

TABLE OF CONTENTS

PART 2

2.1	GENERAL DESIGN/PRECONSTRUCTION	2	
2.2	REFERENCES	2	
2.3	ENGINEER'S RESPONSIBILITIES	2-3	
2.4	CONTRACTOR RESPONSIBILITIES	3	
2.5	EQUIPMENT	3-4	
2.6	DIRECTIONAL BORE PIPE	4-5	
2.7	TRACER WIRE		5
2.8	FITTINGS AND RESTRAINERS	5-6	
2.9	MAINTENANCE OF TRAFFIC	6	
2.10	GENERAL CONSTRUCTION REQUIREMENTS	6	
2.11	CONTRACTOR CONSTRUCTION RESPONSIBILITIES	6-8	
2.12	DRILLING REQUIREMENTS	8-9	
2.13	PIPE INSTALLATION	9-10	
2.14	BUTT FUSION PROCEDURE	10	
2.15	CONNECTING TWO ADJOINING SECTIONS OF DIRECTIONALLY BORED PIPE	10	
2.16	GENERAL POST-CONSTRUCTION	10-11	
2.17	AS-BUILTS	11	
APPENDIX A	DIRECTIONAL BORE DESIGN FACTORS	12-13	
APPENDIX B	DIRECTIONAL BORE GUIDELINES	14	
APPENDIX C	DIRECTIONAL BORE LOG	15	

CITY OF LAKE WALES

DIRECTIONAL BORE STANDARDS

2.1 General Design/Preconstruction

The purpose of this standard is to provide guidelines for use by the development community during the design and installation of underground water mains and wastewater force mains using horizontal directional bores integral to the development of commercial, industrial or residential subdivision properties.

2.2 References

References for horizontal directional drilling include Mini-Horizontal Directional Drilling Manual (1995), North American Society of Trenchless Technology (NASTT), Chicago, IL; PPI Handbook of Polyethylene Piping (1998), Plastics Pipe Institute, Washington, D.C.; PLEXCO Polyethylene Industrial Piping Systems; “Technical Information; Technical Note: Horizontal Directional Drilling (Guided Bore) with PLEXCO Pipe,” et al.

2.3 Engineer’s responsibilities

2.3.1 The ENGINEER should determine if the soils at the site are suitable for directional drilling based on previous experience with the site soils or a geotechnical investigation.

2.3.2 All existing utilities, surface and subsurface structures must be located (in three dimensions) for the design.

2.3.3 The minimum ground cover over a directionally bored water or wastewater utility line shall be 36 inches. There shall be at least 18 inches vertical clearance when crossing under any existing water main with a wastewater force main.

2.3.4 The ENGINEER should limit curvature in any direction to lessen force on the pipe during pull-back. Ideally, the directional bore should lie in a vertical plane.

2.3.5 The ENGINEER shall submit, as part of the permits application plans submittal package, design calculations indicating predicted/permissible (maximum safe) pull force shall be shown on the project design drawings. The ENGINEER assumes all responsibility for proper design of the directional bore. Some factors to be considered in calculating the safe pull force follow. **Additional discussion can be found in Appendix A.**

- The pullback force is calculated at the leading end of the pipe behind the pulling head.
- The frictional resistance is highest just prior to movement and decreases with movement.
- When pullback ceases, frictional forces and drag forces increase due to the thixotropic nature of drilling mud. The mud starts to gel when it is undisturbed.

- Buoyant force pushes the pipe up against the top of the borehole, creating frictional drag between the pipe and the borehole.
- Minimum curvature at the entry and exit pits is limited by the steering capabilities of the boring equipment.
- When the bending radius is too small, the safe pulling strength of PE pipe may be significantly reduced by the additional tensile stresses due to curvature.
- All bending stresses due to various curvatures in the boring path are additive and should be subtracted from the safe pull force.
- The “safe” pull-load is time dependent.

2.3.6 The ENGINEER must show the directional bore in profile view on the plans, showing the pipe, as it should be installed. Maximum pull strength and minimum radius of curvature shall be listed. All existing utilities shall be shown on the plans.

