Dominion Golden to Mars – 230-kV and 500-kV Underground Feasibility Study

Dominion Energy

Golden to Mars 230-kV and 500-kV
Underground Feasibility Study
Project No. 170234

Revision 7
03/27/2025

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Prepared for

Dominion Energy
Golden to Mars 230-kV and 500-kV
Underground Feasibility Study
Loudoun County, Virginia

Project No. 170234

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Prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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RECORD OF REVISION

Revision No.	Date	By	Section Revised	Description
0	07/22/2024	AKM - BMcD	N/A	Initial Draft Deliverable
1	07/26/2024	AKM - BMcD	5.0 Transition Station 6.0 Cost Estimate Analysis	1. Updated transition station design details 2. Included Transition station layouts 3. Updated Transition station assumptions 4. Included transition station cost estimates
2	07/31/2024	AKM - BMcD	5.0 Transition Station 6.0 Cost Estimate Analysis Appendices	1. Included Mars Substation layout 2. Included Mars Substation cost estimate 3. Included Appendix D Preliminary Station Layouts
3	08/30/2024	AKM - BMcD	4.0 UG Feasibility Review 5.0 Transition Station 6.0 Cost Estimate Analysis 7.0 Preliminary Construction Schedule 9.0 Feasibility Summary Appendices	1. Included transition stations (TS3 & TS4) 2. Included UG Routes 6 and 7 3. Included survey analysis of routes 4. Included OH/Engineering Cost estimates 5. Included Section 7.0 and Appendix E for preliminary schedule 6. Updated feasibility summary with new preferred route
4	9/10/2024	AKM-BMcD	7.0 Preliminary Construction Schedule	1. Updated schedule description to remove mention of goal in service date
5	12/06/2024	JMR BMcD	All Sections	1. Added feasibility analysis for 4 new UG Routes. 2. Removed abandoned routes section and moved the routes into the feasibility analysis section. 3. Included class 5 cost estimates for all routes. 4. Removed preliminary schedules. 5. Included Appendices E and F with new routes trenchless crossings feasibility analysis and ampacity memo. 6. Updated feasibility summary with new routes.
6	01/24/2025	JMR BMcD	Section 4 and Section 5	1. Incorporated ERM edits to sections 4 and 5.
7	03/27/2025	JMR BMcD	Executive Summary	1. Included Executive Summary.

EXECUTIVE SUMMARY

As part of the Golden to Mars transmission project, Dominion Energy Virginia (DEV or Dominion) considered the installation of two (2) underground (UG) transmission circuits, one 230-kV circuit rated at 1,572 MVA and another 500-kV circuit rated at 4,357 MVA, connecting two (2) new stations in Loudoun County, Virginia, near Dulles International Airport (IAD). To support this initiative, DEV has contracted Burns & McDonnell Engineering Company, Inc. (BMcD) to conduct a feasibility study for the proposed UG transmission routes. The feasibility analysis included the study of eleven (11) proposed UG routes provided by DEV which focused on routing, technical feasibility for each proposed route, installation methods such as open-cut trenching and trenchless technology, the required cable load ratings, the restrictions of Virginia Department of Transportation (VDOT), existing utility congestion, environmental considerations, permitting requirements, UG transmission cable system and station costs, and other relevant factors. This feasibility analysis only focuses on the UG transmission scope of the project.

Through the feasibility analysis several challenges for the proposed routes were identified, including:

- Construction difficulties through floodplains, wetlands, and existing infrastructure such as concrete culverts.
- Issues obtaining permits and easements, especially on sensitive facilities or federal lands.
- Traffic impacts and spacing constraints for duct bank and splice vault placements.
- The need for significant land acquisition outside of public rights-of-way (ROW) and potential extensive relocation of existing utilities.
- The need for larger ROW on trenchless crossings.
- Complexities with trenchless crossings due to the probable presence of Diabase rock and the requirement for larger equipment.
- Potential for delays due to the drilling process and complex construction conditions in private infrastructure areas.

Due to these significant constructability challenges, none of the proposed eleven (11) UG routes are considered constructable options for the Golden to Mars transmission project.

1.0 PURPOSE

DEV contracted BMcD to conduct a feasibility study based on routing options provided by DEV for installing two (2) UG transmission circuits in Loudoun County, Virginia located northwest of IAD. Additional route alternatives were also included by BMcD based on additional transition station locations provided by DEV and under the assumption that open-cut duct bank installation would be allowed in all roadways, yielding to seven (7) probable routes: UG Route 1 through UG Route 7. DEV also requested to perform a feasibility study on four (4) additional new routes proposed by DEV: UG Route R1 through UG Route R4, considering the constraint imposed by VDOT of not allowing open-cut duct bank installation in some specific roadways and the existing utility congestion found per provided survey that limits the proposed UG transmission line in several of these proposed UG routes. The proposed UG circuits are to be installed between the new Mars Substation and a proposed new transition station where the circuits will transition from UG to overhead (OH) and continue to Golden Substation, except for new routes R3 and R4 where the circuits are proposed to be installed between two (2) proposed new transition stations. For the UG portion of the Golden to Mars Project, DEV is proposing to install one (1) 230-kV circuit rated at 1,572 MVA and one (1) 500-kV circuit rated at 4,357 MVA. This report focuses on the feasibility of the underground transmission solution and routes being evaluated. Based on the desired rating requirements and the proposed installation corridors provided by DEV planning, BMcD has performed a technical feasibility, routing, and construction cost estimate analysis for all proposed UG routes.

The following considerations were taken when performing the feasibility analysis:

- Civil Installation Type
    - Open-cut trench
        - 230-kV and 500-kV duct bank systems installed within the same Right-of-Way (ROW)
        - 230-kV and 500-kV duct bank systems installed in separate ROWs
    - Trenchless

        - 230-kV and 500-kV trenchless crossing systems installed within the same ROW

- Ampacity
    - Required cable ratings
    - Cable size/number of cables required
    - Evaluate both 85% and 100% Daily load factor (DLF) cases for open-cut trench installation
    - Evaluate 100% DLF case for trenchless installation
    - Installation method
- Routing
    - Open-cut trench routing options
    - Trenchless crossing options
    - Proposed transition station location
- Cost Estimates
    - Civil installation costs
    - Electrical systems costs
    - Transition station costs

2.0 SYSTEM CONSIDERATIONS

The design scope is to provide a feasibility analysis and provide recommendations for the design of the proposed Golden to Mars UG transmission lines. Seven (7) transition stations were evaluated in total for the different UG lines route options, Transition Station 1 (TS1) through Transition Station 7 (TS7). The length of the UG cable systems between proposed terminals is in the range of 1.6 miles to 4.6 miles depending on UG route selection.

The anticipated installation method for most of these routes consists entirely of open-cut trenching (concrete encased duct bank). Open-cut trenching is the preference and priority in selecting an UG route. However, for some of these proposed routes there are segments where trenchless technology (Jack & Bore, Microtunneling, Horizontal Directional Drilling) is anticipated to be required

The majority of the proposed UG routes in the project include the utilization of some properties outside of the public Right of Way (ROW). In contrast, the power corridors of Route R1, Route R2, Route R3 and Route R4 travel mainly through private lands. The UG routes take two approaches, a combined construction where both the 230-kV system and the 500-kV systems co-exist within the same ROW and a separated construction where the 230-kV system and the 500-kV duct bank are considered to occupy their own ROW. The separated routes, UG Routes 1, 3, 6 and 7, maximize the use of public ROW and each circuit occupies a separate side of their shared corridors, using separate alignments. Likewise, the portions of these routes that travel through private lands, have a separate alignment and each duct bank requires a separate ROW. The combined routes, UG Routes 2, 4, 5, R1, R2, R3 and R4, travel through mainly private lands so a shared alignment and single ROW for both circuits is utilized. For these routes, the spacing between each duct bank is minimized and both the 230-kV circuit and 500-kV circuit are considered to coexist within the same ROW.

