Welcome to the Post Rover World

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Michigan Pipeline Safety Conference
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Topics to be Covered

- An Overview of the HDD Construction Process
- HDD Drilling Fluid Considerations
- HDD-Related Problems on the Rover Pipeline Project and How They Were Mitigated
- Recommendations

Classes of HDD Rigs

BIG RIG

“Maxi Rig”
Oilfield drill pipe ≈ 30’
Downhole Survey (wireline)

Little Rig

“Mini or Midi Rig”
10’, 15’, 20’ Drill Pipe
Usually Walkover Survey

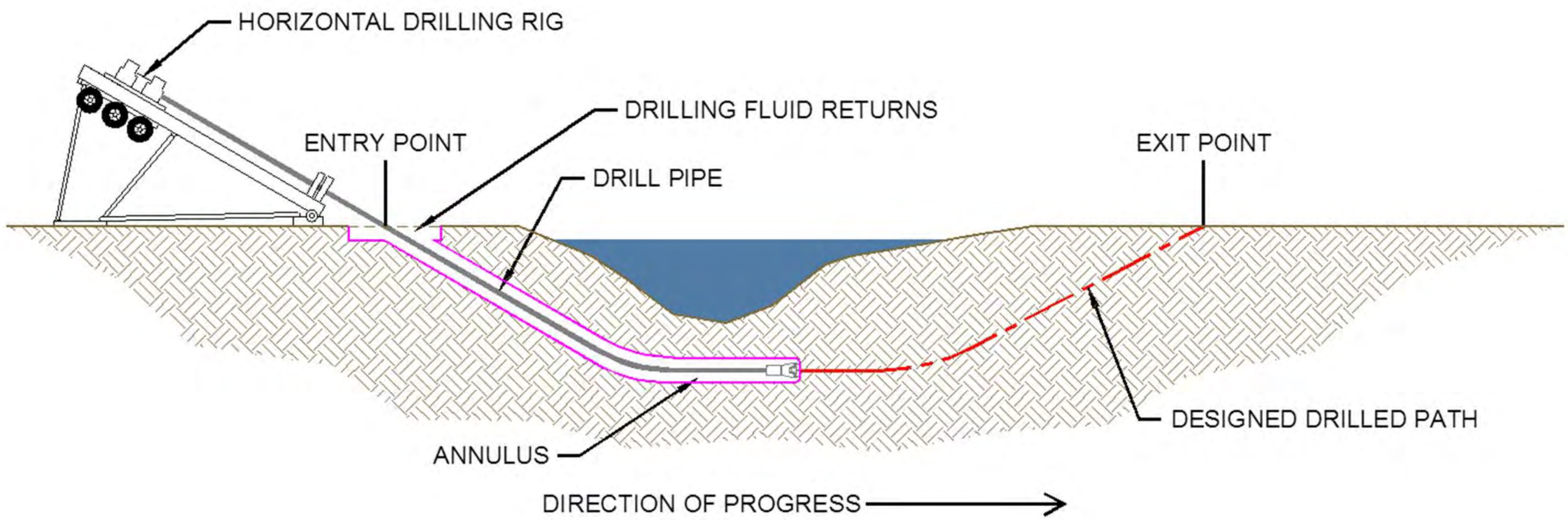
The HDD Process

- **Pilot Hole** – a small diameter hole is drilled along a designed directional path
- **Prereaming** – the hole is enlarged to a diameter that will accommodate the product pipe
- **Pullback** – the product pipe is pulled into the enlarged hole

- All phases of HDD involve pumping drilling fluid through the drill string to a bit or reamer downhole

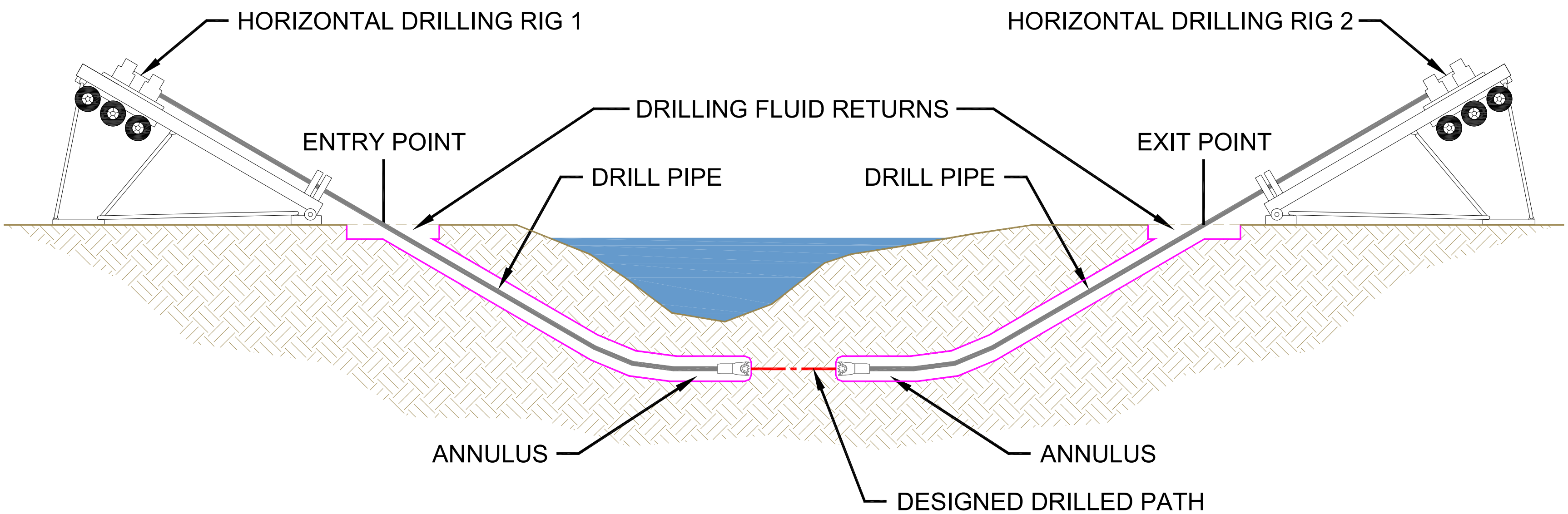
Pilot Hole

- Begins when the bit enters the ground at the entry point
- Complete when the bit "punches out" at the exit point
- Progress achieved in soft soils by hydraulic cutting with a jet nozzle
- Progress achieved in rock by mechanical cutting with a mud motor and bit



Drilled Intersect

- Two pilot holes drilled toward each other intersect at an intermediate point
- Theoretically doubles feasible pilot hole length, some overlap is common
- Also beneficial to reduce annular pressures or when surface casings are needed on both ends of the crossing
- Position relative to the other bit determined by magnetic ranging or radar