2.3.7 The ENGINEER shall provide signed and sealed “As-Built” drawings of the constructed bore path, including any abandoned in place bores. The ENGINEER shall certify that the pipe was installed within acceptable limits per the pipe specifications.

2.4 Contractor’s Responsibilities

2.4.1 The CONTRACTOR shall supply all labor, supervision, tools and equipment, and materials necessary to install carrier pipe by directional bore method for potable water or wastewater systems. Installation of the carrier pipe system includes the installation of water mains or wastewater force mains and/or any other devices or materials deemed necessary for the respective systems. For CITY projects, materials may be supplied by the City.

2.4.2 The CONTRACTOR shall provide experienced operators to perform directional boring. The operator shall have performed at least three directional bores of similar pipe diameter and bore length.

2.4.3 The CONTRACTOR shall be fully responsible for placement of the pipe per the ENGINEER’s specifications. See Paragraph 2.11.7 for tolerances.

2.4.4 The CONTRACTOR shall supply experienced persons who have received proper training in the use of the fusion equipment according to the recommendations of the pipe manufacturer and fusion equipment supplier to perform thermal fusion of the specific HDPE pipe to be used.

2.4.5 The CONTRACTOR shall **NOT** perform any boring work on Fridays.

2.5 Equipment

2.5.1 The directional drilling equipment shall consist of a directional-drilling rig of sufficient capacity to perform the bore and pullback the pipe.

2.5.2 The steerable, directional-boring equipment shall produce a stable fluid lined tunnel with a minimum burial depth of 36 inches for the carrier pip installation.

2.5.3 The tunneling equipment shall employ a fluid cutting technique. The soil shall be cut by small diameter, high pressure jets of drilling fluid. The jets shall cut the soil in advance of the boring tool, impregnating and lining the tunnel wall with drilling fluid. The drilling fluid shall

be inert and pose no environmental risk, such as bentonite or a polymer-surfactant mixture producing a slurry of proper consistency.

- 2.5.4 The hydraulic power system shall be self-contained and free of leaks, with sufficient pressure and volume to power the drilling operation.
- 2.5.5 The boring tool (head) shall be remotely steerable by means of an electronic detection system. The toll location shall be monitored in three dimensions and logged every 10 feet from the drilling rig. The boring tool shall pull the carrier pipe through the fluid lined tunnel as it traverses the surface being crossed.
- 2.5.6 The rig shall have means to monitor and record the maximum pullback force during the pullback operation. The pulling strength of the boring equipment shall not exceed the HDPE pipe safety pull strength as per the manufacturer's recommendation.
- 2.5.7 The butt fusion machine used to join sections of HDPE pipe shall have controls and gauges for setting pressures used for facing, heating, and fusing.

Facing should be conducted at a pressure that produces properly faced pipe ends.
Heating pressure should be set so that the pipe ends maintain contact against the heater, but are not forced against the heater (zero contact pressure).
Fusing pressure shall be as recommended by the pipe manufacturer and fusion equipment supplier.
Heater surfaces must be clean and free of contaminants such as dirt, oil, grease and melted or charred plastic. To clean the heater, only wooden implements and clean, dry, lint-free non-synthetic cloths should be used.
The heater should be checked periodically for uniform surface temperature using a surface pyrometer.

2.6 Directional Bore Pipe

- 2.6.1 Pipe shall be High Density Polyethylene (HDPE) as per AWWA C906.
- 2.6.2 Carrier: HDPE pipe shall be DR 11, working pressure rating of 160 psi. The following are approved pipe manufacturers.
 - CRS, PolyPipe PE 3408, 4" to 24" diameter.
 - PLEXCO PE 3408, 4" to 24" diameter
 - Driscopipe 4000 Series, 4" to 24" diameter.
- 2.6.3 Material for pipes to be used for potable water application shall be approved by the National Sanitation Foundation (NSF).

All fittings, sizes 4 inch and larger shall meet the requirements of AWWA Standard C 906-90 (or most recent revision).
All fittings shall be ductile iron pipe size.
All fittings shall meet the requirements of ANSI NSF Standard 61.
All fittings shall be made of materials conforming to polyethylene code designation PE 3408.
Standard dimension ration shall be DR11
Pressure Class shall be 160 psi.

