APPENDIX J: INADVERTENT RELEASE PLAN AND HDD DESIGN SUMMARY REPORT CASE 10-T-0139

December 13, 2022
File No. 322004-000

Kiewit Engineering (NY) Corporation
470 Chestnut Ridge Rd, 2nd Floor
Woodcliff Lake, NJ 07677

Attention: Jason Neff, PE, PMP - Design Engineering Manager

Subject: DRAFT HDD Inadvertent Release Plan
Champlain Hudson Power Express – Segment 8
Package 5b
Fuera Bush to Selkirk, New York

Dear Mr. Neff:

Brierley Associates Underground Engineers, PLLC (Brierley) is pleased to provide this DRAFT HDD Inadvertent Release Plan for Package 5b of the Champlain Hudson Power Express Project. This work was conducted in general accordance with our contract with Kiewit Engineering (NY) Corporation (Kiewit).

We thank you for this opportunity to be of service to you and your team on this project. Should you have any questions or require additional information, please do not hesitate to contact the undersigned at your convenience.

Sincerely,

Brierley Associates Underground Engineers, PLLC

Nick Strater, P.G.
Sr. Project Manager

Brent Lindelof, P.E.
Sr. Engineer

Brian C. Dorwart, P.G., P.E.
Sr. Consultant

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1.0 Introduction

The Champlain Hudson Power Express (CHPE) project will install a pair of HVDC electrical transmission cables with an associated telecommunications line from Canada to New York City, NY. The portion of the work addressed herein is located in the upland portion of the route from the south end of Lake Champlain to New York City along the uplands of the Hudson River Valley. This work includes approximately 126 crossings under roads, railroads, wetlands water bodies, and obstructions to be installed using horizontal directional drilling (HDD) methods to minimize interference with use or impacts to the surface environment.

This Inadvertent Release Contingency Plan (IRCP) is for Segment 8 - Package 5b which includes 4 HDD crossings. A summary of the crossings is included in Table 1, below.

Package 5b includes a total of 4 crossings, which are summarized in Table 1, below.

Table 1: HDD Locations, Lengths, and Description

HDD #	Approx. Start Station*	Approx. End Station*	Approx. HDD Length, ft	Obstruction Crossed
87B	51106+47	51120+29	1,382	S. Albany St/Route 54, water main
88	51179+09	51193+75	1,466	Coeyman's Creek
89	51201+50	51227+00	2,550	Wetland, Stream
90	51235+01	51247+40	1,239	Route 396/Stream Bank

*Project stationing shown. Each HDD has its own independent stationing.

A primary potential environmental concern associated with HDD involves the inadvertent release of drilling fluids during the drilling process. The purpose of this plan is to establish general procedures to prevent a fluid release (sometimes referred to as a frac-out) during HDD construction and to present steps to manage, control and minimize the impacts in the event that an inadvertent release of drilling fluid occurs. The objectives of this plan are to:

- Provide an overview of the HDD process with a specific focus on the composition, management and use of drilling fluids.

- Identify controls to be implemented during construction to minimize the potential of an inadvertent release.
- Identify the planned means of monitoring to permit early detection of inadvertent releases.
- Identify planned means to protect areas that are considered environmentally sensitive (rivers, wetlands, other biological resources or cultural resources).
- Establish site-specific environmental protection measures to be utilized prior to, during, and following drilling and pipe installation activities to minimize and control erosion and sediment releases to adjoining wetlands or watercourses.
- Have site specific preplanned general response programs in place at the start of construction that is understood and can be implemented immediately by all field crews in the event of an inadvertent release of drilling fluid occurs.
- Establish a chain of command for reporting and notifying, in a timely manner, the construction management team, the Certificate Holders, and the proper authorities in the event of an inadvertent release of drilling fluid and of the preplanned actions that are to be implemented.

It is important to note that the plan in this document serves as the guiding framework for confirming that the HDD Subcontractor is adhering to the specifications and provisions to be protective of the environment. Since there are a variety of potential measures listed in this document available for preventing inadvertent releases and mitigating the effects of a release should one occur, the specifications require that each HDD Subcontractor submit to the project design team, for its review and acceptance, a supplemental site and Subcontractor specific means and methods plan for each HDD crossing reaffirming and detailing how the Subcontractor will conform with the requirements of this plan and the project specifications to prevent inadvertent releases and to mitigate any effects of a release should one occur. The supplemental plan by the Subcontractor shall be consistent with the site conditions and constraints, and the Subcontractor's selected means, methods, and equipment. The selected HDD Subcontractor will be responsible for incorporating specific permit conditions, applicable regulatory requirements, site specific environmental features and geotechnical information not available at this time into its submittal. The submittal shall be reviewed and approved by the design team and the Environmental Inspector prior to the start of construction of a specific HDD location.

2.0 Description of the HDD Process

The Horizontal Directional Drilling process begins by mechanically excavating shallow (approximately 5 feet wide by 10 feet long by 4 to 5 feet deep) entry and exit pits at either end of the directional bore alignment. A small diameter (on the order of 5 to 9 inches in diameter) pilot bore is then drilled from the entry pit using directional boring methods. During the pilot bore, a drilling fluid (typically bentonite and water based with selected inert biodegradable additives to improve and modify fluid stability, carrying capacity, and drilling properties to address site-specific ground characteristics and Subcontractor preferences) is pumped through nozzles in the drill head to support the hole and to hydraulically transport drill cuttings from the drill bit back to the entry pit. Environmentally acceptable inert biodegradable additives are required by specification for use on this project and those planned for use by the Subcontractor will be checked for compliance by the design team prior to their use.

A guidance system is mounted immediately behind the drilling head to allow the crew to track and steer the path of the drilling so that it follows the preplanned alignment within the specification permitted tolerances. The drilling fluid holds the cuttings in suspension and carries the drill cuttings back through the annular space between the drill rods and the bore hole wall to the entry pit where it is collected and processed for re-used by a recycling system. The cuttings are separated from the bentonite, using screens, centrifuges, and desanding units which prepares the bentonite for re-use. Once the pilot bore reaches the exit pit, a larger diameter back-reaming head is then attached to the drill string and pulled back through the pilot hole to enlarge the hole. Depending on the size of the pipe to be installed and the ground conditions, several successively larger reaming passes may be needed. Again, a bentonite and water slurry is pumped into the bore hole during reaming to remove cuttings and to stabilize the bore hole. Lastly, the drill string is pulled back through the bore hole with the new, preassembled conduit attached to it in one continuous process until the lead end of the conduit emerges at the entry pit. Steps two and three may be combined, with the conduit being pulled back through the bore hole immediately behind the final reaming bit or swabbing pass.

Specific to this plan, it is important to have an awareness of the function and composition of the HDD drilling fluids. The drilling fluid composition and drilling fluid management are integral components of the HDD process with the following primary purposes:

- Support and stabilize the drill hole.
- Suspend and transport cuttings from drill bit through the drill hole annulus.
- Control fluid loss through the bore’s side walls by forming a filter cake on the bore hole walls.

- Managing and modifying the drilling fluid mix to improve its cutting carrying characteristics, its pumpability, and its hole stabilization and support characteristics.
- Power the downhole cutting tools (e.g., via mud motors if required).
- Serve as a coolant and lubricant to the drill bit during the drilling process, and lubricant during the pipe insertion process.

The drilling fluids are composed primarily of potable water, which will likely be obtained from nearby sources selected and permitted by the Subcontractor. As mentioned above, the drilling fluid also contains bentonite clay as a viscosifier. Bentonite is a naturally occurring, nontoxic, inert substance that meets NSF/ANSI 60 NSF Drinking Water Additives Standards and is frequently used for drilling potable water wells. While bentonite is non-toxic and commonly used in farming practices, it has the potential to impact plants, fish and their eggs if discharged to waterways in significant quantities. Frequently, additives are used to: amend the drilling fluid, improve its compatibility with the ground and groundwater chemical characteristics, improve its cutting suspension and carrying characteristics, improve its hole stabilization ability, and reduce seepage loss through the ground characteristics. Environmentally acceptable (i.e. inert biodegradable) additives are required by specification for this project.

During the HDD process and subsequent conduit insertion, the drilling fluid pumped downhole will tend to flow along the path of least resistance. Generally, this will be though the annulus between the drill string and the drill hole side wall. However, the bore alignment may encounter ground conditions where the path of least resistance is an existing fracture, fissure or hole of anthropogenic origin, areas with low overburden confinement, areas of hole collapse, or coarse gravel zones in the soil or rock substrate. When this occurs, circulation can be lost or reduced. This is a common occurrence in the HDD process but does not necessarily prevent completion of the bore or result in a release to the surface or adjacent environment. However, the environment may be impacted if the fluid inadvertently releases to the surface at a location on a waterway's banks or within a waterway or wetland. Again, additives to amend the properties of the drilling fluid may be used as necessary to prevent and limit releases and losses through such paths of lower flow resistance.

3.0 Organization and Staffing Responsibilities

The organizational chart shown below list the contact information of the principal organizations involved in this project. The remainder of Section 3 discusses the roles and responsibilities of these principal organizations.

Organizational Chart

Entity	Contact Information
Certificate Holders	Name, Title Phone Email
Construction Manager	TBD
HDD Construction Subcontractor	 TBD
Environmental Inspector	TBD
U.S. Army Corps of Engineers, New York District Office	USACE New York District Upstate Regulatory Field Office ATTN; CENAN-OP-UR, Bldg. 10, 3rd Floor North 1 Buffington Street Watervliet, NY 12189-4000 518-266-6350 cenan.rfo@usace.army.mil
New York State Department of Public Service	TBD
New York State Department of Environmental Conservation	Regional Office(s) Information NYSDEC REGION 5 Sub-Office Regional Permit Administrator 232 Golf Course Rd Warrensburg, NY 12885-1172 518-623-1281 dep.r5@dec.ny.gov
New York State Department of Environmental Conservation (Spills)	NYS Spill Hotline: 1-800-457-7362

3.1 Responsibilities of Various Organizations

The principal organizations involved in this project include the Regulatory Agencies, Certificate Holders, Design Engineer, HDD Construction Subcontractor, Construction Manager, and Environmental Inspector. The roles and responsibilities of the principal organizations are discussed in the following subsections and are shown in the organizational chart included above.

3.2 Regulatory Agencies

The Certificate of Conditions issued by the NY Public Service Commission is the primary regulatory agency for the requirements associated with the project. The Champlain Hudson Power Express (CHPE) Route Project also has permits from the Department of Energy, and the US Army Corps of Engineers, and the New York Water Quality Certification. Various HDDs within this package take place within or adjacent to wetlands, underneath or adjacent to bodies of water, and underneath or adjacent to railroad tracks. Measures are discussed throughout this report to control/mitigate any potential releases before environmentally sensitive boundaries are reached or impacted.

3.3 Certificate Holders

The project Certificate Holders are TDI. TDI's Project Manager will have the overall responsibility to coordinate this project for TDI. The Project Manager, will be responsible for correspondence and coordination among all parties and will have the authority to stop work as necessary.

3.4 Design Engineer

The Design Engineer for the Package 5b HDD's Design is Brierley Associates (Brierley). During construction, the Design Engineer will be responsible for reviewing and approving required Subcontractor submittals, shop drawings, and material certificates. Brierley will also take responsibility for review and acceptance of submittals, and documenting the materials and methods used in performance of the construction work to document that the construction complies with the contract documents.

3.5 Third Party Engineer

The Third-Party Engineer for the HDD inadvertent return analysis is Brierley Associates. During construction, Brierley/Kiewit will review of the Subcontractor's Inadvertent Release Plan and provide technical assistance as needed with the HDD installation.

3.6 Construction Manager

The Construction Manager for this project has yet to be selected. The Construction Manager will be responsible for on-site management of the project for the Certificate Holders to ensure overall Subcontractor compliance with the EM&CP documents, environmental permits, and local and federal regulations.

3.7 HDD Construction Subcontractor

The HDD Construction Subcontractors (Subcontractors) for the various HDD crossings of this project have yet to be selected. The Subcontractor will be responsible for completion of the conduit installation by HDD methods in accordance with the design criteria, contract documents, environmental compliance permits and federal regulations. The Subcontractor will be expected to use the appropriate construction procedures and techniques to complete the project, including supplemental site Inadvertent Release Prevention and Contingency Plan reviewed and accepted by the design team for each crossing in accordance with the contract documents.

The HDD Drill Operator (Drill Operator) will be responsible for operating the HDD drill rig, and observing and managing changes in annular fluid pressure or loss of circulation. The Drill Operator will communicate with other members of the drill crew as needed when issues arise. The Subcontractor will be responsible for developing the specific lines of communication within their organization and shall dedicate a responsible person for communicating inadvertent releases to the Construction Management team and Environmental Inspector.

3.8 Environmental Inspector

The Environmental Inspector for this project has not yet been determined. In general, the Environmental Inspector will perform full-time observation and documentation during the HDD activities at a specific site. The Environmental Inspector will be responsible for coordination with all county, state and federal resource agencies, compliance with and changes to any environmental permits.

The Environmental Inspector shall have the authority to stop work when the environmental permit conditions are not being followed or when appropriate environmental precautions are being disregarded by the Subcontractor.

3.9 Lines of Communication and Authority

Formal lines of communication will generally follow the established lines of authority. However, open communications between all parties will be encouraged to facilitate more efficient communication and coordination.

3.10 Training

The Subcontractor will verify and document that all construction personnel have appropriate environmental training before they begin work. The Environmental Inspector will also conduct a project orientation meeting for staff assigned with specific roles during the HDD installation and will review the site-specific environmental concerns and permit conditions. The Certificate Holders and Design Engineer will also attend the orientation meeting to review the procedures that will be used to document inadvertent releases in accordance with the HDD specifications.

4.0 Fluid Release Minimization Measures

4.1 Geotechnical Investigation

The first steps taken to characterize and minimize the potential risk of an inadvertent release includes conducting a geotechnical investigation at the site to develop an understanding of the surficial soils. Test borings were conducted near the proposed cable alignment within or immediately adjacent to the HDD sites. We understand that each boring has been backfilled and sealed with a cement/bentonite grout to limit the risk of a release through an abandoned bore hole during the HDD construction.

4.2 HDD Design

The HDD crossings are being designed to reduce the potential risk of an inadvertent fluid release during construction. General design considerations for HDD include:

- Depth of cover during profile design (based on test borings) to limit the potential inadvertent release to the water body, road, railway, wetlands, or ground surface.
- Typically, potential exists for releases near the entry and exit pits of an HDD bore. The distance where there is a potential for releases at the ends depends on the soil conditions, the slope of the ground surface and the length of the bore. Generally, the longer and deeper the bore the greater the slurry pressures required to hold the borehole open and to carry the cuttings back to the entry or exit pit.

- Generally, for the formation of inadvertent releases, the more critical stage of the HDD process tends to be during the initial pilot hole drilling when the annular space between the bore sidewall and the drill string is the smallest and therefore requires large slurry pressures to overcome flow resistance to carry cuttings back to the entry pit.
- Adjusting the drill alignment to avoid infrastructure including existing utilities, and other obstacles.
- Establishing a drill alignment line that allows for gradual angular changes to minimize pressure build-up and limit pull back stresses and bending stresses in the conduit, as well as being compatible with the bending capacity of the tool steel.
- Requiring drilling fluid composition and drilling procedures that minimize drilling fluid pressures.
- Requiring drilling fluids that adequately address site-specific drilling concerns while posing the least threat to the environment.
- Requiring that, during the performance of any HDD waterbody crossing, contractors monitor the use of inert biodegradable drilling solution and, in the event of a detected release of fluid, implement the procedures specified in the approved EM&CP. For any release occurring in a waterbody, the Certificate Holders shall immediately notify DPS Staff and NYSDEC of details of the release and the course of action they recommend taking.
- Requiring monitoring and controlling drilling fluid pressures with down-the-hole sensors during pilot hole drilling.

4.3 Contingency Plan

As mentioned above, prior to construction the selected Subcontractor will be required to submit a supplemental site-and Subcontractor-Specific Inadvertent Release Contingency Plan for review and approval by design team. The project specifications require that the following major elements be addressed in detail in the Subcontractor’s Plan:

- Work plan and detailed description of the drilling program (details for executing pilot hole, reaming, pull-back operations, and schedule) this plan shall include necessary procedures for addressing problems that are typically encountered during HDD installations through the anticipated subsurface for each drill location;

- Drilling fluid composition design and on-hand amendments to alter fluid properties to reduce pressures, potential for plugging, and seepage losses;
- Description of the planned drilling equipment and drill site layout;
- Safety Data Sheet (SDS) information for all drilling fluid products proposed for use;
- Procedures for drilling fluid pressure control, and fluid and pressure loss monitoring and management to aid in the detection of an inadvertent release (i.e., metering of makeup water, recording of drilling fluid product quantities utilized, fluid return volumes, fluid and cuttings disposal quantities, turbidity of river water, etc.);
- Contingency plans for addressing inadvertent releases into wetlands, or other sensitive areas, which includes the specific procedures used to halt the release and then contain, clean-up, and remove materials from the release site;
- Notification procedures and chain-of-command in the event of a release;
- Criteria for evaluating the need for a drill hole abandonment and the associated plan for sealing the drill hole if abandoned;
- Drilling fluid management and disposal procedures;
- The work plan and detailed drilling program description should include documentation regarding site restoration, vegetation management, sedimentation and erosion control, and hazardous material usage (if applicable). Intended approach shall be in compliance with those measures presented in the Project EM & CP.
- Notice shall be provided to residents, businesses, and building, structure, and facility (including underground, aboveground and underwater facilities) owners and operators within one hundred (100) feet of any HDD staging area or trenching activity with an offer to inspect foundations before, during, and after construction. Additional detail regarding this notice, associated inspections, intended benefits, proof of notice, cost reimbursements and associated construction initiation schedule is included in General Condition 154.

In addition to providing a site-specific Inadvertent Release Contingency Plan, the specifications require that the Subcontractor implement the additional necessary safeguards to minimize the likelihood of a fluid release and management/control should a release occur. This includes having a readily available supply of spill response devices (containment booms, pumps, straw bales, silt fence, sediment logs, sandbags, vacuum trucks, and storage tanks) and any other materials or equipment necessary to contain and clean up inadvertent releases. To maximize protection to sensitive environmental areas these measures shall be pre-positioned at the site, readily available and operational prior to the start of any drilling. If needed, additional spill response measures shall be employed immediately, as secondary measures, in the event of a fluid release.

The workspace layout for HDD materials and equipment will be configured to reduce the likelihood of a release.

4.4 Drill Fluids Management

As described in the Project EM&CP document, drilling fluid will be National Sanitation Foundation (NSF) certified and all recycling and reuse regulations will be followed where applicable. The drilling fluid management system and subsequent disposal is the responsibility of the subcontractor performing the HDD work. However, the drilling fluid management system and subsequent disposal will adhere to the following requirements:

- Drilling fluid will be processed through an initial clearing that separates the solid materials from the fluid.
- Solids will be sifted out by a screening apparatus/system and the solids deposited into a dump truck and periodically transported off-site and disposed of at an approved disposal facility determined by the HDD construction subcontractor.
- Drilling fluid that is deemed unacceptable to be reused during construction or left over at the end of drilling will be collected and transferred into a tanker truck for disposal at an approved disposal facility determined by the HDD construction subcontractor.
- Drilling fluid accidentally spilled during construction and operation of drilling rigs will be contained following the mitigation measures described in the SPCC (Appendix K of the EM&CP) and disposed of at an approved disposal facility as determined by the HDD construction subcontractor.

- Supply of spill containment equipment and measures shall be maintained and readily available around drill rigs, drilling fluid mixing system, entry and exit pits and drilling fluid recycling system, if used, to prevent spills into the surrounding environment. Pumps, vacuum trucks, and/or storage of sufficient size will be in place to contain excess drilling fluid.
- Under no circumstances will drilling fluid that has escaped containment be reused in the drilling system.

An overview of the drilling fluid system will be submitted to the Environmental Inspector for approval once determined and prior to any HDD installation activities. The role of the Environmental Inspector is discussed in Chapter 3 of the EM&CP.

4.5 Early Fluid Release Detection

The HDD method has the potential for seepage or fluid loss into pervious geologic formations that the bore path crosses. This may occur due to the presence of fractures in the rock, low overburden confinement, or from seepage through porous soils such as coarse gravels or via prior exploratory boreholes. It is important to note that inadvertent releases of drilling fluid can occur even if the down-hole pressures are minimal. Subsurface conditions that could be conducive and lead to inadvertent releases or drill difficulties include:

- Highly permeable soil such as cobbles and gravel.
- Presence of rock fractures, solution features, or other subsurface fractures.
- Considerable differences in the elevations of HDD entry and exit points (typically greater than 20 feet).
- Disturbed soil, such unconsolidated fill.
- Soft soils that have the potential to squeeze.
- Soils that have the potential for collapse.
- Obstructions that require the use of a high flow mud motor.
- Soft soils with low confining capacity.
- Presence of archeological resources.

- Existing deep foundations.
- Existing below-grade utilities.

Our opinions regarding the risks associated with the above conditions at specific crossings are discussed in Section 9 of this report.

An experienced drill crew is the most effective approach to detect drilling fluid seepage prior to a surface release and promptly stop the drilling and they can modify the drilling fluid composition, properties, and pressures to address indications of loss of drill fluid. The HDD Subcontractor is required to utilize experienced drill crews particularly in and adjacent to environmentally sensitive areas. The following factors can be used for identifying the potential for drill fluid release:

- Spikes or loss of pressure within the drill hole utilizing a downhole pressure monitoring system; and
- A substantial reduction in the volume of return fluid (loss of circulation).

In addition to an experienced drill crew, the HDD Subcontractor will be required to perform periodic (at least twice a day) visual inspection and monitoring ground surface in the vicinity of the drill bit or reaming bit for signs of an inadvertent release. Per Article VII Condition 114(n), monitoring of the status of each HDD while construction activities are underway until the crossing has been completed. In the event of any potential or actual failure of the crossing, the Certificate Holders shall have adequate staff and equipment available to take necessary steps to prevent or avoid adverse environmental impacts. If visual monitoring indicates a potential release, additional measures such as turbidity measurements and bentonite accumulation measurements both upstream and downstream of the current active location of the drill bit are required (where applicable)

5.0 Inadvertent Release Monitoring and Notifications

The HDD Subcontractor is responsible for monitoring of the drilling operation to detect a potential inadvertent release by observing and documenting the flow characteristics of drilling fluid returns to the HDD entry/exit pits and by visual inspection along the drill path. If drilling fluid to the HDD entry/exit pits are lost, the Subcontractor shall implement the following steps:

- The Drill Operator will monitor and document pertinent drilling parameters conditions and observe and monitor the drill path for evidence of an inadvertent release, if there is evidence (typically visual) of a release, the Subcontractor will be required to stop the drilling immediately.

- The Subcontractor shall notify the lead Environmental Inspector of any significant loss of drilling fluid returns at the drill rig; and, in the event of a detected release of drilling fluid during the performance of any HDD waterbody crossing, implement the procedures specified in the approved EM&CP. The Certificate Holders shall immediately notify New York State Department of Public Service (NYSDPS) Staff and New York State Department of Environmental Conservation of details of the release and the course of action they recommend taking.
- The subcontractor will take steps to modify the drill fluid properties and pressures to reduce the potential of drill fluid loss or release; and
- The Drill Operator will take steps to restore drilling fluid circulation in accordance with the requirements of the HDD technical specifications.

If a fluid release is identified, an immediate response is necessary and the Subcontractor is required to take proper corrective actions to minimize impacts, particularly to environmentally sensitive resources (e.g. watercourse, waterbodies, and wetlands).

6.0 Inadvertent Release Response (Upland and Road areas)

A common reason for upward movement and surface release (Inadvertent Return, or IR) of drill fluid is from borehole collapse or blockage and a resulting increase in the pressure exerted by drill pumps. Lowering drill fluid pressure is a first step to limiting extent of a release and can be accomplished by stopping drill rig pumps and allowing pressure to bleed off. With no pumping pressure in the hole, surface seepage will generally stop, then the Subcontractor can trip the drill steel back a selected distance and attempt to clear cuttings from the annulus to re-establish circulation. However, it should be noted that reducing the pump rate too much may result in poor cuttings removal and clogging of the hole, which in turn can also result in an IR.

The Subcontractor will be required to contain/isolate and remove any fluid that has emanated from the surface. On land this can be done through use of berms, straw bales, shovels as needed, or silt fence to contain the release in conjunction with excavating a small sump pit and/or use of vacuum collection equipment, if needed. Sufficient spill-absorbent material will also be required on-site.

If a surface release is identified in an upland area, the Subcontractor will be required to immediately respond as described above to limit the extents of the release. After containment is established, cleanup and removal can be conducted by hand, with vacuum trucks, or other equipment. The Environmental Inspector will be present during clean up and removal activities, as they may need to be conducted outside of the pre-authorized temporary workspace areas. The Environmental Inspector, Construction Manager, and the Subcontractor will work closely to determine the best course of action for inadvertent releases occurring within upland areas.

Upon containment of the release, the Subcontractor will be required to evaluate the cause of the seepage and develop mitigation strategies to limit the likelihood of recurrence. The location of the seepage and the area around the seep will be monitored upon the re-start of the HDD operations for changes in conditions. The segments of borehole nearest the entry and exit points and other areas of low overburden cover tend to be the most susceptible to surface seepage as they have the least amount of soil confinement. These locations will generally be in areas of dry land where seepage detection is easily identified and contained. If areas of high risk for inadvertent releases are identified during the HDD design phase, they can be protected from an uncontrolled release through use of strategically placed confinement/filter beds, straw bales, silt fence, or earth berms place prior to the start of drilling or the use of conductor casings if at entry and exit areas.

7.0 Inadvertent Release Response (wetland, railroad, and open water body areas)

For any release occurring in a waterbody, the Certificate Holders shall immediately notify DPS Staff and NYSDEC of details of the release and the course of action they recommend taking. During the performance of any HDD waterbody crossing, contractors monitor the use of inert biodegradable drilling solution and, in the event of a detected release of fluid, implement the procedures specified in the approved EM&CP. If an inadvertent release occurs when working beneath the waterway, wetland, or railroad the Subcontractor will be required to cease drilling operations and reduce pressures in borehole immediately, and notify the Environmental Inspector, the construction management team and the Certificate Holders. The Environmental Inspector, with input from the Drill Operator, will evaluate the potential impact of the release on a site-specific basis and will determine the appropriate course of action. The Subcontractor is required to develop general in-stream or in-rail response methods and pre-place necessary materials and equipment at the site prior to construction. Specific response actions will be determined in consultation with the Environmental Inspector and Subcontractor and could include the following:

- Slowing the drill fluid pumps.
- Modifying the advance rate and rod/tool rpm, to match pump rate.
- Modifying the drill fluid properties, adding agents to reduce drilling fluid pressures through improved carrying capacity
- Tripping the drill steel and tool back a selected distance and attempt to clear cuttings from the annulus to re-establish circulation.
- Swabbing of the borehole, to increase sidewall stability and to remove clogging or squeezing.
- Stopping drilling activities for 24 hours to allow the bentonite in the subsurface pathways to gel and seal the pathways.
- Evaluate the current drill methods to identify site specific improvements to lower the risk of additional inadvertent releases.
- Potentially implementing a loss-control material (LCM), designed to plug fractures.
- Implementation of proper sedimentation control measures including, but not limited to hay bales, vacuum trucks, silt curtains, containment cells, turbidity curtains, or if suitable, sand bags and confinement/filter beds. These activities will require that qualified construction personnel and other support equipment, and supplies be prepositioned and readily available at or near the site.
- Use of a relief well installed at the location of the release. A well or pit equipped with a subsurface pump to control slurry pressures and future releases at that location by evacuating drilling fluid as it accumulates can also be used. The relief well can be utilized to immediately lower the borehole pressures in the event of an inadvertent release and later to control and manage the release as the drilling continues.