Common Pilot Hole Bits

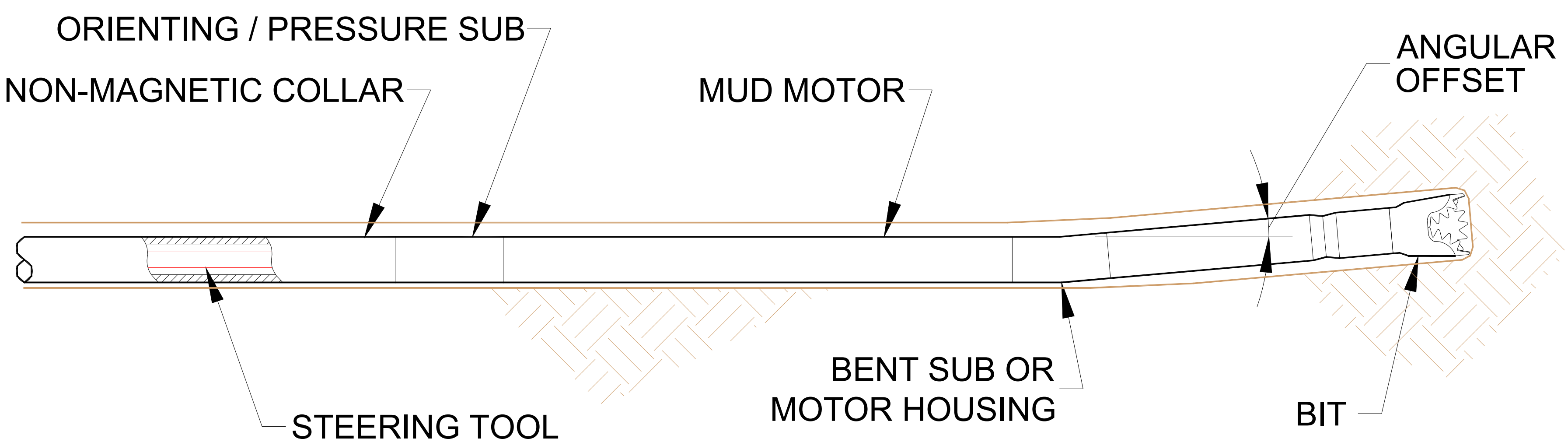
Milled Tooth
(tri-cone)

Tungsten Carbide Insert
(tri-cone)

Polycrystalline Diamond
Compact
(fixed cutter)

Directional Control (Steering)

- Steering bias created by a slight bend near the leading edge of the drill string
- Change in direction achieved by rolling the drill string so the bit points in the desired direction, then advancing the drill string without rotation
- Path of the pilot hole calculated using inclination and azimuth readings from a steering tool located between 6 and 30 feet behind the bit
- Wireline steering tools are either magnetic or gyroscopic



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Pilot Hole Rig-Up

Steering tool being inserted into a non-magnetic collar

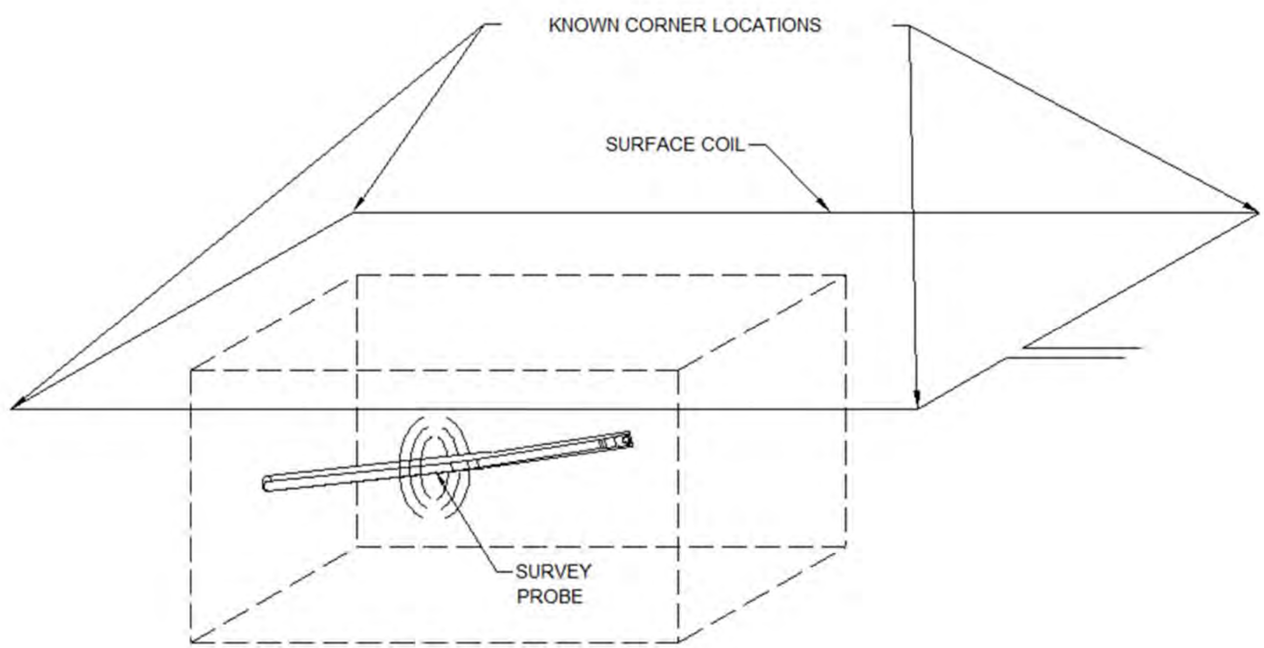
Mud motor with bent housing placed ahead of the steering tool

Steering Tools

- Both Magnetic and Gyroscopic Steering Tools
  - Require a wire through the drill string to transmit power to the downhole probe, and data from the downhole probe to equipment on the surface
  - Provide directional information (inclination and azimuth) that is used to determine the position of the steering tool relative to the entry point on the surface
- Magnetic Steering Tools
  - Azimuth readings are taken from the Earth’s magnetic field and are subject to interference from local magnetic anomalies (i.e. adjacent pipelines, metallic structures, power lines, cathodic protection systems)
  - Typically used in conjunction with a secondary surface monitoring system to eliminate the effects of magnetic interference
- Gyroscopic Steering Tools
  - Azimuth readings are obtained using inertial measurements from an optical gyroscope and are not affected by magnetic interference
  - Provide reasonable accuracy without the need for a surface monitoring system, yielding advantages when access issues prevent placement of a surface wire over the drilled alignment

