27.4135	43.2770
	1701.8400	-13.8744	7.5334	7.5334	-13.8744	-13.8744	0.0000	0.0000	21.4078	13.8744	2761.6062	865.76256	1895.84364	21.4078	0.5299	1.52991926	0.0085	0.0160	0.00037882	0.0031	-0.34637074	8557.57423	59.4275988	1701.8400	-66.0641	-13.8744	1631.9400	21.4078	100.0000	68.6700	134.8650	12.6908	27.9512	40.6420
	1730.3700	-7.2212	7.4146	7.4146	-7.2212	-7.2212	0.0000	0.0000	14.6358	7.22124	1888.0182	450.605376	1437.41282	14.6358	0.5299	1.52991926	0.0085	0.0160	0.00081048	0.0024	-0.34637074	6620.26772	45.9740814	1730.3700	-53.1834	-7.2212	1663.9400	14.6358	100.0000	68.6700	95.4433	9.5181	28.4889	38.0070
	1758.9000	-0.5681	7.6342	7.6342	-0.5681	-0.5681	0.0000	0.0000	8.20236	0.568115	1058.1044	35.450376	1022.65406	8.20236	0.5299	1.52991926	0.0085	0.0160	0.00258048	0.0017	-0.34637074	4154.86739	28.8532457	1758.9000	-40.3027	-0.5681	1695.9400	8.2024	100.0000	68.6700	49.7047	6.3454	29.0265	35.3720
	1787.4200	6.0850	7.8539	7.8539	6.0850	6.0850	0.0000	0.0000	1.76888	0	228.1855	0	228.18552	1.76888	0.5299	1.52991926	0.0085	0.0160	0.05548566	0.0004	-0.34637074	379.312971	2.63411785	1787.4200	-27.4220	6.0850	1727.9400	1.7689	100.0000	68.6700	4.0536	3.1727	29.5642	32.7369
	1815.9500	12.7381	8.7030	8.7030	12.7381	12.7381	0.0000	0.0000	-4.03515	0	-520.5344	0	-520.53435	-4.03515	0.5299	1.52991926	0.0085	0.0160	0.01066248	-0.0009	-0.34637074	-1581.0264		1815.9500	-14.5414	12.7381	1759.9400	-4.0352	100.0000	68.6700		0.0000	30.1019	

Appendix E
Analytic Solution for Operational Pipe Deflection and Unconstrained Collapse

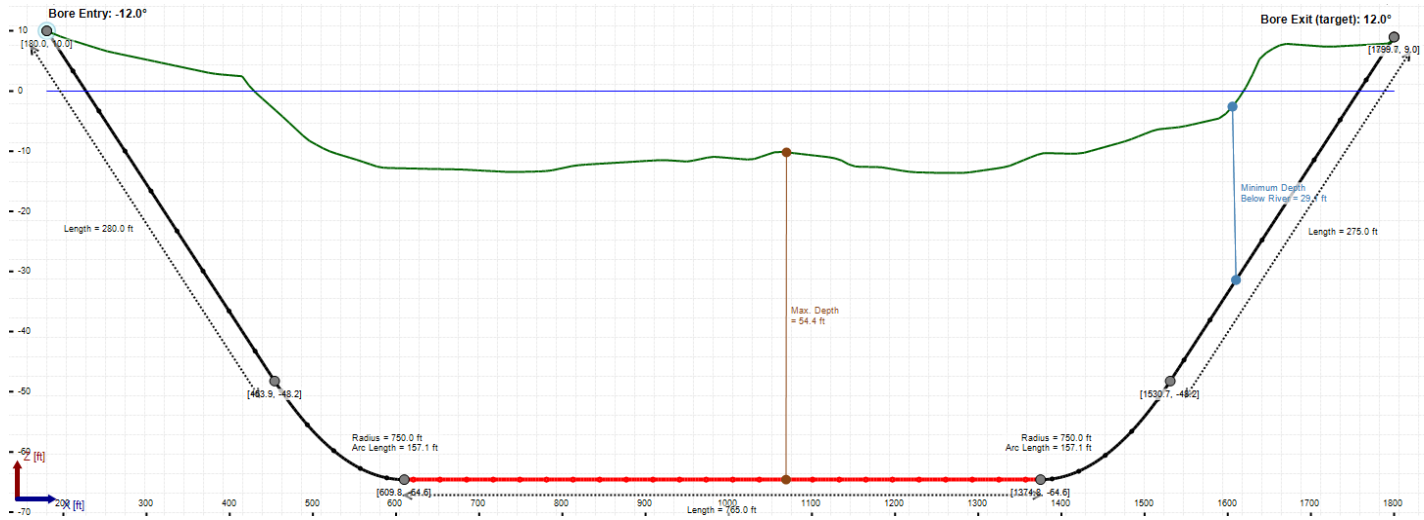
HDD Deflection & Unconstrained Collapse Check | **Brooks Bridge HDD** | **Engineers: D. Worthen, PE**
Check: A. Finney, PE, GE