Placement, frequency, and design of splice vaults were considered based on the following:

- A splice vault location placed approximately every 2,400 feet for the proposed 230-kV UG Cable System.
    - Two (2) splice vaults at each location, housing six (6) splices each.

- A splice vault location is placed approximately every 1,700 feet for the proposed 500-kV system.
  - Three (3) splice vaults at each location.
  - Two (2) splice vaults will house six (6) splices each while the third splice vault will house three (3) splices each.
- Splice vault dimensions and layout is dependent upon the cable system voltage class (As discussed below in Section 2.4).
- Splice vaults to be located based on prudent engineering design to avoid geometric issues with:
  - Existing infrastructure
  - Environmentally sensitive areas
  - Traffic interruptions
  - Existing geography
- A maximum of six (6) cable splices are proposed to be installed in a single vault.

Termination structures are assumed to be typical substation UG single circuit H-frame termination structures at transition station locations.

2.1 Underground Installation Requirements for Open-Cut Installation

The following section outlines the duct bank installation method for open-cut trench construction that is being considered for the proposed Golden to Mars UG project.

2.1.1 Concrete Encased Duct Bank

Concrete-encased duct banks are a form of open-cut trench installation. A typical duct bank system consists of conduits cast in concrete in a trench. This construction method is highly favored in urban areas of major cities or within road ROW. With this type of construction, a trench will be dug at a required depth and width. A layer of bedding material will be placed to provide a stable and level ground. PVC or HDPE conduits with a specified diameter and thickness will be assembled and placed in a trench at a predetermined depth and configuration. Conduit spacers will be utilized to meet the designed configuration and maintain spacing between conduits. The trench is then filled with an approved thermal concrete to facilitate the heat dissipation from the cable and protect the conduit system. Thermal concrete is high density, low air content concrete with a low thermal resistivity. Thermal concrete will extend from the bottom of the trench to cover the conduits, conduit fittings, and reinforcement (if required). After the concrete has cured, it is then backfilled with engineering fill, fluidized thermal backfill (FTB), which is a concrete-like material that has been commonly used historically for underground transmission backfills. It is a mixture of natural mineral aggregate, sand, cement, water, and a fluidizer that is formulated to meet specific thermal and strength requirements. Fly ash is a commonly used fluidizer. However, if fly ash is not readily available, a water-soluble resin or slag can be used. FTB is delivered in fluid state and can be poured or pumped into trenches very easily.

The main benefits of duct bank systems are the physical protection of the conduits and the ability to maintain conduit separation which can help with mutual heating concerns. Additionally, the duct bank system creates a raceway of conduits to pull cable into without the need for additional civil operations. Figure 2-1 shows a typical open trench construction of a duct bank system before being backfilled with concrete.

Figure 2-1: Duct Bank System Example

2.1.1.1 Duct Bank Considerations

Table 2-1 lists some typical considerations associated with open trench installation and details them specifically within the context of a concrete-encase duct bank installation.

Table 2-1: Duct Bank Installation Considerations

Considerations	Duct Bank Installation
Cable Protection	Concrete encasement provides high level of protection for traditional open-cut methods.
Routing Flexibility	Duct banks allow flexibility to route around existing utilities while maintaining appropriate clearances and bending radii.

Considerations	Duct Bank Installation
Private Easements	Any required deviations from the existing route (outside of public ROW) will require private easements in this area.

2.2 Underground Installation Requirements for Trenchless Installations

Trenchless alternatives for the installation of new cables provide advantages such as minimizing disruption to traffic, environmentally sensitive areas, existing utilities, and the general public. Given the project's proximity to main traffic roads, highways and the routes crossings through different waterbodies and future utilities, trenchless installation methods are expected to be necessary for some of these UG route options on this project.

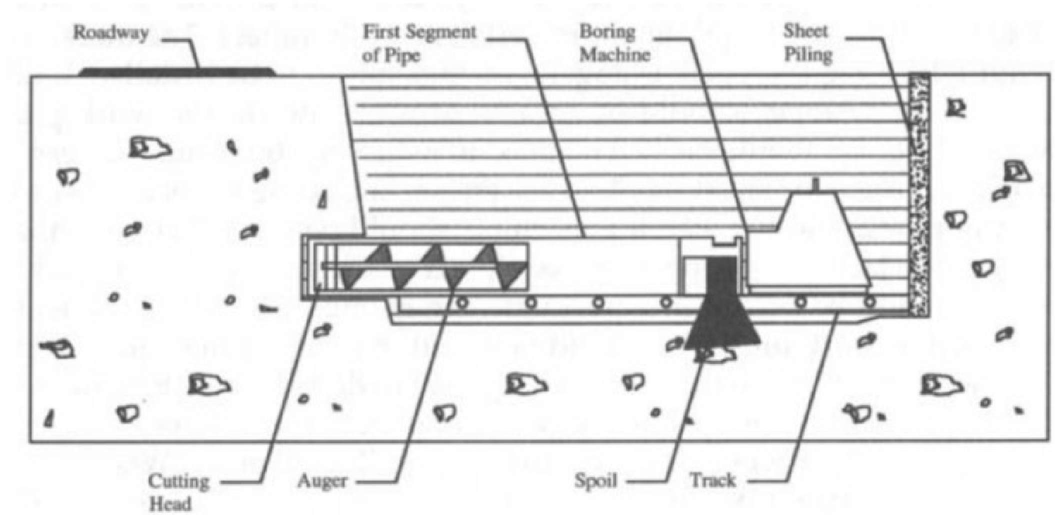
The purpose of this section is to discuss the details of technically feasible trenchless conduit installation options for this project.

2.2.1 Jack & Bore

The Jack and Bore (J&B) installation method (a type of horizontal auger boring) has been developed for pipe diameters ranging from 8" to 60", straight, and short length (<400 feet) trenchless installations. A J&B installation method is preferred for short crossings over other trenchless technologies that have greater minimum recommended installation lengths.

J&B is a multi-stage process that involves jacking a steel casing from a launching pit to a receiving pit (or launching shaft to receiving shaft). The materials encountered at the face of the bore are removed by augers contained within the casing. The spoils removed by the augers are transported to the launching pit, where they are collected for disposal. Typical accuracy of J&B can vary significantly with changing soil conditions; however, this accuracy can be greatly improved by using a pilot tube guidance system to establish the centerline of the alignment. Once the steel casing reaches the receiving pit, it is extruded by a non-metallic casing (e.g., HOBAS pipe) suitable for containment of electrical cables, although at a significantly higher cost. Figure 2-2 details a typical J&B installation taken from ASCE Manuals and Reports on Engineering Practice No. 106: "Horizontal Auger Boring Projects".