2.6.4 Color Coding: The piping shall be permanently coded to provide service identification. Stripes along the entire outside length of the pipe, 120 degrees apart, shall be made by co-extrusion or impregnation in accordance with the following schedule. Fully colored pipe co-extruded from permanently pigmented HDPE is also acceptable.

<u>SERVICE</u>	<u>STRIPED PIPE</u>	<u>SOLID COLORED PIPE</u>
Potable water	Blue Stripes	Blue
Reclaimed water	Purple Stripes	Purple
Wastewater	Green Stripes	Green

2.6.5 Marking on the pipe shall include the following:

- Nominal size and OD base.
- Standard material code designation.
- Dimension ratio.
- Pressure class.
- AWWA designation (AWWA C906).
- Material test category of pipe.

2.7 Tracer Wire

2.7.1 All piping shall be installed with a continuous, insulated, solid #10 gauge copper head extra high strength (EHS) wire for water main or force main location purposes by means of an electronic line tracer.

2.7.2 The wire insulation shall be solid color in accordance with the coding described in 2.6.4, above. Blue coated (for water mains), or green coated (for wastewater), number 10 gauge UF (Underground Feeder per National Electric Code Article 339) solid tracer wire must be taped along all pipes. Sections of wire shall be spliced together using Buchanon connectors or a similar approved method for splicing. Twisting the wires together is not acceptable. Spools of #10 wire are available in 500-foot rolls.

2.7.3 Upon completion of the directional bore, the CONTRACTOR shall demonstrate to the CITY, that the wire is continuous and unbroken through the entire run of the pipe by providing full signal conductivity (including splices) when energizing for the entire run in the presence of the INSPECTOR. If the wire is broken, the CONTRACTOR shall repair or replace it. See Paragraph 2.11.11.

2.8 Fittings and Restraints

2.8.1 Pipe flange joints shall be made using a flange adapter, which is butt fused to the HDPE pipe.

A back-up ring shall be fitted behind the flange adapter sealing surface flange for bolting to the mating flange. Standard back-up rings shall be AWWA C207 Class D for 160 psi and lower pressure ratings.

One edge of the back-up ring must be chamfered to fit up against the back of the sealing surface flange.

2.8.2 Mechanical joints to polyethylene pipe shall be fully constrained by compressing the pipe OD against a rigid tube or stiffener in the pipe bore.

The stiffener shall be stainless steel.

Approved joint restraining devices are Mega-Lug and MJR.

2.9 Maintenance of Traffic

2.9.1 The maintenance of traffic, in accordance with the governing right-of-way authority, shall be the responsibility of the CONTRACTOR.

2.9.2 If the CONTRACTOR has the capability within his organization, he shall provide the necessary personnel and equipment for maintenance of traffic. Persons participating in maintenance of traffic operations must be FDOT qualified and copies of their certificates verifying their qualifications shall be provided to the City's Utility Department prior to start of the directional work.

2.9.3 If the CONTRACTOR is unable to provide the required maintenance of traffic, he shall subcontract the work to supply the necessary personnel and equipment. The use of a subcontractor's personnel and equipment shall in no way transfer the responsibility for the maintenance of traffic from the CONTRACTOR.

2.10 General Construction Requirements

2.10.1 All directional bore operations shall be contained within right-of-way and/or easements shown on the DRAWINGS.

2.10.2 Work shall not start until the CITY provides the CONTRACTOR with necessary permits from the appropriate governing regulatory agencies, including the City of Lake Wales and not until the Utilities Department has been given 48 hours (two working days) prior notification.

2.10.3 CONTRACTOR shall not begin drilling operation until the INSPECTOR is present. The INSPECTOR must be present during the entire boring operation once the ground is penetrated.

2.11 Contractor Construction Responsibilities

2.11.1 The CONTRACTOR shall provide the following materials and services for directional bore unless otherwise specified by the OWNER/DEVELOPER:

Traffic control.

Tracer wire for carrier pipe (#10 gauge or larger, solid), per standards.

Site preparation and excavation.

Dewatering-Groundwater Pump or Well Point System as needed.

Sheeting and shoring, as necessary.

All fusion welding.

Preliminary site restoration (fill open pits, grading).

Site clean up including removal and proper disposal of all waste materials and drilling

fluid.

