SECTION 4.20 EARTH BORING AND JACKING OF CULVERT PIPES

4.20.1 GENERAL (2021)

a. This section addresses important considerations when specifying either horizontal auger boring or a form of conventional pipe jacking for the installation of new pipes under railroad facilities. Where conditions are suitable, the installation of pipe culverts by jacking and/or earth boring can be a viable alternative to more standard methods of installation such as open cut or other trenchless methods. Possible advantages of jacking or boring include:
   (1) Reduced interruption of railway traffic.
   (2) Reduced disturbance of roadbed.

b. Costs may be higher, although not necessarily prohibitive, in unstable soils and embankments containing boulders, stumps, waste from rock cuts, or similar obstructions.

c. Before it is decided that auger boring or jacking is the proper method to use, all conditions involved in the operation should be investigated. Cost estimates for open cut placement or other trenchless methods should be compared with the feasibility and estimated cost for jacking and/or auger boring. Such estimates should include expenses due to interference with traffic and excess maintenance until embankment becomes stabilized. Additionally, relative safety of the various installation methods must be considered.

d. It is recommended that auger boring and jacking operations be performed by an experienced specialty contractor normally engaged in performing this type of service.

e. For further information on earth boring and jacking methods refer to Chapter 1, Part 5 of the AREMA Manual.

4.20.2 DEFINITION OF METHODOLOGIES AND EQUIPMENT (2021)

The following terms as defined by North American Society of Trenchless Technology (NASTT).

a. Horizontal Earth Boring
   Auger boring, boring, and jacking; the use of auger boring machines to prepare holes by the installation of a casing whereby the spoil is removed by the use of augers.

b. Auger Boring
   A technique for forming a bore from a jacking or drive shaft to a receiving shaft by means of a rotating auger with cutting tools. The casings are jacked forward sequentially in a cyclic process while the auger is turned. Spoils are removed back to the drive shaft by helically wound auger flights rotating in the steel casing. The equipment may have limited guidance and steering capability.

c. Tunnel Boring Machine (TBM)
   A full-faced circular mechanized shield machine, usually of man-entry diameter, steerable and with a rotary cutting head. For pipe installation it leads a string of jacked pipes. It may be controlled from within the shield or remotely.

d. Hand Excavation
   The technique used to remove the material (rock, dirt, sand, etc.) by hand held tools (pick, shovel, etc.) from the tunnel face or open ditch.

e. Pipe Jacking
   A system of using hydraulic jacking from a drive shaft to directly install pipes behind a shield machine so that they form a continuous string in the ground.

4.20.3 SUITABLE PIPE MATERIALS FOR BORING AND JACKING (2021)

a. Ideal pipe materials to be used in the boring and jacking process should have a smooth exterior wall. The most commonly used materials for pipes installed by the boring and jacking are smooth wall steel pipe, fiberglass reinforced

polymer mortar (CCFRPM) pipe or straight wall reinforced concrete pipe.

(1) Smooth Steel see Chapter 1, Part 5 of the AREMA Manual for additional data.

(2) Concrete pipe is manufactured with joints which provide a smooth outside surface. An appropriate class of concrete pipe should be selected to provide the compressive strength to resist the axial forces imposed by jacking. Supplemental joint reinforcing may be required if eccentric loading of the joint is a possibility. It is a good practice to consult with the jacking contractor and the pipe manufacturer for recommended joint configuration.

(3) Centrifugally Cast Fiberglass Reinforced Polymer Mortar (CCFRPM) pipe has flush gasket-sealed, bell-spigot joints which provide a smooth, constant outside surface. Pipe design should consider both installation and long-term permanent loads. Consult the pipe manufacturer for additional information.

(4) Tunnel Liner Plate, see Chapter 1, Part 8 of the AREMA Manual for additional data.

b. Non-circular shapes, such as precast reinforced concrete box sections, reinforced concrete elliptical or arch pipe sections, as well as other materials have been successfully installed. See table below; note that size limitations may apply to materials.

Roadway and Ballast

Pipe Materials & Tunnel Linings	Horizontal Auger Boring	Soft Ground Tunnel Boring Machine	Rock Tunnel Boring Machine	Hand Mine Excavation
Smooth Steel Pipe	X	X	X	X
Reinforced Concrete Pipe	X	X	X	X
CCFRPM		X	X	X
Polymer Concrete Pipe		X	X	X
Tunnel Liner Plate		X	X	X
Steel Ring Beam and Wood Lagging		X	X	X
Concrete Segments		X	X	X

4.20.4 METHODOLOGY BY GROUND CONDITION (2021)

The methodologies referenced in the table below are defined above in Section 4.20.2 and based on ASCE MOP 2nd.