8.0 Drill Hole Abandonment Plan

In the event the Subcontractor must abandon the drilled hole, a plan to fill the abandoned hole will be implemented as detailed in the Subcontractor's supplemental Inadvertent Release Contingency Plan and an alternative plan/alignment for crossing shall be evaluated. If it becomes necessary to abandon a partially completed hole, the abandoned hole will be filled with a mixture of high-yield bentonite, water, and drill spoil. The first ten feet of the bore path will be compacted and filled with soil or a cement-bentonite mix to prevent future settlement. The Subcontractor submitted site-specific abandonment plan shall be approved by the Design Engineer and the Construction Manager prior to being performed in the field.

After the abandoned hole has been filled, an alternative entry and exit hole and bore path alignment will be evaluated by the Subcontractor, Construction Manager, and the Design Engineer. The new alignment shall be offset from the abandoned hole by at least 15 feet (except at the ends where a 5- foot offset may be used) to help limit the risk steering difficulties due to the presence of or hydraulic connection causing drill fluid loss to the abandoned hole.

9.0 Crossing Specific Conditions and IR Analysis

A generalized geologic profile and an annular pressure analysis for each crossing is included in Appendix A. In each case the results of the analysis are considered applicable to both HDD installations.

9.1 Analysis Method

The annular pressure analyses compares the anticipated range of downhole annular drill fluid pressures required to complete the pilot bore to the estimated confining capabilities of the surrounding geologic materials. This exercise can be useful in the evaluation of risk of inadvertent returns (IR's, or "fracout") during drilling. The potential for an IR may be considered greatest at locations where the anticipated range of downhole drill fluid pressures are close to or exceed the estimated confining capabilities of the surrounding materials. Note that the pilot hole (vs the reamed hole) is generally the most constrained, and presents the greatest risk of IR during the HDD construction process.

The following should be noted:

- HDD requires drill fluid pressures sufficient to stabilize the borehole and remove cuttings. In general, it may be possible to reduce the risk of drill fluid loss through careful drilling and drill fluid management, but IR risk cannot be completely eliminated.
- The annular pressure analysis is considered to be a tool to identify areas of potential risk. *It is not considered an exact predictor of the location or degree of an IR.*

- The annular pressure analysis does not account for existing pathways or zones of weakness in the subsurface, which may be related to existing utilities, foundations, utility poles and below-grade space. Where present, these features will *increase* the risk of drill fluid loss.
- The annular pressure analysis is not an accurate predictor of borehole leakage, where drill fluid leaks to the adjacent materials through existing porosity or fractures.
- Drill fluid loss from the borehole may not migrate to the surface. In some cases, the drill fluid may escape to the surrounding formation.

The static drill fluid pressure is a function of the density of the drill fluid at a specific location and depth below the drill entry elevation. The dynamic pressure is the pressure required to move the drill fluid (and cuttings) up the borehole annulus, and is a function of pump rates, hole geometry, fluid density, fluid velocity, and fluid rheology. The estimated annular pressures included in Appendix A are based on the API-13D method using a Power Law to model the dynamic pressure of a visco-plastic fluid.

Geotechnical parameters used in the analysis were derived through evaluation of laboratory testing and engineering judgement. The confining capability of the native materials was approximated using a variety of methods, which include the following:

- **Total Stress Model**: The Total Stress Model is based on the dead weight of the formation material above the drill path and excludes the potential strength of the formation. This method is considered *conservative* but is considered a reasonable approximation for the formation pressure capacity of bedrock and very dense soil.

- **Cavity Expansion Model (Delft Equation)**: This method considers the strength of the formation along with the total stress (above) and is based on Ko = 1 conditions. The initial equation was derived from the Mohr-Coulomb failure model adjusted by Delft University for low angle cylindrical cavity expansion in a host material when subjected to internal pressure. This method has been found more realistic in sand, silt, and stiffer cohesive formations than the Total Stress Model. However the method require assumptions of a horizontal surface with homogeneous isotropic soil. Additionally, the equations require significant property assumptions such as the Shear Modulus, G.

- **Stress plus Strength Model**: This method was initially implemented by the US Corps of Engineers to assess the damage potential to levees from the HDD fluids during drilling. This model adds the strength of the formation material to the total stress though results are generally considered to be conservative. The basis of the model, like the cavity expansion model is the Mohr-Coulomb failure approach. This model is generally appropriate for soil or bedrock.

- **Queens Model**: The Queens model was developed at Queens University. This model also adds the strength of the formation material to the total stress. The basis of this model, similar to the cavity expansion model is the Mohr-Coulomb failure approach. The difference between this model and the Delft model is that the Queens approach permits variation in the Ko of the soil and is considered more realistic in softer cohesive soils.

Additional input assumptions included:

- Jetting tools will be used for fill, lacustrine and glaciofluvial deposits.
- A mud motor will be used to complete the pilot hole for bores encountering glacial till and bedrock.
- A drill fluid pump rate of 200 gpm for pilots using jetting and a drill fluid pump rate 400 gpm for mud motors.
- An average drill fluid density of 78 pcf, and maximum drill fluid density of 94 pcf.
- An estimated drill bit diameter of 8.16 inches and a drill rod diameter of 3.5 inches.

9.2 HDD Crossing #87B

<u>Surface conditions at HDD #87B:</u>

HDD #87B passes below S. Albany St/Route 54 which curves from east-west to northwest-southeast in this vicinity. This roadway is supports two lanes of active traffic and is approximately 23-ft wide. The crossing also passes below a 48-in water main operated by the Albany Water Board, and numerous smaller utilities.

To the southwest of S. Albany St/Route 54 (in the vicinity of the HDD alignment) the ground surface slopes downward toward the center of the alignment, from about El. 170 to El. 155. In this area, the crossing passes below a wetland and 60-in CMP culvert. This area is covered with brush and small trees.

The HDD Entry is located to the northwest, on the south side of S. Albany St/Route 54, adjacent to a small commercial facility (single-story buildings, unpaved parking). The ground surface in this area ranges from about El. 175 to El. 178. Overhead utility poles are located on the opposite (north) side of the road.

The HDD Exits are staggered and located in a grassy area on the northeast side of S. Albany St/Route 54. A paved parking area and a brick office building operated by CSX are located to the immediate. Surface grades at the HDD exit range from about El. 175 to El. 177.

<u>Subsurface conditions at HDD #87B</u>:

The subsurface conditions along the HDD #87B alignment consist of a layer surficial fill overlying glacial lake deposits consisting of consisting of silt and clay (loose to medium dense and very soft to soft), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth. It should be noted that the glacial lake deposits contain extensive amounts of "weight-of-hammer" materials.

<u>IR Risk at HDD #87B</u>

In our opinion the conditions conducive to inadvertent releases that may exist this at this site may include:

- Highly permeable soil such as cobbles and gravel in the surficial fill.
- Areas of reduced soil cover.
- Existing below-grade utilities.
- Obstructions such as cobbles and boulders within the overburden soils.
- The soft glacial lake deposits, which do not provide significant capacity for drill fluid pressure containment.

It appears that there is a potential of inadvertent release at the end of the bores (as is common). These could be controlled through the use of conductive casings, haybales, silt fences, erosion control measures and vacuum trucks. There is also the potential for drill fluid loss and IR over the entire length of the crossing due to the soft soils. The drilling contractor will need to monitor drill fluid returns, drill fluid pressures and borehole behavior carefully. Reduced pump volumes and displacement-type drilling and reaming may be necessary. The drilling contractor will need to be prepared to identify and address an IR over the full length of the bore in each case. This will require full surface monitoring and access, including the wetland areas.

9.3 HDD Crossing #88

Surface conditions at HDD #88:

HDD #88 is located to the east of S. Albany St/Route 54 and passes below Coeyman's Creek and an adjacent wetland. The majority of the site vicinity is covered by trees and brush. Farmland is located to the northwest, southwest and northeast.

The HDD Entry is located to the southwest in an open field (farmland). Surface grades in this area range from about El. 163 to El. 165. The HDD exit is located to the northeast in an area covered by brush and small trees, which has been mapped as wetland. Surface grades in this area range from about El. 174 to El. 176.

Surface grades along the HDD alignment slope downward toward Coeyman's Creek at moderate grades from the northeast and southeast. The Creek is oriented approximately north-south, with a bottom elevations estimated at El. 124 to El. 125.

Subsurface conditions at HDD #88:

The subsurface conditions along the HDD #88 alignment consist of a layer surficial fill overlying glacial lake deposits consisting of consisting of silt and clay (loose to medium dense and very soft to soft), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth. It should be noted that the glacial lake deposits contain extensive amounts of "weight-of-hammer" materials.

IR Risk at HDD #88

In our opinion the conditions conducive to inadvertent releases that may exist this at this site may include:

- Highly permeable soil such as cobbles and gravel in the surficial fill.
- Areas of reduced soil cover.
- Existing below-grade utilities.
- Obstructions such as cobbles and boulders within the overburden soils.
- The soft glacial lake deposits, which do not provide significant capacity for drill fluid pressure containment.

It appears that there is a potential of inadvertent release at the end of the bores (as is common). These could be controlled through the use of conductive casings, haybales, silt fences, erosion control measures and vacuum trucks. There is also the potential for drill fluid loss and IR in the vicinity of Coeyman's Creek and the adjacent wetland due to the reduced cover and soft soils. The drilling contractor will need to monitor drill fluid returns, drill fluid pressures and borehole behavior carefully. Reduced pump volumes and displacement-type drilling and reaming may be necessary. The drilling contractor will need to be prepared to identity and address an IR in each case. This will require full surface monitoring and access, including the stream and wetland areas.

9.4 HDD Crossing #89

Surface Conditions at HDD #89:

HDD #89 is located to the southwest of a single CSX rail (oriented northwest-southeast), and passes below a small stream, which is generally oriented north-south. The majority of the HDD alignment is covered by brush and small trees, and has been mapped as wetland. Overhead utility poles are located immediately adjacent to and parallel the northwest portion of the HDD alignment.

In general the surface grades slope downward gently toward the south-southwest. However, moderate slopes are located on either side of the stream. The stream bottom is estimated to be at about El. El. 149.

The HDD entry is located to the southwest, with a surface grade of about El. 158 to El. 160 The HDD exit is located to the northwest, with surface grades of about El. 174 to El. 175. Both the entry and exit areas are covered by brush and small trees and have been mapped as wetlands.

The entirety of the HDD #89 alignments are located within the CSX right-of-way.

Subsurface conditions at HDD #89

The subsurface conditions along the HDD #88 alignment consist of a layer surficial fill overlying glacial lake deposits consisting of consisting of silt and clay (loose to medium dense and very soft to soft), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth. It should be noted that the glacial lake deposits contain extensive amounts of "weight-of-hammer" materials.

IR Risk at HDD #89

In our opinion the conditions conducive to inadvertent releases that may exist this at this site may include:

- Highly permeable soil such as cobbles and gravel in the surficial fill.

- Utility pole locations.
- Existing below-grade utilities.
- Obstructions such as cobbles and boulders within the overburden soils.
- The soft glacial lake deposits, which do not provide significant capacity for drill fluid pressure containment.

It appears that there is a potential of inadvertent release at ends of the bores (as is common). These could be controlled through the use of conductive casings, haybales, silt fences, erosion control measures and vacuum trucks. There is also the potential for drill fluid loss and IR over the entire length of the crossing due to the soft soils and areas of reduced cover. The drilling contractor will need to monitor drill fluid returns, drill fluid pressures and borehole behavior carefully. Reduced pump volumes and displacement-type drilling and reaming may be necessary. The drilling contractor will need to be prepared to identity and address an IR in each case. This will require full surface monitoring and access, including the stream and wetland areas. The adjacent railroad tracks should be monitored in close coordination with the Owner prior to, continuously throughout operations, and 1-2 weeks post installation.

9.5 HDD Crossing #90

Surface Conditions at HDD #90:

HDD #90 is located to the southwest of a single CSX rail (oriented northwest-southeast), and passes below the bank and wetland of a small stream, which is generally oriented northwest-southeast. HDD #90 also passes below Route 396 which is about 27-ft wide and oriented northeast-southwest. In this vicinity the CSX rails are elevated, and pass over Route 396 by means steel bridge with concrete wing walls to the northeast of the crossing. In general, the site grades along the alignment slope downward toward the stream to the southwest.

Two (2) separate, northeast-southwest oriented overhead power lines cross the alignment in the Route 396 vicinity. Numerous power poles associated with these lines are located along the southeast portion if the HDD alignment.

The HDD #90 entry area is located to the southeast. This area is covered by small trees and brush, and mapped wetland is locate to the northeast. Surface grades in this immediate area range from about El. 157 to 159.

The HDD #90 exit area is located to the northwest. This area is covered by small trees and brush, and has been mapped as wetland. mapped wetland is locate to the northeast. Surface grades in this immediate area range from about El. 157 to 159.

The surface grade of the adjacent CSX rail (northeast) ranges from about El. 165 to El. 166. The entirety of the HDD #90 alignments are located within the CSX right-of-way.

Subsurface conditions at HDD #90

The subsurface conditions along the HDD #90 alignment consist of a layer surficial fill overlying glacial lake deposits consisting of consisting of silt and clay (loose to medium dense and very soft to soft), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth. It should be noted that the glacial lake deposits contain extensive amounts of "weight-of-hammer" materials.

IR Risk at HDD #90

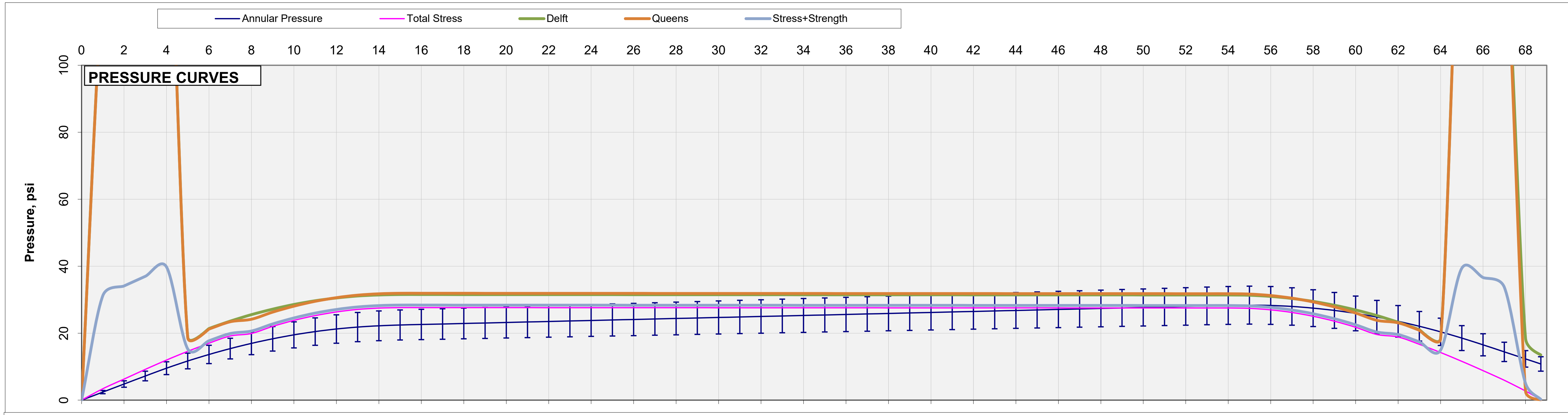
In our opinion the conditions conducive to inadvertent releases that may exist this at this site may include:

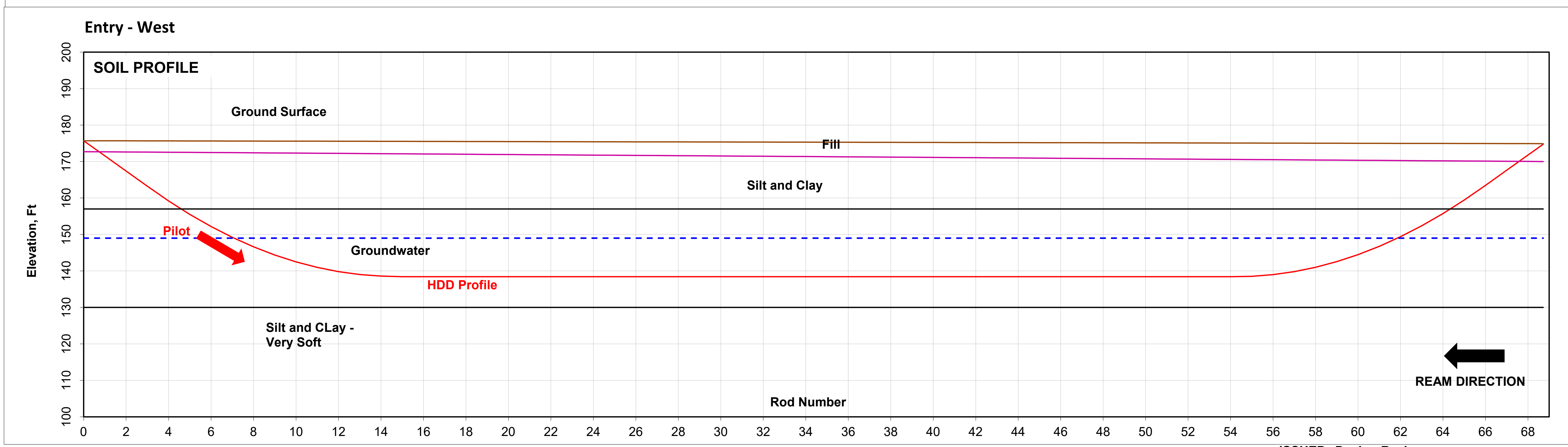
- Highly permeable soil such as cobbles and gravel in the surficial fill.
- Utility pole locations.
- Existing below-grade utilities.
- Potential deep foundations associated with overpass structures.
- Obstructions such as cobbles and boulders within the overburden soils.
- The soft glacial lake deposits, which do not provide significant capacity for drill fluid pressure containment.

It appears that there is a potential of inadvertent release at ends of the bores (as is common). These could be controlled through the use of conductive casings, haybales, silt fences, erosion control measures and vacuum trucks. There is also the potential for drill fluid loss and IR over the entire length of the crossing due to the soft soils and areas of reduced cover. The drilling contractor will need to monitor drill fluid returns, drill fluid pressures and borehole behavior carefully. Reduced pump volumes and displacement-type drilling and reaming may be necessary. The drilling contractor will need to be prepared to identity and address an IR in each case. This will require full surface monitoring and access, including the stream and wetland areas and Route 396. The adjacent railroad tracks should be monitored in close coordination with the Owner prior to, continuously throughout operations, and 1-2 weeks post installation.

APPENDIX A

ANNULAR PRESSURE ANALYSES





ISSUED: Design Review

Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 11/3/2022 8:29

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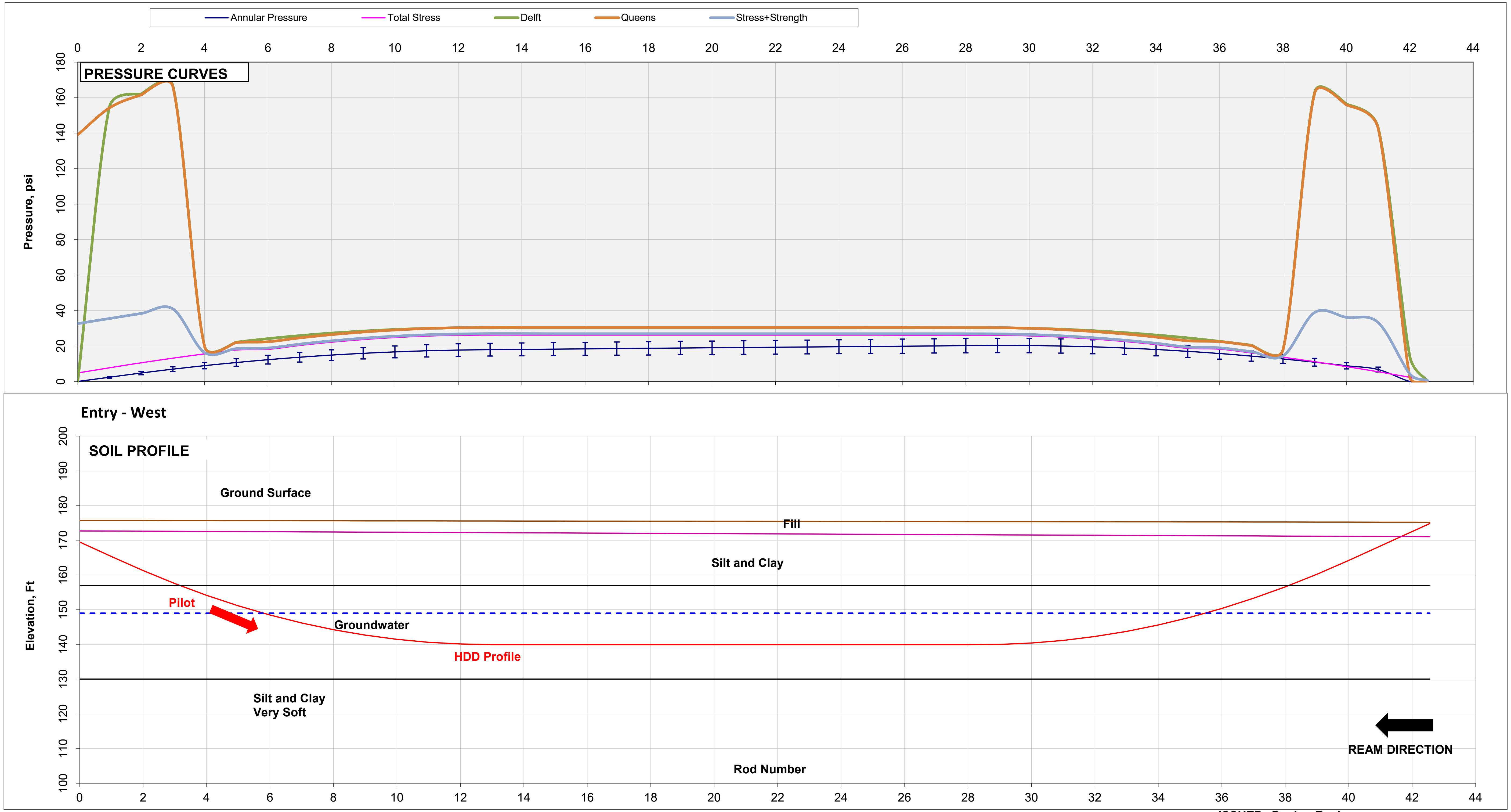
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87B Circuit #1
South Albany Rd & Rt 54

Revision 0

FIGURE 1



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Notes:

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3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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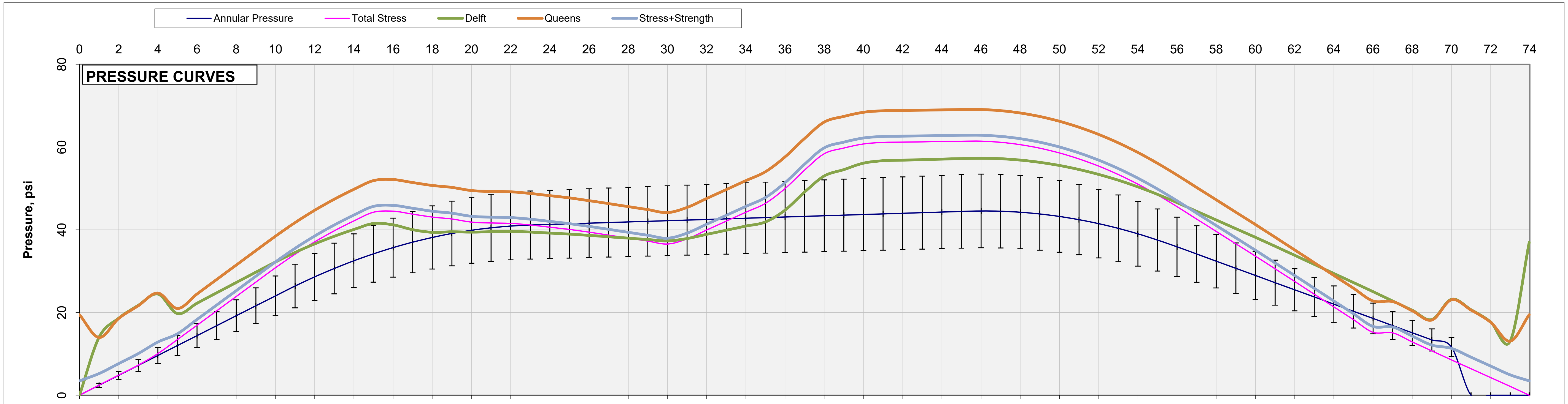
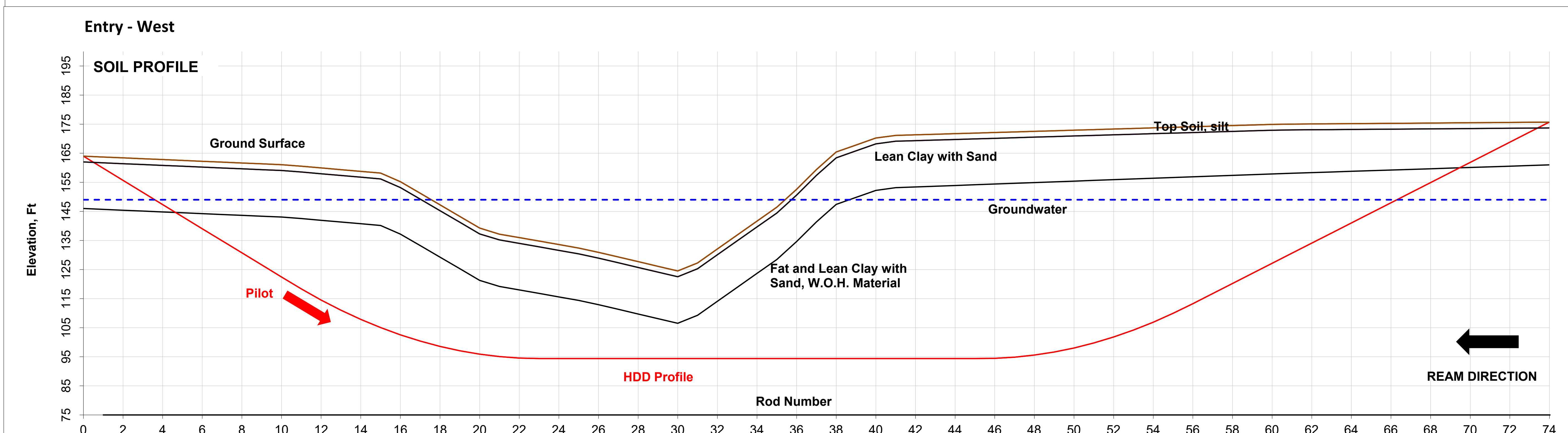
ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87B Circuit #2
South Albany Rd & Rt 54