Surface Monitoring

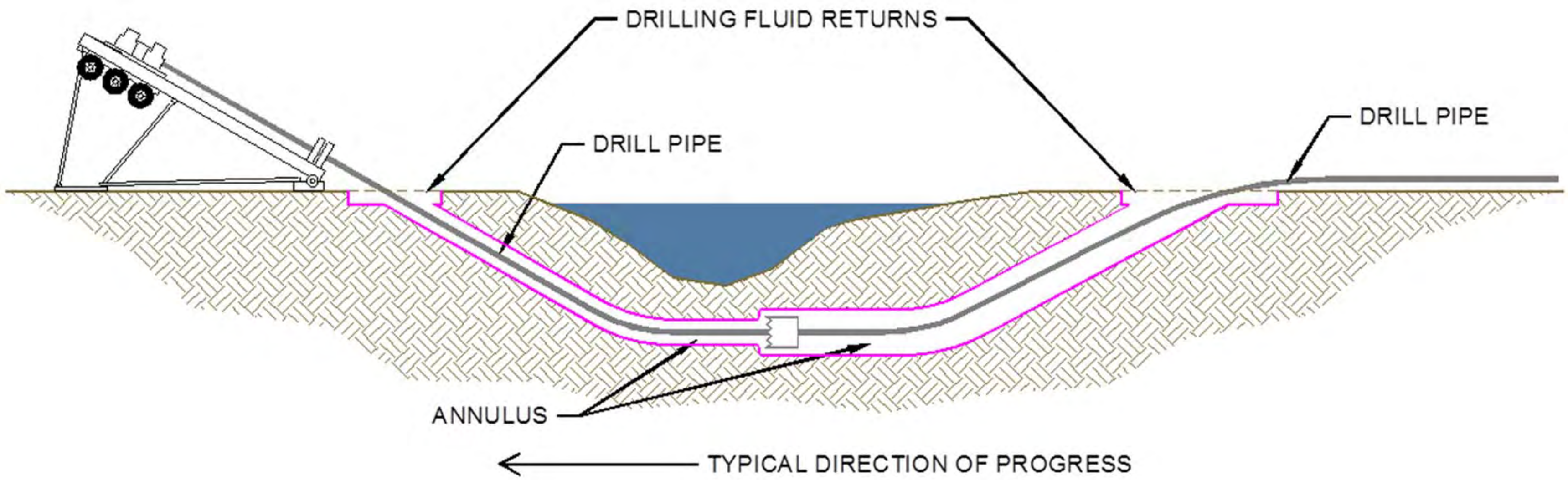
- Secondary means of determining location of downhole probe
- Most common systems are TruTracker (DC) and ParaTrack 2 (AC)
- Wire/coil laid on ground surface; “corner” locations accurately surveyed
- Electrical current through wire induces a predictable magnetic field
- Software triangulates position of probe relative to surface wire



Completed Pilot Hole

Prereaming

- One or more passes conducted to enlarge the pilot hole to a diameter suitable for installation of product pipe
- Reaming tools are typically attached at the exit point then rotated and pulled toward the rig to enlarge the hole, but it's also common to ream from entry to exit
- Drill pipe attached behind reamer so a string of drill pipe is always maintained in the reamed hole



Common Reaming Tools

Barrel Reamer

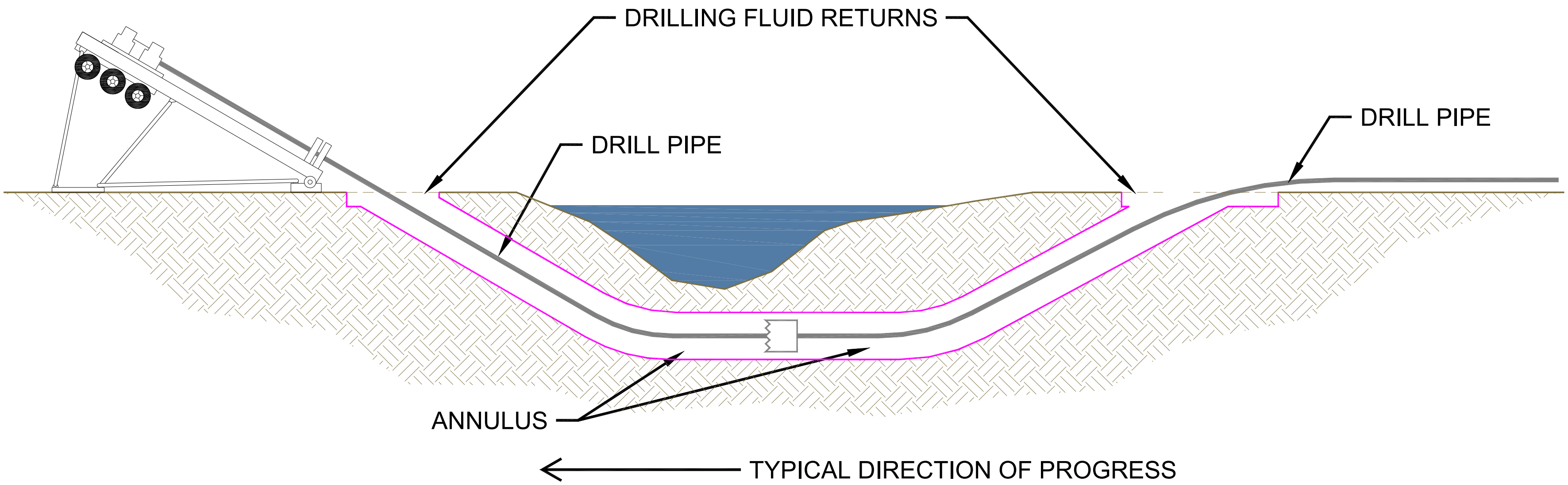
Flycutter

Hole Opener

Start of a Reaming Pass

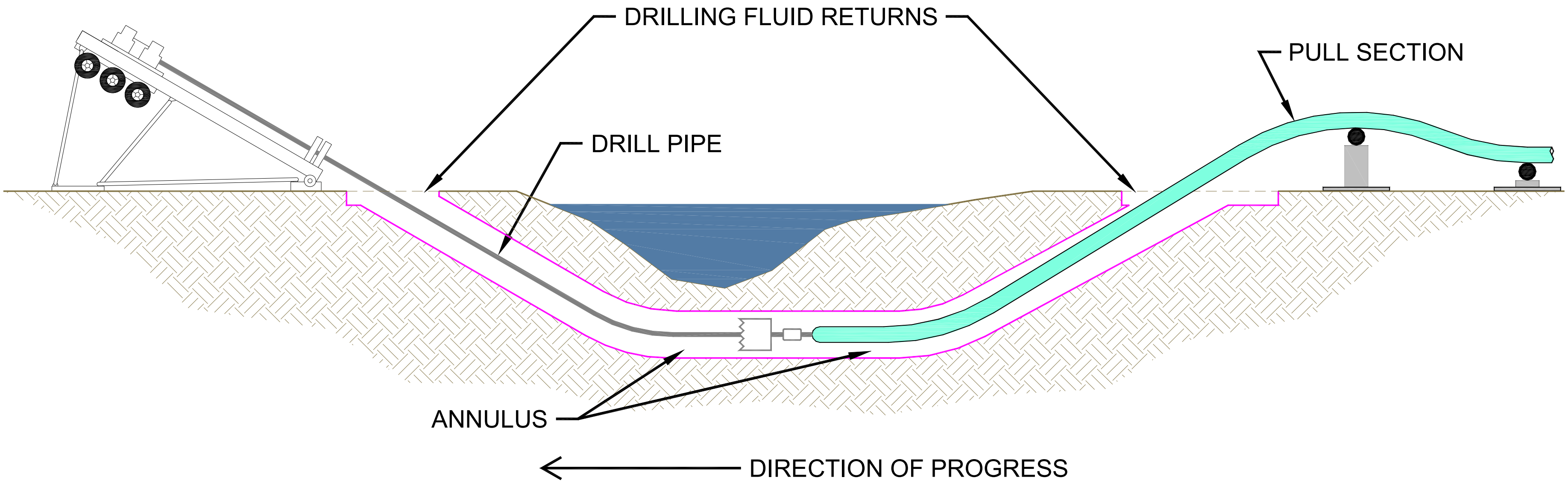
Swab Pass

- Conducted after the final prereaming pass to:
  - Remove remaining cuttings
  - Make sure there are no problem areas in the hole
  - Get good drilling fluid in the hole for pullback
- Typically performed using a barrel reamer or hole opener sized slightly smaller than the diameter of the reamed hole
- Ideally, should be conducted no more than a day before pullback and proceed in the same direction