Ground Conditions	Horizontal Auger Boring	Soft Ground Tunnel Boring Machine	Rock Tunnel Boring Machine	Hand Mine Excavation
Clay	X	X		X
Sand	X (recess cutter head must be dewatered)	X (if dewatered)		X (use sand shelves)
Silt	X (if dewatered)	X (if dewatered)		X
Rock	X (using rock cutting head)		X	X (explosives may be necessary)
Mixed Face		X (if dewatered)		X
Fill	X (if clean)	X (if clean)		X
Cinders	X (Recess cutter head must be dewatered)			X (use sand shelves)
Ballast				X (use sand shelves)
Foreseen Obstructions				X

4.20.5 SIZE AND LENGTH OF PIPE (2021)

a. The size of pipe that can be placed by jacking will vary with local site conditions. An experienced trenchless contractor, an engineer knowledgeable in trenchless technologies and a qualified pipe manufacturer should be consulted regarding suitable size and length limits for all trenchless operations including:

(1) Horizontal Auger Boring
(2) Tunnel Boring
(3) Hand Mine
(4) Pipe Jacking

4.20.6 GEOTECHNICAL CONSIDERATIONS (2021)

Before jacking and boring conduit, a thorough geotechnical investigation of conditions should be made. If unstable soil conditions

are found they should be evaluated by a qualified geotechnical engineer for recommendations on the most appropriate method of soil stabilization or reevaluation of the chosen methodology of installation.

As part of the Geotechnical Investigation prior to performing the borings, the geology of the site should be studied based on geologic and soil maps. This will be useful to determine the anticipated geologic formation and whether soil and/or rock should be anticipated in the borings.

Jacking and boring under track typically is less than 150 feet long, unless going under a railroad yard, and are typically part of a culvert or longer utility installation. A soil boring at each shaft location is generally sufficient for distances less than 150 feet. If the geology of the area is complex with near surface rock or other features, additional borings adjacent to the bore alignment and geophysical methods should be utilized. Depth of borings should be at least two pipe diameters or ten feet below the proposed invert. Drilling methods in soil include hollow stem auger or mud rotary. Sampling methods are typically the Standard Penetration Test (SPT) and Shelby tubes for soils and rock coring for rock formations.

a. Type of Information to Gather

   i. Groundwater

   The Geotechnical investigation should identify the elevation of groundwater at the site. If groundwater is close to the proposed pipe invert, standpipe piezometers should be installed to monitor groundwater elevation after the borings are completed. Soil samples should be classified according to the Uniform Soil Classification System (ASTM D2488) that assigns a soil symbol to each soil type less than 3-inches in size including gravel, sand, silt and clay. Soil laboratory tests include gradation for coarse soils and water content and Atterberg limits for fine soils.

   ii. Rock

   When working with rock it is important to consider the rock's unconfined compressive strength (per ASTM D7012), CERCHAR abrasivity index (per ASTM D7625-10), and abrasivity index (per ASTM C131). Rock core samples should be classified according to ASTM D2113 including type of rock, spacing and surface of discontinuities, core recovery, and Rock Quality Designation (RQD) among other characteristics. If cobbles and/or boulders are identified from the geologic study or encountered in the borings, additional exploration such as test pits and geophysical methods should be utilized to determine the typical size and distribution of cobbles and/or boulders along the alignment.

   iii. Soft Ground

   Soil conditions are relatively soft and stable, such as clay, silt, and sand above the water table per ASCE Guidelines MOP 106, Horizontal Boring Projects, 2nd edition. It is important that the soil conditions not be a flowing ground condition. Flowing ground is commonly found below the ground water table in sands and silts. Flowing soils may occur above the ground water table when a loosely placed granular material such as sand, gravel, and cinders are present.

b. Location of Borings and Sample Intervals

   It is not recommended to place the soil boring directly on alignment with the trenchless installation. Rather, borings should be located near the alignment but not on the alignment centerline to avoid future complications during tunnel construction such as creating a path for surface water to reach the tunnel excavation. Borings should be at least 10-feet off the centerline and should be backfilled with bentonite or cementitious grout. Sample intervals for SPT sampling is typically every 2.5 feet up to a depth of 10 feet and at 5-foot intervals thereafter.

c. Friction Reduction Considerations

   When pipe jacking, it is beneficial to work continuously to minimize the tendency of the material to "freeze" around the pipe. However, lubricants such as bentonite slurry or polymer additives are available to minimize the freezing tendency. The launch or receiving pit or shaft should follow all support of excavation requirements on the sides and working face, to accommodate expected railroad loading. Wet sandy soils can be de-watered by various means including well points. The excavation should not be carried more than a few inches ahead of the pipe. If the pipe seizes, jacking may have to be done from both ends, or installation of intermediate hydraulic jacking stations may be required. In some instances, switching to trenching or open cut methods may be required.

