Suggested General Guidelines
Horizontal Directional Drilling (HDD)
Installations of Ductile Iron Pipes

1.0 Scope

This document contains guidelines applicable to the installation of Flex-Ring®, flexible restrained joint ductile iron pipe, in sizes 4-in. through 48-in. manufactured per ANSI/AWWA C151/A21.51, using horizontal directional drilling (HDD). It includes minimum requirements for design, materials, and equipment used for the horizontal directional drilling installation of ductile iron pipes and joints for the substantially trenchless construction of pipelines or portions of pipelines.

These guidelines also include materials, dimensions, and other pertinent properties of pipes and required accessories. They provide several minimum performance requirements for various components including joints.

Commentary:
Some aspects of these guidelines and the pipe specified may also be helpful in design and construction of replacement pipelines by ("pulled") pipe bursting installations. This is where new ductile iron pipe is pulled into the path formed by a bursting cone or other cutter fracturing an existing pipe and expanding the broken pipe pieces radially out into the adjacent soil.

2.0 Reference

The following standards contain provisions that, through reference in this text, constitute provisions of these guidelines. All standards are subject to revision, and users of these guidelines are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI/AWWA C150/A21.50 -- American National Standard for the Thickness Design of Ductile-Iron Pipe
ANSI/AWWA C151/A21.51 -- American National Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water
ANSI/AWWA C111/A21.11 -- American National Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
ANSI/AWWA C104/A21.4 -- American National Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
ASTM A746 - Ductile Iron Gravity Sewer Pipe
ASTM A716 – Standard Specification for Ductile Iron Culvert Pipe
ANSI/AWWA C105/A21.5 -- American National Standard for Polyethylene Encasement for Ductile-Iron Pipe Systems
ANSI/AWWA C110/A21.10 -- American National Standard for Ductile-Iron and Gray-Iron Fittings, 3-inch through 48-inch, for Water and Other Liquids
ANSI/AWWA C153/A21.53 -- American National Standard for Ductile-Iron Compact Fittings 3-inch through 24-inch and 54-inch through 64-inch, for Water Service

ANSI/AWWA C600 -- AWWA Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances

3.0 Horizontal Directional Drilling

The HDD contractor or sub-contractor must submit the following information as described in sections 3.1 through 3.7 for review by the Engineer _____ (insert number) of days after the bid, notice to proceed, or days prior to mobilizing to the project site.

3.1. General. Prior to the start of drilling, reaming, and pipe placement operations, the Contractor shall properly locate and identify all existing utilities in proximity to the pipeline alignment. The Contractor shall confirm the alignment of all critical utilities, by pot-holing/day-lighting using vacuum excavation or other suitable excavation method, for further detailed confirmations as necessary

3.2 Equipment. Provide the description of the HDD equipment proposed for use on the project including the thrust and torque capacities.

3.3 Operator Experience. Provide project references for the operator and project manager or supervisor that they were directly involved in completing. This reference list shall include the projects description, location, owner and contact information, quantity, size and type of pipe installed by HDD.

3.4 Drilling Plan. The drilling plan shall provide a detail of the planned drilled borepath and the method for monitoring and controlling the speed, line, grade, and rate of fluids delivery. It shall include the sequence, size and description of each reamer and the capabilities of each through various geologic formations. The HDD contractor or sub-contractor (CONTRACTOR) must maintain the alignment and minimum radii as detailed on the plan sheets. Any drill plan should include a final swabbing of the borepath prior to pipe pullback. Unless approved by the ENGINEER prior to the start of drilling operations, pipe pullback of the new Flex-Ring® joint pipe without prior swabbing of the borepath to the finished borepath inside diameter will not be permitted.

3.4.1 Estimated Pullback Thrust. The CONTRACTOR shall submit to the ENGINEER an estimate of the anticipated pullback thrust that will be required to install the new Flex-Ring® pipe. This estimate shall include the calculated buoyant force or buoyant weight of the new pipe and any proposed method for counter-weighting the pipe during pullback.

3.5 Drilling Fluids Management. A fluids management plan shall be submitted to the Engineer for review. This plan shall include the proposed mix design for each specific geological strata or formation anticipated during drilling of the borepath, an estimate of quantities, delivery volume and pressure for each and the proposed method for monitoring. This plan shall also include details of the drilling fluid / soil slurry solids separation, recycling or disposal plan that will describe the equipment and capacities for separation and recirculation. If direct vacuum excavation of the slurry is selected the disposal site shall be identified and copies of all required permits shall be presented to the Engineer for approval. The CONTRACTOR shall submit a written plan that details the estimated quantity of slurry to be vacuum excavated and provide substantiation that there is sufficient equipment to adequately pump or shuttle the slurry to and from the disposal site(s) as required to maintain a near continuous drilling and pipe pull-back.