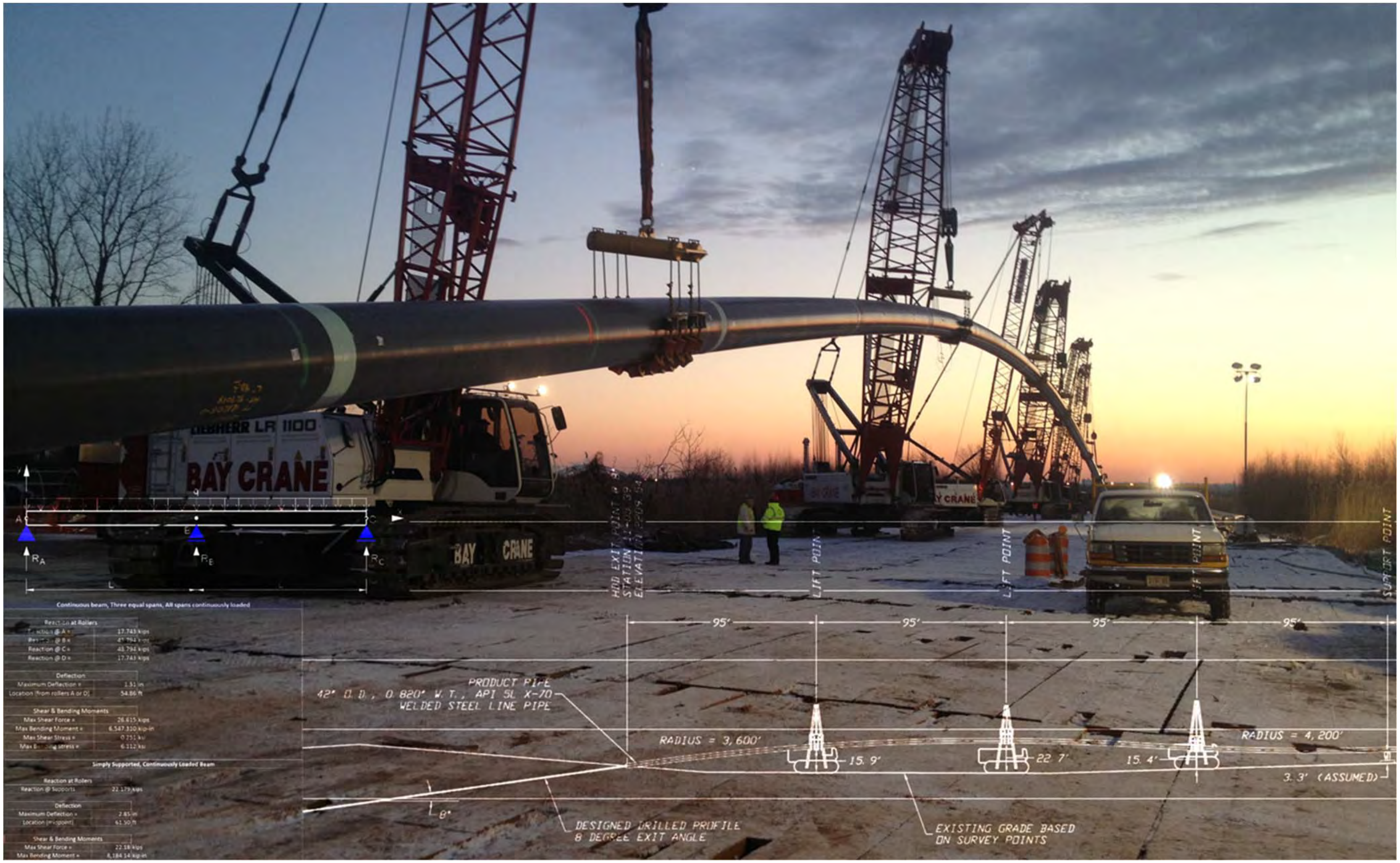
Pullback

- Pull section attached behind a reamer at the exit point and pulled to the rig
- A swivel is placed between the reamer and pull section to minimize rotation of the product pipe as it's pulled into the hole
- Pull section supported using a combination of roller stands and pipe handling equipment (i.e. sidebooms, cranes, and roller cradles)



Pullback Assembly

Pipe Handling Equipment



Pull Section Breakover

Pullback Complete

Drilling Fluid Considerations

All phases of HDD involve pumping drilling fluid through the drill string to a bit or reamer downhole

- ❖ Ideally, drilling fluid flows back to the entry or exit point through the drilled annulus
- ❖ In reality, drilling fluid flows in the path of least resistance

This can result in:

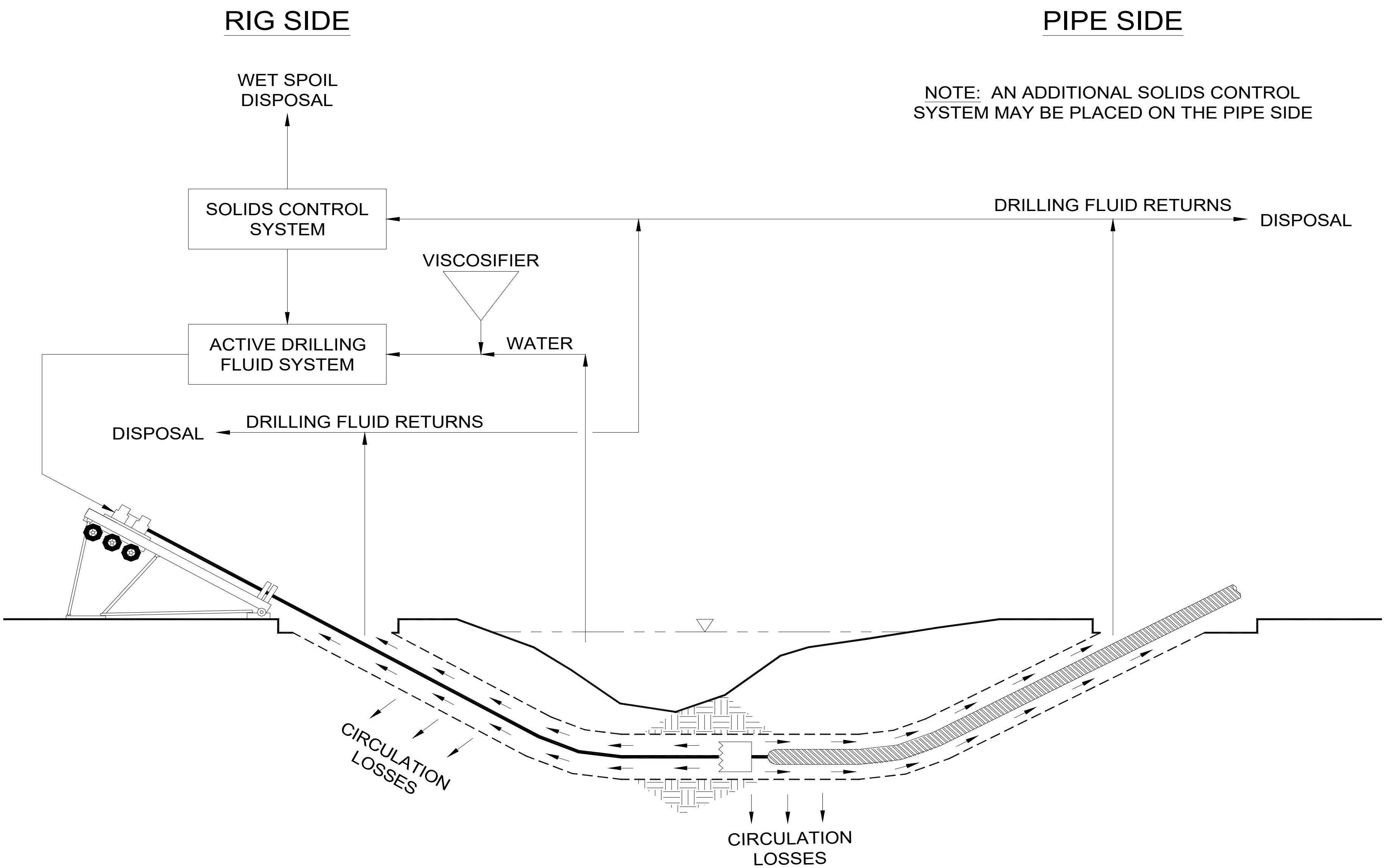
  - ➢ Lost circulation - dispersal of drilling fluid to the surrounding soil
  - ➢ Inadvertent returns - surface discharge of drilling fluid at a random location