- 2.11.2** The CONTRACTOR shall record location and depth measurements every ten (10) feet over the course of the bore and provide that data to the CITY. Data collected by the City inspector does not relieve the Contractor from the responsibility of recording his own data. The CONTRACTOR shall log all necessary data from the locator/tracing system:

- Position
- Roll Angle
- Tilt Angle
- Depth
- Temperature of Data Transmitter
- Remaining Battery Life
- Pull back force (Maximum pull back force shall be recorded.)

- 2.11.3** The CONTRACTOR shall supply the following materials:

- All HDPE fittings, couplings and carrier pipe (unless otherwise specified).
- Final site restoration (sod, seed, mulch, concrete/asphalt repair).
- Required Right-Of-Way Permits.

- 2.11.4** An INSPECTOR for the CITY shall witness and verify the CONTRACTOR'S logging of pertinent data. The INSPECTOR may log his own data in the Department's own Directional Bore Log sheet for the City's use.

- 2.11.5** The CONTRACTOR shall notify all involved agencies prior to the start of construction. The CONTRACTOR is responsible for verifying that all permits are current and not expired. The CONTRACTOR shall notify the ENGINEER of Record and the CITY, if expired.

- 2.11.6** The CONTRACTOR shall call "Sunshine State One-Call" (phone number: 800-432-4770) 48 hours prior to performing any excavation.

- 2.11.7** The CONTRACTOR shall perform directional bore in accordance with the approved project DRAWINGS. In no case shall the bore extend into private property unless an easement is provided prior to start of construction. Vertical tolerances shall be plus or minus 1 foot of elevations shown on drawings. Horizontal tolerances shall be plus or minus 2 feet of alignment shown in drawings. These tolerances shall be met unless required separations for other utilities must be met and puts the bore in conflict. Failure to meet tolerances, if not preapproved by ENGINEER, may be grounds for rejecting the bore. The CONTRACTOR may, at the discretion of the ENGINEER, be required to abandon the bore and re-drill a new one at the CONTRACTOR'S own expense.

- 2.11.8** The CONTRACTOR shall provide all structures, safety equipment and professional services required for the health and safety of the general public and of personnel involved in directional boring work in accordance with the requirements of the Federal, State and Local Authorities. This includes proof of construction personnel certificates of trench safety training at the time of construction.

- 2.11.9** The CONTRACTOR shall take all measures necessary to protect surrounding public and private property, adjacent buildings, roads, drives, sidewalks, drains, sewers, utilities, trees, structures and appurtenances from damage due to directional bore work.

- 2.11.10** The CONTRACTOR shall exercise due care at all times and shall not apply more than the safe pull force to the carrier pipe recommended by the ENGINEER.
- 2.11.11** The CONTRACTOR shall install a blue coated #10 gauge solid tracer wire on all water carrier pipe and green coated #10 gauge solid tracer wire on all wastewater force main carrier pipe. The CONTRACTOR will be responsible to provide a tracer wire that tests positive for continuity the entire length of the bore prior to acceptance by the INSPECTOR.
- 2.11.12** The CONTRACTOR shall give 48 hours (two working days) advance notice to the CITY prior to the start of work. The INSPECTOR is required to inspect materials and to be on site during the boring operation and installation of the pipe.
- 2.11.13** The CONTRACTOR shall be fully responsible for all steerable, fluid lined directional boring operation. Any noticeable surface defects resulting from operation of this boring equipment shall be repaired by the CONTRACTOR at his expense. The CONTRACTOR is recommended to take preconstruction videos of the construction site to avoid unwarranted claims for damages resulting from the construction.
- 2.11.14** The CONTRACTOR shall meet all CITY insurance requirements, as defined by the City's Risk Management Department, when working in a City right of way, using a City Right-of-Way Use Permit.