Figure 2-2: J&B Typical Installation



Shallow groundwater may present ground stability problems with J&B, particularly if loose, clean sands are present. Where applicable, the groundwater table may need to be lowered by dewatering. In addition, the trenchless contractor may reduce risk of ground instability by maintaining a plug of soil between the head to the augers, and the edge of the lead casing. The effectiveness of these methods will vary depending on soil conditions, site access (for dewatering) and depth of groundwater. J&B may be used in bedrock, depending on the compressive strength of the materials present. This may require use of a cutting head equipped with discs.

2.2.1.1 Jack & Bore Risks

Potential sources of risk associated with J&B construction for the Project are summarized in Table 2-2 below.

Table 2-2: J&B Installation Risks

Risk Source	Potential Outcome	Comments
Encountering obstructions – cobbles or boulders, debris	May require clearance through excavation from ground surface, or from within the jack and bore casing.	Oversized materials need to be characterized, and contingency plans for handling should be developed. The jack and bore alignment would need to be located below the fill, within the underlying native soils.

Risk Source	Potential Outcome	Comments
Unanticipated subsurface conditions	Project delays, additional contractor costs.	The subsurface conditions should be characterized by test borings prior to trenchless design. If shallow (<30 feet), the depth of bedrock should be determined. The depth of groundwater shall be determined.
Encountering underground utilities	Encountering utilities could result in utility damage, failure of installation.	Location of all utilities within 20 feet of the jack and bore installations should be determined prior to construction. Crossing shall be designed to maintain clearance from existing utilities. Utility owners should be notified in advance of construction.
Elevated jacking pressures	Jacking pressures can exceed ability of jacks to maintain forward progress, causing reduced penetration rate, pipe damage.	Estimated jacking loads need to be calculated. Casing pipe needs to be designed to withstand estimated installation pressures. Site-specific lubrication needs to be considered.
Surface settlement adjacent to pits	Surface settlement could occur adjacent to pits, impacting pavements, building foundations.	Pit excavation support would need to be designed to minimize ground movements. Equipment excavation rates need to be monitored carefully to avoid over-excavation. Surface monitoring points shall be used to detect settlement during construction.

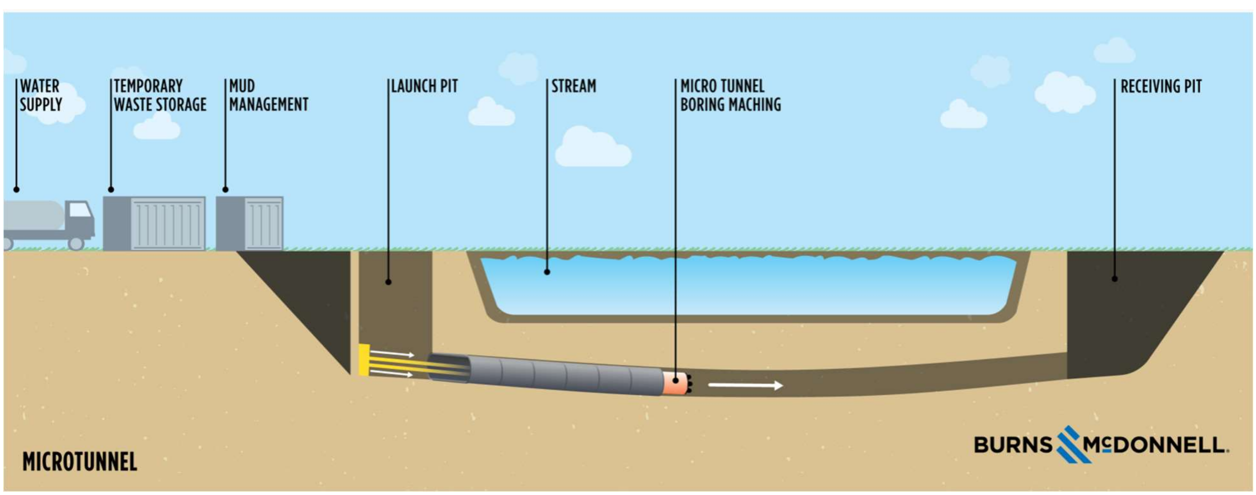
Risk Source	Potential Outcome	Comments
		Pit design would need to include site-specific dewatering plan sufficient to provide a stable, dry work surface (both pits).
Surface settlement or heave along jack and bore alignment(s)	Surface settlement or heave could occur during jack and bore, impacting pavements.	Equipment excavation rates need to be monitored carefully to avoid over-excavation. Dewatering may be necessary to reduce potential for uncontrolled inflow of saturated granular soils if present. Surface monitoring points should be used to detect settlement during construction. An appropriate installation depth should be selected based on the site-specific subsurface conditions present.
Groundwater Seepage	If bore is below the groundwater table, groundwater may present stability problems with the J&B, particularly if loose, clean sands are present.	Groundwater table may be lowered by dewatering. A soil plug can be utilized between the head to the augers, and the edge of the lead casing.

2.2.2 Microtunneling

Microtunneling is a remotely controlled pressurized face operation where the pipe is hydraulically pushed or jacked from a launch shaft to a retrieval shaft. The pressurized face characteristic refers to the ability of this trenchless method to apply positive face stabilization at all times in all types of soil and under groundwater head pressure up to approximately 80 to 100 ft. Face support is applied through the use of pressurized slurry which is pumped in a circulating loop from holding tanks at the ground surface to the slurry chamber located at the front of the microtunnel boring machine (MTBM) through slurry lines. A bulkhead at the front of the MTBM isolates the groundwater and earth pressure at the face of the MTBM from the atmospheric pressure within the installed pipe.

As the MTBM advances, the cutter wheel excavates material in front of the machine. The excavated material passes through the crushing chamber and falls into a collection/slurry chamber where the spoil mixes with the clean slurry water pumped down from the holding tanks. The heavier slurry is then pumped back through the installed pipe sections and up the jacking shaft to a separation plant. The separation plant is used to process the slurry by removing the soil constituents to allow the fluid component to be recycled for re-use. The recycled water falls into holding tanks until pumped down to the MTBM slurry chamber in the closed slurry loop. By controlling the amount of material entering the machine with the advance rate of the MTBM and controlling the fluid pressures within the slurry chamber, the MTBM is capable of independently balancing earth and groundwater pressures simultaneously. This characteristic allows excavation of very soft material and materials under high ground water pressures without the need for dewatering. A laser/theodolite system is typically used to monitor line and grade as the MTBM is advanced through the subsurface. Steering jacks coupled with an articulation joint within the MTBM are used to steer the machine to line and grade tolerances of plus or minus 1" over the length of the installation. A schematic of a typical microtunnel installation is provided in Figure 2-3 below.

Figure 2-3: Typical Microtunneling Schematic



Microtunneling installations typically involve installing pipelines ranging in 30-inch up to 10 ft in diameter. For installations greater in length, intermediate jacking stations (IJS) are required. An IJS consists of a series of hydraulic rams installed within shaft located along the microtunnel alignment at the tunnel depth that, when activated, moves a telescoping steel shell that clamps to and advances the pipe string in front of the IJS. IJS's are placed along the microtunnel alignment and travel with the pipe string as it is pushed through the formation by the main hydraulic jacks in the launch shaft. When needed, the hydraulic rams in the IJS can be activated to provide additional jacking force within the pipe string to overcome frictional forces or face pressure. For risk mitigation purposes of long-drive microtunnels, it is common to require placement of an initial IJS within 100 ft of the front of the launch shaft and at a regular spacing of approximately 500 ft along the remainder of the microtunnel alignment, depending upon the anticipated jacking force requirements.