Revision 0

FIGURE 1





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Notes:
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3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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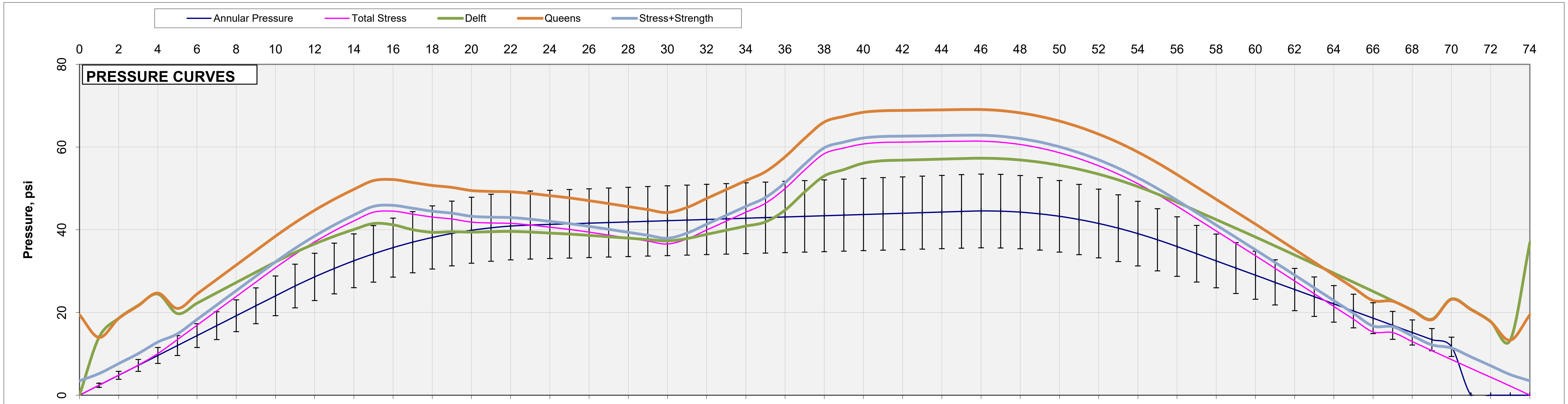
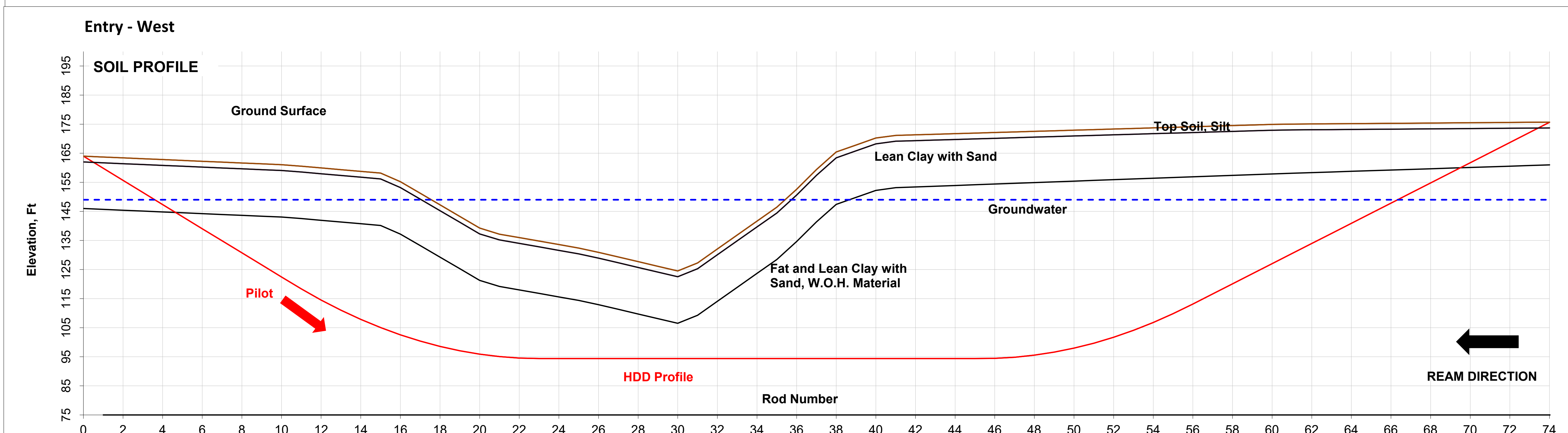
ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 88 Circuit #1
Coeyman's Creek

Revision 0

FIGURE 1





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Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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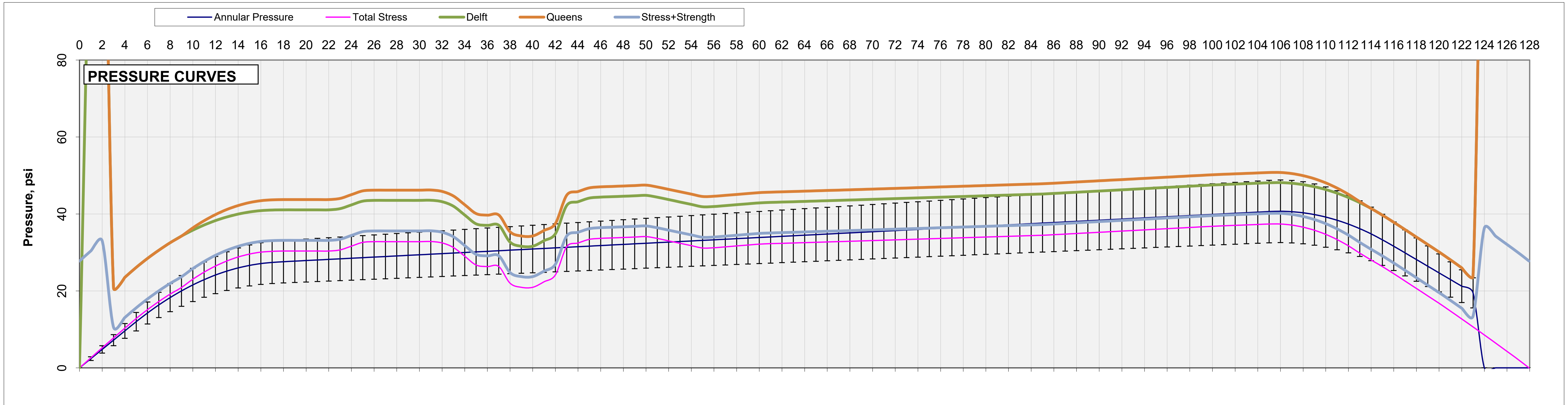
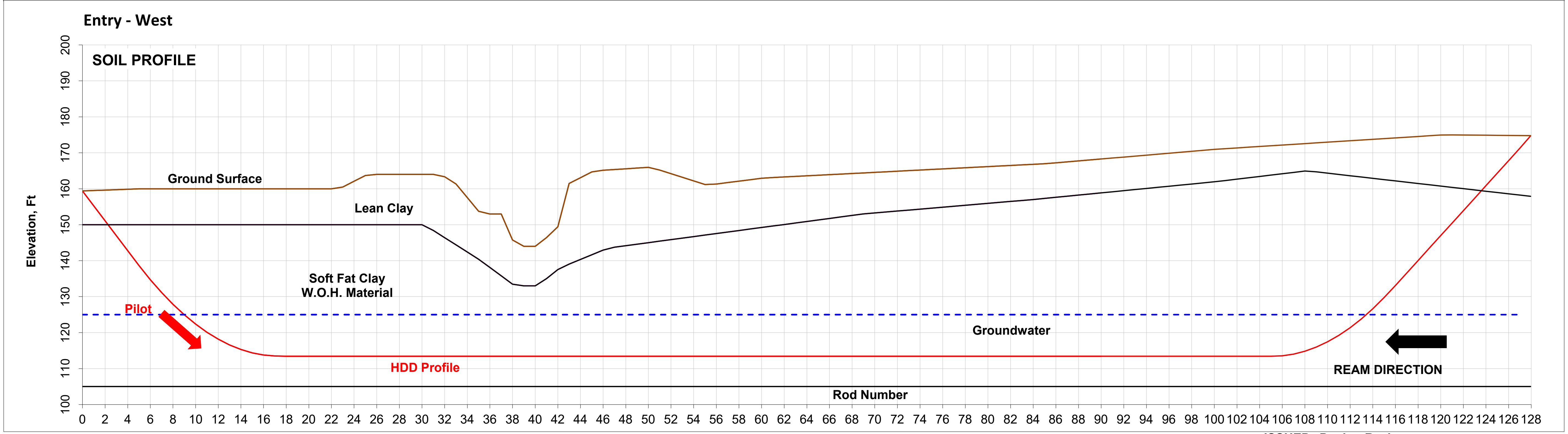
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 88 Circuit #2
Coeyman's Creek

Revision 0

FIGURE 1





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Notes:

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4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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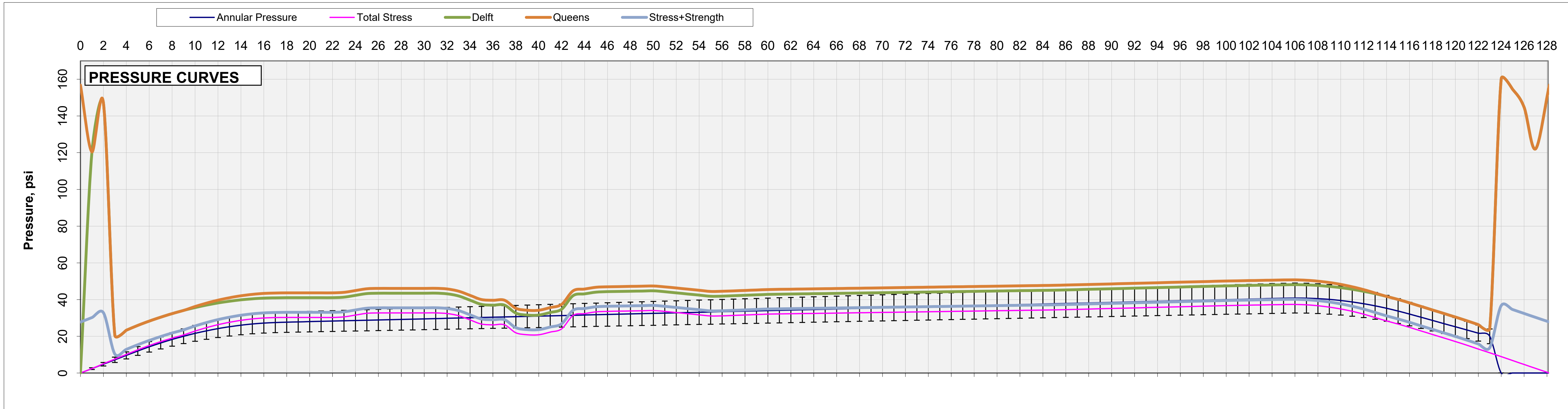
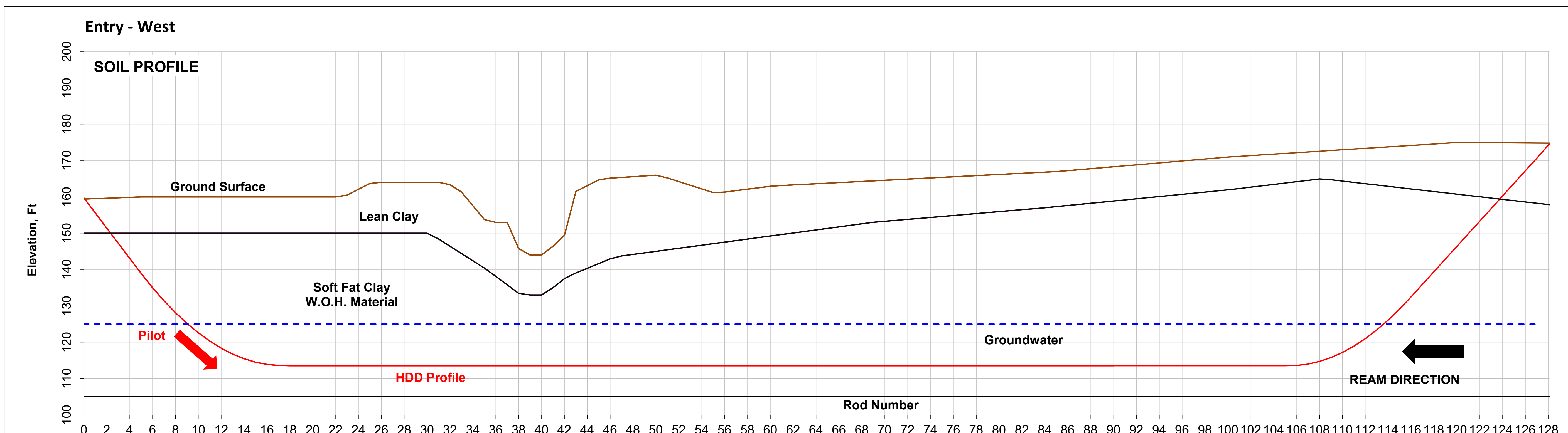
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 89 Circuit #1
Wetlands Crossing

Revision 0

FIGURE 1





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Notes:

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3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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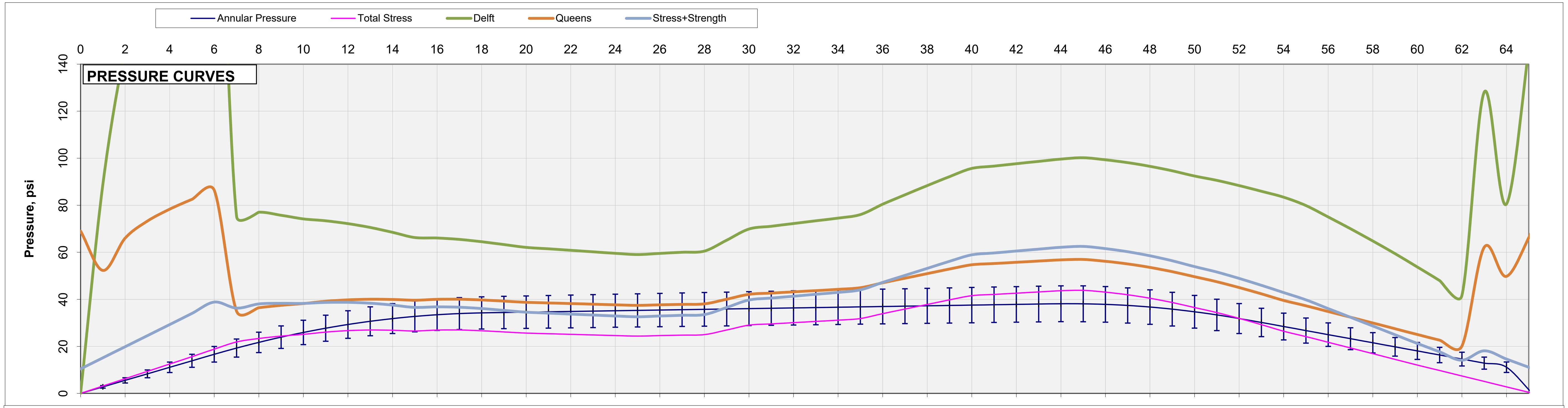
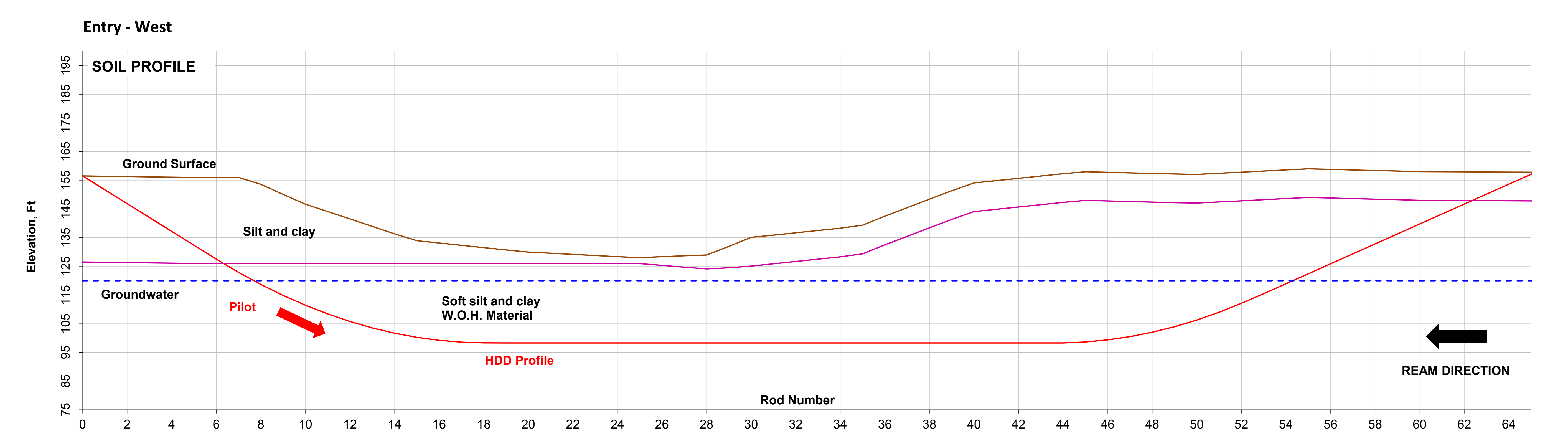
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 89 Circuit #2
Wetlands Crossing

Revision 0

FIGURE 1





Notes:
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3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

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Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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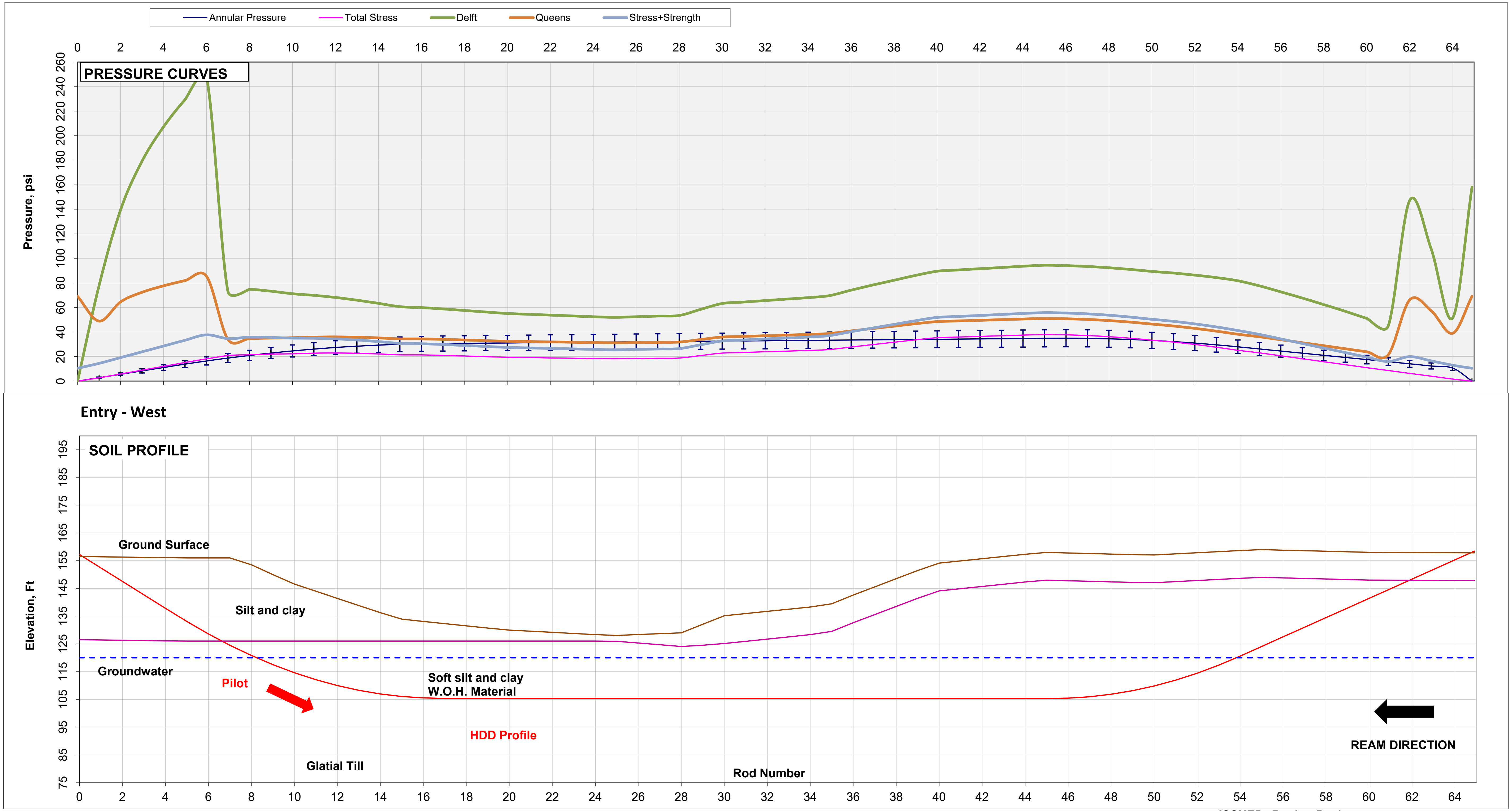
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 90 Circuit #1
Route 396 & Stream Bank

Revision 0

FIGURE 1



ISSUED: Design Review

Notes:
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4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 90 Circuit #2
Route 396 & Stream Bank

Revision 0

FIGURE 1

BRIERLEY ASSOCIATES
Creating Space Underground

December 13, 2022
File No. 322004-000

Kiewit Engineering (NY) Corporation
470 Chestnut Ridge Rd, 2nd Floor
Woodcliff Lake, NJ 07677

Attention: Jason Neff, PE, PMP - Design Engineering Manager

Subject: DRAFT HDD Design Summary Report
Champlain Hudson Power Express – Segment 5B
Fuera Bush to Bethlehem, New York

Dear Mr. Neff:

Brierley Associates Underground Engineers, PLLC (Brierley) is pleased to provide this DRAFT HDD Design Summary Report for Segment 5B of the Champlain Hudson Power Express Project. This work was conducted in general accordance with our contract with Kiewit Engineering (NY) Corporation (Kiewit).

We thank you for this opportunity to be of service to you and your team on this project. Should you have any questions or require additional information, please do not hesitate to contact the undersigned at your convenience.

Sincerely,

Brierley Associates Underground Engineers, PLLC

Nick Strater, P.G.
Sr. Project Manager

Brent Lindelof, P.E.
Sr. Engineer

Brian C. Dorwart, P.G., P.E.
Sr. Consultant

TABLE OF CONTENTS

1.0 Introduction

The Champlain Hudson Power Express (CHPE) project will install a pair of HVDC electrical transmission cables with an associated telecommunications line from Canada to New York City, NY. This work includes approximately 126 crossings under roads, railroads, wetlands water bodies, and obstructions to be installed using horizontal directional drilling (HDD) methods to minimize interference with use or impacts to the surface environment. This Draft Design Summary Report addresses the design for the HDD crossings in Package 5b which extends from Fuera Bush to Bethlehem. Package 5b includes a total of 4 crossings, which are summarized in Table 1, below.

Table 1: HDD Locations, Lengths, and Description

HDD #	Approx. Start Station*	Approx. End Station*	Approx. HDD Length, ft	Obstruction Crossed
87B	51106+47	51120+29	1,382	S. Albany St/Route 54, water main
88	51179+09	51193+75	1,466	Coeyman's Creek
89	51201+50	51227+00	2,550	Wetland, Stream
90	51235+01	51247+40	1,239	Route 396/Stream Bank

*Project stationing shown. Each HDD has its own independent stationing.

The purposes of this Draft Design Summary Report are to provide the following:

- Review of the existing geological and geotechnical conditions for each HDD crossing.
- Provide a descriptive narrative of the HDD crossings in support of the design drawings and technical specifications.
- Present pipe stress and annular pressure analyses that support the proposed designs.
- Present construction considerations including inadvertent return mitigation.

2.0 Project Description

The proposed CHPE route follows the Hudson River Valley of New York. The new transmission line will be approximately 146 miles in length, extending from the south end of Lake Champlain to Astoria, NY. Project Maps showing the locations of the HDD crossings are presented in Figure 1.

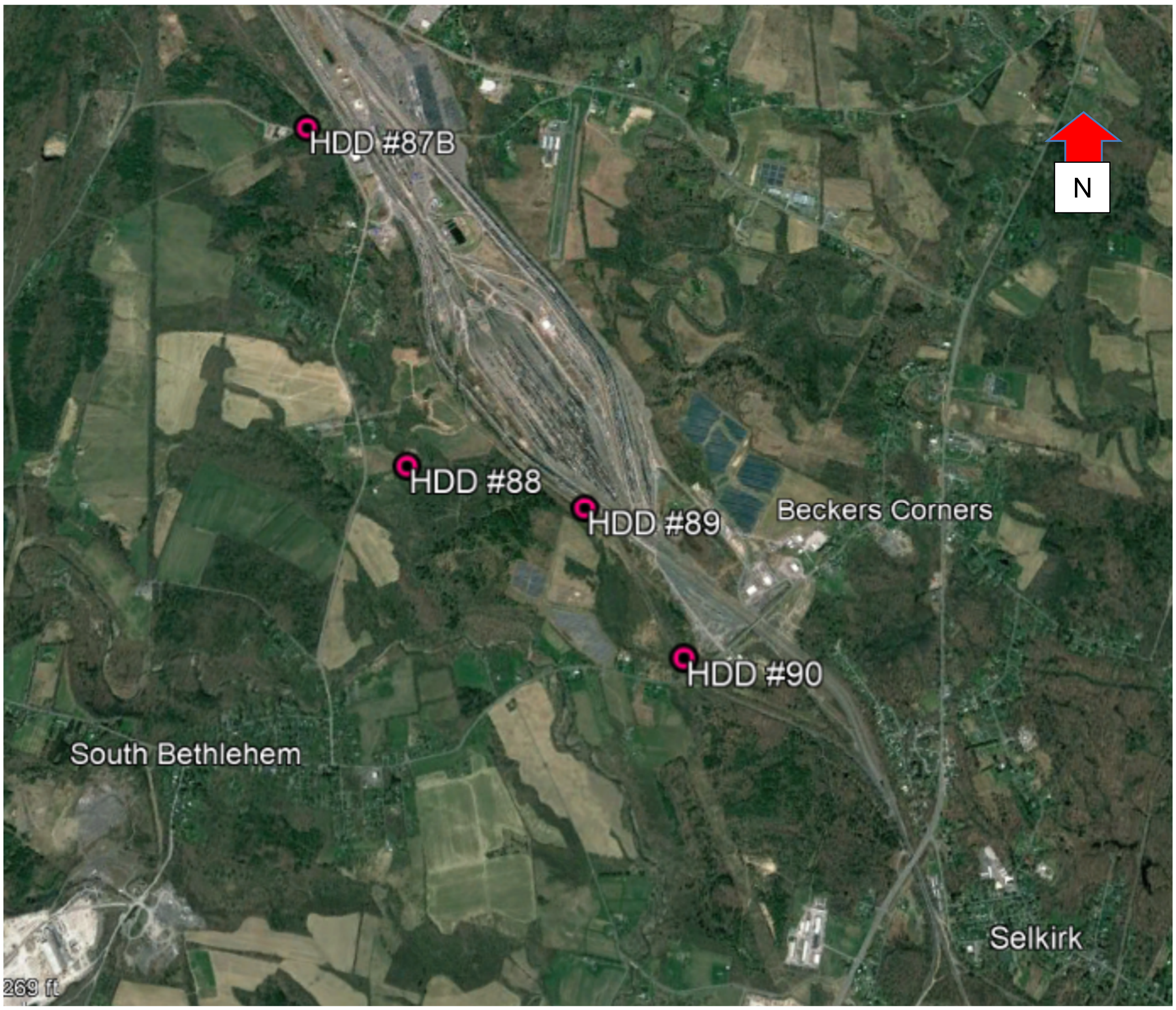

Figure 1 – Crossing Location Plan, HDD #87B through HDD #90. Photo from www.googleearth.com. Not to scale.