HDD ANALYSIS - PIPE DEFLECTION & UNCONSTRAINED COLLAPSE - OPERATIONAL

Brooks Bridge 20" DR11

Max Depth Location - Shutdown Occurence - ASSUMES PIPE IS NOT EMPTIED

References:
ASTM F1962-05 Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings.



Pipe Inputs

$D := 21.6in = 548.64 \cdot mm$	Pipe Diameter (OD)
$DR := 11$	Dimension Ratio (OD/t)
$E := 28200psi$	Long-term Elastic Modulus for HDPE (See Table X1.1)
$\mu := 0.45$	Poisson's ratio - 0.45 (long-term) [0.35 (short term)]
$R := 750ft$	Design Bending Radius
$Y_A := 9ft$	Elevation of Pipe Connection (use lowest value of entry or exit points)
$Y_B := -64.6ft$	Elevation of Pipe at Maximum Depth

1. Earth Pressure Calculation

$B := 36in = 3\,ft$		"Silo" Diameter - conservative approach is to set equal to borehole diameter
$H_1 := 10ft$	$\gamma_1 := 62.4 \frac{lbf}{ft^3}$	Layer 1 - Free water

$H_2 := 23.2ft$ $\gamma_{2sat} := 129 \frac{lbf}{ft^3}$ Layer 2 - M. Dense Sand

$H_3 := 5.8ft$ $\gamma_{3sat} := 125 \frac{lbf}{ft^3}$ Layer 3 - Loose Sand

$H_4 := 4.2ft$ $\gamma_{4sat} := 113 \frac{lbf}{ft^3}$ Layer 4 - Silty Sand

$H_5 := 1.8ft$ $\gamma_{5sat} := 110 \frac{lbf}{ft^3}$ Layer 5 - Clay

$H_6 := 19.2ft$ $\gamma_{6sat} := 135 \frac{lbf}{ft^3}$ Layer 6 - V. Dense Sand

$\phi_6 := 42deg$ Angle of Internal Friction

$\delta_6 := \phi_6$ Angle of Wall Friction - set equal to angle of internal friction (Eqn. X2.3)

$K_6 := \tan\left(45deg - \frac{\phi_6}{2}\right)^2 = 0.2$ Earth Pressure Coefficient (Eqn. X2.4)

$H := H_1 + H_2 + H_3 + H_4 + H_5 + H_6 = 64\,ft$ Total Soil Column Above Pipe at Max Depth Point

$\sigma_1 := \gamma_1 \cdot H_1 = 4.33\,psi$ Total/Effective Stress

$\sigma_2 := \left(\gamma_{2sat} - 9.81 \frac{kN}{m^3}\right) \cdot H_2 = 10.72\,psi$

$\sigma_3 := \left(\gamma_{3sat} - 9.81 \frac{kN}{m^3}\right) \cdot H_3 = 2.52\,psi$

$\sigma_4 := \left(\gamma_{4sat} - 9.81 \frac{kN}{m^3}\right) \cdot H_4 = 1.47\,psi$

$\sigma_5 := \left(\gamma_{5sat} - 9.81 \frac{kN}{m^3}\right) \cdot H_5 = 0.59\,psi$

$\sigma_6 := \left(\gamma_{6sat} - 9.81 \frac{kN}{m^3}\right) \cdot H_6 = 9.67\,psi$

$\kappa_6 := \frac{1 - e^{-2\frac{K_6 \cdot H}{B} \cdot \tan\left(\frac{\delta_6}{2}\right)}}{2 \cdot \frac{(K_6 \cdot H)}{B} \cdot \tan\left(\frac{\delta_6}{2}\right)} = 0.3$ Arching Factor (Eqn. X2.3)