3.5.1 Inadvertent surface discharge of drilling fluid (Frac-out). The CONTRACTOR shall submit to the ENGINEER a plan for a quick response team to address inadvertent fluid discharges to the surface (frac-outs).

3.6 Equipment and Expertise: The Contractor should have equipment and expertise, appropriate for horizontal directional drilling installations of the size and scope of the project covered by this document. This includes the preparation and maintenance of the borepath using drilling fluids appropriate for the geology of the soils. The Contractor should also have experience in safely and dependably installing, in similar geology, similar size and length of piping involved.

3.7. Safety Plan. The Contractor shall be responsible for securing a safe worksite that meets all Federal, State, and Local government codes.

Commentary: There are several key factors that impact the success of any HDD installation, they include soil type and geology, drilling fluid, borepath radii, and borepath inside diameter.

4.0 Ductile Iron Pipe for HDD

4.1 General. Ductile iron pipe used for directional drilling shall meet all requirements of ANSI/AWWA C151/ A21.51. Unless otherwise specified pipe shall be lined with cement mortar per ANSI/AWWA C104/ A21.4, with all operations completed in a single facility by a one manufacturer. Pipe shall be AMERICAN Flex-Ring® or approved equal.

4.2 Pipe Joints. Joints used for directional drilling shall be boltless, flexible restrained, with smooth contoured bells and shall have the minimum properties as shown in Table 1. Joints with bulky glands or flanges that may prevent the smooth flow of the drilling fluid/soil slurry over the joint are not acceptable. Pipe shall be AMERICAN Flex-Ring® or approved equal.

4.2.1 Pressure and Thrust (Pulling). Joint seals and Flex-Ring® joint pipe used for HDD, when properly assembled and installed, shall be capable of dependably handling the specified internal pressure and pulling loads, in straight alignment or at maximum rated joint deflection. Maximum internal pressure and allowable pulling loads for all sizes are provided in Table 1; please contact AMERICAN for any application requiring capabilities greater than those shown.

4.2.2 Proof-of-Design Tests: The manufacturer shall make available to the Engineer representative proof-of-design tests for each size and type of flexible restrained joint pipe used. These tests shall establish the basis for the maximum allowable pulling loads shown in Table 1. Proof-of-design tests for the pulling heads shall also be made available to the Engineer.

4.3 External Loads and Buckling. In cases where the borepath alignment is at an extreme depth or if the Contractor anticipates high pumping pressures particularly for larger sizes of pipes, the Contractor shall consult the pipe Manufacturer to assure that the buckling strength of the pipe has been properly evaluated.

Commentary: By virtue of its material properties and common available thicknesses, ductile iron pipe possesses greater long-term buckling strength and thermal resistance than many other pipes; however, when non-pressurized pipes are expected to be subjected to very high (differential from outside compared to inside) external pressures or depth of cover, as by deep bore paths or high fluid pumping pressures, the buckling capability of the pipe should be checked. Evaluations should be made in accordance with the DIPRA Technical Report, "Critical Buckling Pressure for Ductile Iron Pipe", with adjustments as necessary for higher external pressures or densities of fluid surrounding the pipe etc.

4.4 Lining and Coating. Ductile iron pipe for water service shall be lined with cement mortar per ANSI/AWWA C104/A21.4.

Ductile iron pipe for wastewater service and for application as culvert pipes shall be lined with cement mortar per ANSI/AWWA C104/A21.4 unless otherwise specified.

The exterior of all ductile iron pipe and fittings shall be coated with an asphalt-based coating as required by ANSI/AWWA C151/A21.51.

4.4.1 Special Linings (If required, see *Commentary* below). The interior of the ductile iron pipe shall be coated with 40 mils of Protecto 401® as manufactured by Induron Coatings. The applicator shall apply the coating to the interior of the pipe in strict accordance with the procedure approved by the coating manufacturer.

Commentary: In wastewater applications when aggressive or septic sewerage is anticipated the interior of ductile iron pipe should be coated with Protecto 401®, a ceramic epoxy.

4.5 Pipe Weight – Net Unit Buoyancy

Pipe buoyant force or buoyant weight required in section 3.4.1 shall be calculated based on the density of drilling fluid(s) to be used. Any counter-weight placed inside the pipe shall be free from any dirt, grease, oil, or other contaminants that may prevent proper disinfection for waterlines.