3.0 Background

The underground construction of two HVDC electrical transmission cables is proposed to be housed in individual 10-inch-diameter plastic conduit spaced approximately 15 feet apart. A third, minimum 2-inch-diameter plastic conduit will be bundled with one of the 10-inch diameter conduits for a telecommunications line.

The proposal is to install the cable duct at least 25 feet below congested areas, roads, railroads, under/around other obstructions, 15 to 25 feet below wetland, and 35 to 45 feet below open bodies of water using horizontal directional drilling (HDD) methods.

HDD is a widely used trenchless construction method to install pipe and conduits with limited disturbance to the ground around the bore alignment. The goal for using HDD methods is to install the conduits while controlling and minimizing the amount of impact to congested areas, existing underground obstructions, and to the adjacent wetlands to the extent possible.

4.0 Surface Conditions

HDD #87B

HDD #87B passes below S. Albany St/Route 54 which curves from east-west to northwest-southeast in this vicinity. This roadway is supports two lanes of active traffic and is approximately 23-ft wide. The crossing also passes below a 48-in water main operated by the Albany Water Board, and numerous smaller utilities.

Southwest of S. Albany St/Route 54 (in the vicinity of the HDD alignment) the ground surface slopes downward toward the center of the alignment, from about El. 170 to El. 155. In this area, the crossing passes below a wetland and 60-in CMP culvert. This area is covered with brush and small trees.

The HDD Entry is located to the northwest, on the south side of S. Albany St/Route 54, adjacent to a small commercial facility (single-story buildings, unpaved parking). The ground surface in this area ranges from about El. 175 to El. 178. Overhead utility poles are located on the opposite (north) side of the road.

The HDD Exits are staggered and located in a grassy area on the northeast side of S. Albany St/Route 54. A paved parking area and a brick office building operated by CSX are located to the immediate east. Surface grades at the HDD exit range from about El. 175 to El. 177.

HDD #88

HDD #88 is located to the east of S. Albany St/Route 54 and passes below Coeyman's Creek and an adjacent wetland. The majority of the site vicinity is covered by trees and brush. Farmland is located to the northwest, southwest and northeast.

The HDD Entry is located to the southwest in an open field (farmland). Surface grades in this area range from about El. 163 to El. 165. The HDD exit is located to the northeast in an area covered by brush and small trees, which has been mapped as wetland. Surface grades in this area range from about El. 174 to El. 176.

Surface grades along the HDD alignment slope downward toward Coeyman's Creek at moderate grades from the northeast and southeast. The Creek is oriented approximately north-south, with a bottom elevation estimated at El. 124 to El. 125.

HDD #89

HDD #89 is located to the southwest of a single CSX rail (oriented northwest-southeast), and passes below a small stream, which is generally oriented north-south. The majority of the HDD alignment is covered by brush and small trees, and has been mapped as wetland. Overhead utility poles are located immediately adjacent to and parallel the northwest portion of the HDD alignment.

In general the surface grades slope downward gently toward the south-southwest. However, moderate slopes are located on either side of the stream. The stream bottom is estimated to be at about El. 149.

The HDD entry is located to the southwest, with a surface grade of about El. 158 to El. 160 The HDD exit is located to the northwest, with surface grades of about El. 174 to El. 175. Both the entry and exit areas are covered by brush and small trees and have been mapped as wetlands.

The entirety of the HDD #89 alignments are located within the CSX right-of-way.

HDD #90

HDD #90 is located to the southwest of a single CSX rail (oriented northwest-southeast), and passes below the bank and wetland of a small stream, which is generally oriented northwest-southeast. HDD #90 also passes below Route 396 which is about 27-ft wide and oriented northeast-southwest. In this vicinity the CSX rails are elevated, and pass over Route 396 by means of steel bridge with concrete wing walls to the northeast of the crossing. In general, the site grades along the alignment slope downward toward the stream to the southwest.

Two (2) separate, northeast-southwest oriented overhead power lines cross the alignment in the Route 396 vicinity. Numerous power poles associated with these lines are located along the southeast portion if the HDD alignment.

The HDD #90 entry area is located to the southeast. This area is covered by small trees and brush, and mapped wetland is locate to the northeast. Surface grades in this immediate area range from about El. 157 to El. 159.

The HDD #90 exit area is located to the northwest. This area is covered by small trees and brush, and has been mapped as wetland. Surface grades in this immediate area range from about El. 157 to El. 159.

The surface grade of the adjacent CSX rail (northeast) ranges from about El. 165 to El. 166. The entirety of the HDD #90 alignments are located within the CSX right-of-way.

5.0 Below-grade Structures

5.1 Utilities

The location of existing known below-grade utilities are shown on the design drawings. Additional soft dig information will be evaluated during final design and prior to issued-for-construction drawing submittal. Minimum offsets between the known utilities and the HDD borepaths are included on the profiles.

5.2 Foundations

The location of existing foundations (bridges, retaining walls) will be added to the issued-for-construction drawings based on as-built information provided by others, where available.

6.0 Subsurface Conditions

The subsurface conditions in the vicinity of the HDD crossings were investigated by subsurface investigations and laboratory testing completed by others. Subsurface investigations included sampled test borings and cone penetrometer testing.

In general, the subsurface conditions at each of the 5b crossings are generally similar, and consist of surficial fill overlying glacial lake deposits consisting of silt and clay (loose to medium dense and very soft to soft), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth. It should be also noted that the glacial lake deposits contain extensive amounts of “Weight-of-Hammer” materials.

7.0 HDD Process

HDD involves drilling a small diameter (4 to 9-in) "pilot hole" along a pre-established, design alignment from and entry pit to an exit pit. The pilot is then enlarged as necessary by a series of reaming passes, and the product pipe or duct bundle is pulled into place. HDD generally does not require pits (or shafts), or dewatering. The depth and trajectory of the HDD needs to be carefully designed to account for subsurface conditions and the bending tolerances of the drill rods, steering limits of the drill tools, anticipated reaction of the subsurface conditions, and bending tolerances and the product pipe/conduit. All stages of the HDD process involve pumping a bentonite-based, environmentally safe drilling fluid into the borehole through the drill rods. The drilling fluid travels back to the surface within the annular space between the drill rods and surrounding soil. The drilling fluid maintains borehole stability, removes cuttings, and cools the drilling tools. A common risk associated with HDD is release of drilling fluid to the ground surface, which is referred to as an inadvertent return (IR) or "frac-out". This may occur when the downhole drill fluid pressure exceeds the confining capability of the surrounding soil, or if zones of weakness or previous disturbance are present (e.g., existing utilities, utility poles, deep foundations). Drilling fluid and drilling fluid additives are chemically inert, biodegradable, and non-toxic. However, the occurrence of a frac-out typically requires cleanup, may result in surface heave or settlement, and may result in borehole instability (e.g., collapse, squeezing).

8.0 Design Components

8.1 HDD Geometry

The proposed bore path alignments, entry and exit locations, entry angle, exit angle, and a vertical and horizontal design radii of curvature for each HDD crossing in this segment are shown in the design drawings. The HDD technical specifications are found in Section 33 05 07.13 of the Technical Specifications. Inadvertent release prevention and mitigation plans for each HDD crossing are provided as separate documents.

The HDD design alignments for Package 5b have been developed in general accordance with the Project Design Criteria Manual (document entitled "Project Design Criteria", Champlain Hudson Power Express, 400kV HVDC Underground Transmission Line, KIEWIT PROJECT NO. 104809, Dated June 2022, herein referred to as the "Design Manual").

8.2 Annular Pressure Analysis

Drill fluid loss from the borehole typically occurs as a result of one or a combination of the following:

- Hydraulic Jacking: Hydraulic jacking occurs when there are existing cracks in the formation such as fractures within bedrock or stiff cohesive soils, or relatively high permeability zones contained within a relatively low permeability materials (e.g. a sand lense in clay). When the drill fluid pressure exceeds the weight or force restraining the materials on the sides of the fracture or higher permeability zone, the confining material will be hydraulically jacked open resulting in an enlarged opening with more fluid volume capacity and eventually, the possibility of a new flow path for the fluid. The Total Stress calculations provides a conservative method for assessment of this type of drill fluid loss.

- Hydraulic Fracturing. Hydraulic fracturing occurs when the drill fluid pressure exceeds the static stress state in the formation *plus* the strength of the formation material. The result is a fracturing of the formation providing access for the drill fluid to a path that will continue to grow until the drill fluid pressure is reduced or the formation strength increases. The stress plus strength and the Kirsch methods may be used to assess this type of drill fluid loss in rock. In soil formations the Delft may be used to model for drill fluid loss when hydraulic fracturing occurs.

- Leakage: Flow of the drill fluid into existing open space, such as open bedrock fractures and soil porosity.

It's common to loose upwards of 30% (or more) of the drill fluid to the adjacent formation (soil and bedrock) during HDD construction. If the drill fluid reaches to ground surface or water (river) mudline, it's referred to as a "fracout" or inadvertent drill fluid return ("IR"). This may require conditioning of the borehole to stop the drill fluid loss, and cleanup of the drill fluid, if accessible.

A preliminary annular pressure analysis was completed for the pilot hole for each of the currently proposed HDD borepath geometries, based on the currently available geotechnical data. This process compares the anticipated range of downhole annular drill fluid pressures required to complete the pilot bore to the estimated confining capabilities of the surrounding geologic materials. This exercise can be useful in the evaluation of risk of inadvertent returns (IR's, or "fracout") during drilling. The potential for an IR may be considered greatest at locations where the anticipated range of downhole drill fluid pressures are close to or exceed the estimated confining capabilities of the surrounding materials. Note that the pilot hole (vs the reamed hole) is generally the most constrained, and presents the greatest risk of IR during the HDD construction process.

The following should be noted:

- HDD requires drill fluid pressures sufficient to stabilize the borehole and remove cuttings. In general, it may be possible to reduce the risk of drill fluid loss through careful drilling and drill fluid management, but IR risk cannot be completely eliminated.
- The annular pressure analysis is considered to be a tool to identify areas of potential risk. *It is not considered an exact predictor of the location or degree of an IR.*
- The annular pressure analysis does not account for existing pathways or zones of weakness in the subsurface, which may be related to existing utilities, foundations, utility poles and below-grade space. Where present, these features will *increase* the risk of drill fluid loss.
- The annular pressure analysis is not an accurate predictor of borehole leakage, where drill fluid leaks to the adjacent materials through existing porosity or fractures.
- Drill fluid loss from the borehole may not migrate to the surface. In some cases, the drill fluid may escape to the surrounding formation through localized fractures, porosity, or dilation.

The anticipated range of downhole drill fluid pressures (combined static and dynamic) for each HDD crossing in Package 5b are shown in Appendix B along with a generalized subsurface profile for each bore. The static drill fluid pressure is a function of the density of the drill fluid at a specific location and depth below the drill entry elevation. The dynamic pressure is the pressure required to move the drill fluid (and cuttings) up the borehole annulus, and is a function of pump rates, hole geometry, fluid density, fluid velocity, and fluid rheology. The estimated annular pressures included in Appendix B are based on the API-13D method using a Power Law to model the dynamic pressure of a visco-plastic fluid.

Geotechnical parameters used in the analysis were derived through evaluation of laboratory testing and engineering judgement. The confining capability of the native materials was approximated using a variety of methods, which include the following:

- **Total Stress Model**: The Total Stress Model is based on the dead weight of the formation material above the drill path and excludes the potential strength of the formation. This method is considered *conservative* but is considered a reasonable approximation for the formation pressure capacity of bedrock and very dense soil.

- **Cavity Expansion Model (Delft Equation)**: This method considers the strength of the formation along with the total stress (above) and is based on Ko = 1 conditions. The initial equation was derived from the Mohr-Coulomb failure model adjusted by Delft University for low angle cylindrical cavity expansion in a host material when subjected to internal pressure. This method has been found more realistic in sand, silt, and stiffer cohesive formations than the Total Stress Model. However the method require assumptions of a horizontal surface with homogeneous isotropic soil. Additionally, the equations require significant property assumptions such as the Shear Modulus, G. *This model is not generally appropriate for most bedrock, particularly hard sedimentary bedrock, and metamorphic and igneous lithologies.*

- **Stress plus Strength Model**: This method was initially implemented by the US Corps of Engineers to assess the damage potential to levees from the HDD fluids during drilling. This model adds the strength of the formation material to the total stress though results are generally considered to be conservative. The basis of the model, like the cavity expansion model is the Mohr-Coulomb failure approach. This model is generally appropriate for soil or bedrock.

- **Queens Model**: The Queens model was developed at Queens University. This model also adds the strength of the formation material to the total stress. The basis of this model, similar to the cavity expansion model is the Mohr-Coulomb failure approach. The difference between this model and the Delft model is that the Queens approach permits variation in the Ko of the soil and is considered more realistic in softer cohesive soils.

Additional input assumptions included:

- Jetting tools will be used for fill, lacustrine and glaciofluvial deposits.
- A mud motor will be used to complete the pilot hole for bores encountering glacial till and bedrock.
- A drill fluid pump rate of 150 gpm for pilots using jetting and a drill fluid pump rate 400 gpm for mud motors.

- An average drill fluid density of 78 pcf, and maximum drill fluid density of 94 pcf.
- An estimated drill bit diameter of 8.16 inches and a drill rod diameter of 3.5 inches.

The results of the annular pressure analyses included in Appendix B suggest that each of the 5b HDD centerlines will encounter very soft silty fat clays with very low strength characteristics, Weight of Hammer (W.O.H.) materials, with a stronger lean clay layer above, providing some pressure capacity for the drills.

- For these 4 crossings, there is an apparent risk of IR for the entire length of each bore. This is due to the poor strength characteristics (W.O.H. material) of the formation and equates to limited confining capabilities. At these locations careful consideration during drilling operations needs to be given to maintain borehole stability.
- In W.O.H materials, it is common to lose returns without IR, as the formation dilates. However, this may require additional drill fluid volumes and hole conditioning.
- HDDs #89 and #90 have critical areas with Factors of Safety below 1.0.
    - Contingency plans for track movement and impact should be developed in coordination with the Owner prior to executing the work.
    - The adjacent railroad tracks should be monitored in close coordination with the Owner prior to, continuously throughout operations, and 1-2 weeks post installation.

The HDD contractor(s) should be prepared to monitor the downhole drill fluid pressures in each bore, and respond to elevated pressures and drill fluid loss. The Inadvertent Return Contingency Plan details additional methods for mitigating inadvertent returns.

8.3 Conduit Material Selection

The conduit installed by HDD for the CHPE project must be plastic to satisfy cable ampacity requirements. The conduit must also be designed to withstand the short-term installation (pullback) loads, and the long-term external loads.

The conduit selected for the Package 5b HDD installations is PE4710 DR9 High Density Polyethylene (HDPE), consistent with the requirements of the Design Manual. Note that we have assumed that the telecommunications conduit will be minimum 3-in diameter (versus 2-in) to improve pullback survivability.

Pullback calculations for each HDD crossing are included in Appendix B, along with the conduit details. These will be updated during final design. These calculations have been developed in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. The safe pull force has been calculated in accordance with recommendations of the Plastic Pipe Institute. Both water ballasted and unballasted conduit have been considered. Water ballasting is recommended to reduce the pull force in each case.

It should be noted that HDPE is assembled through butt-fusion, which creates an internal "bead" which must be removed during fusion ("debeading") to reduce risk of cable damage during cable pulling.

9.0 Construction Considerations

The following construction considerations are presented for discussion purposes.

9.1 Subsurface Conditions

The following soils encountered along the package 5b alignment present specific construction considerations:

- Fill: Fill soils were encountered at each of the HDD crossing locations. These materials are expected to be uncontrolled, and could contain obstructions to HDD construction, including debris, abandoned utilities, cobbles and boulders, and trash. In addition, fill soils located within and adjacent to railway easements may contain contamination which could impact the performance of HDD drill fluid, requiring more frequent replacement. Drill fluid containing contamination may require specialized disposal.
- Glacial Lake Deposits: Glacial Lake Deposits (fine sand, silt, clay) were encountered at numerous HDD crossing locations. Where soft to very soft, fine grained soils are present, squeezing behavior may result in choking of the hole and increased risk of downhole pressure spikes and inadvertent drill fluid returns. Drill fluid additives and frequent hole conditioning may be required to control this behavior. In addition, very soft soils may present difficulties in maintaining the drill tool alignment.
    - In W.O.H materials, it can be common to lose returns without IR, as the formation dilates. However, this may require additional drill fluid volumes and hole conditioning.

9.2 Steering Tools

A downhole steering tool will be required for each HDD to maintain the desired alignment, and offsets from adjacent sensitive structures. Walkover steering tools are not considered appropriate to potential magnetic interference associated adjacent utilities and railroad structures, and (depending on the crossing) the depth of the installation.

9.3 Drill Fluid Pressure Monitoring

The HDD contractor should employ a downhole pressure tool during pilot hole drilling to monitor and the annular drill fluid pressures. This will help maintain pressure levels below an established threshold, reduce risk of IR's, and may provide details on locations where drilling fluid is lost.

9.4 Conduit Laydown and Pullback

As-noted, butt-fused plastic conduit (HDPE) used for cable raceway must be completely assembled and de-beaded prior to pullback. This will require significant work space in each case. The conduit is typically assembled during drilling, and will need to be protected prior to installation.

In each case, pullback of the conduit should be completed without interruption to reduce the risk of the conduit becoming stuck and damaged. We recommend that the conduit be fully water-ballasted to reduce the pullback forces.

10.0 References

American Petroleum Institute (API) API Specification 13A, Specification for Drilling-Fluid Materials - Sixteenth Edition, ANSI/API 13A/ISO 13500, July 2004.

ASTM 1962-20: Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings, ASTM 2005

Kennedy, M., Skinner, G and I Moore, 2004, Elastic Calculations of Limiting Mud Pressures to Control Hydro-fracturing During HDD, NASTT No-Dig 2004 Proceedings.

Mayne, P.W., and Kulhawy, F.H. (1990). Manual on Estimating Soil Properties for Foundation Design. Electric Power Research Institute (EPRI).

Mechanics of Hydraulic Fracturing, 1957, M.K. Hubert and D.W. Willis, Shell Development Co., AIME Petroleum Transactions.

Plastic Pipe Institute, Handbook of PE Pipe - Second Edition, https://plasticpipe.org/publications/pe-handbook.html.

US Army Corps of Engineers EM 1110-2-2902a December 31, 2020, Conduits, Pipes, and Culverts Associated with Dams and Levee Systems.

APPENDIX A
GEOTECHNICAL DATA

APPENDIX B

HDD CALCULATIONS PER CROSSING

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 87B Circuit #1**
South Albany Rd Wetlands

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
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Project No: 322004-000
Print Date: 2-Nov-2022

Revision	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	13+68.35	FT	

Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)

	East	North	Elevation
Entry	666688.6490	1358433.0220	175.70 ft
Horizontal Curve PI	667408.6750	1358419.1130	
Exit	667939.8080	1358009.5460	174.90 ft
Depth to Mudline	1.70 ft	Clearance Depth =	35.50 ft
Measured Plan Length at ties =	1368.3543 ft		
Coordinate Length =	1368.3543 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	149.00 ft
Mudline Elev.*	174.00 ft
Lowest centerline Elev.	138.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start Station	Start Easting	Start Northing	End Station	End Easting	End Northing	End Azimuth	Length	Radius	Angle
Tangent	0+00.00	666688.6490	1358433.0220	3+90.12	667078.6972	1358425.4873	E 091.10667 N	390.12		
Curve	3+90.12	667078.6972	1358425.4873	10+27.69	667670.0334	1358217.5744	E 127.63652 N	637.57	1000.00	36.530 deg.
Tangent	10+27.69	667670.0334	1358217.5744	13+68.35	667939.8080	1358009.5460	E 127.63652 N	340.67		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	390.12	Input Radius, ft.	1000.00	Plan Length, ft.	340.67	
Entry Azimuth, deg.[5]	N 091.10667 E	Curve, deg	36.530 deg.	Exit Azimuth, deg.[5]	N 127.63652 E	
Entry Azimuth, rad.[5]	1.59011	Curve, rad	0.63757	Exit Azimuth, rad.[5]	2.22768	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	626.82	Easting	667939.8080	***Check***
PCH Easting	667078.6972	Arc Length, ft.	637.57	Northing	1358009.5460	***Delta***
PCH Northing	1358425.4873	Chord Azimuth, deg	109.3716			**0.0000**
		PI Easting =	667408.6750			**0.0000**
		PI Northing =	1358419.1130			**OK CALC**
		PTH Easting =	667670.0334			
		PTH Northing =	1358217.5744			**Exit Station**
						13+68.35
Cum Plan Length	390.12	Cum Plan Length	1027.69	Cum Plan Length	1368.354348	**OK STA**

Pull Geometry

Pipe Entry: Exit — Enter the pipe entry location into the hole: Entry/Exit

Segment	Elevations Start	Elevations End	Vertical Angle Start	Vertical Angle End	Δ Angle	Path Length	Curve Radius
Entry Tangent	174.90 ft	162.54 ft	-12.00 deg	-12.00 deg	0.00 deg	59.46 ft	0.00 ft
Entry Curve	162.54 ft	138.50 ft	-12.00 deg	0.00 deg	12.00 deg	230.38 ft	1100.00 ft
Bottom Tangent	138.50 ft	138.50 ft	0.00 deg	0.00 deg	0.00 deg	790.86 ft	0.00 ft
Exit Curve	138.50 ft	162.54 ft	0.00 deg	12.00 deg	12.00 deg	230.38 ft	1100.00 ft
Exit Tangent	162.54 ft	175.70 ft	12.00 deg	12.00 deg	0.00 deg	63.31 ft	0.00 ft
					Total Check =	1374.40 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	290.63	390.12	No, Horiz > Entry V(Tan+Curve)
Exit	286.86	340.67	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		SUMS
Entry Angle	-12.000 deg.	Vertical Radius	1100.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	174.90	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	12.000 deg.	Design Exit Angle	12.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		
Plan Length	61.924 ft	Plan Length	228.703 ft	Plan Length	790.86425 ft	Plan Length	228.703 ft	Plan Length	58.160 ft	1,368.354 ft
Rod Length	63.307 ft	Arc Rod Length	230.383 ft	Rod Length	790.86425 ft	Arc Rod Length	230.383 ft	Rod Length	59.460 ft	1,374.398 ft
Vertical Depth	-13.162 ft	Curve Δ Vert Depth	-24.038 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	24.038 ft	Vertical Depth	12.362 ft	-0.800 ft
		Lowest Elevation	138.500 ft			Lowest Elevation	138.500 ft	CK Total Cum Depth	-0.800 ft	
Start Elevation	175.700 ft	Start Elevation	162.538 ft	Start Elevation	138.500 ft	Start Elevation	138.500 ft	Start Elevation	162.538 ft	
End Elevation	162.538 ft	End Elevation	138.500 ft	End Elevation	138.500 ft	End Elevation	162.538 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	12.000 deg	***Prop. Plan Length***	***1368.354348***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+61.92	Start Station	2+90.63	Start Station	10+81.49	Start Station	13+10.19	**Stationing Check**
PVC Station	0+61.92	PTV Station	2+90.63	PCV Station	10+81.49	PTV Station	13+10.19	Exit Station	13+68.354	**OK STATIONING**
Cum Plan Length	61.92	Cum Plan Length	290.63	Cum Plan Length	1081.49 ft	Cum Plan Length	1310.19	Cum Plan Length	1368.35	**Plan Length Check** / **OK CALCULATION**
Cum Rod Length	63.31	Cum Rod Length	293.69	Cum Rod Length	1084.56 ft	Cum Rod Length	1314.94	Cum Rod Length	1374.40	**Elevation Change Check**
Cum Depth	-13.16	Cum Depth	-37.20	Cum Depth	-37.20 ft	Cum Depth	-13.1624	Cum Depth	-0.80	**OK CALCULATION**

Summary of Drill Calculations

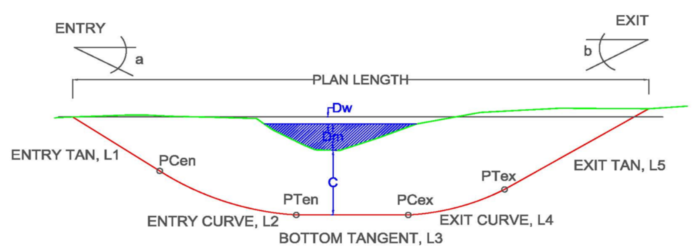
Entry to Exit Elevation Change =	**-0.80 ft**
Minimum Design Elevation =	**138.50 ft**
Invert Depth below exit =	**36.40 ft**
Invert Depth below entry =	**37.20 ft**
Path Length =	**1,374.40 ft**
Plan Length =	**1,368.35 ft**
Minimum Plan Length (No Tangent) =	**577.49 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**12.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

NOTES:
1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs
Indicates status on internal design checks

ISSUE: **Design Review**

BRIERLEY ASSOCIATES Limited Liability Company
"Creating Space Underground"

Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 87B Circuit #1
South Albany Rd Wetlands

Revision 0 TBD

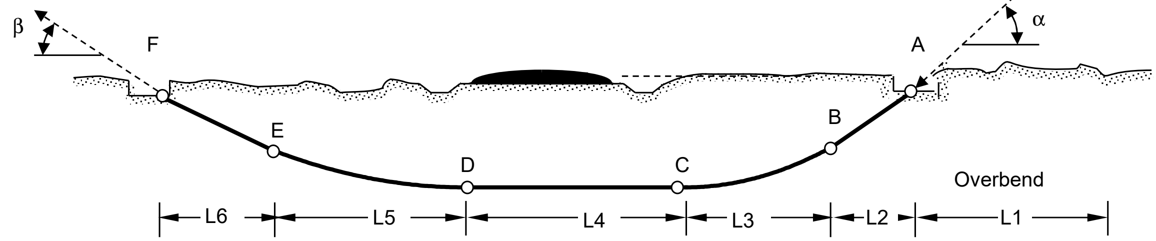
Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	59.5 ft	α =	-12.0 ˚	-0.2094	
L3 =	230.4 ft				1,100.0 ft
L4 =	790.9 ft	χ =	0.0 ˚	0.0000	
L5 =	230.4 ft				1,100.0 ft
L6 =	63.3 ft	β =	12.0 ˚	0.2094	
LT =	1474.4 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 175.70 ft **Pipe Entry El =** 174.90 ft



INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	17.36 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	174.00 ft	
Ballast Water El., H_W =	174.00 ft	
Lowest Invert El., El_m =	138.50 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.64 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.01 Lb/LF	-11.58 Lb/LF

Calculated Pull Force

POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
A	2,614 lb	143 psi	OK	2,614 lb	143 psi	OK	OK	OK
B	3,180 lb	80 psi	OK	3,231 lb	82 psi	OK	OK	OK
C	4,885 lb	158 psi	OK	4,049 lb	137 psi	OK	OK	OK
D	8,359 lb	211 psi	OK	7,524 lb	190 psi	OK	OK	OK
E	13,088 lb	365 psi	OK	10,026 lb	288 psi	OK	OK	OK
F	14,296 lb	361 psi	OK	10,600 lb	267 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, P_{PA} > ΔP invert $P_{PA} = P_AF_R$ = 97.63 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.912631239	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.158786659	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	365 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	3.85	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	19.23	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O$+4"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O$+12"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

ISSUE: Design Review

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"Creating Space Underground"

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87B Circuit #1
South Albany Rd Wetlands

Revision 0

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #1

South Albany Rd Wetlands

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INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi	Test Pressure, P_{TEST}	0 psig — At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 cf/LF	$V_{Di} = \pi*(D_i/2)^2/144$	
HDB =	1,600 psi	Based on PPI Publication TR-4/2015 and ASTM 2837	
Design Factor for HDB, DF =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 psi	HDS = HDB*DF	
Environmental Factor, Af_e =	1	Reference 2: Use for pressure rating only	

Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #1

South Albany Rd Wetlands

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term **Design for operating conditions**

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	37.20 ft	Ballast depth to invert, H_B	36.40 ft	Drill Fluid depth to invert, H_{DF}	36.40 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	15.84 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	19.80 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	20.30 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	15.84 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	87.18 psi	13.12 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	86.67 psi	12.61 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.02 psi	28.96 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.51 psi	28.45 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	91.14 psi	17.08 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #1

South Albany Rd Wetlands

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3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 SPS = π*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**FE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, Ty*f_{temp} =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = Ty*f_{temp}*DF	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, P_{CRR} = P_{CR}*f_r

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	448 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.91263		
r = σ_i/2*(SSAS) =	0.15879	Example from Table T5, σ_i =	365 psi
P_{CRR} =	244.1 psi		
FS =	2.0		
P_{ACRR} = P_{CRR}/FS =	122.0 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1}	118.08 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2}	117.57 psi	Pull Back Condition - C	**OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

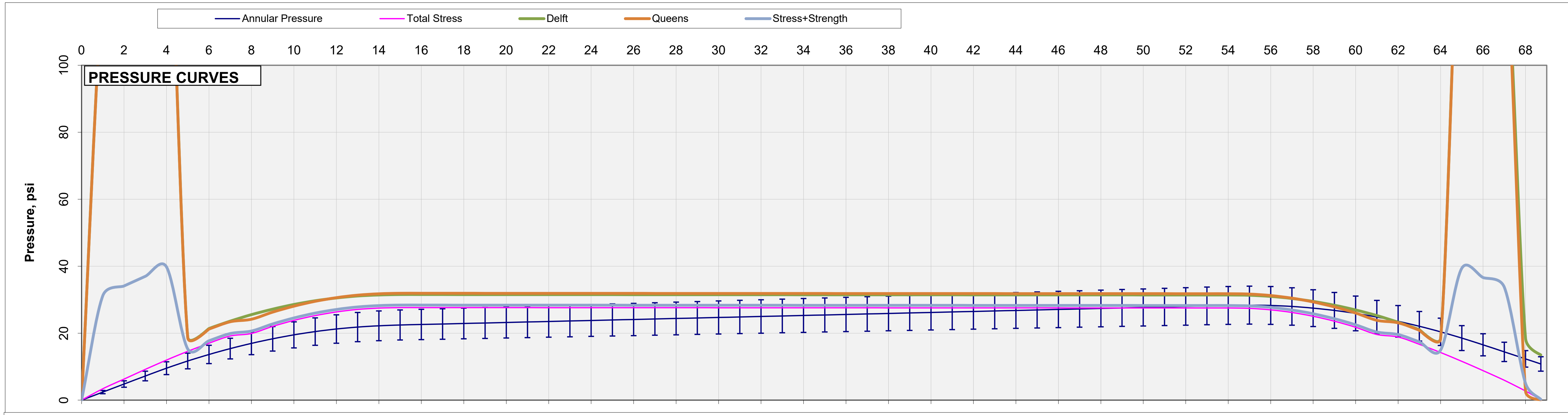
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2

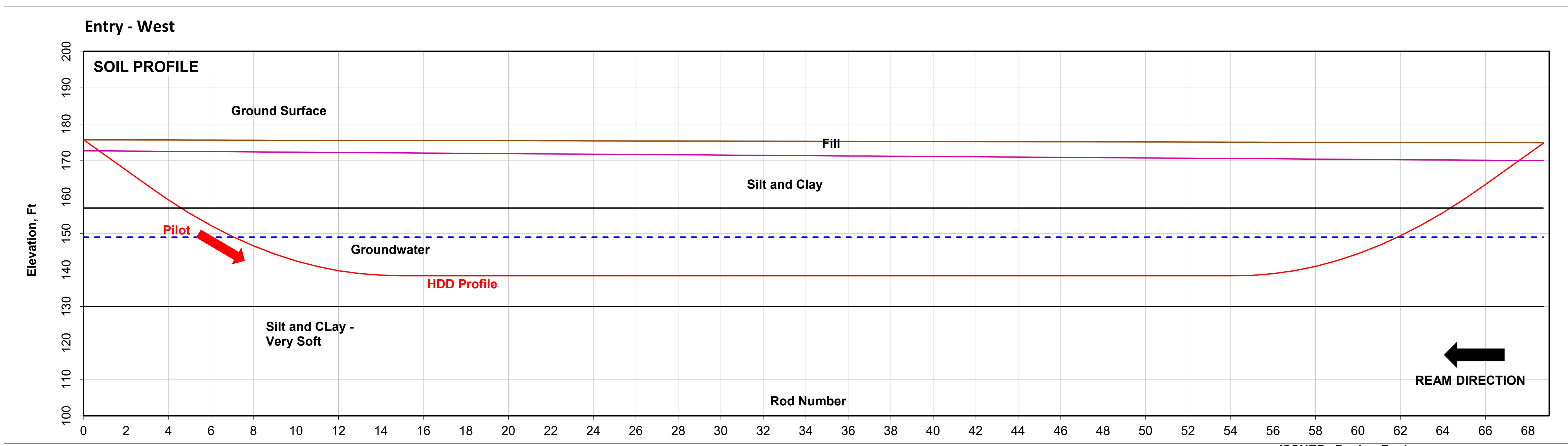
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/[HDD#87B CIR #1_APC_20221025.xlsb]T4 Plastic Stress





ISSUED: Design Review

Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87B Circuit #1
South Albany Rd & Rt 54

Revision 0

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 87B Circuit #2**
South Albany Rd Wetlands

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
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Project No: 322004-000
Print Date: 2-Nov-2022

Revision	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	8+46.04	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	667153.9290	1358436.4480	169.50 ft
Horizontal Curve PI	667517.1360	1358373.9910	
Exit	667896.3270	1358065.1070	174.90 ft
Depth to Mudline	1.50 ft	Clearance Depth =	28.00 ft
Measured Plan Length at ties =	846.0399 ft		
Coordinate Length =	846.0399 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	149.00 ft
Mudline Elev.*	168.00 ft
Lowest centerline Elev.	140.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	667153.9290	1358436.4480	1+06.11	667258.5061	1358418.4649	E 099.75714 N	106.11		
Curve	1+06.11	667258.5061	1358418.4649	6+19.39	667720.6004	1358208.2515	E 129.16581 N	513.28	1000.00	29.409 deg.
Tangent	6+19.39	667720.6004	1358208.2515	8+46.04	667896.3270	1358065.1070	E 129.16581 N	226.65		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	106.11	Input Radius, ft.	1000.00	Plan Length, ft.	226.65	
Entry Azimuth, deg.[5]	N 099.75714 E	Curve, deg	29.409 deg.	Exit Azimuth, deg.[5]	N 129.16581 E	
Entry Azimuth, rad.[5]	1.74109	Curve, rad	0.51328	Exit Azimuth, rad.[5]	2.25437	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	507.66	Easting	667896.3270	***Check***
PCH Easting	667258.5061	Arc Length, ft.	513.28	Northing	1358065.1070	***Delta***
PCH Northing	1358418.4649	Chord Azimuth, deg	114.4615			**0.0000**
		PI Easting =	667517.1360			**0.0000**
		PI Northing =	1358373.9910			**OK CALC**
		PTH Easting =	667720.6004			
		PTH Northing =	1358208.2515			**Exit Station**
						8+46.04
Cum Plan Length	106.11	Cum Plan Length	619.39	Cum Plan Length	846.0399386	**OK STA**

Pull Geometry

Pipe Entry	Exit	Enter the pipe entry location into the hole: Entry/Exit					
	Elevations		Vertical Angle			Path	Curve
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Length**	**Radius**
Entry Tangent	174.90 ft	164.04 ft	-12.00 deg	-12.00 deg	0.00 deg	52.25 ft	0.00 ft
Entry Curve	164.04 ft	140.00 ft	-12.00 deg	0.00 deg	12.00 deg	230.38 ft	1100.00 ft
Bottom Tangent	140.00 ft	140.00 ft	0.00 deg	0.00 deg	0.00 deg	311.83 ft	0.00 ft
Exit Curve	140.00 ft	164.04 ft	0.00 deg	12.00 deg	12.00 deg	230.38 ft	1100.00 ft
Exit Tangent	164.04 ft	169.50 ft	12.00 deg	12.00 deg	0.00 deg	26.27 ft	0.00 ft
					Total Check =	**851.12 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	254.40	106.11	Yes, Horiz < Exit V(Tan+Curve
Exit	279.81	226.65	Yes, Horiz < Exit V(Tan+Curve

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		
Entry Angle	-12.000 deg.	Vertical Radius	1100.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	174.90	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	12.000 deg.	Design Exit Angle	12.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	25.698 ft	Plan Length	228.703 ft	Plan Length	311.83244 ft	Plan Length	228.703 ft	Plan Length	51.103 ft	846.040 ft
Rod Length	26.273 ft	Arc Rod Length	230.383 ft	Rod Length	311.83244 ft	Arc Rod Length	230.383 ft	Rod Length	52.245 ft	851.117 ft
Vertical Depth	-5.462 ft	Curve Δ Vert Depth	-24.038 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	24.038 ft	Vertical Depth	10.862 ft	5.400 ft
		Lowest Elevation	140.000 ft			Lowest Elevation	140.000 ft	CK Total Cum Depth	5.400 ft	
Start Elevation	169.500 ft	Start Elevation	164.038 ft	Start Elevation	140.000 ft	Start Elevation	140.000 ft	Start Elevation	164.038 ft	
End Elevation	164.038 ft	End Elevation	140.000 ft	End Elevation	140.000 ft	End Elevation	164.038 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	12.000 deg	***Prop. Plan Length***	***846.0399386***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+25.70	Start Station	2+54.40	Start Station	5+66.23	Start Station	7+94.94	**Stationing Check** / **OK STATIONING**
PVC Station	0+25.70	PTV Station	2+54.40	PCV Station	5+66.23	PTV Station	7+94.94	Exit Station	8+46.040	**Plan Length Check**
Cum Plan Length	25.70	Cum Plan Length	254.40	Cum Plan Length	566.23 ft	Cum Plan Length	794.94	Cum Plan Length	846.04	**OK CALCULATION**
Cum Rod Length	26.27	Cum Rod Length	256.66	Cum Rod Length	568.49 ft	Cum Rod Length	798.87	Cum Rod Length	851.12	**Elevation Change Check**
Cum Depth	-5.46	Cum Depth	-29.50	Cum Depth	-29.50 ft	Cum Depth	-5.4624	Cum Depth	5.40	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**5.40 ft**
Minimum Design Elevation =	**140.00 ft**
Invert Depth below exit =	**34.90 ft**
Invert Depth below entry =	**29.50 ft**
Path Length =	**851.12 ft**
Plan Length =	**846.04 ft**
Minimum Plan Length (No Tangent) =	**534.21 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**12.00 deg**
Compound Curve at Entry =	**740 ft**
Compound Curve at Exit =	**740 ft**

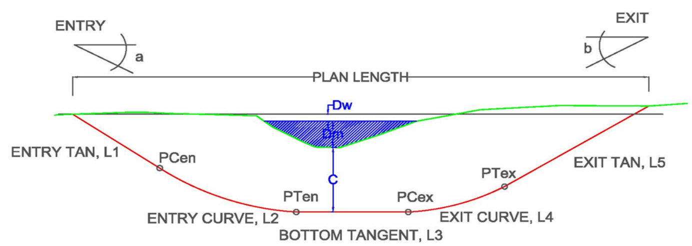
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

ISSUE: **Design Review**

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"Creating Space Underground"

Brierley Associates
167 S. River Road, Suite 8
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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 87B Circuit #2
South Albany Rd Wetlands

Revision 0 TBD

Pull Geometry

Lengths (Path)	Angles			Radius, R
L1 = 100.0 ft	Overbend	deg	radian	500.0 ft
L2 = 52.2 ft	α =	-12.0 ˚	-0.2094	
L3 = 230.4 ft				1,100.0 ft
L4 = 311.8 ft	χ =	0.0 ˚	0.0000	
L5 = 230.4 ft				1,100.0 ft
L6 = 26.3 ft	β =	12.0 ˚	0.2094	
LT = 951.1 ft				

INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	Pipe	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	10.75	Pipe or Bundle	
Pipe Dry Weight, W_P =	15.68 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	8.22 in	Bundle Multiplier F_D	1.0000
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	169.00 ft	
Ballast Water El., H_W =	169.00 ft	
Lowest Invert El., El_m =	140.00 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	33.77 in	
Wall Section Area, A_W	37.70738915	
Volume Outside, V_{DO}	0.630 cf/LF	
Volume Inside, V_{DI}	0.368 cf/LF	
q_d =	2.03 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.77 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

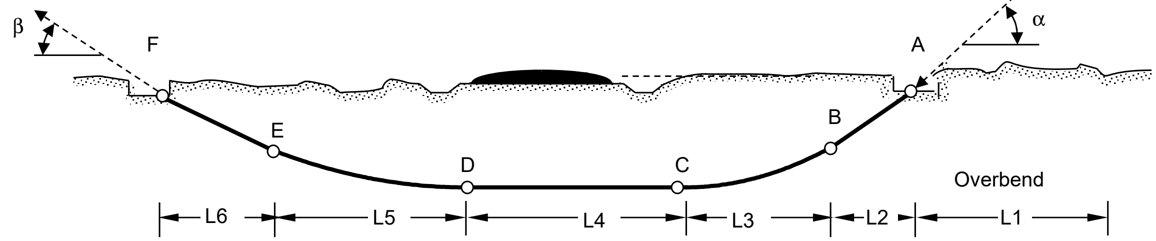
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.68 Lb/LF	38.67 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.48 Lb/LF	-10.49 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 169.50 ft

Pipe Entry El = 174.90 ft



POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
	Calculated Pull Force							
A	1,523 lb	101 psi	OK	1,523 lb	101 psi	OK	OK	OK
B	1,901 lb	53 psi	OK	1,921 lb	54 psi	OK	OK	OK
C	3,294 lb	118 psi	OK	2,511 lb	97 psi	OK	OK	OK
D	4,205 lb	117 psi	OK	3,422 lb	95 psi	OK	OK	OK
E	8,203 lb	255 psi	OK	5,407 lb	177 psi	OK	OK	OK
F	8,663 lb	242 psi	OK	5,619 lb	157 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_AF_R$ = 100.73 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.941644171	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.111008727	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	255 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	3.14	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	15.71	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87B Circuit #2
South Albany Rd Wetlands

Brierley Associates
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Revision 0

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #2

South Albany Rd Wetlands

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INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi		Test Pressure, P_{TEST} 0 psig At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification			Design resin with minimum PENT test of 10,000 hours
Standard Dimension	10		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	8.219 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	1.194 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	35.85681985		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	405.27 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.630 cf/LF		$V_{Do} = \pi*(D_o/2)^2/144$
Unit Inside Volume, V_{Di} =	0.368 cf/LF		$V_{Di} = \pi*(D_i/2)^2/144$
HDB =	1,600 psi		Based on PPI Publication TR-4/2015 and ASTM 2837
Design Factor for HDB, DF =	0.63		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	1008 psi		HDS = HDB*DF
Environmental Factor, Af_e =	1		Reference 2: Use for pressure rating only
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	15.68	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-33.48 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.74 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.67 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.49 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.75 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.99 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	49.16 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	50.42 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #2

South Albany Rd Wetlands

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, ^oF =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, ^oF =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	34.90 ft	Ballast depth to invert, H_B	29.50 ft	Drill Fluid depth to invert, H_{DF}	29.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	12.98 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	16.22 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	16.64 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	12.98 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	90.75 psi	16.69 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	90.34 psi	16.28 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.73 psi	29.67 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.31 psi	29.26 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.00 psi	19.94 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

TABLE 4 **Pg 3 of 3**

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HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #2

South Albany Rd Wetlands

3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, $DF = f_T*f_Y$	0.4	**FE PULL STRENTH, SPS =**	**16,064 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	40,160 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	$SAS = Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	16,064 lb	**Useing SSAS =**	**41,235 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR}*f_r$

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	448 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.94164		
$r = \sigma_i/2*(SSAS)$ =	0.11101	Example from Table T5, σ_i =	255 psi
P_{CRR} =	251.8 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	125.9 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	122.67 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	122.26 psi	Pull Back Condition - C	**OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

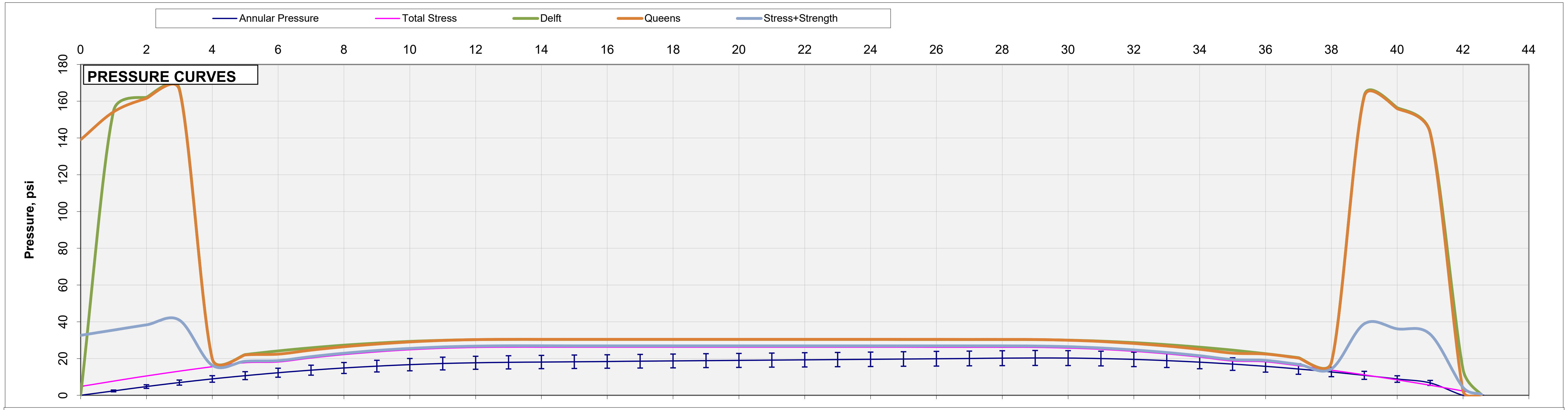
Design Factor (fe) to apply to HDB

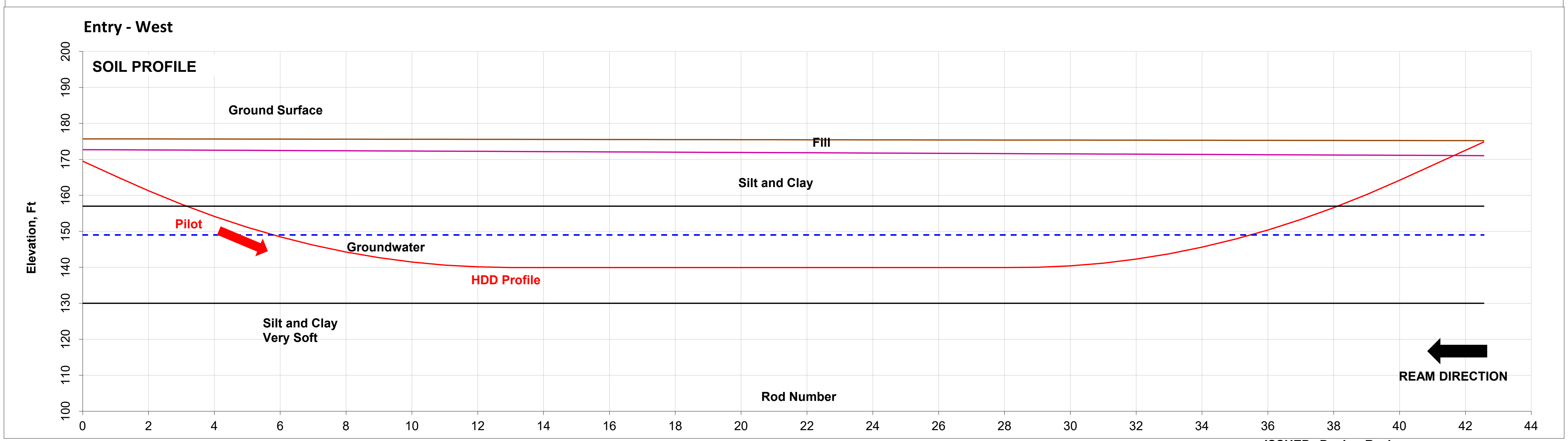
CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24





ISSUED: Design Review

Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 11/3/2022 8:30

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87B Circuit #2
South Albany Rd & Rt 54

Revision 0

FIGURE 1

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 88 Circuit #1**
Wetlands Crossing

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
167 S. River Road, Suite 8
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Project No: 322004-000
Print Date: 2-Nov-2022

Date	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	14+66.36	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	669912.3610	1352972.7580	164.00 ft
Horizontal Curve PI	670589.5950	1353253.6580	
Exit	671266.8300	1353534.5580	175.70 ft
Depth to Mudline	1.00 ft	Clearance Depth =	68.60 ft
Measured Plan Length at ties =	1466.3579 ft		
Coordinate Length =	1466.3579 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	153.00 ft
Mudline Elev.*	163.00 ft
Lowest centerline Elev.	94.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start Station	Start Easting	Start Northing	End Station	End Easting	End Northing	End Azimuth	Length	Radius	Angle
Tangent	0+00.00	669912.3610	1352972.7580	7+33.18	670589.5950	1353253.6580	E 067.47253 N	733.18		
Curve	7+33.18	670589.5950	1353253.6580	7+33.18	670589.5950	1353253.6580	E 067.47256 N	0.00	0.00	0.000 deg.
Tangent	7+33.18	670589.5950	1353253.6580	14+66.36	671266.8300	1353534.5580	E 067.47256 N	733.18		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	733.18	Input Radius, ft.	0.00	Plan Length, ft.	733.18	
Entry Azimuth, deg.[5]	N 067.47253 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 067.47256 E	
Entry Azimuth, rad.[5]	1.17762	Curve, rad	0.00000	Exit Azimuth, rad.[5]	1.17762	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	671266.8300	**Check**
PCH Easting	670589.5950	Arc Length, ft.	0.00	Northing	1353534.5580	**Delta**
PCH Northing	1353253.6580	Chord Azimuth, deg	67.4725			**0.0000**
		PI Easting =	670589.5950			**0.0000**
		PI Northing =	1353253.6580			**OK CALC**
		PTH Easting =	670589.5950			
		PTH Northing =	1353253.6580			**Exit Station**
						14+66.36
Cum Plan Length	733.18	Cum Plan Length	733.18	Cum Plan Length	1466.357907	**OK STA**

Pull Geometry

Pipe Entry: Exit — Enter the pipe entry location into the hole: Entry/Exit

Segment	Elevations Start	Elevations End	Vertical Angle Start	Vertical Angle End	Δ Angle	Path Length	Curve Radius
Entry Tangent	175.70 ft	112.63 ft	-10.00 deg	-10.00 deg	0.00 deg	363.20 ft	0.00 ft
Entry Curve	112.63 ft	94.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	94.40 ft	94.40 ft	0.00 deg	0.00 deg	0.00 deg	446.73 ft	0.00 ft
Exit Curve	94.40 ft	120.62 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	120.62 ft	164.00 ft	12.00 deg	12.00 deg	0.00 deg	208.63 ft	0.00 ft
					Total Check =	1479.33 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry			No, Horiz > Entry V(Tan+Curve)
Exit			No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	175.70	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	204.073 ft	Plan Length	249.494 ft	Plan Length	446.72896 ft	Plan Length	208.378 ft	Plan Length	357.684 ft	1,466.358 ft
Rod Length	208.632 ft	Arc Rod Length	251.327 ft	Rod Length	446.72896 ft	Arc Rod Length	209.440 ft	Rod Length	363.202 ft	1,479.330 ft
Vertical Depth	-43.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	63.069 ft	11.700 ft
		Lowest Elevation	94.400 ft			Lowest Elevation	94.400 ft	CK Total Cum Depth	11.700 ft	
Start Elevation	164.000 ft	Start Elevation	120.623 ft	Start Elevation	94.400 ft	Start Elevation	94.400 ft	Start Elevation	112.631 ft	
End Elevation	120.623 ft	End Elevation	94.400 ft	End Elevation	94.400 ft	End Elevation	112.631 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*1466.357907*	

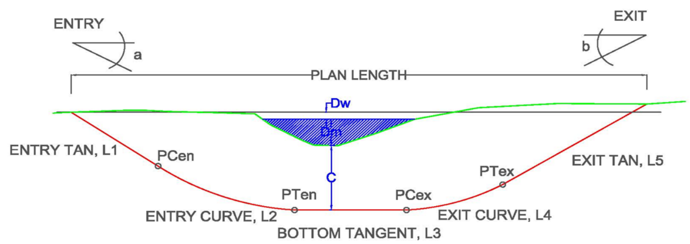
SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	2+04.07	Start Station	4+53.57	Start Station	9+00.30	Start Station	11+08.67	**Stationing Check** / **OK STATIONING**
PVC Station	2+04.07	PTV Station	4+53.57	PCV Station	9+00.30	PTV Station	11+08.67	Exit Station	14+66.358	**Plan Length Check**
Cum Plan Length	204.07	Cum Plan Length	453.57	Cum Plan Length	900.30 ft	Cum Plan Length	1108.67	Cum Plan Length	1466.36	**OK CALCULATION**
Cum Rod Length	208.63	Cum Rod Length	459.96	Cum Rod Length	906.69 ft	Cum Rod Length	1116.13	Cum Rod Length	1479.33	**Elevation Change Check**
Cum Depth	-43.38	Cum Depth	-69.60	Cum Depth	-69.60 ft	Cum Depth	-51.3693	Cum Depth	11.70	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	11.70 ft
Minimum Design Elevation =	94.40 ft
Invert Depth below exit =	81.30 ft
Invert Depth below entry =	69.60 ft
Path Length =	1,479.33 ft
Plan Length =	1,466.36 ft
Minimum Plan Length (No Tangent) =	1,019.63 ft
Entry Angle =	-12.00 deg
Exit Angle =	10.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	NO

NOTES:
1. Sign convention for angles - positive (+) angles are counterclockwise. Due East is defined as 0 degrees.
0
0
4. All calculation locations represent the center of the drill hole.