2.2.2.1 Microtunneling Risks

Potential sources of risk associated with microtunneling construction for the Project are summarized in Table 2-3 below.

Table 2-3: Microtunnel Installation Risks

Risk Source	Potential Outcome	Comments
Encountering obstructions – cobbles or boulders, debris	May slow down drilling or require clearance through the microtunnel casing.	Oversized materials need to be characterized, and contingency plans for handling should be developed. Appropriate drill heads shall be selected for the environment
Unanticipated subsurface conditions	Project delays, additional contractor costs.	The subsurface conditions should be characterized by test borings prior to trenchless design. If shallow (<30 feet), the depth of bedrock should be determined. The depth of groundwater shall be determined.

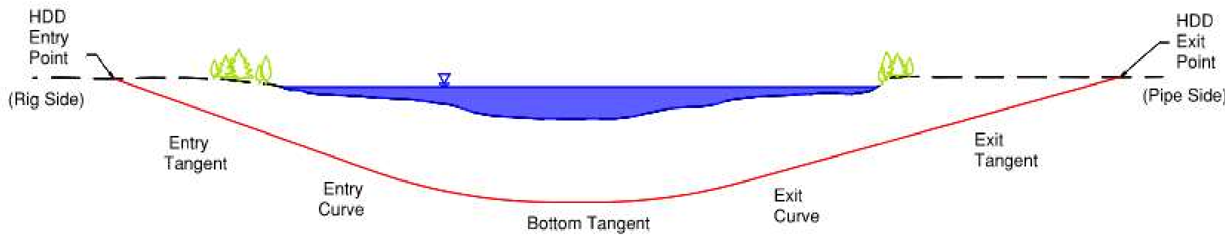
Risk Source	Potential Outcome	Comments
Encountering underground utilities	Encountering utilities could result in utility damage, failure of installation. Most likely location to encounter them will be near the excavation pits	Location of all utilities within 20 feet of the jack and bore installations should be determined prior to construction. Crossing shall be designed to maintain clearance from existing utilities. Utility owners should be notified in advance of construction.
Surface settlement adjacent to pits	Surface settlement could occur adjacent to pits, impacting pavements, building foundations.	Pit excavation support would need to be designed to minimize ground movements. Equipment excavation rates need to be monitored carefully to avoid over-excavation. Surface monitoring points shall be used to detect settlement during construction. Pit design would need to include site-specific dewatering plan sufficient to provide a stable, dry work surface (both pits).
Surface settlement or heave along microtunnel alignment(s)	Surface settlement or heave could occur during microtunneling, affecting the surface	Equipment excavation rates need to be monitored carefully to avoid over-excavation. Surface monitoring points should be used to detect settlement during construction. An appropriate installation depth should be selected based on the site-specific subsurface conditions present.

2.2.3 Horizontal Directional Drill

A Horizontal Directional Drill (HDD) is a form of trenchless technology utilized to minimize surface impacts. The typical installation length of an HDD ranges from a few hundred feet up to a few thousand feet, depending on installation geometry, ground conditions, and capabilities of the drill rig. Installation of conduits by an HDD is generally accomplished in three stages: pilot hole drilling, reaming, and conduit pulling. The pilot hole drilling stage involves drilling a small pilot hole along the designed HDD path. The reaming stage involves enlarging the pilot hole to a diameter which will accommodate the conduit bundle. The conduit pulling stage involves pulling the conduit bundle back through the enlarged hole.

A typical HDD profile consists of five (5) parts: the entry tangent, entry curve, bottom tangent, exit curve, and exit tangent. The entry tangent is typically between 10 and 12 degrees below grade; however, they can range anywhere from 8 to 20 degrees below grade. The exit tangent can be angled between 5 and 12 degrees below grade, but is frequently oriented at 8 to 10 degrees. Increased exit angles will require the pull section to undergo more stress and potentially require suspension at an elevated position as the cable bundle in HDD installations is pulled towards the HDD rig. Exit angles that are too small can increase the likelihood of inadvertent returns near the exit point. The bottom tangent depth can be determined by several factors, including soil/ground materials, borehole diameter, existing obstacles (such as utilities and structures), environmental concerns, and permitting requirements. The bottom tangent depth is designed to reduce the risk of inadvertent return, reduce the risk of surface settlement or heaving, provide allowance for error in existing grade survey or account for future grade changes, and account for the cable derating factor for electrical installations. The typical industry standard for entry and exit curve radius is 100 times the conduit bundle where the minimum entry and exit curve radius is defined by 1,200 times the diameter of the drill rod. See Figure 2-4 for the typical HDD geometry.

Figure 2-4: Typical HDD Geometry



Inadvertent return can occur when the overburden soil's confinement strength is insufficient to withstand the downhole pressure exerted by drilling fluid. As a result, drilling fluid would escape the borehole and emerge to the ground through void and cracks of the soils and rocks fractures. Inadvertent returns could happen because of various reasons such as excess fluid flow, high fluid pressure, improper drilling mixture, improper rate of penetration, annular space obstruction, and unstable geological formations. Inadvertent return typically occurs in drilling through the weak cohesive soils with low shear strength like soft silts and clays. In soils such as these, a casing can be installed with the HDD as a way to support the borehole during drilling, which also helps to reduce settling of soil and facilities at grade. Additionally, casings can be installed with the conduits and filled with thermal grout to reduce the cable derating throughout the HDD in electrical installations.

2.2.3.1 Horizontal Directional Drill Risks

Potential sources of risk associated with HDD construction for the Project are summarized in Table 2-4 below.

Table 2-4: HDD Installation Risks

Risk Source	Potential Outcome	Comments
Encountering obstructions – cobbles or boulders, debris	May require clearance through excavation from ground surface or relocation of the drill rig and a new bore to be drilled depending on obstruction depth	Oversized materials need to be characterized, and contingency plans for handling should be developed.

Risk Source	**Potential Outcome**	**Comments**
Unanticipated subsurface conditions	Project delays, additional contractor costs.	The subsurface conditions should be characterized by test borings prior to trenchless design. If shallow (<30 feet), the depth of bedrock should be determined. The depth of groundwater shall be determined.
Encountering underground utilities	Encountering utilities could result in utility damage, failure of installation.	Location of all utilities within 20 feet of the HDD installation should be determined prior to construction. Crossing shall be designed to maintain clearance from existing utilities. Utility owners should be notified in advance of construction.
Insufficient Drill Rig Pulling Capabilities	Conduit bundle weights can exceed pulling capabilities of certain drill rigs, causing conduit bundles to be stuck within the bore	Estimated pulling loads required must be calculated prior to HDD operations and a rig of sufficient pulling capabilities shall be selected to complete the drill
Surface settlement or heave along HDD alignment(s)	Surface settlement or heave could occur during the HDD operations, impacting pavements.	Surface monitoring points should be used to detect settlement during construction. An appropriate installation depth should be selected based on the site-specific subsurface conditions present.