Commentary: Some authorities assume that the fluid of a typical borepath (normally composed of drilling fluid and some mix or dispersion of soil cuttings) may be about 20% more dense than water. With such assumption, the net unit buoyancy of pipes would in effect be more positive than the values shown in Table 1. For this reason, it may be advisable, and particularly in some cases with large diameter pipe and/or long pulls, to employ schemes of reasonably uniform internal weighting. Careful weighting of large pipes in the drill path may lessen pulling loads.

Per Archimedes Principle: A body in a fluid, whether floating or submerged, is acted on by a buoyant force equal to the weight of the fluid displaced. The buoyant force acts vertically upward through the centroid of the displaced volume and can be defined mathematically as $F=\lambda V$, where F is the buoyant force (e.g. lb), λ is the specific weight of the fluid (e.g. lb/ft^3), and V is the volume of the fluid (e.g. ft^3) displaced by the body. The "Net Unit Buoyancy" is in effect the approximate vertical force per unit length (e.g. lb/ft) that an empty pipeline would exert if at rest in the drilling fluid. A minus or negative number would indicate that even an empty pipe would tend to sink in the fluid, whereas a positive value would indicate it would float in the fluid. Net unit buoyancy is one factor that can influence pulling loads on pipe strings, as it effects the unit normal bearing force on either the top or bottom of the borepath in pulling friction calculations.

Table 1 - Flex-Ring Dimensions and Other Parameters

Nominal Pipe Size (in.)	Maximum Working Pressure[1] (psi)	Pipe Barrel O.D. (in.)	Pipe Bell Outside Diameter (in.)	Unit Weight Lined PC 350 Pipe (lb/ft)	Bulk Density of Empty Pipe (lb/ft3)	Net Unit Buoyancy[2], Empty Pipe in Water (lb/ft)	Allowable Pulling Loads (lbs)	Allowable Deflection (Deg.)
4	350	4.80	7.06	13	100	Minus 5	10,000	5
6	350	6.90	9.19	18	69	Minus 2	20,000	5
8	350	9.05	11.33	25	55	3	30,000	5
10	350	11.10	13.56	31	46	11	45,000	5
12	350	13.20	15.74	40	42	19	60,000	5
14	350	15.30	19.31	53	41	27	75,000	4
16	350	17.40	21.43	65	40	38	95,000	3.75
18	350	19.50	23.70	78	37	52	120,000	3.75
20	350	21.60	25.82	90	35	69	150,000	3.5
24	350	25.80	29.88	122	34	104	210,000	3
30	250	32.00	36.34	173	31	175	220,000	2.5
36	250	38.30	42.86	233	29	266	310,000	2
42	250	44.50	49.92	315	29	359	390,000	2
48	250	50.80	56.36	395	28	484	500,000	2

1 Working pressure is the maximum pressure rating of the joint and is based on its capability to resist thrust due to internal pressure. If higher working pressure is required, check AMERICAN. Pressure rating of the joint is limited by the pressure rating of the parent pipe.
2 Based on weight of empty (full of air) Pressure Class 350 Flex-Ring pipe with standard cement lining immersed in water. Positive numbers indicate such pipe will float.

4.6 Entry and Exit Angles. The entry angle of the drill string shall range from 8 degrees to 20 degrees. Exit angles for the drill string shall take into consideration the allowable deflection (reference Table 1) and the method of installation proposed for the new Flex-Ring®, flexible restrained joint ductile iron pipe, see section 5.1 HDD Installation Methods. The CONTRACTOR shall submit a detailed plan showing the connection between the HDD installed piping and the next section of pipeline

Commentary: The entry angle for the HDD drill string should normally be between 10 and 12 degrees (from horizontal), but can range from between 8 and 20 degrees. For Flex-Ring sectional joints the exit angle for the drill string varies according to the method of assembly. For the assembled-line method (to be discussed herein) the drill string exit angle shall be such that when the new Flex-Ring®, flexible restrained joint ductile iron pipe is pulled back using the assembled-line option, any transition from the surface of the ground or from rollers placed on the surface onto the entry ramp or into the borepath is within the manufacturers allowable joint deflection as shown in Table 1.

4.7 Minimum Radius of curvature. The Contractor shall maintain the borepath alignment and radii that are indicated on the project drawings. Any alternate designs must be submitted to the Engineer for approval prior to commencement of drilling operations, and shall be based on a range from 50-feet to 100-feet per inch of nominal diameter, using 20-foot joint lengths.