Indicates inputs
Indicates status on internal design checks

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 88 Circuit #1
Wetlands Crossing

Revision 0 TBD

Pull Geometry

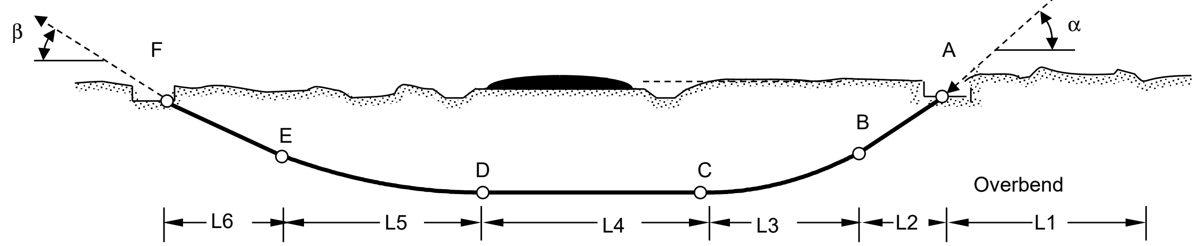
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	363.2 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	446.7 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	208.6 ft	β =	12.0 °	0.2094	
LT =	1579.3 ft				

Pipe Entry Location - Drill: **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 164.00 ft

Pipe Entry El = 175.70 ft



INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	17.36 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	163.00 ft	
Ballast Water El., H_W =	163.00 ft	
Lowest Invert El., El_m =	94.40 ft	

Calculated Pull Force

POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
A	2,790 lb	148 psi	OK	2,790 lb	148 psi	OK	OK	OK
B	5,836 lb	147 psi	OK	6,372 lb	161 psi	OK	OK	OK
C	7,622 lb	224 psi	OK	7,280 lb	216 psi	OK	OK	OK
D	8,979 lb	226 psi	OK	8,637 lb	218 psi	OK	OK	OK
E	14,124 lb	388 psi	OK	11,385 lb	319 psi	OK	OK	OK
F	18,498 lb	467 psi	OK	13,413 lb	338 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 94.62 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.88446413	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.202861709	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	467 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	7.43	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	37.16	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O$+4"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O$+12"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.60 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 88 Circuit #1
Wetlands Crossing

Revision 0

HDPE PROPERTIES

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HDD 88 Circuit #1

Wetlands Crossing

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INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi	Test Pressure, P_{TEST} 0 psig	At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 cf/LF	$V_{Di} = \pi*(D_i/2)^2/144$	
HDB =	1,600 psi	Based on PPI Publication TR-4/2015 and ASTM 2837	
Design Factor for HDB, DF =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 psi	HDS = HDB*DF	
Environmental Factor, Af_e =	1	Reference 2: Use for pressure rating only	
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

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Schenectady County, NY

HDD 88 Circuit #1

Wetlands Crossing

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	81.30 ft	Ballast depth to invert, H_B	69.60 ft	Drill Fluid depth to invert, H_{DF}	69.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	30.22 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	37.78 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	38.75 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	30.22 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	69.20 psi	-4.86 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	68.23 psi	-5.83 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	99.42 psi	25.36 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	98.45 psi	24.39 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	76.75 psi	2.69 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

HDPE PROPERTIES

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Schenectady County, NY

HDD 88 Circuit #1

Wetlands Crossing

3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi * DF * (Ty) * D_o^2 * ((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = $f_T * f_Y$	0.4	**FE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty * f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty * f_{temp} * DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR} * f_r$

(ASTM F-1962 EQ. 22)

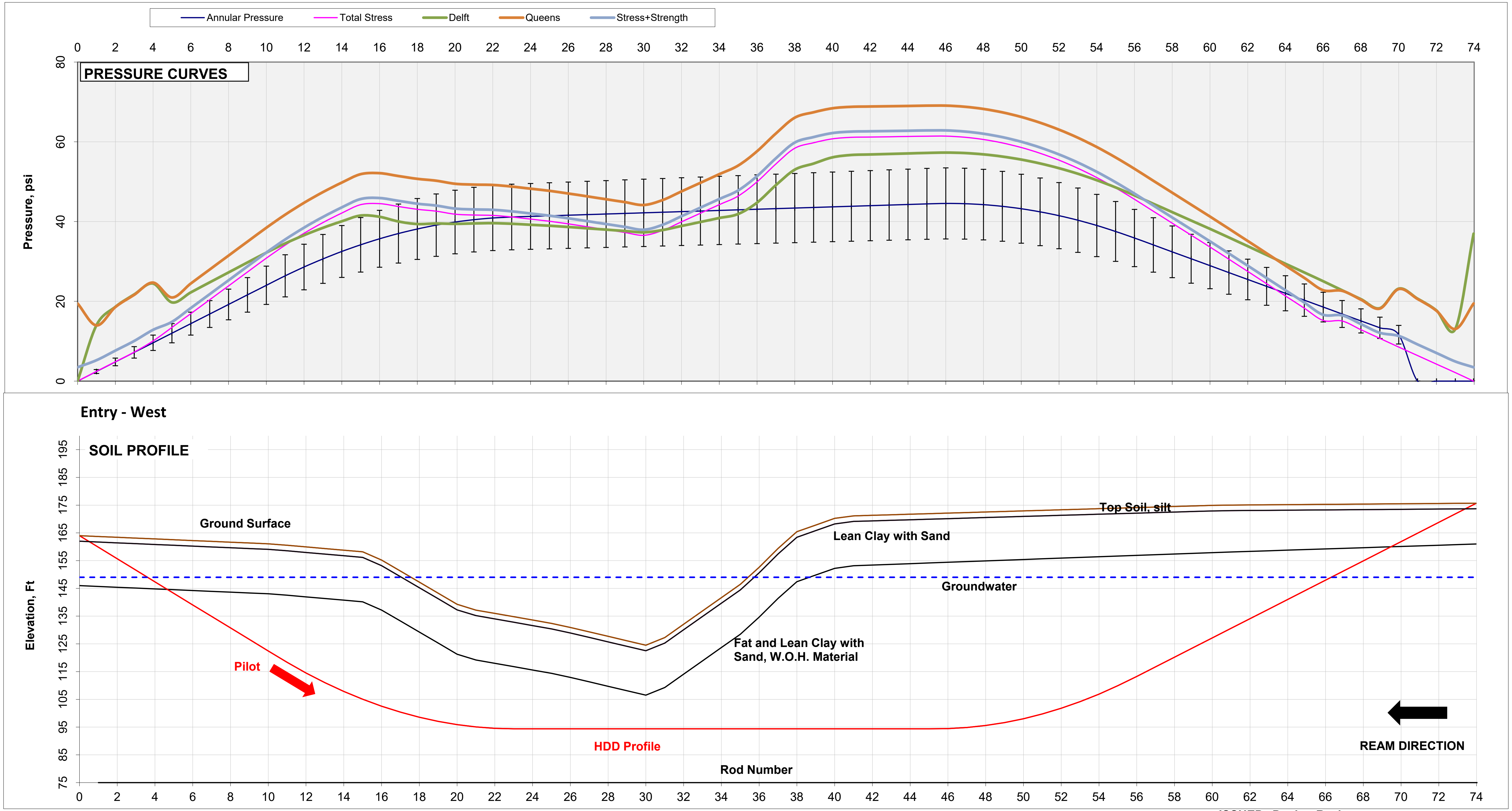
Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	448 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.88446		
r = σ_i/2*(SSAS) =	0.20286	Example from Table T5, σ_i =	467 psi
P_{CRR} =	236.5 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	118.3 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	110.71 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	109.74 psi	Pull Back Condition - C	**OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24



ISSUED: Design Review

Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 11/3/2022 8:31

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 88 Circuit #1
Coeyman's Creek

Revision 0

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 88 Circuit #2**
Wetlands Crossing

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
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Project No: 322004-000
Print Date: 2-Nov-2022

Date	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	14+67.09	FT

Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)

	East	North	Elevation
Entry	669904.6160	1352991.2610	164.00 ft
Horizontal Curve PI	670582.2020	1353272.2750	
Exit	671259.7880	1353553.2890	175.70 ft
Depth to Mudline	1.00 ft	Clearance Depth =	68.60 ft
Measured Plan Length at ties =	1467.0946 ft		
Coordinate Length =	1467.0946 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	153.00 ft
Mudline Elev.*	163.00 ft
Lowest centerline Elev.	94.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start Station	Start Easting	Start Northing	End Station	End Easting	End Northing	End Azimuth	Length	Radius	Angle
Tangent	0+00.00	669904.6160	1352991.2610	7+33.55	670582.2020	1353272.2750	E 067.47484 N	733.55		
Curve	7+33.55	670582.2020	1353272.2750	7+33.55	670582.2020	1353272.2750	E 067.47484 N	0.00	0.00	0.000 deg.
Tangent	7+33.55	670582.2020	1353272.2750	14+67.09	671259.7880	1353553.2890	E 067.47484 N	733.55		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	733.55	Input Radius, ft.	0.00	Plan Length, ft.	733.55	
Entry Azimuth, deg.[5]	N 067.47484 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 067.47484 E	
Entry Azimuth, rad.[5]	1.17766	Curve, rad	0.00000	Exit Azimuth, rad.[5]	1.17766	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	671259.7880	**Check**
PCH Easting	670582.2020	Arc Length, ft.	0.00	Northing	1353553.2890	**Delta**
PCH Northing	1353272.2750	Chord Azimuth, deg	67.4748			**0.0000**
		PI Easting =	670582.2020			**0.0000**
		PI Northing =	1353272.2750			**OK CALC**
		PTH Easting =	670582.2020			
		PTH Northing =	1353272.2750			**Exit Station 14+67.09**
Cum Plan Length	733.55	Cum Plan Length	733.55	Cum Plan Length	1467.094619	**OK STA**

Pull Geometry

Pipe Entry	Exit	Enter the pipe entry location into the hole: Entry/Exit					
	Elevations		Vertical Angle			Path	Curve
Segment	Start	End	Start	End	Δ Angle	Length	Radius
Entry Tangent	175.70 ft	112.63 ft	-10.00 deg	-10.00 deg	0.00 deg	363.20 ft	0.00 ft
Entry Curve	112.63 ft	94.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	94.40 ft	94.40 ft	0.00 deg	0.00 deg	0.00 deg	447.47 ft	0.00 ft
Exit Curve	94.40 ft	120.62 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	120.62 ft	164.00 ft	12.00 deg	12.00 deg	0.00 deg	208.63 ft	0.00 ft
					Total Check =	1480.07 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry			No, Horiz > Entry V(Tan+Curve)
Exit			No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		SUMS
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	175.70	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	204.073 ft	Plan Length	249.494 ft	Plan Length	447.46567 ft	Plan Length	208.378 ft	Plan Length	357.684 ft	1,467.095 ft
Rod Length	208.632 ft	Arc Rod Length	251.327 ft	Rod Length	447.46567 ft	Arc Rod Length	209.440 ft	Rod Length	363.202 ft	1,480.067 ft
Vertical Depth	-43.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	63.069 ft	11.700 ft
		Lowest Elevation	94.400 ft			Lowest Elevation	94.400 ft	CK Total Cum Depth	11.700 ft	
Start Elevation	164.000 ft	Start Elevation	120.623 ft	Start Elevation	94.400 ft	Start Elevation	94.400 ft	Start Elevation	112.631 ft	
End Elevation	120.623 ft	End Elevation	94.400 ft	End Elevation	94.400 ft	End Elevation	112.631 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*1467.094619*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	2+04.07	Start Station	4+53.57	Start Station	9+01.03	Start Station	11+09.41	**Stationing Check** / **OK STATIONING**
PVC Station	2+04.07	PTV Station	4+53.57	PCV Station	9+01.03	PTV Station	11+09.41	Exit Station	14+67.095	**Plan Length Check**
Cum Plan Length	204.07	Cum Plan Length	453.57	Cum Plan Length	901.03 ft	Cum Plan Length	1109.41	Cum Plan Length	1467.09	**OK CALCULATION**
Cum Rod Length	208.63	Cum Rod Length	459.96	Cum Rod Length	907.43 ft	Cum Rod Length	1116.87	Cum Rod Length	1480.07	**Elevation Change Check**
Cum Depth	-43.38	Cum Depth	-69.60	Cum Depth	-69.60 ft	Cum Depth	-51.3693	Cum Depth	11.70	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**11.70 ft**
Minimum Design Elevation =	**94.40 ft**
Invert Depth below exit =	**81.30 ft**
Invert Depth below entry =	**69.60 ft**
Path Length =	**1,480.07 ft**
Plan Length =	**1,467.09 ft**
Minimum Plan Length (No Tangent) =	**1,019.63 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

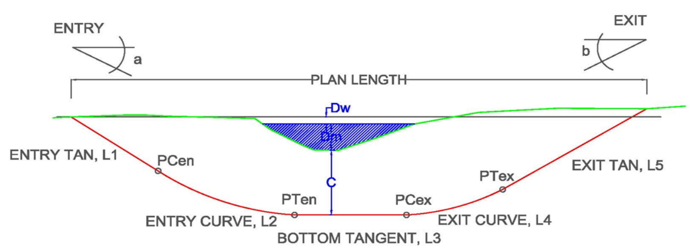
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

ISSUE: **Design Review**

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 88 Circuit #2
Wetlands Crossing

Revision 0 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	363.2 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	447.5 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	208.6 ft	β =	12.0 °	0.2094	
LT =	1580.1 ft				

INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	15.68 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	1.0000
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf	
Drill Fluid Density	78	pcf	*Estimated for pull*
Drill fluid elevation, H_F =	163.00 ft		
Ballast Water El., H_W =	163.00 ft		
Lowest Invert El., El_m =	94.40 ft		

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	37.70738915	
Volume Outside, V_{DO}	0.630 cf/LF	
Volume Inside, V_{DI}	0.368 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.60 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

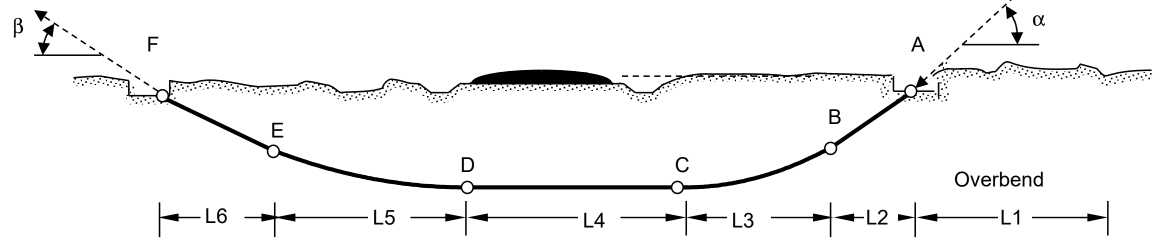
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.68 Lb/LF	38.67 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.48 Lb/LF	-10.49 Lb/LF

Pipe Entry Location - Drill | **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 164.00 ft

Pipe Entry El = 175.70 ft



Calculated Pull Force							ASSESS	
POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	F_x < SPS Air	F_x < SPS Ballast
A	2,521 lb	148 psi	OK	2,521 lb	148 psi	OK	OK	OK
B	5,196 lb	145 psi	OK	5,680 lb	158 psi	OK	OK	OK
C	6,864 lb	224 psi	OK	6,556 lb	215 psi	OK	OK	OK
D	8,094 lb	226 psi	OK	7,785 lb	217 psi	OK	OK	OK
E	12,813 lb	390 psi	OK	10,337 lb	321 psi	OK	OK	OK
F	16,821 lb	469 psi	OK	12,225 lb	341 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 94.53 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.883696398	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.204033434	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	469 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	7.43	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	37.16	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O$+4"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O$+12"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

ISSUE: Design Review

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 88 Circuit #2
Wetlands Crossing

Revision 0

TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 88 Circuit #2
Wetlands Crossing

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INPUTS
Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi	Test Pressure, P_{TEST} 0 psig	At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	10		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	8.219 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	1.194 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	35.85681985	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	405.27 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.630 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.368 cf/LF	$V_{Di} = \pi*(D_i/2)^2/144$	
HDB =	1,600 psi	Based on PPI Publication TR-4/2015 and ASTM 2837	
Design Factor for HDB, DF =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 psi	HDS = HDB*DF	
Environmental Factor, Af_e =	1	Reference 2: Use for pressure rating only	
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	15.68	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-33.48 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.74 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.67 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.49 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.75 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.99 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	49.16 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	50.42 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 88 Circuit #2

Wetlands Crossing

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	81.30 ft	Ballast depth to invert, H_B	69.60 ft	Drill Fluid depth to invert, H_{DF}	69.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	30.35 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	37.94 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	38.92 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	30.35 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	69.03 psi	-5.03 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	68.06 psi	-6.00 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	99.39 psi	25.33 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	98.41 psi	24.35 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	76.62 psi	2.56 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 88 Circuit #2

Wetlands Crossing

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3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 SPS = π*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**AFE PULL STRENTH, SPS =**	**16,064 lb**	
Temperature factor, f_{temp} =	1	Jltimate Pull Strength, UPS =	40,160 lb	
Temp Corr Tensile Yield, Ty*f_{temp} =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = Ty*f_{temp}*DF	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	16,064 lb	**Useing SSAS =**	**41,235 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, P_{CRR} = P_{CR}*f_r

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	448 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.88370		
r = σ_i/2*(SSAS) =	0.20403	Example from Table T5, σ_i =	469 psi
P_{CRR} =	236.3 psi		
FS =	2.0		
P_{ACRR} = P_{CRR}/FS =	118.2 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1}	110.58 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2}	109.61 psi	Pull Back Condition - C	**OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

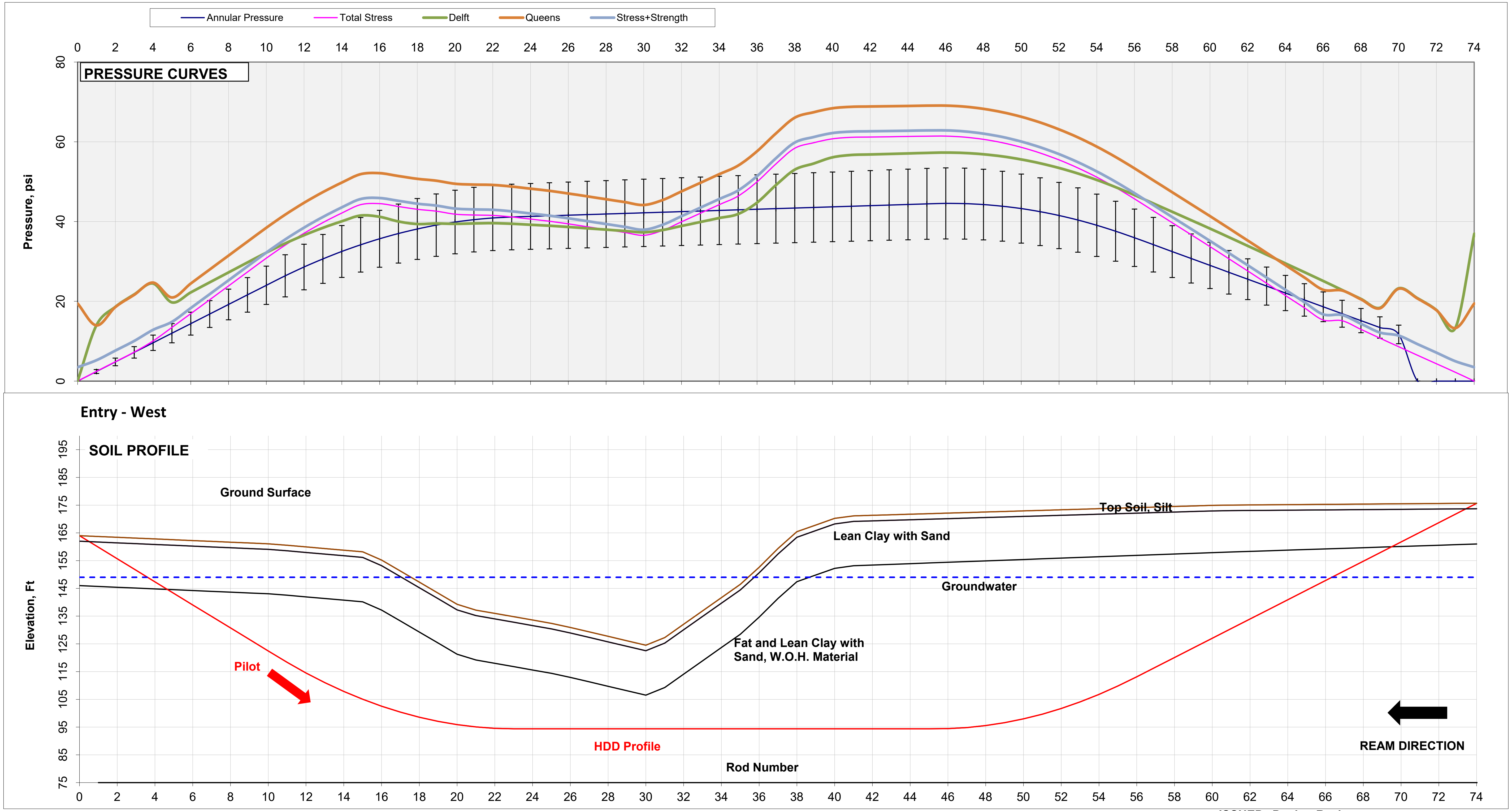
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24



ISSUED: Design Review

Notes:
1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 88 Circuit #2
Coeyman's Creek

Revision 0

FIGURE 1

BRIERLEY ASSOCIATES
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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 89 Circuit #1**
Wetlands Crossing

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
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Project No: 322004-000
Print Date: 2-Nov-2022

Date	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	25+50.00	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	674059.411000	1352073.916000	159.40 ft
Horizontal Curve PI	673243.793000	1352891.563000	
Exit	671989.784000	1353515.982000	174.70 ft
Depth to Mudline	1.40 ft	Clearance Depth =	44.50 ft
Measured Plan Length at ties =	2550.0007 ft		
Coordinate Length =	2550.0007 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	152.00 ft
Mudline Elev.*	158.00 ft
Lowest centerline Elev.	113.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	674059.4110	1352073.9160	8+27.37	673475.1005	1352659.6801	E 315.07118 N	827.37		
Curve	8+27.37	673475.1005	1352659.6801	14+76.66	672950.6041	1353037.5530	E 296.47047 N	649.29	2000.00	-18.601 deg.
Tangent	14+76.66	672950.6041	1353037.5530	25+50.00	671989.7840	1353515.9820	E 296.47047 N	1073.35		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	827.37	Input Radius, ft.	2000.00	Plan Length, ft.	1073.35	
Entry Azimuth, deg.[5]	N 315.07118 E	Curve, deg	-18.601 deg.	Exit Azimuth, deg.[5]	N 296.47047 E	
Entry Azimuth, rad.[5]	5.49903	Curve, rad	-0.32464	Exit Azimuth, rad.[5]	5.17439	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	646.44	Easting	671989.7840	**Check**
PCH Easting	673475.1005	Arc Length, ft.	649.29	Northing	1353515.9820	**Delta**
PCH Northing	1352659.6801	Chord Azimuth, deg	305.7708			**0.0000**
		PI Easting =	673243.7930			**0.0000**
		PI Northing =	1352891.5630			**OK CALC**
		PTH Easting =	672950.6041			
		PTH Northing =	1353037.5530			**Exit Station**
						25+50.00
Cum Plan Length	827.37	Cum Plan Length	1476.66	Cum Plan Length	2550.000667	**OK STA**

Pull Geometry

Pipe Entry: ENTRY — Enter the pipe entry location into the hole: Entry/Exit

Segment	Elevations Start	Elevations End	Vertical Angle Start	Vertical Angle End	Δ Angle	Path Length	Curve Radius
Entry Tangent	159.40 ft	139.72 ft	-12.00 deg	-12.00 deg	0.00 deg	94.64 ft	0.00 ft
Entry Curve	139.72 ft	113.50 ft	-12.00 deg	0.00 deg	12.00 deg	251.33 ft	1200.00 ft
Bottom Tangent	113.50 ft	113.50 ft	0.00 deg	0.00 deg	0.00 deg	1755.86 ft	0.00 ft
Exit Curve	113.50 ft	131.73 ft	0.00 deg	10.00 deg	10.00 deg	209.44 ft	1200.00 ft
Exit Tangent	131.73 ft	174.70 ft	10.00 deg	10.00 deg	0.00 deg	247.45 ft	0.00 ft
					Total Check =	2558.72 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	342.07	827.37	No, Horiz > Entry V(Tan+Curve)
Exit	452.07	1073.35	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		SUMS
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	174.70	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	92.574 ft	Plan Length	249.494 ft	Plan Length	1,755.86422 ft	Plan Length	208.378 ft	Plan Length	243.691 ft	2,550.001 ft
Rod Length	94.642 ft	Arc Rod Length	251.327 ft	Rod Length	1,755.86422 ft	Arc Rod Length	209.440 ft	Rod Length	247.450 ft	2,558.723 ft
Vertical Depth	-19.677 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	42.969 ft	15.300 ft
		Lowest Elevation	113.500 ft			Lowest Elevation	113.500 ft	CK Total Cum Depth	15.300 ft	
Start Elevation	159.400 ft	Start Elevation	139.723 ft	Start Elevation	113.500 ft	Start Elevation	113.500 ft	Start Elevation	131.731 ft	
End Elevation	139.723 ft	End Elevation	113.500 ft	End Elevation	113.500 ft	End Elevation	131.731 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*2550.000667*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+92.57	Start Station	3+42.07	Start Station	20+97.93	Start Station	23+06.31	Stationing Check OK STATIONING
PVC Station	0+92.57	PTV Station	3+42.07	PCV Station	20+97.93	PTV Station	23+06.31	Exit Station	25+50.001	Plan Length Check OK CALCULATION
Cum Plan Length	92.57	Cum Plan Length	342.07	Cum Plan Length	2097.93 ft	Cum Plan Length	2306.31	Cum Plan Length	2550.00	
Cum Rod Length	94.64	Cum Rod Length	345.97	Cum Rod Length	2101.83 ft	Cum Rod Length	2311.27	Cum Rod Length	2558.72	Elevation Change Check OK CALCULATION
Cum Depth	-19.68	Cum Depth	-45.90	Cum Depth	-45.90 ft	Cum Depth	-27.6693	Cum Depth	15.30	