$P_{EVsoil} := (\sigma_1 + \sigma_2 + \sigma_3 + \sigma_4 + \sigma_5 + \sigma_6) = 29.3 \cdot psi$ External Effective Earth Pressure

$P_{EV\_arch} := \kappa_6 \cdot P_{EVsoil} = 8.7\,psi$ Arched External Earth Pressure

$H_{static} := Y_A - Y_B = 73.6\,ft$ Height of Static Water Column @ Shutdown

$P_{int\_static} := H_{static} \cdot 62.4 \frac{lbf}{ft^3} = 31.89\,psi$ Internal Static Pressure at Max Depth @ Shutdown

$H_w := 74.6ft$ Groundwater Height Above Max Depth Point

$P_w := H_w \cdot 62.4 \frac{lbf}{ft^3} = 32.33\,psi$ Groundwater Pressure

$P_{net\_int} := P_{int\_static} - P_w = -0.43\,psi$ Net Internal Water Pressure in Pipe @ Shutdown
assumes: groundwater pressure is equal around entire external circumference
+ value = internal pressure outward

$P_{deflect} := P_{EV\_arch} - P_{net\_int} = 9.09\,psi$ Net Pressure Acting to Deflect Pipe:
Arched Earth Load reduced by
Net Internal Water Pressure @ Shutdown

2. Earth Load Deflection

$$\Delta := \frac{0.0125 P_{deflect}}{\frac{E}{12\,(DR-1)^3}} = 4.8 \cdot \%$$

$\Delta_{final} := \Delta \cdot D = 26.5 \cdot mm$ Ring Deformation (Eqn. X2.5)

Note: Table X2.1 indicates safe long-term deflection limit for DR 11 is 5.0% x D =
Δ x D = 26.5 mm < 27.4 mm

** OK **

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TABLE X2.1 Safe Long-Term Design Deflection values for Buried Pressurized Polyethylene Pipe

DR or SDR	Deflection Limits as % of Diameter
21	7.5
17	6.0
15.5	6.0
13.5	6.0
11	5.0
9	4.0
7.3	3.0

3. Buoyant Deflection

$\gamma_w := 68.7 \frac{lbf}{ft^3} = 0.04 \cdot \frac{lbf}{in^3}$ Weight of Drilling Fluid in Borehole - use value from BoreAid analysis

$t := \frac{D}{DR} = 1.96 \cdot in$ Minimum Wall Thickness

$I := \frac{t^3}{12} = 0.63 \cdot \frac{in^4}{in}$ Moment of Inertia

$\Delta_{Buo} := 0.1169 \cdot \gamma_w \cdot \frac{\left(\frac{D}{2}\right)^4}{(E \cdot I)} \cdot D = 1.95 \cdot mm$

$\%D_{buo} := \frac{\Delta_{Buo}}{D} = 0.4 \cdot \%$

Note: 0.4% < 5%

** OK **

4. Check Reissner Effect - additive effect of longitudinal bending
(applies at bend locations - conservative to add at max depth location)
{negligible when R > 40D and DR < 21}

$R = 750\ ft$
$40 \cdot D = 72\ ft$
$DR = 11$

$z := \frac{\frac{3}{2} \cdot \left(1 - \mu^2\right) \cdot (D - t)^4}{16 \cdot t^2 \cdot R^2} = 0.00004$ Intermediate Factor

$\Delta_R := \left(\frac{2}{3}\right) \cdot z + \left(\frac{71}{135}\right) \cdot z^2 = 0.0024 \cdot \%$ Reissner Ovality

$\Delta + \Delta_R = 4.8 \cdot \%$ Max Ovality Deflection

5. Unconstrained Collapse

$FS := 2$ Safety Factor for Unconstrained Collapse (recommended = 2.0)