Commentary: The diameter of the drill rod used in HDD installation will generally dictate the minimum radii for the borepath due to consideration for dynamic stresses in the rods, which increase when tighter radii are required. Tighter radii than the 50-feet per inch of nominal diameter have been successfully installed with standard 20-foot lengths or using shorter standard pipe lengths. However it important to realize that tighter radii generally will result in higher pulling loads during pipe pull back.

4.8 Borepath inside diameter. The finished inside diameter of the borepath shall be nominally 1.5 times the outside diameter of the Flex-Ring bell (see Table 1) for pipe sizes 4-inch through 24-inch. The inside diameter of the borepath for pipe sizes 30-inch through 48-inch shall be equal to the outside diameter of the Flex-Ring bell (see Table 1) plus 12-inches. To assure proper borepath size and integrity, the borepath shall be swabbed prior to final pipe pullback.

Commentary: In general, the borepath should be reamed to an inside diameter of approximately 1-1/2 times greater than the outside diameter of the bell for sizes 4-inch through 24-inch and for 30-inch through 48-inch the borepath shall be equal to the bell outside diameter plus 12-inches. The borepath should also be adequately reamed, swabbed, and/or otherwise prepared to the appropriate size prior to the pull back of the new pipe string so as to allow passage of straight and/or deflecting pipe sections with dimensions as per Table 1. If borepath radii are based on minimum allowable radii of the new pipe, the borepath inside diameter may need to be increased to allow the passage of full length pipe. The geometry of the pipe within the borepath should be checked to assure proper clearance.

4.9 External Protection. (If required, see *Commentary* below)

4.9.1 Polyethylene Encasement. Polyethylene (PE) encasement shall be applied by the Contractor according to the following procedure. Using only tube-type polyethylene sleeves, the polyethylene tube shall be centered onto the barrel of the pipe and firmly secured as per the requirements of AWWA C105, Method A and other requirements as described herein to follow, see Figure 1. The contractor shall insure that all excess material along the barrel of the pipe is creased and the excess folded over itself longitudinally so that the polyethylene wrap is tight up against the pipe barrel. The Contractor shall then secure the wrap tightly to the pipe by applying circumferential wraps of tape applied over the folded polyethylene encasement, and applied at intervals of approximately 2-ft to within 18 to 24-inches of either end of the pipe. Applying tape in a helical pattern should only be used as a supplementary wrap

The excess PE encasement shall be pulled back over itself to expose approximately 18" to 24" of both end of the pipe. The Contractor must first overlap the PE encasement so that this first layer can be securely anchored to the pipe barrel, without interference from the PE encasement on that pipe section, using tape. The excess material should be trimmed, or the length and/or positioning of the PE tube may need adjustment to accomplish this.

After engaging the spigot into the bell and verifying engagement of the restraining flex-ring or flex-ring segments, the following sequence is recommended for securing and completing the PE encasement at the pipe joints. This sequence should be followed so that the final overlap is made opposite to the direction of the pull, preventing any catching of the edge and minimizing any collection of drilling fluids etc. inside the wrap. For each layer of PE encasement the Contractor shall always complete the joint by first overlapping the end of the tube from the spigot end over the bell and secure the end of the tube onto the pipe barrel with several contiguous circumferential wraps of tape. It is important to assure that the PE encasement is secured to the pipe barrel with sufficient number of circumferential wraps to anchor the PE encasement so that any possibility of slippage is reduced. The PE encasement from the pipe closest to the HDD drilling machine (bell end of pipe) shall then be overlapped over its' bell and secured to the barrel on the spigot end of the pipe being installed with circumferential wraps of tape. When double PE encasement is specified the same procedure is repeated, with the final overlap being secured to the barrel on the spigot end of the pipe with circumferential wraps of tape.

In the case of double polyethylene wrapping, each layer shall be applied in the same manner with the exception that the excess PE encasement should be folded over itself in such a way as to avoid the excess in the first layer. Also, all bell over-laps (and fastening to the pipe barrel etc.) should be accomplished one layer at a time.

The Contractor should apply one final, tight circumferential wrap a few inches from the bell face on the last polyethylene wrap overlap over the most recently assembled spigot end. This final wrap should consist of strong strapping tape or other firm fastening means (that will not damage the wrap and) that will further minimize any slippage or bunching of the wrap in installation. The Contractor must have any other proposed methods of installing and fastening PE encasement approved by the Engineer.