Drilling Fluid Functions

- Hydraulic excavation
- Transmission of hydraulic power
- Transportation of drilled spoil
- Cooling and cleaning of cutters
- Reduction of friction
- Hole stabilization
- Soil modification

Drilling Fluid Composition

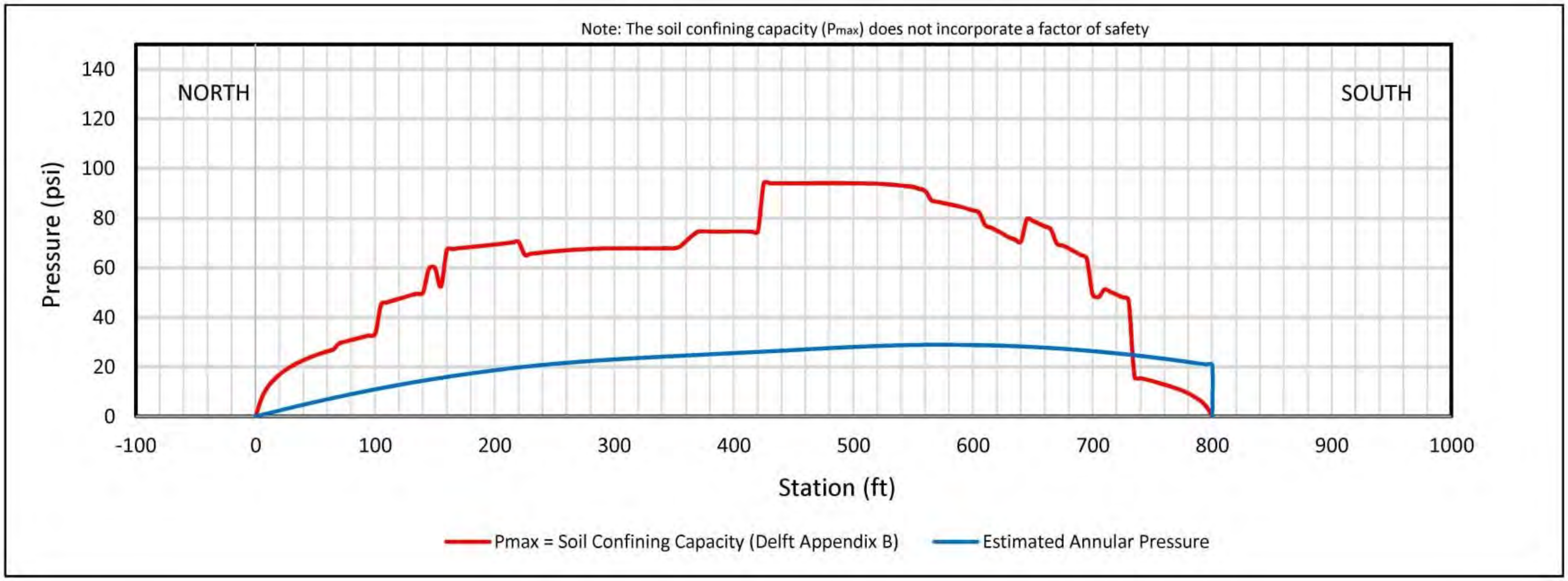
- Fresh water – typically withdrawn from the waterway being crossed or obtained from a municipal source
- High yield bentonite – naturally occurring clay containing trace amounts of polymers to enhance properties (i.e. yield, gel strength, fluid loss control)
- Drilled spoil – soil and rock cuttings accumulated as drilling operations progress
- Nontoxic additives – as needed to handle specific problems or conditions (i.e. reactive clay, flowing sand, high rotary torque, lost circulation)

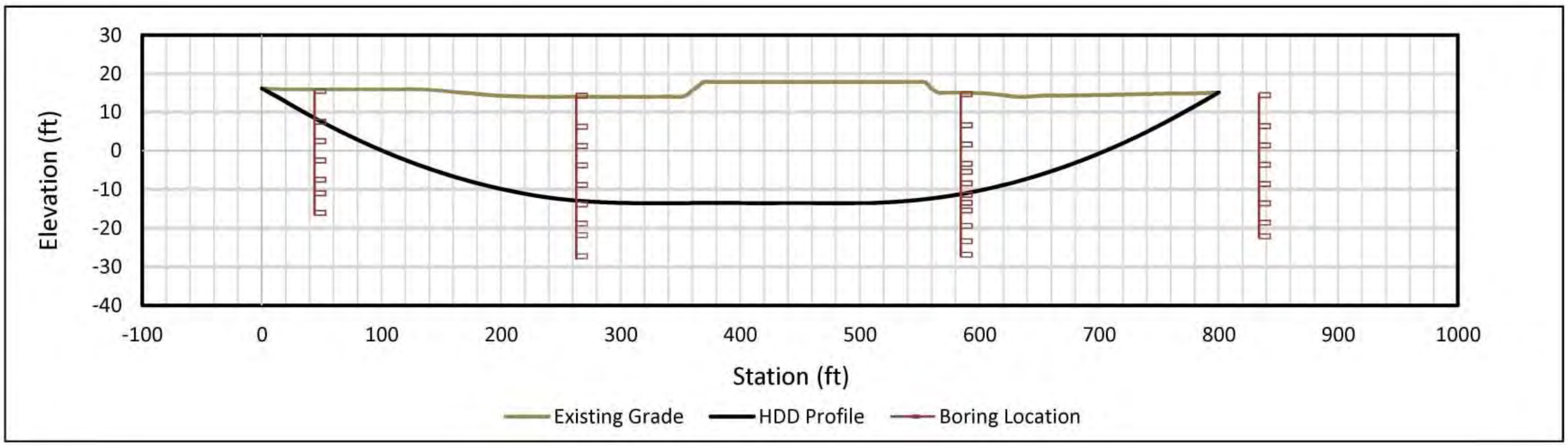


Drilling Fluid Flow Circuit

Inadvertent Drilling Fluid Return on Land

Inadvertent Drilling Fluid Return in a Waterway





Hydrofracture Evaluation

Drilling Fluid Takeaways

- In general, drilling fluid products used in the HDD industry are nontoxic and are not a threat to public health and safety or the environment
- On an HDD installation, the possibility of lost circulation and inadvertent returns cannot be eliminated
- The risk of inadvertent returns can often be reduced by designing crossings with an appropriate depth of cover
- Hydrofracture analysis can be used to assess the risk of inadvertent returns, but it is not always accurate
- Regulatory bodies should be informed that circulation loss and inadvertent returns may occur
- Regulatory bodies should recognize that in many cases inadvertent returns have no negative environmental impact
- Contingency plans and mitigative measures for dealing with inadvertent returns should be developed prior to construction