d. Annular Grouting Considerations

   Excessive voids should not be permitted in the jacking and boring process. Grout ports should be installed in pipe and all voids should be filled by pressure grout as soon as possible after the completion of the pipe installation.

   i. Grouting of the annulus is recommended in areas where it is believed that over excavation beyond one (1) inch over the top of the casing or jacked tunnel liner has occurred during the trenchless installation.

ii. Grouting around the conduit or jacked tunnel liner's OD annular space of the trenchless installation may not be feasible if you are in raveling ground. It is possible that any void may have been filled up against the casing/tunnel lining and has migrated up the embankment. It may not be possible to apply enough grouting pressure to fill the voids above the crown of the pipe. It may be necessary for grout holes from the ground surface to be installed to fill any voids over the pipe in some ground conditions.

iii. Grouting the conduit or jacked tunnel liner's OD annular space can be accomplished by the installation of grout ports into the casing/tunnel lining and pumping a slurry into the annulus. Typically, grouting the annular space is performed in 42-inch diameter pipe and larger.

iv. If the ground conditions are stable such that the overcut has remained open at the completion of the installation, then simply installing ports through the casing/ tunnel lining can be left open and when the annulus between the casing and carrier is filled the grout will go outside of the casing/ tunnel lining to fill the annulus outside of the trenchless installation as well. If segmental tunnel support is used during the installation, intermediate grouting intervals may be appropriate to limit potential ground settlement. Intermediate grouting is not done when jacking a continuous casing.

v. It is critical to control the pressures of the grouting to ensure you will not cause any soil heave or damage to the lining or the carrier pipe.

4.20.7 RISK MITIGATION TO CONTROL GROUND DISTURBANCE (2021)

Items to consider during design and review of submittals for each methodology should include the evaluation of the following items:

a. How soil conditions affect clearance band placement, pipe lubrication plan, auger cutter head placement inside the pipe, cutter head design, potential obstructions, and water table elevations. If the ground water needs to be lowered by dewatering, the consequences of potential settlement need to be evaluated.

b. It is recommended to understand each railroads criterion regarding how boring and jacking operations may proceed when trains are operating over the excavation site. In absence of a standard it is suggested that boring and jacking pause during passage of trains when the leading edge of the pipe is within the track zone of influence.

c. If settlement or heave is noted during boring and jacking operations, then reduction in track speeds (slow order) may be warranted.

4.20.8 PROTECTION OF CULVERT AGAINST SEEPAGE, PIPING, AND SCOUR (2021)

a. If it is anticipated that the culvert will discharge under hydraulic head for any considerable period, and particularly if it lies in easily eroded material, precautions against seepage or piping along the outside of the culvert should be taken.

b. Concrete collars, grout injected collars, cut-off walls, slope paving or similar impermeable slope barriers may be considered as a precaution against seepage or piping along the outside of the culvert.

c. To protect the ends of the culvert against scour, concrete pavement or riprap with filter protection may be provided. In extreme cases energy dissipaters can be used to reduce the outlet velocity of flow to acceptable limits.

4.20.9 SAFETY (2021)

Trenching is inherently dangerous. Since a jacking operation generally involves some form of trenching or pit construction, the jacking contractor or railway forces must strictly conform to all Federal, State and local regulations which may include the requirements of the Occupational Safety and Health Administration (OSHA) and Federal Railroad Administration (FRA) where applicable.

a. It is recommended that monitoring of track conditions for heave, settlement, and alignment are done with proper track protection as required by the operating railroad. In critical applications continuous monitoring for track movement may be required.

b. The above conditions should be checked at regular intervals and typically more frequently with shallower installations.

c. Additional monitoring is recommended after the completion of the installation to check for settlement that may not be evident during construction or at the immediate conclusion of the work.

   (1) A weekly inspection should be performed for the first month after the installation.

   (2) A monthly inspection should be performed until such time that the railroad is assured that any settlement risk has passed.

d. The following safety equipment may be required in addition to standard railroad required PPE, OSHA, and MSHA required equipment.
   (1) Self-rescuers upon entrance into the pipe
   (2) Air monitor and ventilation

e. It is suggested to complete a subsurface utility engineering (SUE) report prior to boring and jacking pipe. ASCE Standard 38-02 is a recommended guideline to follow when determining the quality level of utility location that needs to be done. See ASCE Standard 38-02.

f. For guidance on support of excavation for jacking and receiving pits refer Chapter 1, Part 5.

4.20.10 ADDITIONAL GUIDANCE (2021)

a. Horizontal Boring Projects – Manual of Practice No. 106 ASCE Second Edition, 2004
b. NUCA Trenchless Technology Manual