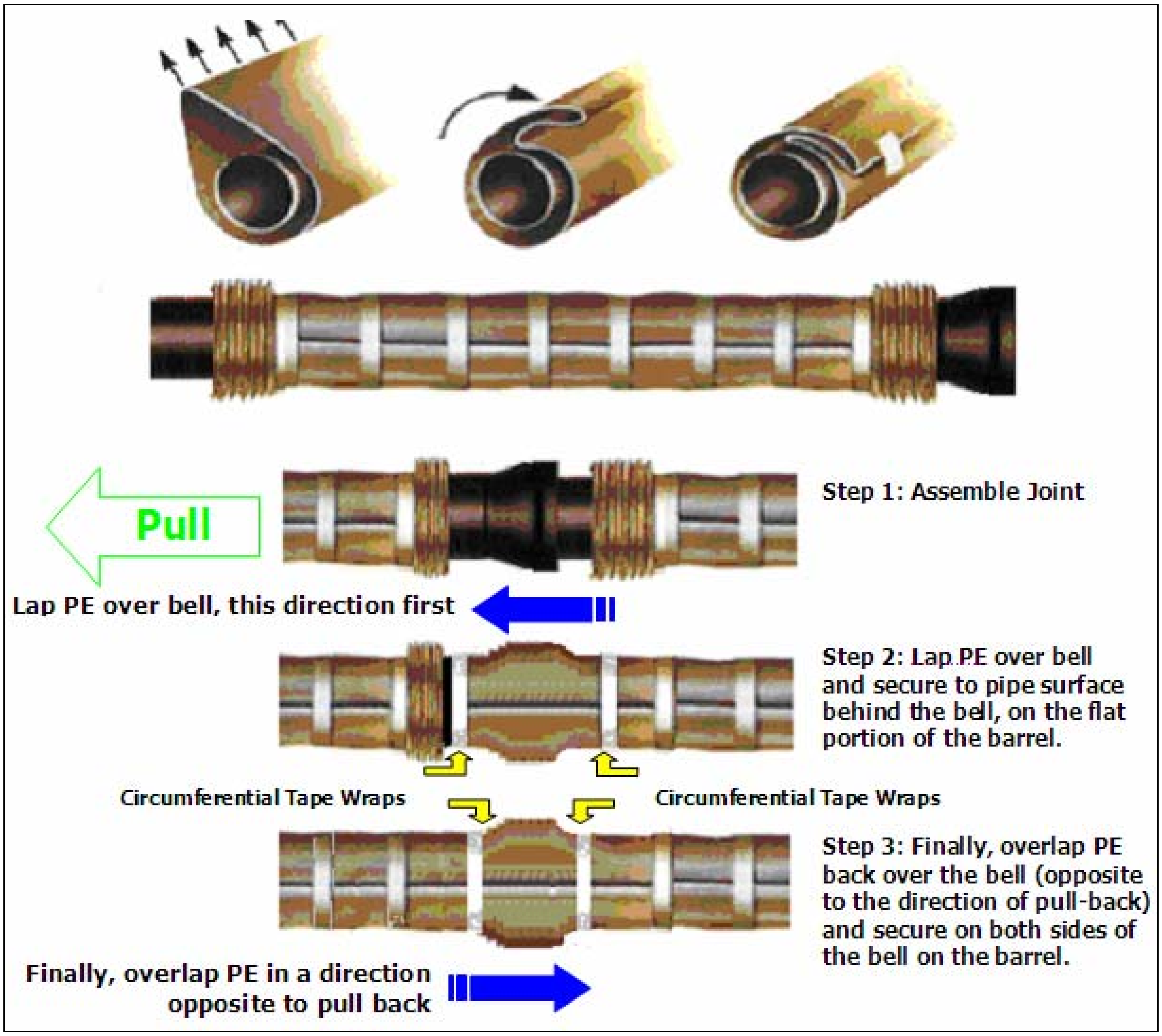

Figure 1 – Wrapping procedure for PE encasement, per AWWA C105, Appendix A, except as modified above.

4.9.2 Joint Bonding (If required, see *Commentary* below). The Contractor shall provide electrical continuity for each joint using the number and size insulated AWG copper wire bonding cable given in Table 2. Each wire bonding cable shall have approximately 1.5 to 2-inches of the insulation removed from one end with the opposite end prepared with a crimped-on electrical terminal suitable for connection to a tapped pipe with a ¼-inch bolt. In all cases the Contractor shall apply the bonding cables in the field prior to the pipe pull back using the following procedure and as modified by the Corrosion Engineer.