2.12 Drilling Requirements

- 2.12.1** The horizontal alignment shall be as shown on the drawings, plus or minus 2 feet. The vertical alignment shall be as shown on the drawings, plus or minus 1 foot. If the CONTRACTOR cannot meet these tolerances for whatever reason, he shall confer with the ENGINEER prior to the start of the bore and the ENGINEER shall approve any changes.
- 2.12.2** The pipe shall have a minimum cover of 36 inches.
- 2.12.3** Compound curvatures should be minimized as the safe pulling strength of the pipe may be significantly reduced by the additional tensile stresses due to curvatures. This is limited by the maximum deflection as set forth by the HDPE pipe manufacturer or AWWA Standards, whichever is more stringent.
- 2.12.4** The entry angle should be 12° to 14° ideally (not to exceed 15°). Exit angle should be 6° to 12° to facilitate the pullback operation.
- 2.12.5** Erosion and sedimentation control measures and on-site containers shall be installed to prevent drilling mud from spilling out of entry and/or exit pits.
- 2.12.6** Drilling mud shall be disposed of off-site in accordance with applicable local, State and Federal requirements and/or permit conditions.
- 2.12.7** Pilot hole shall be drilled on bore path with no deviation greater than plus or minus 1 foot from the design depth over a length of 100 feet. In the event that the allowable deviation is exceeded, the CONTRACTOR shall notify the CITY and the CITY may require the CONTRACTOR to pullback and re-drill from a location along the bore path before the

deviation.

- 2.12.8** Upon successful completion of the pilot hole, the borehole shall be reamed to a minimum of 25 percent greater than the outside diameter of the pipe being installed. For bores with more than two radii of curvature (entrance and exit), the bore hole should be reamed up to 50 percent larger than the outside diameter of the carrier pipe.
- 2.12.9** The CONTRACTOR shall not attempt to ream at a rate greater than the drilling equipment and mud system are designed to safely handle.
- 2.12.10** In the event of a drilling hole blowout, the CONTRACTOR shall be responsible for restoring to original condition any damaged property and cleaning up the environment in the vicinity of the blowout.

2.13 Pipe Installation

- 2.13.1** After reaming the bore hole to the required diameter, the pipe shall be pulled through the hole. In front of the pipe shall be a swivel and barrel reamer to compact the bore hole walls.
- 2.13.2** Once pullback operations have commenced, the operation shall continue without interruption until the pipe is completely pulled into the borehole. The frictional resistance is the highest just prior to movement and decreases with movement. When pullback ceases, frictional forces and drag forces increase due to the thixotropic nature of drilling mud. The mud starts to gel when it is undisturbed. Therefore, **PULLBACK SHALL NEVER BE STOPPED, EXCEPT FOR DRILLING ROD REMOVAL, UNTIL THE PIPE IS COMPLETELY PULLED INTO ITS PERMANENT POSITION.**
- 2.13.3** Adequate lengths of pipe shall be provided at both the launching and receiving ends to facilitate service connection assemblies.
- 2.13.4** After pullback, pipe may take several hours to recover from the axial strain. When pulled from the reamed borehole, the pull-nose should be pulled out 3-4 percent longer than the total length of the pull to avoid having the pull-nose sucked back below the borehole exit level due to stretch recovery and thermal contraction to an equilibrium temperature.
- 2.13.5** The pipe entry area shall be graded as needed to provide support for the pipe and to allow free movement into the borehole. The pipe shall be guided into the borehole to avoid deformation of, or damage to, the pipe.
- 2.13.6** The pipe shall be installed in a manner that does not cause upheaval, settlement, cracking and movement or distortion of surface features. Any damages caused by the CONTRACTOR'S operations shall be corrected by the CONTRACTOR.
- 2.13.7** In the event that unexpected subsurface conditions impeding drilling operations are encountered, the procedure shall be stopped and not continued until the CITY has been consulted. The pipe shall be pulled back through the borehole using the wet insertion construction technique.
- 2.13.8** If final grade of the finished bore is not satisfactory to the CITY or any other jurisdictional entity, the pipe shall be abandoned, full pressure grouted in place, and an alternate installation shall be made. The abandoned pipe shall be properly shown on "as-built"

drawings to be submitted following conclusion of the construction work.

- 2.13.9** The INSPECTOR shall inspect the installed pipe for roundness and/or damage. Evidence of over-pulling or significant surface scratching shall be brought to the attention of the ENGINEER and the CITY. Deformations of more than 10 percent may be grounds to abandon the bore and have the CONTRACTOR re-drill another line.