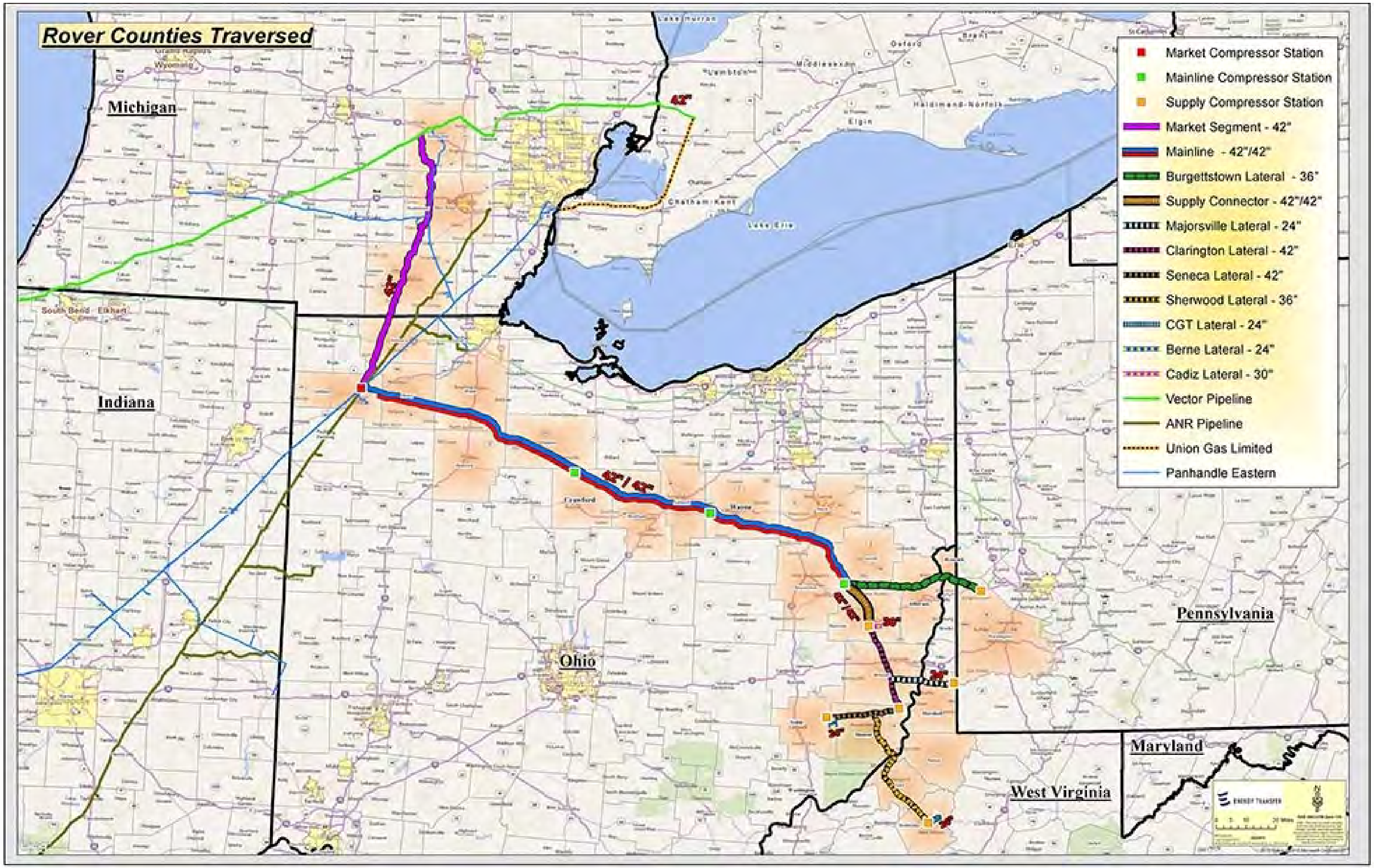
Rover Pipeline Project

- Project Description
- What Went Wrong?
- First Tuscarawas River Crossing (Line A)
  - Summary
  - Timeline
  - What Caused the Inadvertent Return?
  - Why Wasn't it Discovered Sooner?
  - Mitigation & Completion
- Second Tuscarawas River Crossing (Line B)
  - Mitigation
  - Timeline

Rover Pipeline Project Description

- Constructed in 2017 and 2018 by Energy Transfer Partners
- Consists of approximately 713 miles of 24-inch to 42-inch diameter pipeline
- Parallel 42-inch mainlines designated Line A and Line B
- Transports up to 3.25 billion cubic feet of natural gas per day from the Marcellus and Utica Shale production areas in West Virginia, Pennsylvania, and southeast Ohio to markets in the U.S. and Canada
- Extends across the state of Ohio to a delivery point near the city of Defiance, then northward into Michigan where it interconnects with the existing Vector Pipeline in Livingston County
- 49 HDD crossings were used in the construction of the pipeline