Table No. 2

Pipe Size (Inches)	AWG Wire Gauge	No. Bonding Cables
4 through 14	8	2
16 through 36	4	2
42 through 48	2	2

1. Spigot End - at the "Field-Top" position and at a distance not to exceed 4-inches from the assembly stripe painted on the spigot end of the pipe, the bare end of the copper wire shall be CAD-welded to the pipe barrel. The CAD welds and any exposed wire shall be coated using an aerosol primer and then covered with mastic filled Handi-Cap as manufactured by Royston or approved equal.

2. Bell End – at the "Field-Top" position the vertical face of the bell shall be drilled and tapped, to a depth of 5/8-inch, to accept a ¼-inch NC-Thread x 0.5-inch NC-Thread bolt for the number of copper wire bonding cables shown in Table 2.

Commentary: The Engineer may choose to employ the services of CORRPRO Company, Inc., to evaluate the characteristics of the soil and provide recommendations for pipeline protection based on AWWA C105, Appendix A, and the Design Decision Model (DDM). Preliminary studies co-sponsored by the Ductile Iron Pipe Research Association suggests that polyethylene encasement and/or joint bonding be considered based on the following criteria.

1. Polyethylene Encasement – Not Required. Polyethylene encasement will not be required when all of the following parameters are met.

- *a. Native soil at the pipe installation depth must be less than 10 points based on soil analysis as stated in the appendix of AWWA C105 or the native soil must be in the no-polyethylene zone of the DDM.*
- *b. The pipe should not be in a tidal zone, anywhere there is a rising or lowering of the water table where the native soils are cyclically wet then dry.*
- *c. A drilling mud that is non-aggressive to ductile iron pipe based on Table No. 3.*
- *d. Unless the conditions are met for the entire length of the HDD pull, polyethylene encasement must be used.*

2. Single Layer Polyethylene Encasement. A single layer of 8 mil linear low density polyethylene encasement applied to the exterior or the ductile iron pipe in accordance with the procedure in 4.9.1 will be required when all of the following parameters are met.

- *a. Native soils free from rocks with 10 point or greater soil or in the polyethylene zone (Zone 2) of the DDM.*
- *b. The pipe should not be in a tidal zone, anywhere there is a rising or lowering of the water table where the native soils are cyclically wet then dry.*
- *c. A drilling mud that is non-aggressive to ductile iron pipe based on Table No. 3.*

3. Double Layer Polyethylene Encasement. A double layer of 8 mil linear low density polyethylene encasement applied to the exterior or the ductile iron pipe in accordance with the procedure in 4.9.1 will be required when all of the following parameters are met.

a. Native soils with some rock present with 10 point or greater soil or in Zone 2 or 3 of the DDM.
b. Bonded joints with test stations should be considered based on the size of the line, the depth of the borepath, service application, and accessibility to the pipe in the event of a suspected corrosion anomaly

4. Double Layer Polyethylene Encasement with Bonded Joints and Test Stations. A double layer of 8 mil linear low density polyethylene encasement applied to the exterior or the ductile iron pipe in accordance with the procedure in section 4.9.1 and bonded joints in accordance with section 4.9.2 will be required when all the following parameters are met.

c. Native geology containing significant rock strata with greater than 10 point soils or greater than Zone 2 on the DDM.
d. Bonded joints with test stations should be considered, based on the size of the line, depth of the borepath, service application, and accessibility to the pipe in the event of a suspected corrosion anomaly.

Table No. 3 – Drilling Fluid Guide

Drilling Fluid	Does Drilling Fluid Require PE Encasement in otherwise Non-Corrosive Environments?	Performance
BARIOD BORE-GEL® with inhibitors (Oxygon, Boiler Solution, and Dinomul)	Not Required	Preferred
BARIOD BORE-GEL®	Optional	Satisfactory
BARIOD BORE-GEL®	Optional	Satisfactory
CETCO Hydraul-EZ®	Optional	Satisfactory
M-I L.L.C. PARGEL 220	Required	Avoid

5.0 Installation

5.1 Cartridge Assembly (Option 1). Cartridge assembly option shall be defined by the assembling of individual sections of Flex-Ring®, flexible restrained joint ductile iron pipe in a secured entry and assembly pit. The pipe sections are assembled individually and then progressively pulled into the borepath a distance equivalent to a single pipe section. This assembly-pull process is repeated for each pipe length until the entire line is pulled through the borepath to the exit point. At all times prior to the pipe entering the bore path the Contractor shall monitor the pipe to assure that the allowable joint deflection, as shown in Table 1, is not exceeded. When polyethylene encasement is required the Contractor shall repair any damage to the wrap prior to the pipe section entering the borepath.