Summary of Drill Calculations

Entry to Exit Elevation Change =	15.30 ft
Minimum Design Elevation =	113.50 ft
Invert Depth below exit =	61.20 ft
Invert Depth below entry =	45.90 ft
Path Length =	2,558.72 ft
Plan Length =	2,550.00 ft
Minimum Plan Length (No Tangent) =	794.14 ft
Entry Angle =	-12.00 deg
Exit Angle =	10.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	NO

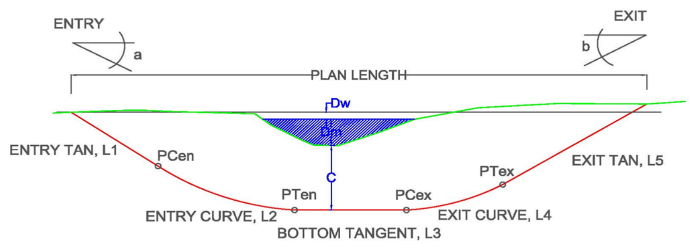
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 89 Circuit #1
Wetlands Crossing

Revision 0 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	94.6 ft	α =	-12.0 ˚	-0.2094	
L3 =	251.3 ft				1,200.0 ft
L4 =	1755.9 ft	χ =	0.0 ˚	0.0000	
L5 =	209.4 ft				1,200.0 ft
L6 =	247.5 ft	β =	10.0 ˚	0.1745	
LT =	2658.7 ft				

INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	17.36 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	158.00 ft	
Ballast Water El., H_W =	158.00 ft	
Lowest Invert El., El_m =	113.50 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.34 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

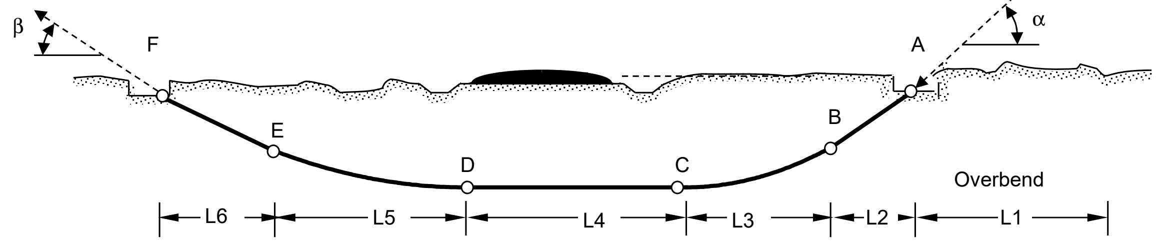
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 174.70 ft

Pipe Entry El = 159.40 ft



Calculated Pull Force							ASSESS	
POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	F_x < SPS Air	Ballast
A	4,713 lb	196 psi	OK	4,713 lb	196 psi	OK	OK	OK
B	5,593 lb	141 psi	OK	5,674 lb	143 psi	OK	OK	OK
C	7,567 lb	223 psi	OK	6,682 lb	201 psi	OK	OK	OK
D	15,848 lb	400 psi	OK	14,964 lb	377 psi	OK	OK	OK
E	20,274 lb	544 psi	OK	17,479 lb	473 psi	OK	OK	OK
F	23,718 lb	598 psi	OK	19,307 lb	487 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_AF_R$ = 90.48 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.845769381	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.26010996	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	598 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	4.82	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	24.10	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 89 Circuit #1
Wetlands Crossing

Revision 0

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 89 Circuit #1

Wetlands Crossing

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INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi		Test Pressure, P_{TEST}: 0 psig — At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification			Design resin with minimum PENT test of 10,000 hours
Standard Dimension	3		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	2.680 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	0.389 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	3.80093926		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.067 cf/LF		$V_{Do} = \pi*(D_o/2)^2/144$
Unit Inside Volume, V_{Di} =	0.039 cf/LF		$V_{Di} = \pi*(D_i/2)^2/144$
HDB =	1,600 psi		Based on PPI Publication TR-4/2015 and ASTM 2837
Design Factor for HDB, DF =	0.63		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	1008 psi		HDS = HDB*DF
Environmental Factor, Af_e =	1		Reference 2: Use for pressure rating only
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

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HDD 89 Circuit #1

Wetlands Crossing

1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	61.20 ft	Ballast depth to invert, H_B	45.90 ft	Drill Fluid depth to invert, H_{DF}	45.90 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	19.95 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	24.94 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.58 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	19.95 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	82.03 psi	7.97 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.39 psi	7.33 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.99 psi	27.93 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.35 psi	27.29 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	87.02 psi	12.96 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 89 Circuit #1

Wetlands Crossing

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3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**FE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	$SAS = Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR}*f_r$

(ASTM F-1962 EQ. 22)

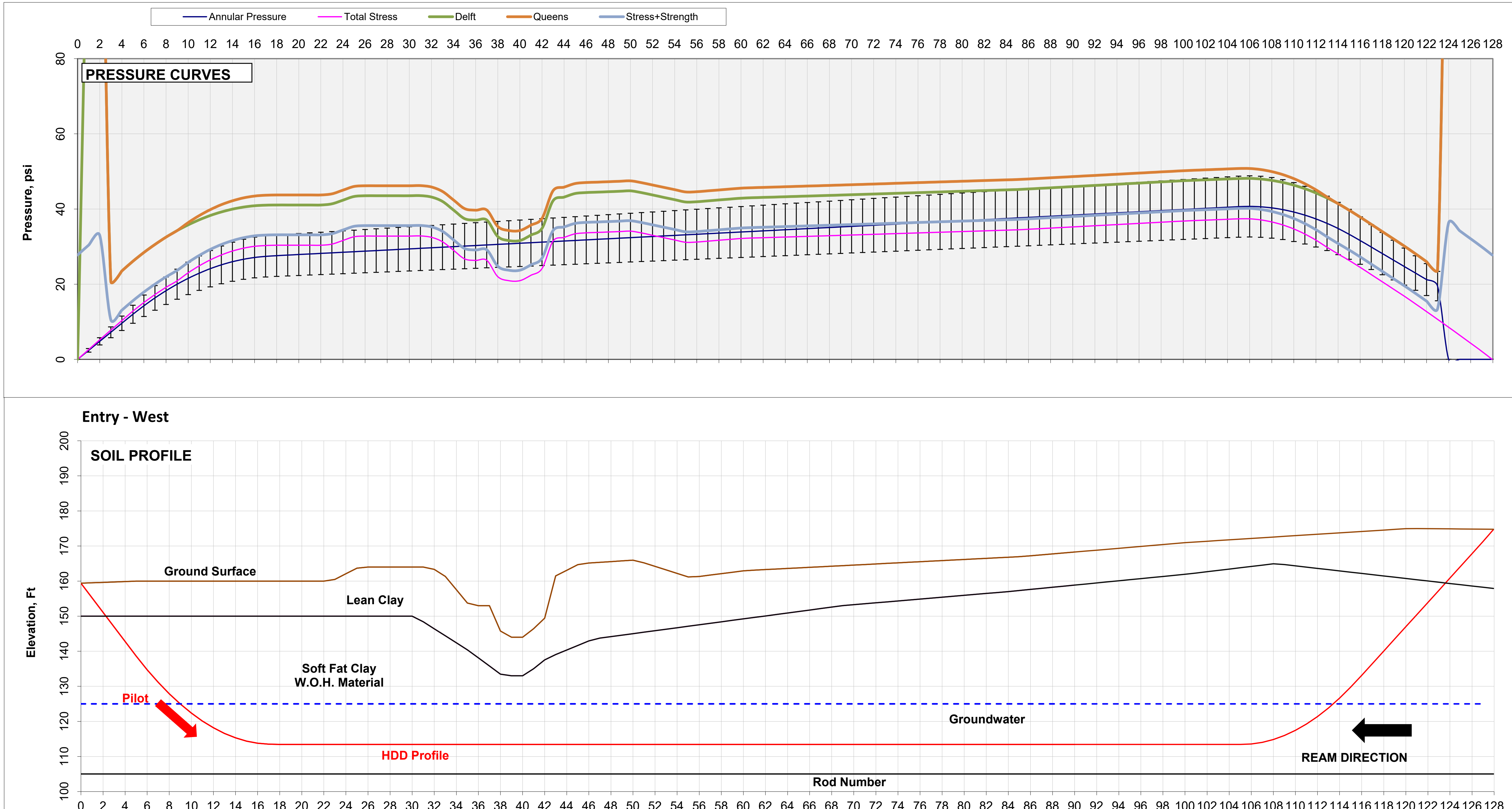
Pull Duration Time =	12 Hr		Pcr =	267.4 psi
SAS =	448 psi		Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum		
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.84577			
$r = \sigma_i/2*(SSAS)$ =	0.26011		Example from Table T5, σ_i =	598 psi
P_{CRR} =	226.2 psi			
FS =	2.0			
$P_{ACRR} = P_{CRR}/FS$ =	113.1 psi	Allowable Reduced Short Term Buckling pressure during pull		
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	108.11 psi	Pull Back Condition - C	**OK as >0**	
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	107.47 psi	Pull Back Condition - C	**OK as >0**	

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24



ISSUED: Design Review

Notes:
1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 11/3/2022 8:43

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 89 Circuit #1
Wetlands Crossing

Revision 0

FIGURE 1

BRIERLEY ASSOCIATES
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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 89 Circuit #2**
Wetlands Crossing

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
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Project No: 322004-000
Print Date: 2-Nov-2022

Date	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	25+55.39	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	674071.228000	1352090.502000	159.70 ft
Horizontal Curve PI	673242.167000	1352924.022000	
Exit	671997.902000	1353534.435000	175.00 ft
Depth to Mudline	1.70 ft	Clearance Depth =	44.40 ft
Measured Plan Length at ties =	2555.3888 ft		
Coordinate Length =	2555.3888 ft		
OK-HORIZONTAL CURVE			

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	125.00 ft
Mudline Elev.*	158.00 ft
Lowest centerline Elev.	113.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	674071.2280	1352090.5020	8+40.55	673478.4676	1352686.4505	E 315.15367 N	840.55		
Curve	8+40.55	673478.4676	1352686.4505	15+04.54	672941.3381	1353071.6030	E 296.13170 N	663.99	2000.00	-19.022 deg.
Tangent	15+04.54	672941.3381	1353071.6030	25+55.39	671997.9020	1353534.4350	E 296.13170 N	1050.85		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	840.55	Input Radius, ft.	2000.00	Plan Length, ft.	1050.85	
Entry Azimuth, deg.[5]	N 315.15367 E	Curve, deg	-19.022 deg.	Exit Azimuth, deg.[5]	N 296.13170 E	
Entry Azimuth, rad.[5]	5.50047	Curve, rad	-0.33200	Exit Azimuth, rad.[5]	5.16847	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	660.95	Easting	671997.9020	***Check***
PCH Easting	673478.4676	Arc Length, ft.	663.99	Northing	1353534.4350	***Delta***
PCH Northing	1352686.4505	Chord Azimuth, deg	305.6427			**0.0000**
		PI Easting =	673242.1670			**0.0000**
		PI Northing =	1352924.0220			**OK CALC**
		PTH Easting =	672941.3381			
		PTH Northing =	1353071.6030			**Exit Station 25+55.39**
Cum Plan Length	840.55	Cum Plan Length	1504.54	Cum Plan Length	2555.388793	**OK STA**

Pull Geometry

Pipe Entry: **ENTRY** — **Enter the pipe entry location into the hole: Entry/Exit**

	Elevations		Vertical Angle			Path	Curve
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Length**	**Radius**
Entry Tangent	159.70 ft	139.82 ft	-12.00 deg	-12.00 deg	0.00 deg	95.60 ft	0.00 ft
Entry Curve	139.82 ft	113.60 ft	-12.00 deg	0.00 deg	12.00 deg	251.33 ft	1200.00 ft
Bottom Tangent	113.60 ft	113.60 ft	0.00 deg	0.00 deg	0.00 deg	1759.18 ft	0.00 ft
Exit Curve	113.60 ft	131.83 ft	0.00 deg	10.00 deg	10.00 deg	209.44 ft	1200.00 ft
Exit Tangent	131.83 ft	175.00 ft	10.00 deg	10.00 deg	0.00 deg	248.60 ft	0.00 ft
					Total Check =	**2564.15 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	343.01	840.55	No, Horiz > Entry V(Tan+Curve)
Exit	453.20	1050.85	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	175.00	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	93.515 ft	Plan Length	249.494 ft	Plan Length	1,759.17716 ft	Plan Length	208.378 ft	Plan Length	244.825 ft	2,555.389 ft
Rod Length	95.604 ft	Arc Rod Length	251.327 ft	Rod Length	1,759.17716 ft	Arc Rod Length	209.440 ft	Rod Length	248.602 ft	2,564.150 ft
Vertical Depth	-19.877 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	43.169 ft	15.300 ft
		Lowest Elevation	113.600 ft			Lowest Elevation	113.600 ft	CK Total Cum Depth	15.300 ft	
Start Elevation	159.700 ft	Start Elevation	139.823 ft	Start Elevation	113.600 ft	Start Elevation	113.600 ft	Start Elevation	131.831 ft	
End Elevation	139.823 ft	End Elevation	113.600 ft	End Elevation	113.600 ft	End Elevation	131.831 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***2555.388793***	

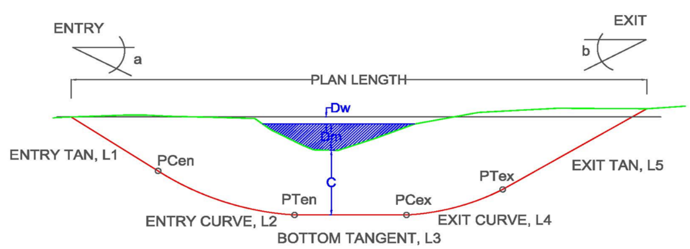
SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+93.51	Start Station	3+43.01	Start Station	21+02.19	Start Station	23+10.56	**Stationing Check** **OK STATIONING**
PVC Station	0+93.51	PTV Station	3+43.01	PCV Station	21+02.19	PTV Station	23+10.56	Exit Station	25+55.389	**Plan Length Check**
Cum Plan Length	93.51	Cum Plan Length	343.01	Cum Plan Length	2102.19 ft	Cum Plan Length	2310.56	Cum Plan Length	2555.39	**OK CALCULATION**
Cum Rod Length	95.60	Cum Rod Length	346.93	Cum Rod Length	2106.11 ft	Cum Rod Length	2315.55	Cum Rod Length	2564.15	**Elevation Change Check**
Cum Depth	-19.88	Cum Depth	-46.10	Cum Depth	-46.10 ft	Cum Depth	-27.8693	Cum Depth	15.30	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**15.30 ft**
Minimum Design Elevation =	**113.60 ft**
Invert Depth below exit =	**61.40 ft**
Invert Depth below entry =	**46.10 ft**
Path Length =	**2,564.15 ft**
Plan Length =	**2,555.39 ft**
Minimum Plan Length (No Tangent) =	**796.21 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

NOTES:
1. Sign convention for angles - positive (+) angles are counterclockwise.
 Due East is defined as 0 degrees.
0
 0
4. All calculation locations represent the center of the drill hole.



Indicates inputs
Indicates status on internal design checks

ISSUE: **Design Review**

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"Creating Space Underground"
Brierley Associates
167 S. River Road, Suite 8
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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 89 Circuit #2
Wetlands Crossing

Revision 0 TBD

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/[HDD#89 CIR #2_APC_20221101.xlsb]Inputs

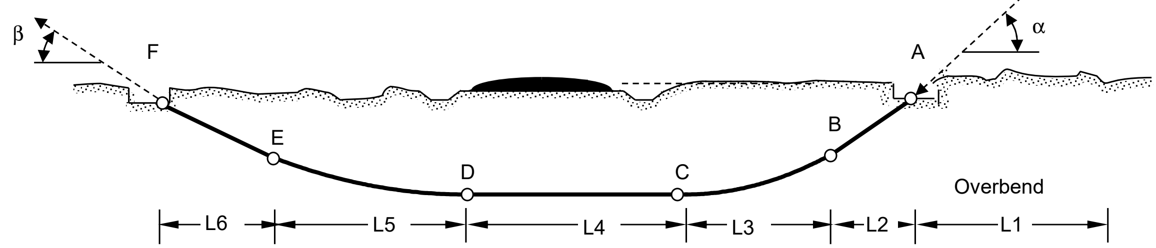
Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	95.6 ft	α =	-12.0 ˚	-0.2094	
L3 =	251.3 ft				1,200.0 ft
L4 =	1759.2 ft	χ =	0.0 ˚	0.0000	
L5 =	209.4 ft				1,200.0 ft
L6 =	248.6 ft	β =	10.0 ˚	0.1745	
LT =	2664.1 ft				

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 175.00 ft **Pipe Entry El =** 159.70 ft



INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	17.36 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	158.00 ft	
Ballast Water El., H_W =	158.00 ft	
Lowest Invert El., El_m =	113.60 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.34 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.01 Lb/LF	-11.58 Lb/LF

Calculated Pull Force

POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
A	4,723 lb	196 psi	OK	4,723 lb	196 psi	OK	OK	OK
B	5,606 lb	141 psi	OK	5,688 lb	143 psi	OK	OK	OK
C	7,581 lb	223 psi	OK	6,696 lb	201 psi	OK	OK	OK
D	15,878 lb	401 psi	OK	14,993 lb	378 psi	OK	OK	OK
E	20,305 lb	544 psi	OK	17,510 lb	474 psi	OK	OK	OK
F	23,744 lb	599 psi	OK	19,340 lb	488 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 90.45 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.845565582	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.260402117	r = $\sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	599 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	4.81	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	24.05	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

ISSUE: Design Review

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Limited Liability Company
"Creating Space Underground"

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 89 Circuit #2
Wetlands Crossing

Revision 0

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 89 Circuit #2

Wetlands Crossing

BRIERLEY ASSOCIATES Limited Liability Company "Creating Space Underground"

INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi		Test Pressure, P_{TEST} 0 psig At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification			Design resin with minimum PENT test of 10,000 hours
Standard Dimension	3		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	2.680 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	0.389 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	3.80093926		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.067 cf/LF		$V_{Do} = \pi*(D_o/2)^2/144$
Unit Inside Volume, V_{Di} =	0.039 cf/LF		$V_{Di} = \pi*(D_i/2)^2/144$
HDB =	1,600 psi		Based on PPI Publication TR-4/2015 and ASTM 2837
Design Factor for HDB, DF =	0.63		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	1008 psi		HDS = HDB*DF
Environmental Factor, Af_e =	1		Reference 2: Use for pressure rating only
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 89 Circuit #2

Wetlands Crossing

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	61.40 ft	Ballast depth to invert, H_B	46.10 ft	Drill Fluid depth to invert, H_{DF}	46.10 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	20.04 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	25.05 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.69 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	20.04 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	81.93 psi	7.87 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.28 psi	7.22 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.96 psi	27.91 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.32 psi	27.26 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	86.94 psi	12.88 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

TABLE 4 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

BRIERLEY ASSOCIATES Limited Liability Company

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HDD 89 Circuit #2

Wetlands Crossing

3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**FE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR}*f_r$

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr		Pcr =	267.4 psi
SAS =	448 psi		Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum		
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.84557			
r = σ_i/2*(SSAS) =	0.26040		Example from Table T5, σ_i =	599 psi
P_{CRR} =	226.1 psi			
FS =	2.0			
$P_{ACRR} = P_{CRR}/FS$ =	113.1 psi	Allowable Reduced Short Term Buckling pressure during pull		
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	108.06 psi	Pull Back Condition - C	**OK as >0**	
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	107.42 psi	Pull Back Condition - C	**OK as >0**	

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

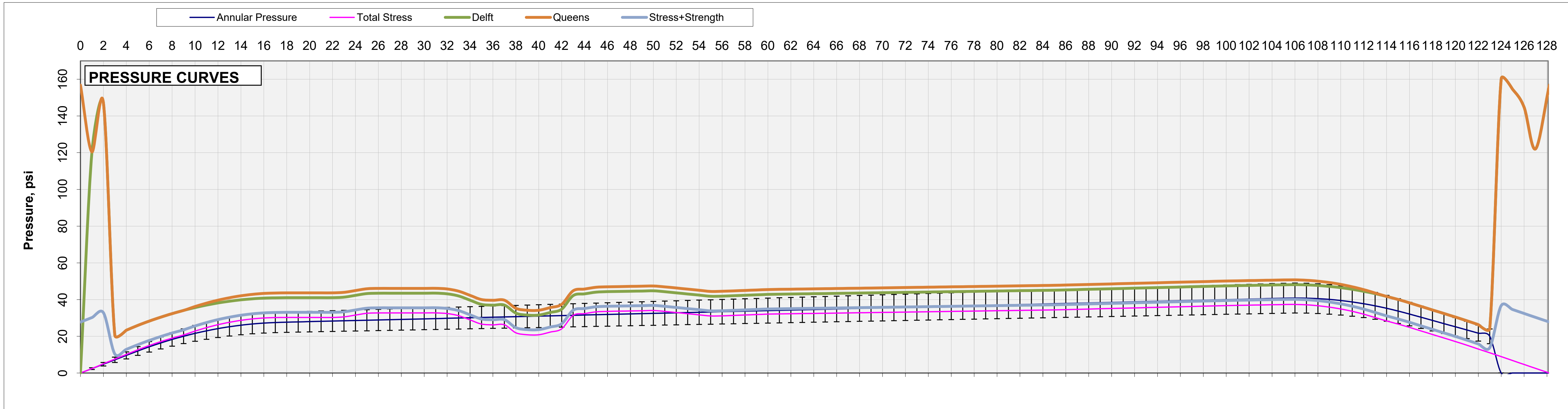
Design Factor (fe) to apply to HDB

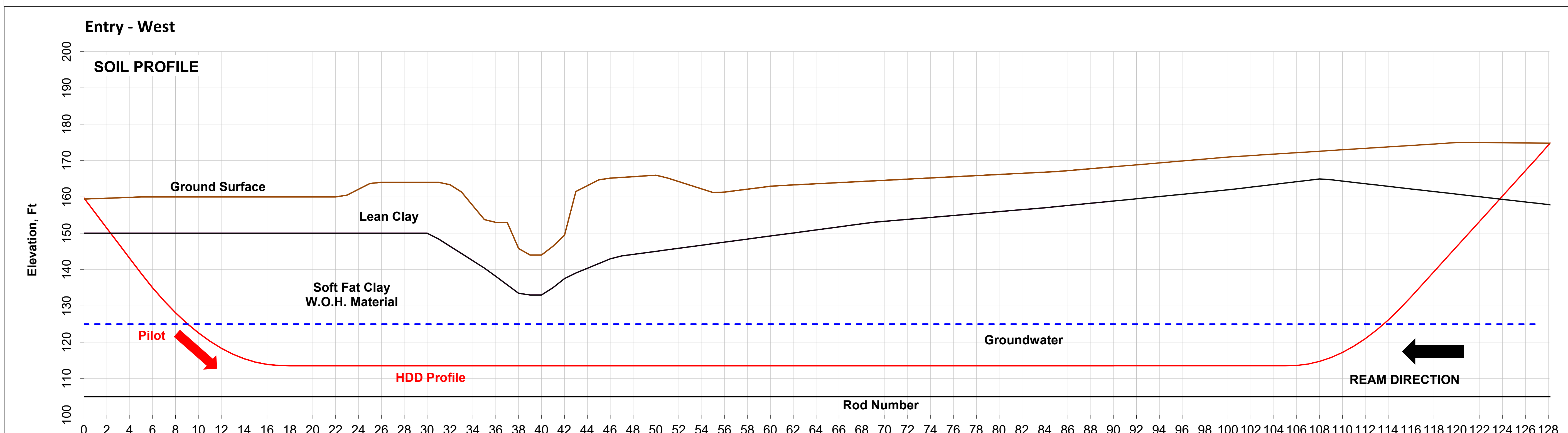
CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24





Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

ISSUED: Design Review

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 11/3/2022 8:44

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 89 Circuit #2
Wetlands Crossing

Revision 0

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 90 Circuit #1**
Bridge Street

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

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Project No: 322004-000
Print Date: 2-Nov-2022

Date	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	12+92.45	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	675577.4160	1350672.4560	156.50 ft
Horizontal Curve PI	675004.6580	1351031.8530	
Exit	674615.2080	1351514.1970	157.80 ft
Depth to Mudline	0.50 ft	Clearance Depth =	57.70 ft
Measured Plan Length at ties =	1292.4478 ft		
Coordinate Length =	1292.4478 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	152.00 ft
Mudline Elev.*	156.00 ft
Lowest centerline Elev.	98.30 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	675577.4160	1350672.4560	4+75.64	675174.5232	1350925.2651	E 302.10765 N	475.64		
Curve	4+75.64	675174.5232	1350925.2651	8+73.04	674878.6796	1351187.8806	E 321.08220 N	397.40	1200.00	18.975 deg.
Tangent	8+73.04	674878.6796	1351187.8806	12+92.45	674615.2080	1351514.1970	E 321.08220 N	419.40		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	475.64	Input Radius, ft.	1200.00	Plan Length, ft.	419.40	
Entry Azimuth, deg.[5]	N 302.10765 E	Curve, deg	18.975 deg.	Exit Azimuth, deg.[5]	N 321.08220 E	
Entry Azimuth, rad.[5]	5.27277	Curve, rad	0.33117	Exit Azimuth, rad.[5]	5.60394	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	395.59	Easting	674615.2080	**Check**
PCH Easting	675174.5232	Arc Length, ft.	397.40	Northing	1351514.1970	**Delta**
PCH Northing	1350925.2651	Chord Azimuth, deg	311.5949			**0.0000**
		PI Easting =	675004.6580			**0.0000**
		PI Northing =	1351031.8530			**OK CALC**
		PTH Easting =	674878.6796			
		PTH Northing =	1351187.8806			**Exit Station**
						12+92.45
Cum Plan Length	475.64	Cum Plan Length	873.04	Cum Plan Length	1292.447788	**OK STA**

Pull Geometry

Pipe Entry: ENTRY — Enter the pipe entry location into the hole: Entry/Exit

Segment	Elevations Start	Elevations End	Vertical Angle Start	Vertical Angle End	Δ Angle	Path Length	Curve Radius
Entry Tangent	156.50 ft	128.00 ft	-14.00 deg	-14.00 deg	0.00 deg	117.79 ft	0.00 ft
Entry Curve	128.00 ft	98.30 ft	-14.00 deg	0.00 deg	14.00 deg	244.35 ft	1000.00 ft
Bottom Tangent	98.30 ft	98.30 ft	0.00 deg	0.00 deg	0.00 deg	511.31 ft	0.00 ft
Exit Curve	98.30 ft	113.49 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	113.49 ft	157.80 ft	10.00 deg	10.00 deg	0.00 deg	255.16 ft	0.00 ft
					Total Check =	1303.13 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	356.21	475.64	No, Horiz > Entry V(Tan+Curve)
Exit	424.93	419.40	Yes, Horiz < Exit V(Tan+Curve