Risk Source	Potential Outcome	Comments
Inadvertent Return	Drilling fluid escapes the borehole, either underground or at the entry/exit points, and flows into the environment	A site-specific geotechnical study shall be completed prior to drilling operations. Annular pressure calculations shall also be performed to determine whether borehole integrity can remain intact during the drills. A drill fluid clean up kit shall also remain on site during drilling operations

2.3 Cross-Linked Polyethylene (XLPE) Cable

XLPE is a type of cable that consists of a metal conductor surrounded by XLPE as the insulating material, a metallic sheath and commonly a polyethylene jacket. XLPE cables have the benefit of being durable enough to be pulled long distances in a variety of environments while remaining flexible enough to be pulled through geometrically complex conduit raceways. XLPE cables can be constructed with both aluminum and copper conductors and at a variety of sizes while not requiring any sort of fluid system or rigid pipe design. Although the historical data on XLPE cables is not as extensive as some fluid filled pipe-type systems, modern installations are increasingly utilizing XLPE cable system. Figure 2-5 from the Southwire cable catalog shows an example of a typical high-voltage UG XLPE cable.

Figure 2-5: XLPE UG Power Cable

XLPE cables will be installed between vaults spaced approximately 2,400 feet apart for 230-kV and approximately 1,700 feet apart for 500-kV. The primary drivers for this spacing are the cable reel transportation logistics and the pulling tensions experienced by the cables. Detailed design would include of pulling calculations to determine the exact spacing of these splice vaults and a determination of which constraint controls for this alignment. The vaults for each UG cable system would be designed to house up to a total of 6 splices per vault. Based on the 230-kV system requirement detailed in Section 3.0 below, two (2) vaults are required for each vault location, to splice the four (4) cables-per-phase circuit. Based on the 500-kV system requirement detailed in Section 3.0 below, three (3) vaults are required for each vault location, to splice the five (5) cables-per-phase circuit.

2.4 Splice Vaults

Splice vault locations are anticipated along the underground route to facilitate cable installation and splicing as well as for operation and maintenance access over the lifespan of the installation. The vault size and layout are determined by the space required for cable size, cable pulling, splicing, and supporting the cable in the vault. Based on these factors, the anticipated interior dimensions of the vaults for the 230-kV system are 10 feet wide by 8 feet tall by 26 feet long (10' x 8' x 26').[1] The anticipated interior dimensions of the vaults for the 500-kV system are 15 feet wide by 8 feet tall by 40 feet long (15' x 8' x 40').[1] Almost all transmission cable splice vaults have two access manholes to facilitate cable installation. These splice vaults can be precast or cast-in-place depending on the area of installation and if other utility lines are nearby preventing the installation of a precast splice vault.

It is always recommended that splice vaults be the first item to be installed for an underground cable system. This helps prevent unknown utilities from necessitating moving the splice vaults. Relocating the splice vaults will affect the cable cut lengths that have been previously determined. See Figure 2-6 below for typical 230-kV splice vault details and see Figure 2-7 below for typical 500-kV splice vault details.

[1] Interior vault size is a function of minimum interior dimensions necessary for installation, racking, and splicing of high voltage cables. Final wall, ceiling and floor thicknesses, and thus final exterior dimensions, will be determined during the final design process based on depth of installation, anticipated soil and groundwater conditions, and traffic loading requirements.

Figure 2-6: Typical 230-kV UG Splice Vault

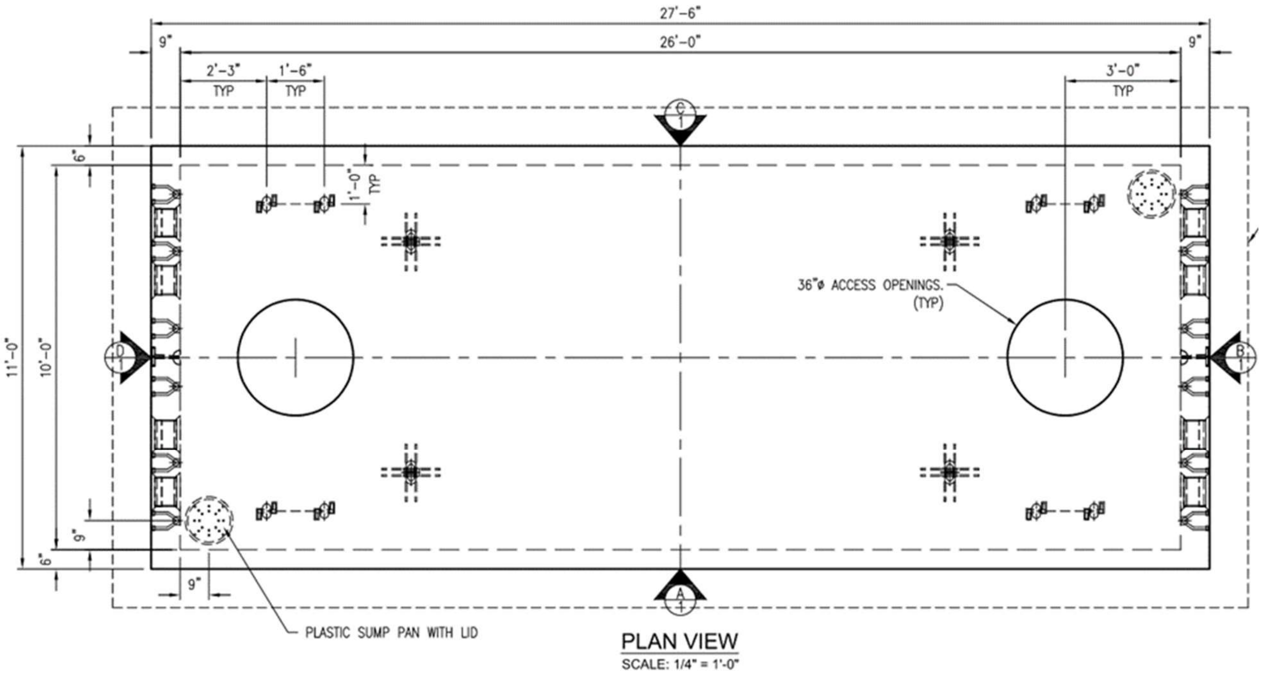
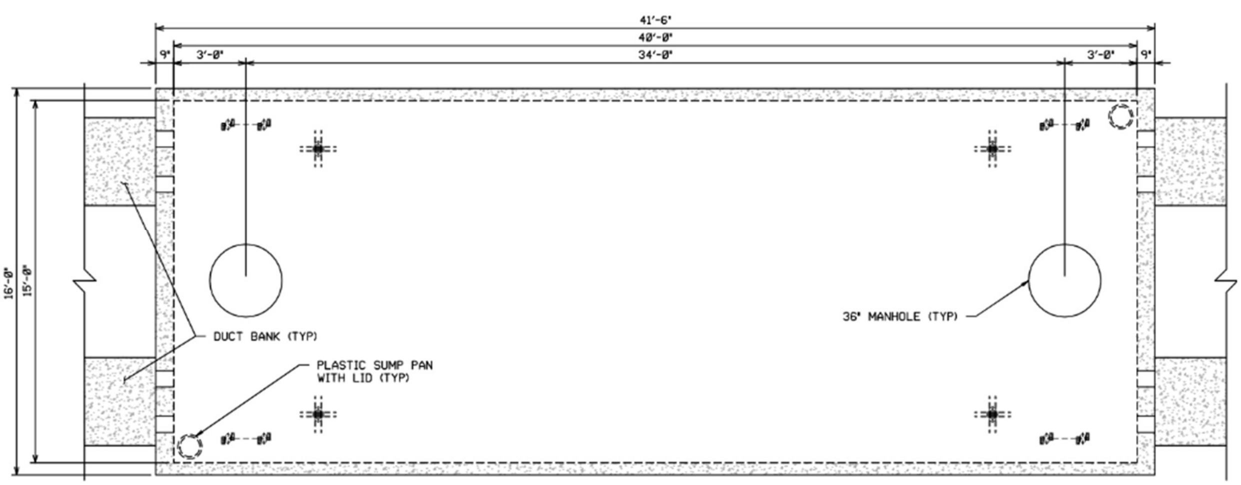