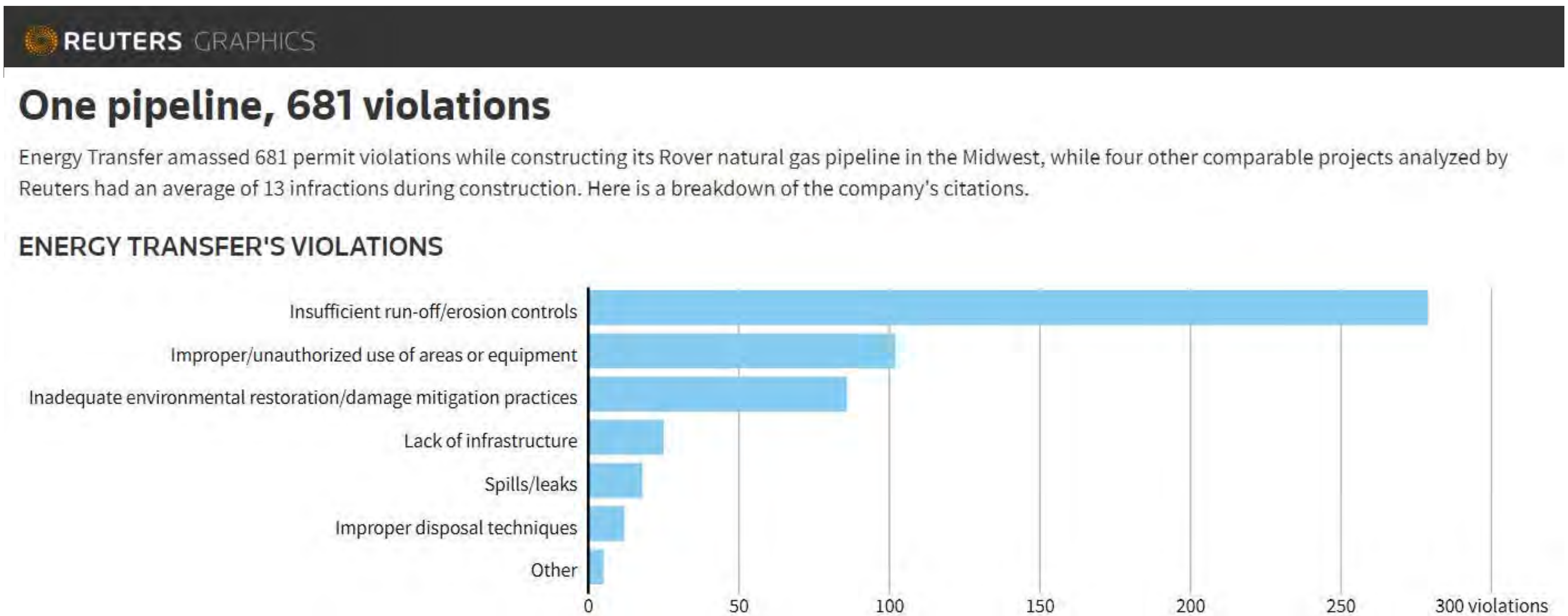
Rover Pipeline Route Map



Source Rover Pipeline Fact Sheet (https://www.roverpipelinefacts.com)

What Went Wrong?

- According to Reuters analysis of FERC documents, the Rover Pipeline amassed 681 permit violations compared to an average of 13 violations on four comparable projects
- Most of these violations involved insufficient erosion and sedimentation controls, unauthorized use of areas or equipment, and inadequate environmental restoration
- 25 of the 681 violations were categorized as spills or leaks, some of which were inadvertent drilling fluid returns on HDD installations



What Went Wrong?

- While there were numerous permit violations and inadvertent returns on the project, one specific inadvertent return was a game changer
- On April 13, 2017, an inadvertent return with an estimated volume of 2,000,000 gallons covering 6.5 acres was discovered in a wetland on the west side of the Tuscarawas River (Line A crossing)
- HDD operations at the Tuscarawas River crossing were immediately suspended so the drilling fluid could be cleaned up
- On May 10, 2017, FERC issued an order prohibiting Rover from starting HDD operations at locations where drilling had not commenced
- On May 15, 2017 at the direction of FERC, Rover solicited proposals for a comprehensive third-party review to:
  - Evaluate the incident at the Tuscarawas River crossing and determine its cause
  - Recommend measures that will minimize the potential for future incidents

What Went Wrong?

Source Ohio EPA Presentation titled “Horizontal Directional Drilling (HDD) Projects and The Rover Pipeline Inadvertent Return in Stark County, Ohio

What Went Wrong?

Note: Taken April 27 at site of Rover Tuscarawas HDD spill in Stark County, OH.

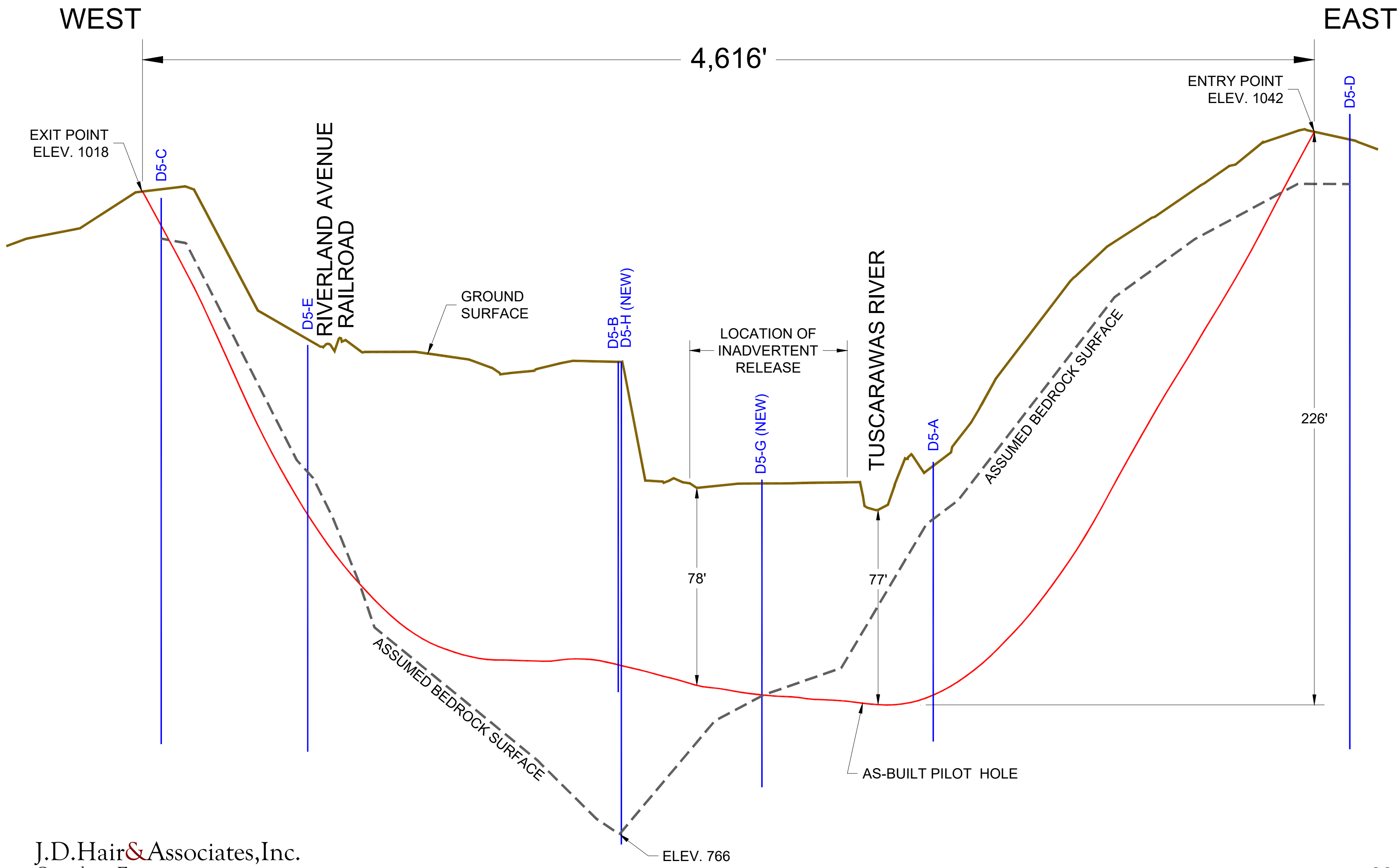
Source: Ohio Environmental Protection Agency