2.14 Butt Fusion Procedure

- 2.14.1** Fusion welds shall be performed by an experienced technician that has been properly trained to meet the pipe manufacturer's procedures. All welds shall meet the pipe manufacturer's recommendations.
- 2.14.2** As the pipe ends are melted against the heater during the heating period, the molten plastic will swell and form melt beads around the pipe ends. The melt beads should be the same size on both pipe ends and uniformly sized all the way around.
- 2.14.3** After melting has been completed, the ends should be separated just enough to remove the heater, observed for uniformity of the beads and quickly (within three seconds) brought together with the recommended pressure.

If melted plastic sticks to heater, the two ends should not be joined. The ends should be allowed to cool and the procedure started over.

Excess pressures should not be used as this will squeeze too much melt out of the fusion area and result in a weakened joint.

- 2.14.4** The CONTRACTOR may do a preliminary pressure test on the completed string of pipe prior to installation. A pressure test shall be required on the completed directional bore prior to final acceptance.

2.15 Connecting Two Adjoining Sections of Directionally Bored Pipe

- 2.15.1** If the overall length of the required utility installation cannot be safely pulled using a directional bore, then the CONTRACTOR shall be required to make more than one pull to accomplish the installation.
- 2.15.2** Where two adjacent pulls meet, the CONTRACTOR shall dig a pit and join the two sections together at the elevation of the two segments as if it were a continuous pull-in.
- 2.15.3** The two sections of HDPE shall be joined together using an electrofusion coupling per the coupling manufacturer's recommendations.

2.16 General Post-Construction

- 2.16.1** The as-built variance from the specified bore path shall not exceed plus or minus 1 foot in the vertical plane and plus or minus 2 feet in the horizontal plane. The CONTRACTOR shall notify the ENGINEER and the CITY prior to start of the boring operation if these tolerances cannot be met.
- 2.16.2** The CONTRACTOR shall be considered as having completed the requirements of the

directional bore when he has successfully completed the work, including pressure testing to the satisfaction of the DEVELOPER/OWNER's ENGINEER and the CITY INSPECTOR.

- 2.16.3** The completed HDPE water main or force main shall be pressure tested at 150 psig for two hours for final acceptance and the pressure shall not fall below 145 psig during the test period.

2.17 As-Builts

- 2.17.1** When the directional bore is completed, the CONTRACTOR shall provide data log sheets and marked up as built drawings to the INSPECTOR, and the DEVELOPER/OWNER's ENGINEER, if required.

APPENDIX A

DIRECTIONAL BORE DESIGN FACTORS

Calculations for computing the maximum safe pull back force should be submitted with the project design package.

The following equations from the PLEXCO Polyethylene Industrial Piping Systems; “Technical Information; Technical Note: Horizontal Directional Drilling (Guided Bore) with PLEXCO Pipe,” are presented for estimating **some** of the factors to be considered in designing a successful directional bore. They are based upon approximations and are for “ideal” conditions. They are by no means all of the considerations to be used in designing a directional bore.

The designer is totally responsible for the design of the directional bore and use of the following shall not transfer any of that responsibility to the CITY. The CITY makes no claim to the accuracy or completeness of the equations.