Assembled-Line (Option 2). Assembled-line option shall be defined by the pre-assembly of multiple pieces of Flex-Ring®, flexible restrained joint ductile iron pipe, with subsequent pulling installation into the borepath as one continuous pipe string. With this option the Contractor shall provide an entry ramp to the entrance of the borepath. The ramp should be of sufficient length and grade such that no pipe joint exceeds the allowable joint deflection as shown in Table 1, at any point prior to the pipe string entering the properly designed and prepared borepath. The Contractor shall be responsible for providing the necessary equipment or ground surface preparation to allow the pipe to be pulled back along the surface prior to the entry ramp and borepath. If polyethylene encasement is required, the contractor shall provide a sufficient number of pipe rollers such that the pipe is supported every 20-feet for the entire length of the assembled pipe length. At all times prior to the pipe entering the bore path the Contractor shall monitor the pipe to assure that the allowable joint deflection, as shown in Table 1, is not exceeded. When polyethylene encasement is required the Contractor shall repair any damage to the wrap prior to the pipe section entering the borepath.

Commentary: Flex-Ring®, flexible restrained joint ductile iron pipe allows for alternative HDD installation techniques. Installation can be accomplished readily by either the "cartridge" or the assembled-line methods. Whenever polyethylene encased pipe is required and the pipe is either lifted or supported in the construction processes, such lifts should be accomplished with wide-bearing nylon slings or other appropriately padded/bearing devices that will not damage the wrap.

Cartridge Assembly Option: The cartridge method involves excavating a safe entry or assembly pit and then connecting the joints during pulling installation one at a time in this entry pit. Generally, the invert of the entry/assembly pit is excavated to allow for the pipe to be assembled in essentially straight alignment prior to entering the borepath. The entry or insertion pit need only be a few feet longer than an individual pipe length, and it is often significantly shorter than length of excavation and right-of-way needed for soil "ramps" etc. used in pulling welded or fused pipelines. Flex-Ring joints can be securely made much quicker than joint welding or fusion, and also do not require the long waiting time that must be allotted for a fused joint of HDPE or PVC to cool/cure. In locations where there is insufficient right-of-way or easements the cartridge assembly method is preferred over the assembled line method.

To expedite assembly it is suggested that whenever possible the pipe should be prepared by performing the following tasks. First, if joint bonding is required by project specification bonding wires can be pre-installed per the procedure outlined below. Next the polyethylene encasement can be pre-applied per the procedure outlined in section 4.9.1. Finally, the Contractor can pre-install the Fastite sealing gaskets, pre-install AMERICAN's rubber-backed flex-rings for locking into the sockets (only if 14-in through 48-in. Flex-Ring® Pipe, 4"-12" flex-rings are shipped from the factory taped on the spigot end of each), and also positioning/stacking individual pipes conveniently next to the entry/assembly pit. All pipe prepared in this fashion should be appropriately *cushioned to prevent damage to wrap and to keep bells, spigots, and wrap reasonably clean prior to assembly.*

If the pipe requires bonded joints for electrical continuity, each pipe must have the bonding wires CAD-welded to the barrel of the spigot-end prior to pull back. The Contractor can begin preparation by first, CAD-welding the bonding wires to the spigot end per the vendor's recommendation. Each CAD-weld should be located on the barrel of the spigot-end of the pipe, beyond the depth of the socket, but no more than 4-inches from the assembly stripe on the spigot end. The CAD welds and any exposed wire shall be coated using an aerosol primer and then covered with mastic filled Handi-Cap as manufactured by Royston or approved equal.

At the bell end of the same pipe section, in direct axial kllalignment with the CAD welds, the contractor should drill two(2) 13/64-inch holes, 5/8-inch deep into the vertical face of the bell. The drilled holes should then be tapped to full depth to receive a ¼-inch NC Thread x ½-inch long bolt. During final assembly, and after the Flex-Ring® joint has been successfully engaged, the Contractor shall complete the joint bond using the following procedure. First, the Contractor shall attach then free end of the bonding wire, which has been prepared with a crimped-on electrical connector, to the two (2) drilled and tapped holes in the vertical face of the bell using two (2) ¼-inch NC thread x ½-inch long bolt. Finally, after tightening the two (2) bolts the Contractor shall coat the ends of both bonding wires using an aerosol primer and a generous application of mastic as manufactured by Royston.