Tuscarawas River (Line A) Summary

- 42-inch diameter HDD crossing in Stark County, Ohio
- Horizontal drilled length 4,616 feet
- Crosses a broad river valley encompassing the Tuscarawas River and adjacent wetlands, as well as a road and a railroad
- The HDD design provided approximately 49’ of cover beneath the river and 61’ of cover beneath the wetland to the west of the river
- Subsurface conditions consisted of sand, silt, and clay with occasional gravel overlying sedimentary bedrock (primarily shale & siltstone with some sandstone and limestone)
- Bedrock falls off sharply in the middle of the crossing forming a deep, V-shaped trough filled with unconsolidated sediments
- The design was generally in accordance with HDD industry standards, except that it passed out of bedrock, into unconsolidated soils, and back into bedrock again

Tuscarawas River (Line A) Plan View

Tuscarawas River (Line A) Profile



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Tuscarawas River (Line A) Timeline

3/18/2017	Started 12.25” diameter pilot hole (east to west) – lost drilling fluid circulation 216 feet from entry. Pumping 400 GPM.
3/25/2017	Completed pilot hole, started 30” back ream (west to east). Lost circulation ≈ 90’ into pass, tripped out and regained returns. Pumping 350 to 400 GPM.
3/27/2017	Lost circulation again ≈ 300’ to 500’ into 30” pass.
4/3/2017	Completed 30” back ream, started 42” back ream (west to east). Pumping 350 to 400 GPM.
4/4/2017	Lost circulation ≈ 435’ into 42” pass.
4/5/2017	Tripped out to modify reamer ≈ 590’ into 42” pass, then tripped back in. Briefly regained circulation but eventually lost all returns. Pumping 400 to 550 GPM.
4/9/2017	Torque increased and penetration rate slowed significantly ≈ 3,250’ into 42” pass – suspect hole opener is “balled up” with sticky clay/shale. Began pumping from both sides at 800 to 1,100 GPM in an attempt to clean cuttings from the reamer.
4/11–4/12	High torque and slow penetration rate ≈ 3,780’ to 3,840’ into 42” back ream – pumping from both sides at 800 to 1,100 GPM.
4/13/2017	Inadvertent return with an estimated volume of 2,000,000 gallons discovered in a wetland on the west side of the Tuscarawas River ≈ 4,200’ into 42” pass.

What Caused the Inadvertent Return?

- Weak overburden soils beneath the wetland area resulted in a much lower confining pressure than expected (revealed by an exploratory boring conducted after the inadvertent return occurred).
- Annular pressure increases resulting from the HDD contractor’s remedial actions to reduce high torque caused by reactive clay/shale
  - ➢ The increased pumping rate caused a rapid increase in the height of the drilling fluid column in the hole (increased hydrostatic head)
  - ➢ If the hole had become plugged by cuttings at a point west of the river, a sudden increase in drilling fluid flow would have pressurized the zone beneath the wetland
- Failure to use appropriate drilling fluid additives to counteract reactive clay/shale, eliminate bit balling, and reduce rotary torque
  - ❖ Note that the use of such additives appears to have been prohibited by governing agencies

Why Wasn't It Discovered Sooner?

- The wetland where the inadvertent returns occurred was not visible or accessible from the right-of-way without going through water
- Monitoring personnel were not permitted off Rover's right-of-way
  - ➢ Essentially prevented pedestrian access to the wetland where the IRs occurred
  - ➢ Made it difficult to detect IRs that surfaced off the right-of-way
- The wetland where the IRs occurred was flooded until a few days before the IR was discovered
- HDD operations were being conducted 24 hours per day
  - Difficult to monitor the right-of-way at night
  - Safety concerns associated with monitoring at night
- Rover's technical specifications and contingency plans were somewhat vague concerning the frequency with which the HDD alignment should be monitored if drilling fluid circulation was lost

Line A Mitigation & Completion

- After cleaning up the April 13 inadvertent return, Rover resumed work on the Tuscarawas crossing (Line A) in early May of 2017
- Based on the limited information provided to JDH&A, numerous problems were encountered once HDD operations resumed, including:
  - Lost circulation and inadvertent returns continued
  - Tools became temporarily lodged in the hole during the 54” & 60” reaming passes
  - A drill pipe failure occurred downhole
  - Multiple “fishing” passes were required to recover from the drill pipe failure
  - Two 54” hole opener cones were lost in the hole and eventually recovered
  - A sinkhole developed 85’ from the entry point (10’ wide, 25’ long, 20’ deep)
- At a minimum, mitigating measures upon resuming HDD operations included:
  - More stringent monitoring requirements
  - Access to the wetland so any new IRs could be quickly contained and collected
  - Much greater oversight than was present prior to discovery of the April 13 IR
- Despite the issues noted above, the crossing was successfully completed on July 21, 2017

Crossing Successfully Completed

…people cheered and sang Boomer Sooner

Tuscarawas River (Line B) Mitigation

- 42-inch diameter HDD crossing parallel to the problematic, previously completed Line A crossing
- HDD design 330 feet longer and more than 100 feet deeper than the Line A design in order to stay within bedrock
- Other mitigating measures included:
  - More stringent monitoring requirements – crew member stationed at the Line A IR location as well as hourly right-of-way walks, documented on a log form
  - Monitoring of annular pressure during pilot hole drilling
  - Access to the wetland so any new IRs could be quickly contained and collected
  - Much greater oversight than was present prior to discovery of the Line A IR
  - Drones and infrared cameras used to aid in monitoring efforts
  - Drilling fluid specialist retained to develop a drilling fluid program and adjust drilling fluid properties as needed to promote circulation
  - Drilling fluid additives to counteract reactive clay/shale, eliminate bit balling, reduce rotary torque, etc. were approved by governing agencies
  - Pilot hole drilled from exit to entry (west to east) due to the exit point being lower than the entry point

Tuscarawas River (Line B) Timeline

12/28/2017	Pilot hole from exit to entry started – struggled with lost circulation right away but did not experience inadvertent returns.
12/30-1/19	Pumped various LCMs, set nearly 600 feet of 16-inch casing, and grouted annulus around casing in an attempt to stop circulation losses.
1/24/2018	FERC ordered Rover to suspend HDD operations due to lost circulation (but no inadvertent returns) due to pressure by the Ohio EPA.
2/6/2018	FERC allowed Rover to resume pilot hole drilling – maintained returns until about 3,800 feet from entry, after which returns were intermittent.
2/23/2018	Completed pilot hole.
2/24-4/13	Moved rig to entry point and pulled all reamers (30, 42, and 54-inch) from west to east, generally maintaining circulation for the first ≈ 4,000 feet, briefly losing returns, then regaining circulation closer to the exit point.
3/21/2018	An inadvertent drilling fluid return occurred during the 42-inch reaming pass – estimated to be 1,000 gallons in the wetland. Contained and collected.
4/18–4/19	Two swab passes were conducted, with full returns maintained from start to finish.
4/20/2017	Pullback successfully completed.

Crossing Successfully Completed

Recommendations

- Involve an engineering firm with specialized expertise in HDD
- Obtain adequate survey and geotechnical information
- Determine locations of all underground utilities in the vicinity of proposed HDD installations
- Design crossings in accordance with HDD industry standards, taking site-specific considerations into account
- Complete a hydrofracture analysis for HDD installations in soft soils
- Develop an appropriate inadvertent return monitoring and contingency plan, and document that it is followed
- Obtain access to adjacent tracts if possible so they can be monitored during construction
- Select an appropriately qualified HDD contractor with a track record of safe operations and environmental compliance
- Provide appropriate oversight during construction

Questions?