- (a) **PULLBACK FORCE:** The pullback force is calculated at the leading end of the pipe behind the pulling head. For pipe pulled in straight level bores, the frictional resistance or required pulling force, F_p , is approximated by:
 $F_p = \mu \times w_B \times L$, Where μ is the coefficient of friction between pipe and ground; w_B is the net downward or upward force on the pipe (lb/ft); and L is the length (ft).
- (b) **FRictional RESISTANCE OF DRILLING MUD:** The frictional resistance is highest just prior to movement and decreases with movement. When pullback ceases, frictional forces and drag forces increase due to the thixotropic nature of drilling mud. The mud starts to gel when it is undisturbed. Therefore, pullback should never be stopped, except for drilling rod removal, until the pipe is completely pulled into its permanent position.
- (c) **BUOYANT FORCE:** The pullback force will depend on whether the pipe is full or deliberately weighted to reduce buoyancy. Buoyant force pushes the pipe up against the top of the borehole, creating a frictional drag between the pipe and the borehole. The buoyant weight of the pipe is:
 $F_b = (\gamma_b \pi D^2) / 576 - w_a$. Where: D = pipe outside diameter, γ_b = specific weight of the mud slurry (lb/ft³), and w_a = weight of empty pipe.
- (d) **MINIMUM RADIUS OF CURVATURE:** Drill path curvature, at the entry and exit pits, is limited by the steering capabilities of the boring equipment. Drilling rod typically has a recommended bend radius of $1200 \times D_{ROD}$, where D_{ROD} is the nominal rod diameter. When the bending radius is around $150 \times D_{PIPE}$ or less, the safe pulling strength of PE pipe may be significantly reduced by the additional tensile stresses due to curvature.
- (e) **CAPSTAN EFFECT:** For pipe pulled around a curve (vertical or horizontal) creating an angle, θ (in radians), the capstan effect, $F_C = e^{\mu\theta} (\mu w_b L)$
 Where: μ = coefficient of friction between pipe and slurry or pipe and ground,
 w_b = net downward (or upward) force on pipe (lb/ft),
 e = natural logarithm base ($e = 2.71828$) and
 L = length (ft).

- (f) **SAFE PULL FORCE:** The safe pull stress, σ_{SP} , may be calculated by subtracting the bending stress due to curvature from the allowable tensile stress:
$$\sigma_{SP} = \sigma_{allow} - (E \times D) / 2r$$

The “safe pull force” can be found by multiplying the safe pull stress by the cross-sectional area of the pipe.

Where: σ_{allow} = allowable tensile stress (psi), **D** = outer diameter of pipe (in), **DR** = Dimension Ratio and **E** = time-dependent modulus of elasticity (psi) from tables.

- (g) **NET SAFE PULL FORCE:** All bending stresses due to various curvatures in the boring path are additive and should be subtracted from the safe pull force.
- (h) **TIME DEPENDENCE:** The “safe” pull-load is time dependent. See ASTM F-1804 for safe pullback values for PE pipe, less bending stresses.

For additional sources of information, the designer is referred to the following reference sources:

Mini-Horizontal Directional Drilling Manual (1995), North American Society of Trenchless Technology (NASTT), Chicago, IL

PPI Handbook of Polyethylene Piping (1998), Plastics Pipe Institute, Washington, D.C.

APPENDIX B

DIRECTIONAL BORE GUIDELINES

Directional Bore – Safe Pull Strength (for DR11, DIP Size HDPE)

Pipe Size (inches)	Safe Pull Strength (lbs)	Minimum Bend Radius (inches)	Wall Thickness	Maximum Defect Depth
4	7,600	96	.36	1/16
6	15,800	138	.55	1/11
8	27,200	181	.73	5/32
10	41,000	222	.91	3/16
12	57,900	264	1.10	1/4

Schedule the bore with City of Lake Wales Utilities 48 hours (2 working days) prior to boring.

If bore is over 100 linear feet, the contractor needs to fuse pipe together the day before.

The contractor needs to physically locate existing utilities, following the 48 hour Sunshine One-Call Guidelines.

Material Inspection: To be done before the bore is scheduled.

Surface cuts or scratches greater than or equal to maximum defect depth are not acceptable.

Blue stripe for Water.

Green stripe for Sewer.

#10 gauge wire attached to pipe.

Performing the bore:

Set up the bore log.

Calibrate Contractor's locator with actual depth measurement – check the depth of the first rod.

Ream the borehole.

Check the flow of bentonite – must be continuous.

Check the pulling pressure.

Do not allow operator to exceed safe pull strength.

Mark up drawing with “As-Built” data.

Record pull back pressure.

Fuse DR11 together – minimum 440° F to maximum 460° F.

Cool down time equals: Diameter ÷ 2.

**City of Lake Wales
Directional Bore Log**

Project Name: _____

Project Number: _____ **Date:** _____

Contractor/Site Representative: _____

Bore Location/Number: _____ **Size/Material:** _____

Starting Location: _____ **Bore Rod Length:** _____

	Total Length Bored	Distance from Start Point	Depth	Pull Back Pressure	Comments
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					

***Lengths to be measured in rod length increments**

Inspector/City Representative: _____ **Contractor:** _____