$f_o := .62$ Ovality Compensation Factor (See Fig. 2) $\Delta = 4.83 \cdot \%$

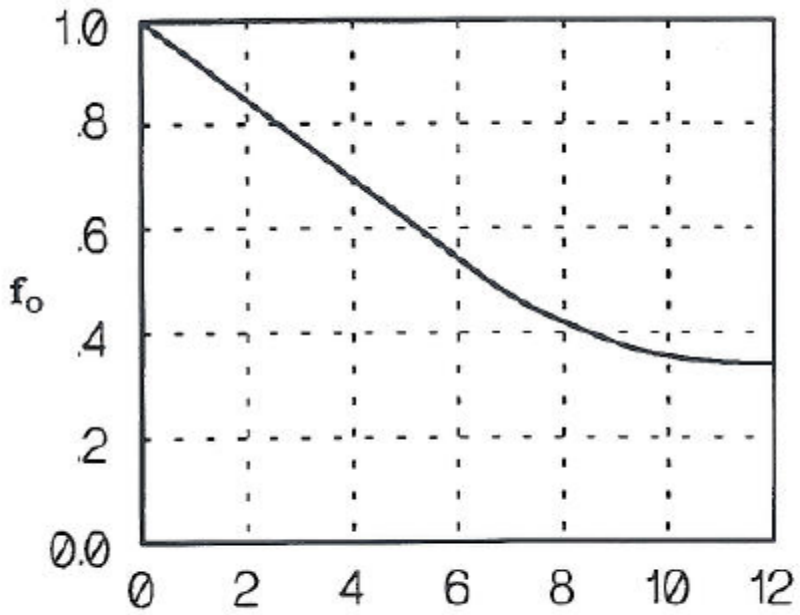

FIG. 2 Ovality Compensation Factor

$$P_{ua} := \frac{2 \cdot E}{\left(1 - \mu^2\right)} \cdot \left(\frac{1}{DR - 1}\right)^3 \cdot \frac{f_o}{FS} = 21.9\,psi$$ Allowable External Collapse Pressure (Eqn. 5)

$P_{tot\_ext} := P_{EV\_arch} + P_w = 41\,psi$ Total External Pressure on Pipe (8.2.3: effective earth pressure [reduced for arching] + hydrostatic pressure)

$P_{int\_static} = 31.89\,psi$ Internal Pressure on Pipe @ Shutdown Case

$P_{net} := P_{tot\_ext} - P_{int\_static} = 9.1\,psi$ Net External Pressure on Pipe @ Shutdown Case (assumes pipe is full)

Check P_{ua} with the value from Table X3.1:

$P_{crit} := 71psi$ Critical Buckling Pressure (Table X3.1) - 50 yrs for Long Term - 138psi

TABLE X3.1 Critical Collapse Pressure for Unconstrained HDPE Pipe[A,B,C] at 73°F

NOTE—**Table does not include ovality compensation or safety factor.**

	Pipe SDR, psi, ft H_2O, in Hg						
Service Life	7.3	9	11	13.5	15.5	17	21
Short-term	1003, 2316, 2045	490, 1131, 999	251, 579, 512	128, 297, 262	82, 190, 168	61, 141, 125	31, 72, 64
100 h	488, 1126, 995	238, 550, 486	122, 282, 249	62, 144, 127	40, 92, 82	30, 69, 61	15, 35, 31
50 years	283, 653, 577	138, 319, 282	71, 163, 144	36, 84, 74	23, 54, 47	17, 40, 35	9, 20, 18

[A]Axial Tension during pull-back reduces collapse strength.
[B]Full vacuum is 14.7 psi, 34 ft water, 30 in Hg.
[C]Multipliers for temperature rerating:

60°F (16°C)	73.4°F (23°C)	100°F (38°C)	120°F (49°C)
1.08	1.00	0.78	0.63

$P_{allow} := P_{crit} \cdot \left(\frac{f_o}{FS} \right) = 22\,psi$ Allowable Collapse Pressure - should approx. equal P_{ua} from Eqn. 5

$P_{ua} = 21.9\,psi$

P_{ua} exceeds P_{net} (see 8.2.4.2) ** OK **

$P_{ua} = 21.9\,psi$

$P_{net} = 9.1\,psi$

PRE-BID CONFERENCE

ITB: WS 66-18 Brooks Bridge Water Main Replacement

DATE/TIME: September 13, 2018/ 10:00 AM PURCHASING REPRESENTATIVE: DeRita Mason

PLEASE PRINT NEATLY & CLEARLY! IF AVAILABLE, PLEASE LEAVE BUSINESS CARD

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