Figure 2-7: Proposed 500-kV Splice Vault



For the Golden to Mars project, two (2) splice vaults are anticipated to be required at each 230-kV splice location and three (3) splice vaults are anticipated to be required at each 500-kV splice location to accommodate the number of cables needed to reach the desired per circuit ratings. See Figure 2-6 and Figure 2-7 above for the assumed 230-kV and 500-kV splice vault details. For routes where, the 230-kV and 500-kV duct banks share the same ROW, the splice vaults may be staggered to to minimize foot print impacts. See Figure 2-8 and Figure 2-9 below for an example of how these vaults may be arranged.

Figure 2-8: Golden-Mars Splice Vault Location, 85% DLF

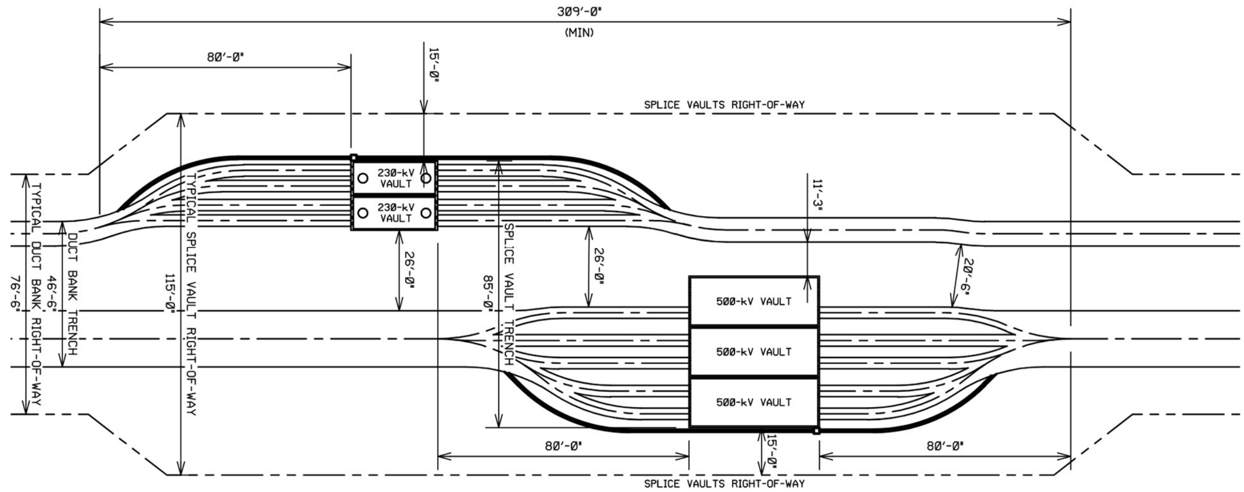
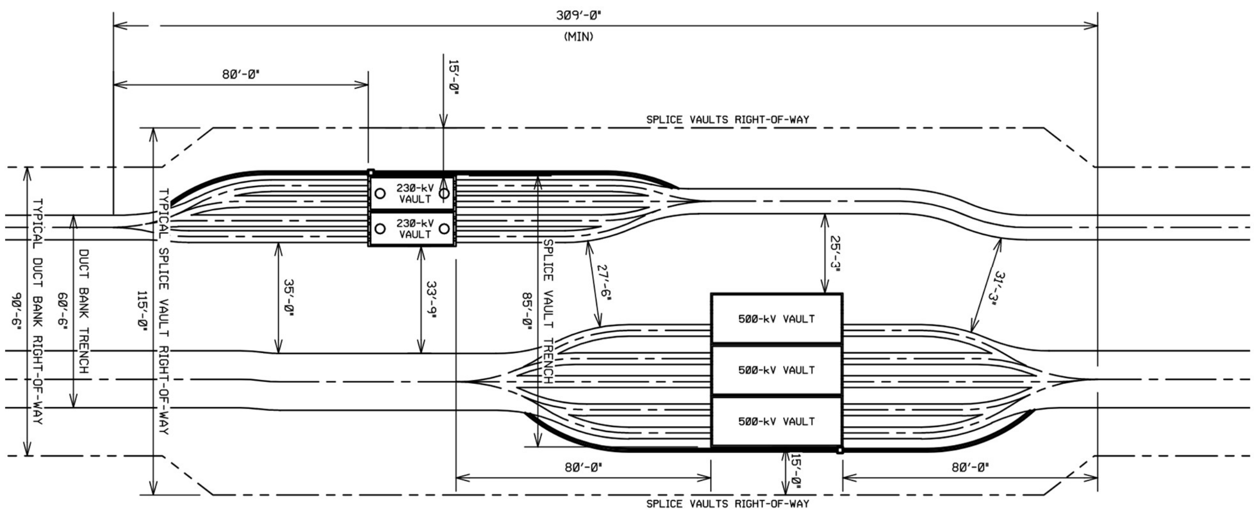


Figure 2-9: Golden-Mars Splice Vault Location, 100% DLF



3.0 DESIGN AND INSTALLATION CRITERIA

3.1 System Requirements & Environment

System ratings for the proposed underground Golden to Mars transmission circuits were provided by Dominion Engineering for the evaluation included in this report. The cables, splices, grounding system and other components shall meet the following requirements in Table 3-1 and Table 3-2 below:

Table 3-1: System Rating for Golden to Mars 230-kV Underground Transmission Circuit

Design Parameter	Parameter Value
Number of Circuits	One (1)
Nominal Voltage	230-kV
Nominal Frequency	60 Hertz
Normal Ampacities	3,950 Amps (1,572 MVA)
Continuous Conductor Temperature	90 ºC
Emergency Conductor Temperature	105 ºC
Daily Load Factor (DLF)*	85% and 100%
Maximum Short Circuit Conductor Temperature	250 ºC
Cable Sheath Bonding	Single point bonded

* For each open-cut duct bank configuration, both 85% DLF and 100% DLF will be evaluated. For trenchless configurations only 100% DLF will be evaluated.

Table 3-2: System Rating for Golden to Mars 500-kV Underground Transmission Circuit

Design Parameter	Parameter Value
Number of Circuits	One (1)
Nominal Voltage	500-kV
Nominal Frequency	60 Hertz
Normal Ampacities	5,031 Amps (4,357 MVA)
Continuous Conductor Temperature	90 ºC

Design Parameter	Parameter Value
Emergency Conductor Temperature	105 ºC
Daily Load Factor*	85% and 100%
Maximum Short Circuit Conductor Temperature	250 ºC
Cable Sheath Bonding	Single point bonded

* For each open-cut duct bank configuration, both 85% DLF and 100% DLF will be evaluated. For trenchless configurations only 100% DLF will be evaluated.