The Assembled Line Option method requires significantly greater length of right-of-way and access. Special care/precautions should also be taken with this method to prevent damage to polyethylene encasement, when unsupported, wrapped pipe lines are pulled along ground or paving surfaces into the borepath. Such precautions might include suitably protective, multiple supporting pipe rollers (composed of non-marring polyurethane or coated rolls etc.), plastic slides placed between the wrapped pipe and the ground, or protective/sacrificial circumferential bearing pads or skids banded in the bell area on the outside the polyethylene encasement. For all circumferential bearing pads, the bearing pad shall extend at least slightly beyond the bell and be secured tightly with circumferential wraps of tape or other approved ties/tensioning bands. It is also recommended that the angle of ramp approaches be carefully considered/controlled to keep any joint articulation to within allowable deflection limits of pipe joints.

5 Basic Assembly/Pulling Methods

5.0 Pulling Head Assemblies. Pulling head assembly for ductile iron pipe shall be designed and furnished by American Ductile Iron Pipe. The pulling bell shall be a boltless, glandless, flexible restrained joint that will allow for the smooth flow of the drilling fluid/soil slurry over the joint and must also have the same performance characteristics as the pipe to which it is connecting. They shall also be fabricated with filling/testing ports, of appropriate size, for testing of the pipe after it is pulled through the borepath. For pipe that is installed using the Assembled Line method the pulling bell may also be used to test the pipe prior to pull back.

5.1 Joint Assembly. The Contractor shall be responsible for the proper assembly of all pipe and appurtenances in accordance with the Manufacturers written procedure and as supplemented by these guidelines. Prior to joint assembly all joints and joint components shall be thoroughly cleaned and examined to assure proper assembly and performance. In the event that the Contractor is not experienced with the assembly of the type of flexible restrained joint being used, it shall be the responsibility of the Contractor to contact a factory-trained representative for recommendations on the proper and efficient installation of the joint.

Commentary
Importance of Proper Joint Cleaning/Assemblies in HDD, and Testing of HDD Pipe Segments: The quality of ductile iron pipe, available only from a relatively few, very large, well-established ductile iron pipe producers and confirmed by required high-pressure factory testing of each and every pipe is well known. Likewise, basic joining designs available for a great many years are generally quite robust and have been assembled successfully by widely diverse skilled and relatively unskilled laborers and technicians around the world. However, there are significant construction/schedule and cost ramifications of an improperly cleaned or assembled, or even a damaged pipe, in some HDD-type installations (at least if not diagnosed before the pipe is installed in the borepath). Costs and impacts of problems in some HDD installations might be more profound than with much common open-cut pipeline construction, where most joints are reasonably accessible by digging before final acceptance of the pipeline. For this reason, particular care should be taken in HDD joint assemblies to avoid problems such as pushed or "fish-mouthed" gaskets. In this regard, thorough cleaning/examination of pipe features such as gasket grooves, proper, fully-seating gaskets in proper gasket grooves (all around the sockets), careful lubrication using Fastite Joint Lubricant, alignment of pipes in pushing assembly, and proper positioning of locking mechanisms must be accomplished.

5.2 Testing. The contractor shall be responsible for hydrostatically testing the HDD installed pipeline per the requirements of ANSI/AWWA C600.

Commentary
Depending on the criticality of the installation and/or experience of/with parties involved, some installers might elect also to do some extra diagnostic testing of assembled pipes before the entire pipe section is installed inside the borepath. This can be readily accomplished, and often with relatively low cost, e.g. with a very low pressure (e.g. 2-4 psi) air test or other means. Such pre-testing can forestall problems and increase confidence levels in the installed line, prior to final placement and eventual hydrostatic acceptance testing of the ductile iron pipeline required in accordance with ANSI/AWWA C600.

For ductile iron pipe installed by the cartridge method, installers may choose to provide a periodic low pressure air test which can be accomplished quite readily when using this method of installation. This can be accomplished by temporarily/periodically installing an available inflatable testing device (e.g. a sewer ball or stopper) inside the open bell *end of the most recently installed pipe and then pumping the progressively longer piping section up for a low pressure air test, e.g. 2-4 psi.*

Extreme care should be taken in installations involving diagnostic air-testing of pipelines, higher air pressures should generally never be used for any piping material/system, due to safety concerns.

Note: An air test is not a substitute for, nor is it intended to replace a properly specified and accomplished hydrostatic test after complete installation.