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		SUMS
Entry Angle	-14.000 deg.	Vertical Radius	1000.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	157.80	
		Vert. Curve, deg.	14.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	114.290 ft	Plan Length	241.922 ft	Plan Length	511.30585 ft	Plan Length	173.648 ft	Plan Length	251.282 ft	1,292.448 ft
Rod Length	117.789 ft	Arc Rod Length	244.346 ft	Rod Length	511.30585 ft	Arc Rod Length	174.533 ft	Rod Length	255.158 ft	1,303.132 ft
Vertical Depth	-28.496 ft	Curve Δ Vert Depth	-29.704 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	44.308 ft	1.300 ft
		Lowest Elevation	98.300 ft			Lowest Elevation	98.300 ft	CK Total Cum Depth	1.300 ft	
Start Elevation	156.500 ft	Start Elevation	128.004 ft	Start Elevation	98.300 ft	Start Elevation	98.300 ft	Start Elevation	113.492 ft	
End Elevation	128.004 ft	End Elevation	98.300 ft	End Elevation	98.300 ft	End Elevation	113.492 ft	Ck Exit Elevation		
End Vert Angle	-14.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*1292.447788*	

Summary of Drill Calculations

Entry to Exit Elevation Change =	1.30 ft
Minimum Design Elevation =	98.30 ft
Invert Depth below exit =	59.50 ft
Invert Depth below entry =	58.20 ft
Path Length =	1,303.13 ft
Plan Length =	1,292.45 ft
Minimum Plan Length (No Tangent) =	781.14 ft
Entry Angle =	-14.00 deg
Exit Angle =	10.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	768 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+14.29	Start Station	3+56.21	Start Station	8+67.52	Start Station	10+41.17	**Stationing Check**
PVC Station	1+14.29	PTV Station	3+56.21	PCV Station	8+67.52	PTV Station	10+41.17	Exit Station	12+92.448	**OK STATIONING**
Cum Plan Length	114.29	Cum Plan Length	356.21	Cum Plan Length	867.52 ft	Cum Plan Length	1041.17	Cum Plan Length	1292.45	**Plan Length Check**
Cum Rod Length	117.79	Cum Rod Length	362.14	Cum Rod Length	873.44 ft	Cum Rod Length	1047.97	Cum Rod Length	1303.13	**OK CALCULATION**
Cum Depth	-28.50	Cum Depth	-58.20	Cum Depth	-58.20 ft	Cum Depth	-43.0078	Cum Depth	1.30	**Elevation Change Check**
										OK CALCULATION

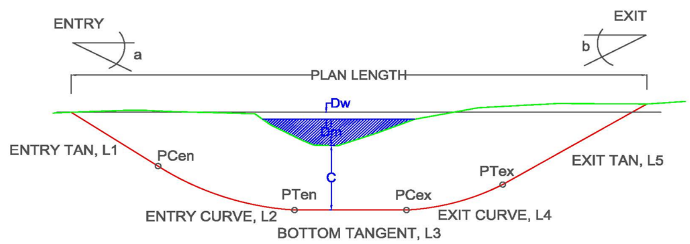
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



(yellow)	Indicates inputs
(orange)	Indicates status on internal design checks

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 90 Circuit #1
Bridge Street

Revision 0 TBD

Pull Geometry

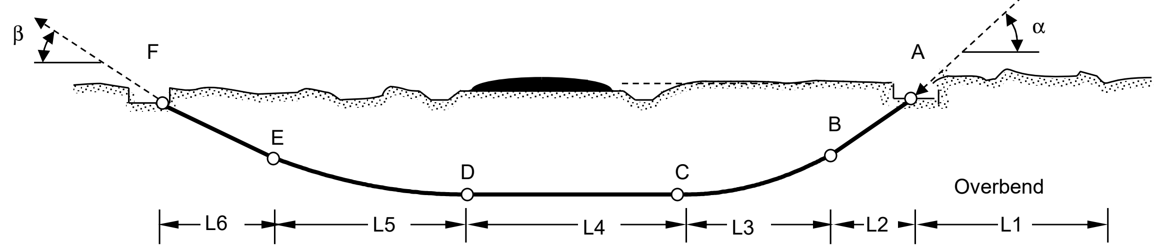
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	117.8 ft	α =	-14.0 °	-0.2443	
L3 =	244.3 ft				1,000.0 ft
L4 =	511.3 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	255.2 ft	β =	10.0 °	0.1745	
LT =	1403.1 ft				

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 157.80 ft

Pipe Entry El = 156.50 ft



INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE
Material Density, γ	59.28 pcf	
Outside Diameter, D_{OD}	14.25	Pipe or Bundle
Pipe Dry Weight, W_P =	17.34 lb/ft	Pipe or Bundle
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75 inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D 0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F
Poisson Ratio, μ =	0.45	
Ovality Factor, f_o =	0.84	2%
Buckling Safety, N =	2.5	
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	157.00 ft	
Ballast Water El., H_W =	157.00 ft	
Lowest Invert El., El_m =	98.30 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.68 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

	Pipe Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.34 Lb/LF	42.78 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.03 Lb/LF	-11.60 Lb/LF

Calculated Pull Force

POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
A	2,493 lb	140 psi	OK	2,493 lb	140 psi	OK	OK	OK
B	4,033 lb	102 psi	OK	4,035 lb	102 psi	OK	OK	OK
C	5,760 lb	184 psi	OK	4,928 lb	163 psi	OK	OK	OK
D	7,513 lb	190 psi	OK	6,681 lb	169 psi	OK	OK	OK
E	10,952 lb	315 psi	OK	8,524 lb	254 psi	OK	OK	OK
F	16,034 lb	404 psi	OK	10,930 lb	276 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 96.48 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.901892388	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.175845454	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	404 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	6.36	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	31.80	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 90 Circuit #1
Bridge Street

Revision 0

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #1

Bridge Street

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INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi		Test Pressure, P_{TEST} 0 psig At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification			Design resin with minimum PENT test of 10,000 hours
Standard Dimension	3		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	2.680 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	0.389 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	3.80093926		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.067 cf/LF		$V_{Do} = \pi*(D_o/2)^2/144$
Unit Inside Volume, V_{Di} =	0.039 cf/LF		$V_{Di} = \pi*(D_i/2)^2/144$
HDB =	1,600 psi		Based on PPI Publication TR-4/2015 and ASTM 2837
Design Factor for HDB, DF =	0.63		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	1008 psi		HDS = HDB*DF
Environmental Factor, Af_e =	1		Reference 2: Use for pressure rating only
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

Champlain Hudson Power Express

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HDD 90 Circuit #1

Bridge Street

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE

OK	**OK if P_A >= to P_{TEST}**

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING

OK	**OK if PR >= to P_{WORK}**

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	**Long Term**
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	59.50 ft	Ballast depth to invert, H_B	58.20 ft	Drill Fluid depth to invert, H_{DF}	58.20 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	25.28 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	31.60 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	32.41 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	25.28 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	**Short Term**	**Long Term**	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	75.37 psi	1.31 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	74.56 psi	0.50 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	100.65 psi	26.59 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	99.84 psi	25.78 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	81.69 psi	7.63 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

HDPE PROPERTIES

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3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi * DF * (Ty) * D_o^2 * ((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = $f_T * f_Y$	0.4	AFE PULL STRENTH, SPS =	1,703 lb	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty * f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty * f_{temp} * DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR} * f_r$

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	448 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.90189		
r = σ_i/2*(SSAS) =	0.17585	Example from Table T5, σ_i =	404 psi
P_{CRR} =	241.2 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	120.6 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	114.28 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	113.47 psi	Pull Back Condition - C	**OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

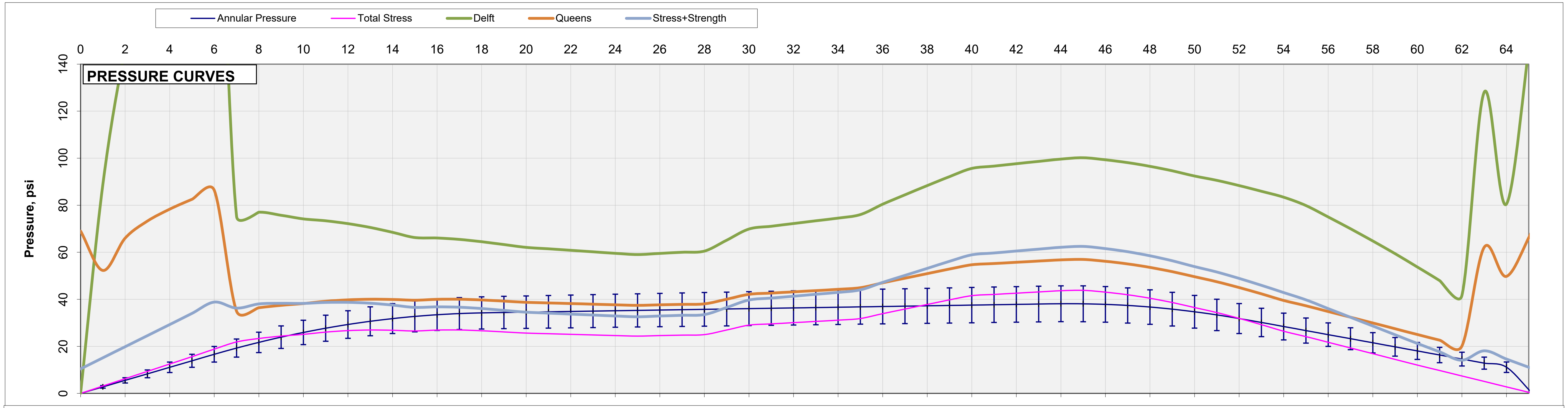
Design Factor (fe) to apply to HDB

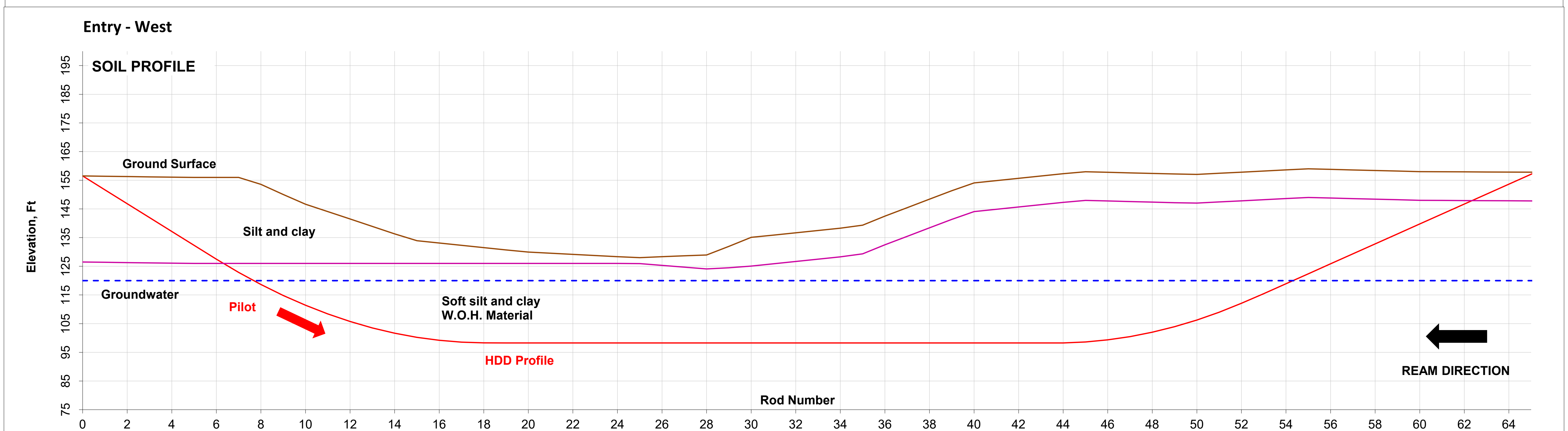
CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24





Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

ISSUED: Design Review

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 11/3/2022 9:22

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Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 90 Circuit #1
Route 396 & Stream Bank

Revision 0

FIGURE 1

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 90 Circuit #2**
Bridge Street

ISSUE: **Design Submittal**

Contents:

Table 1	DESIGN SUMMARY, ASSUMPTIONS, CONDITIONS
Table 2	DESIGN DRILL PATH CALCULATION
Table 3	ANTICIPATED PULLING FORCE - CONSTANT FORCE
Table 4	PLASTIC STRESS
Figure 1	APC AND FPC CURVES AND ASSUMED GEOLOGIC SECTION

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Project No: 322004-000
Print Date: 2-Nov-2022

Date	ID	DESCRIPTION	BY
11/2/2022	0	Design Submittal	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	12+88.59	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	675585.6770	1350685.5920	157.20 ft
Horizontal Curve PI	675025.8270	1351048.1650	
Exit	674628.6200	1351530.0700	158.50 ft
Depth to Mudline	-0.80 ft	Clearance Depth =	52.60 ft
Measured Plan Length at ties =	1288.5925 ft		
Coordinate Length =	1288.5925 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	152.00 ft
Mudline Elev.*	158.00 ft
Lowest centerline Elev.	105.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	675585.6770	1350685.5920	4+81.50	675181.5290	1350947.3284	E 302.92811 N	481.50		
Curve	4+81.50	675181.5290	1350947.3284	8+49.59	674907.8409	1351191.3097	E 320.50317 N	368.09	1200.00	17.575 deg.
Tangent	8+49.59	674907.8409	1351191.3097	12+88.59	674628.6200	1351530.0700	E 320.50317 N	439.00		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	481.50	Input Radius, ft.	1200.00	Plan Length, ft.	439.00	
Entry Azimuth, deg.[5]	N 302.92811 E	Curve, deg	17.575 deg.	Exit Azimuth, deg.[5]	N 320.50317 E	
Entry Azimuth, rad.[5]	5.28709	Curve, rad	0.30674	Exit Azimuth, rad.[5]	5.59384	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	366.65	Easting	674628.6200	**Check**
PCH Easting	675181.5290	Arc Length, ft.	368.09	Northing	1351530.0700	**Delta**
PCH Northing	1350947.3284	Chord Azimuth, deg	311.7156			**0.0000**
		PI Easting =	675025.8270			**0.0000**
		PI Northing =	1351048.1650			**OK CALC**
		PTH Easting =	674907.8409			
		PTH Northing =	1351191.3097			**Exit Station**
						12+88.59
Cum Plan Length	481.50	Cum Plan Length	849.59	Cum Plan Length	1288.592527	**OK STA**

Pull Geometry

Pipe Entry: ENTRY — Enter the pipe entry location into the hole: Entry/Exit

Segment	Elevations Start	Elevations End	Vertical Angle Start	Vertical Angle End	Δ Angle	Path Length	Curve Radius
Entry Tangent	157.20 ft	135.10 ft	-14.00 deg	-14.00 deg	0.00 deg	91.33 ft	0.00 ft
Entry Curve	135.10 ft	105.40 ft	-14.00 deg	0.00 deg	14.00 deg	244.35 ft	1000.00 ft
Bottom Tangent	105.40 ft	105.40 ft	0.00 deg	0.00 deg	0.00 deg	569.42 ft	0.00 ft
Exit Curve	105.40 ft	120.59 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	120.59 ft	158.50 ft	10.00 deg	10.00 deg	0.00 deg	218.30 ft	0.00 ft
					Total Check =	1297.93 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	330.54	481.50	No, Horiz > Entry V(Tan+Curve)
Exit	388.63	439.00	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		SUMS
Entry Angle	-14.000 deg.	Vertical Radius	1000.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	158.50	
		Vert. Curve, deg.	14.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	88.621 ft	Plan Length	241.922 ft	Plan Length	569.41579 ft	Plan Length	173.648 ft	Plan Length	214.986 ft	1,288.593 ft
Rod Length	91.334 ft	Arc Rod Length	244.346 ft	Rod Length	569.41579 ft	Arc Rod Length	174.533 ft	Rod Length	218.302 ft	1,297.931 ft
Vertical Depth	-22.096 ft	Curve Δ Vert Depth	-29.704 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	37.908 ft	1.300 ft
		Lowest Elevation	105.400 ft			Lowest Elevation	105.400 ft	CK Total Cum Depth	1.300 ft	
Start Elevation	157.200 ft	Start Elevation	135.104 ft	Start Elevation	105.400 ft	Start Elevation	105.400 ft	Start Elevation	120.592 ft	
End Elevation	135.104 ft	End Elevation	105.400 ft	End Elevation	105.400 ft	End Elevation	120.592 ft	Ck Exit Elevation		
End Vert Angle	-14.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*1288.592527*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+88.62	Start Station	3+30.54	Start Station	8+99.96	Start Station	10+73.61	**Stationing Check**
PVC Station	0+88.62	PTV Station	3+30.54	PCV Station	8+99.96	PTV Station	10+73.61	Exit Station	12+88.593	**OK STATIONING**
Cum Plan Length	88.62	Cum Plan Length	330.54	Cum Plan Length	899.96 ft	Cum Plan Length	1073.61	Cum Plan Length	1288.59	**Plan Length Check**
Cum Rod Length	91.33	Cum Rod Length	335.68	Cum Rod Length	905.10 ft	Cum Rod Length	1079.63	Cum Rod Length	1297.93	**OK CALCULATION**
Cum Depth	-22.10	Cum Depth	-51.80	Cum Depth	-51.80 ft	Cum Depth	-36.6078	Cum Depth	1.30	**Elevation Change Check**
										OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	1.30 ft
Minimum Design Elevation =	105.40 ft
Invert Depth below exit =	53.10 ft
Invert Depth below entry =	51.80 ft
Path Length =	1,297.93 ft
Plan Length =	1,288.59 ft
Minimum Plan Length (No Tangent) =	719.18 ft
Entry Angle =	-14.00 deg
Exit Angle =	10.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	NO

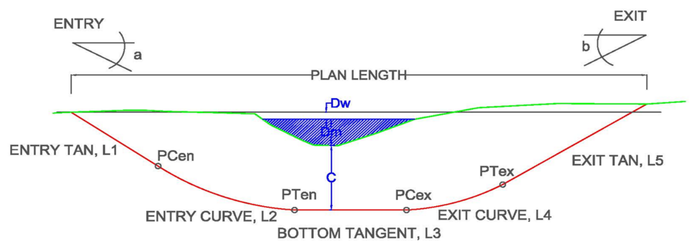
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 90 Circuit #2
Bridge Street

Revision 0 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	91.3 ft	α =	-14.0 °	-0.2443	
L3 =	244.3 ft				1,000.0 ft
L4 =	569.4 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	218.3 ft	β =	10.0 °	0.1745	
LT =	1397.9 ft				

INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	Pipe	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	10.75	Pipe or Bundle	
Pipe Dry Weight, W_P =	15.68 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
$DR = D_O/t_{min}$ =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	8.22 in	Bundle Multiplier F_D	1.0000
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	$PR = 2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf	
Drill Fluid Density	78	pcf	*Estimated for pull*
Drill fluid elevation, H_F =	152.00 ft		
Ballast Water El., H_W =	152.00 ft		
Lowest Invert El., El_m =	105.40 ft		

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	33.77 in	
Wall Section Area, A_W	37.70738915	
Volume Outside, V_{DO}	0.630 cf/LF	
Volume Inside, V_{DI}	0.368 cf/LF	
q_d =	2.03 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.50 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

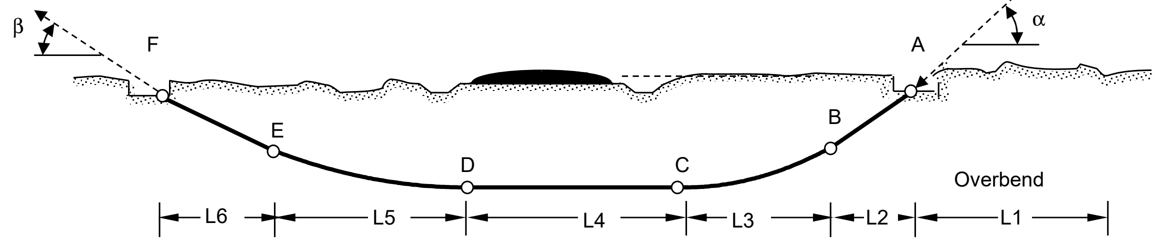
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.68 Lb/LF	38.67 Lb/LF	
In Hole with Drill Fluid, w_b/w_{bf} =	-33.48 Lb/LF	-10.49 Lb/LF	

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 158.50 ft

Pipe Entry El = 157.20 ft



POINT	**Calculated Pull Force** Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
A	2,246 lb	121 psi	OK	2,246 lb	121 psi	OK	OK	OK
B	3,203 lb	89 psi	OK	3,204 lb	89 psi	OK	OK	OK
C	4,632 lb	158 psi	OK	3,879 lb	137 psi	OK	OK	OK
D	6,555 lb	183 psi	OK	5,802 lb	162 psi	OK	OK	OK
E	9,581 lb	296 psi	OK	7,385 lb	235 psi	OK	OK	OK
F	12,951 lb	361 psi	OK	9,009 lb	251 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_AF_R$ = 97.74 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m)) + E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	$SSPS = \sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.913688705	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.157089241	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	361 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	5.05	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	25.24	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 90 Circuit #2
Bridge Street

Revision 0

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #2

Bridge Street

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INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Test Pressure, P_{TEST} = 0 psig — At high point

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	HDPE		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification			Design resin with minimum PENT test of 10,000 hours
Standard Dimension	10		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	8.219 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	1.194 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	35.85681985		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	405.27 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.630 cf/LF		$V_{Do} = \pi*(D_o/2)^2/144$
Unit Inside Volume, V_{Di} =	0.368 cf/LF		$V_{Di} = \pi*(D_i/2)^2/144$
HDB =	1,600 psi		Based on PPI Publication TR-4/2015 and ASTM 2837
Design Factor for HDB, DF =	0.63		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	1008 psi		HDS = HDB*DF
Environmental Factor, Af_e =	1		Reference 2: Use for pressure rating only
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	15.68	Lb/LF	
Tensile Yield, Ty psi =	1,120 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	2%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-33.48 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.74 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.67 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.49 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.75 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.99 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	49.16 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	50.42 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #2

Bridge Street

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	280 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	53.10 ft	Ballast depth to invert, H_B	51.80 ft	Drill Fluid depth to invert, H_{DF}	51.80 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	22.64 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	28.30 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	29.03 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	22.64 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	78.67 psi	4.61 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	77.95 psi	3.89 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.31 psi	27.26 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.59 psi	26.53 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	84.33 psi	10.27 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #2

Bridge Street

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3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 SPS = π*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**AFE PULL STRENTH, SPS =**	**16,064 lb**	
Temperature factor, f_{temp} =	1	Jltimate Pull Strength, UPS =	40,160 lb	
Temp Corr Tensile Yield, Ty*f_{temp} =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = Ty*f_{temp}*DF	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	16,064 lb	**Useing SSAS =**	**41,235 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, P_{CRR} = P_{CR}*f_r

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr		Pcr =	267.4 psi
SAS =	448 psi		Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum		
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.91369			
r = σ_i/2*(SSAS) =	0.15709		Example from Table T5, σ_i =	361 psi
P_{CRR} =	244.4 psi			
FS =	2.0			
P_{ACRR} = P_{CRR}/FS =	122.2 psi	Allowable Reduced Short Term Buckling pressure during pull		
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1}	116.52 psi	Pull Back Condition - C	**OK as >0**	
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2}	115.79 psi	Pull Back Condition - C	**OK as >0**	

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

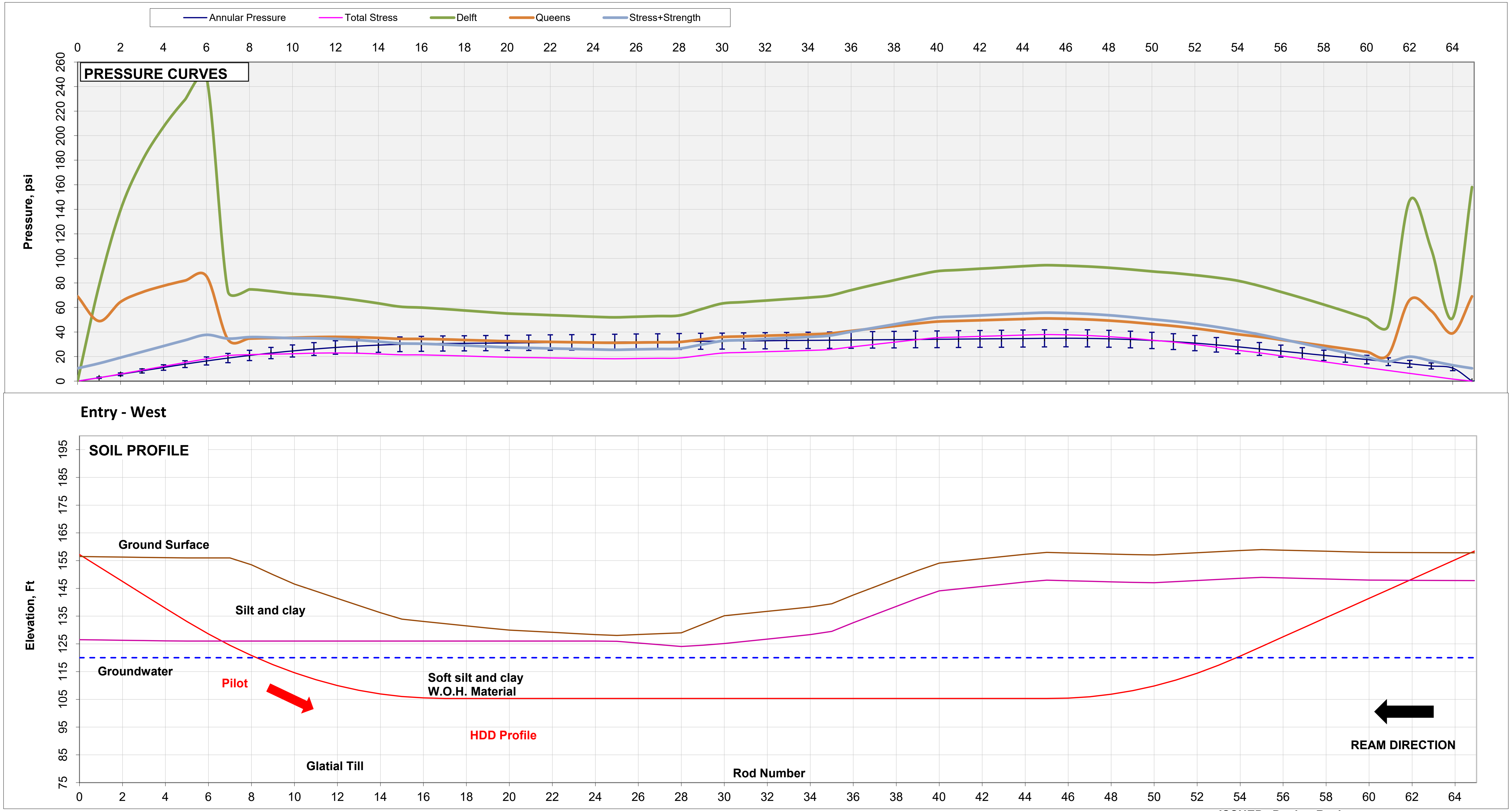
Design Factor (fe) to apply to HDB

CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24



ISSUED: Design Review

Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

8.16 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
150 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 90 Circuit #2
Route 396 & Stream Bank

Revision 0

FIGURE 1