3.2 Operating Environment

The following describes the assumed operating environment in which the cables will be installed and operated within.

3.2.1 General

The proposed cable systems will be installed using primarily concrete-encased duct bank installation methods within a mixture of existing public ROW, private, and/or public property available in the project vicinity area in Dulles, Virginia. Some of the proposed routes will require trenchless installation methods at determined crossings.

- The duct bank will consist of polyvinyl chloride (PVC) conduits to carry the power cables. The duct bank design will include one (1) spare conduit per subcircuit for emergency repair scenarios. In addition to the power cable conduits, one (1) smaller PVC conduit will be included, per cable set, to carry the ground continuity conductors (GCC), in addition to one (1) smaller PVC conduit to carry a fiber communication cable per circuit.
- The trenchless installation will consist of:
- HOBAS casings (centrifugally cast, fiberglass reinforced, polymer mortar) to carry the conduit bundle for J&B and Microtunneling installations. These casings will be filled-in with thermal grout to aid the power cables load capacity. The conduit bundle will consist of PVC conduits to carry the power cables, including one (1) spare conduit per subcircuit for emergency repair scenarios. In addition to the power cable conduits, one (1) smaller PVC conduit will be included, per cable set, to carry the GCC, in addition to one (1) smaller PVC conduit to carry a fiber communication cable per circuit.

- High-Density Polyethylene (HDPE) casings to carry the conduit bundle for HDD installations. These casings will be filled-in with thermal grout to aid the power cables load capacity. The conduit bundle will consist of HDPE conduits to carry the power cables, including one (1) spare conduit per subcircuit for emergency repair scenarios. In addition to the power cable conduits, one (1) smaller HDPE conduit will be included, per cable set, to carry the GCC, in addition to one (1) smaller HDPE conduit to carry a fiber communication cable per circuit.

3.2.2 Assumed Operating Environment

At the time of publication of this report, no field investigation into existing soil conditions of the project site have been performed. Based on experience and engineering judgement, the operating environment parameters were therefore assumed for the purpose of this study as follows in Table 3-3 below.

Table 3-3: Golden-Mars UG Transmission Assumed Operating Environment

Parameter	Assumptions
Summer Ambient Earth Temperature	28 ^{o}C for 3-7 feet of cover 20 ^{o}C for 7-20 feet of cover 12 ^{o}C for >20 feet of cover
Native Soil Thermal Resistivity*	150 ^{o}C C-cm/watt for 85% DLF 115 ^{o}C C-cm/watt for 100% DLF
Concrete Thermal Resistivity	65 ^{o}C C-cm/watt
Flowable Fill Thermal Resistivity	70 ^{o}C C-cm/watt
Grout Thermal Resistivity	80 ^{o}C C-cm/watt
Minimum Burial Depth to Top of Duct Bank	3 feet

*Actual native soil thermal resistivity is unknown, and these values are assumed. It is lower for the 100% DLF, as this is the maximum allowable value to meet ampacity requirements using the same number of cables per phase as the 85% DLF option.

Note that the ambient temperature values are based on previous project data in a similar geographic location. The actual native soil thermal resistivity for the UG routes is unknown and a conservative number of 150 ^{o}C C-cm/watt is assumed for the 85% DLF case. However, the native soil thermal resistivity value for the 100% DLF is lower (115 ^{o}C C-cm/watt) as this is the maximum allowable value to meet the ampacity requirements while keeping all other operating environment assumptions the same. Final soil thermal resistivity will be predicated on geotechnical investigations performed during the design phase of the Project.

3.2.3 Subsurface Conditions

The suitability of civil construction methods will depend on the site-specific subsurface conditions, including the following:

- Fill depth and gradation
- Native soil thickness, gradation. density/consistency, and permeability
- Bedrock depth, rock type, hardness, abrasiveness, compressive strength, and weathering
- Groundwater depth

A project-specific subsurface investigation has not been completed. For the purpose of discussion, we have assumed the following:

- Fill will be variable in gradation will range from about one to five feet in thickness.
- The native overburden will include residual soils, reflective of the underlying bedrock. Alluvial deposits may be present adjacent to streams and wetlands.
- Bedrock depths will range from about 10 to 30 feet below grade and will consist of sedimentary lithologies (shale, sandstone, siltstone).
- Groundwater may be present at depths ranging from 5 to 20 feet below existing ground surface.

3.3 Ampacity Analysis

Ampacity calculations were modeled for the proposed XLPE cable systems to verify that the system meets the load criteria for all installation scenarios. The ampacity calculations for the 230-kV cable were performed using a Southwire 230-kV 5,000 kcmil enameled segmented copper conductor XLPE cable cutsheet. The ampacity calculations for the 500-kV cable were performed using a Taihan 500-kV 5,000 kcmil enameled segmented copper conductor XLPE cable cutsheet.

The ampacity of the cables was then calculated as a function of the maximum conductor temperature to verify the cable could achieve the ratings provided by DEV. It was determined that a five (5) cables per phase (CPP) configuration was required to meet the ampacity ratings for the 500-kV circuit, within a single duct bank and that a four (4) CPP configuration was required for the 230-kV circuit, within a single duct bank. These results are outlined in Section 3.4 below and the ampacity executions are attached in Appendix B for duct banks, and are detailed in Appendix F for the different trenchless installations.

After the initial ampacity request, DEV has requested two (2) additional ampacity scenarios. For the first scenario, the 500-kV circuit is split into two (2) duct banks and the number of CPP is reduced to four (4) CPP. For the second scenario, both the 230-kV and 500-kV single circuit duct banks are reduced by one CPP to identify the maximum ampacity rating that can be achieved by running the cables to their maximum operating temperature of 90°C. An ampacity memorandum was created to analyze these scenarios. Please see Appendix B for the detailed ampacity memorandum of the additional scenarios and all ampacity executions.

Once the scenarios described above where completed, DEV requested to analyze three (3) additional ampacity scenarios for trenchless crossings installations considering five (5) CPP for the 500-kV circuit and four (4) CPP for the 230-kV circuit coexisting in the same power ROW. The first scenario consisted of J&B installations subdivided into two different settings: one considering a combination of bores with two (2) CPP in the same bore and one (1) CPP per bore, the other considering all bores each with one (1) CPP. The second scenario consisted of Microtunneling installations subdivided into the similar settings previously described for J&B. Finally, the third scenario corresponded to HDD installations considering all bores each with one (1) CPP. For each scenario, a parametric study was performed to reach at least the minimum ampacity requirements from Table 3-1 and Table 3-2. An additional ampacity memorandum was created to analyze these scenarios. Please see Appendix F for the detailed ampacity memorandum of the additional scenarios and all ampacity executions.

Ampacity calculations were completed utilizing the CYMCAP ampacity program to verify the conductor size(s) required and the duct bank design needed for the XLPE options. CYMCAP is the industry-accepted software (utilizing IEC and ICEA standards) used for underground cable ampacity calculations. It allows the user to model many different system parameters to give more project specific results. These parameters include, but are not limited to, native soil thermal resistivity, different types of backfills (including the associated thermal resistivity), conduit types, customized conduit configurations, and customized cable construction.

For each ratings scenario, calculations were run based on an assumed worst-case scenario or "pinch point". The "pinch points" are typically the result of deeper duct bank installations, trenchless crossings, and adjacent heat sources (i.e., existing underground electrical circuits, steam lines, etc.). Since a detailed investigation of the subsurface conditions has not been performed at the time of this report, the thermal "pinch point" assumed for the open-cut installation was:

- Deep duct bank installation (8' to top of concrete)
- Parallel duct banks (Reference Figure 3-4 and Figure 3-5 below for minimum separation between duct banks)

The thermal "pinch points" assumed for trenchless installations are detailed in Appendix F.

These "pinch points" will be subject to change during future investigation of the actual site conditions that will be encountered. The sections below summarize ampacity results for the various installation scenarios and associated ampacity calculation results.

3.4 XLPE Ampacity Results

Table 3-4 through Table 3-7 below outline the ampacity calculations that were performed for the XLPE cable system. The required loading for the proposed 230-kV circuit is 3,950 Amps under normal loading conditions. The required loading for the proposed 500-kV circuit is 5,000 Amps under normal loading conditions. For open-cut installation scenarios, both 85% DLF and 100% DLF were evaluated. For trenchless installations scenarios only 100% DLF was evaluated. The following tables show the calculated ampacity for the open-cut trench concrete encased duct bank installations and trenchless installations.

Table 3-4: 230-kV Ampacity Results – Open-Cut Duct Bank Installations

Installation Type	DLF	Native Soil Thermal Resistivity ºC C-cm/watt	Horizontal Center-Center Conduit Separation (Feet)	Vertical Center-Center Conduit Separation (Feet)	Required Normal Ratings (Amps)	Calculated Normal rating (Amps)
Duct Bank	85%	150	2	2	3,950	4,444
Duct Bank	100%	115	2	2	3,950	4,296
Duct Bank	100%	150	2	2	3,950	4,196

Table 3-5: 500-kV Ampacity Results – Open-Cut Duct Bank Installations

Installation Type	DLF	Native Soil Thermal Resistivity ºC C-cm/watt	Horizontal Center-Center Conduit Separation (Feet)	Vertical Center-Center Conduit Separation (Feet)	Required Normal Ratings (Amps)	Calculated Normal rating (Amps)
Duct Bank	85%	150	4	1.5	5,000**	5,130
Duct Bank	100%	115	4	1.5	5,000**	5,025
Duct Bank	100%	150	4	2	5,000**	4,620*

*Ampacity results indicate that with a DLF of 100% an assumed native soil resistivity of 150 ºC C-cm/watt, the 500-kV circuit is unable to meet DEV ampacity requirements. Native soil thermal resistivity is lowered for the 100% DLF case, as this is the maximum allowable value to meet ampacity requirements.
** Further calculations are required to confirm that all executions meet ampacity requirements.

Table 3-6: 230-V and 500-kV Circuits in same ROW Ampacity Results – Open-Cut Duct Bank Installations

Installation Type	DLF	Native Soil Thermal Resistivity (ºC C-cm/watt)	Circuit Voltage (kV)	Horizontal Center-Center Conduit Separation (Feet)	Vertical Center-Center Conduit Separation (Feet)	Required Normal Ratings (Amps)	Calculated Normal rating (Amps)
Duct Bank	85%	150	230	2	2	3,950	4,202
			500	4	1.5	5,000*	5,008
Duct Bank	100%	115	230	2	2	3,950	4,183
			500	4	2	5,000*	5,005

* Further calculations are required to confirm that all executions meet ampacity requirements.

Table 3-7: 230-V and 500-kV Circuits in same ROW Ampacity Results – Trenchless Installations

Installation Type**	DLF	Native Soil Thermal Resistivity (ºC C-cm/watt)	Circuit Voltage (kV)	Horizontal Center-Center Casign Separation (Feet)	Maximum Depth of Cover Assumed (Feet)	Required Normal Ratings (Amps)	Calculated Normal rating (Amps)
J&B and Microtunneling	100%	115	230	15	30	3,950	4,047
			500	45		5,000***	5,043
J&B and Microtunneling	100%	115	230	15	40	3,950	3,972
			500	60		5,000***	5,140
HDD	100%	115	230	20*	45	3,950	4,061
			500	65		5,000***	5,006

*Center-to-center separation between 230-kV bore and 500-kV bore is 70 feet.
**All trenchless detailed executions can be found in Appendix F.
*** Further calculations are required to confirm that all executions meet ampacity requirements.

For the proposed 230-kV XLPE circuit, the ampacity ratings were met with a four (4) cables per phase system, without exceeding the 90 ºC operating temperature. For both the 85% DLF and 100% DLF case, the ampacity ratings were achievable with 115 ºC C-cm/watt or 150 ºC C-cm/watt native soil thermal resistivity, respectively.

For the proposed 500-kV XLPE circuit, the ampacity ratings were met with a five (5) cables per phase system, without exceeding the 90 ºC operating temperature. For the 85% DLF and case, the ampacity ratings were achievable with 115 ºC C-cm/watt or 150 ºC C-cm/watt active soil thermal resistivity.

However, for the 100% DLF case, the ampacity ratings were only achievable with a maximum of 115 ºC C-cm/watt native soil thermal resistivity.

3.4.1 230-kV Duct Bank

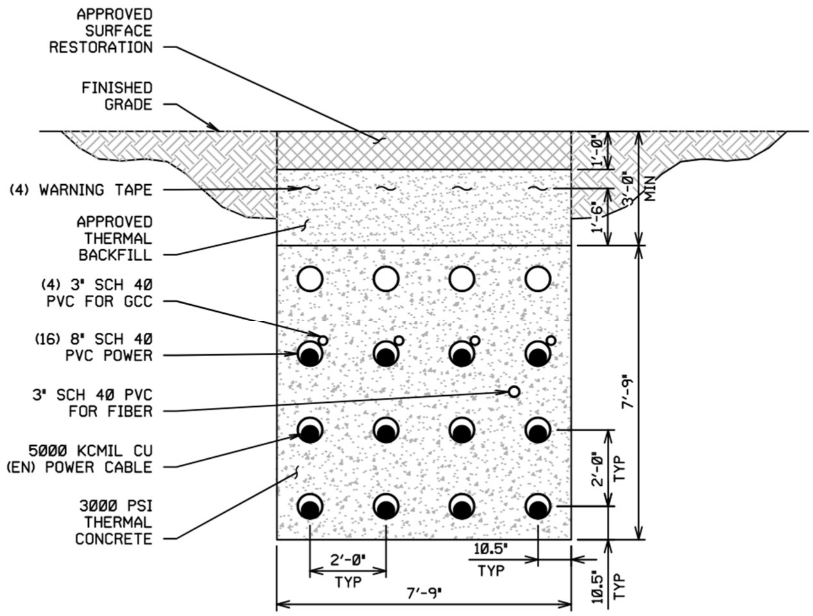
The cross section in Figure 3-1 below represents the anticipated open-cut duct bank configuration for the XLPE cable system, including 15 feet at each side for working space. For the 230-kV circuit, the vertical and horizontal spacing between the duct banks remains the same for the 85% DLF case and the 100% DLF case.

The 230-kV model was created with the following parameters:

- One (1) UG circuit (4x4) conduit arrangement
- Four (4) cables per phase
- 8' depth of cover
- 24" center to center spacing on conduits

The ampacity calculations concluded that this configuration of cables could meet the project ampacity requirements for both 85% and 100% DLFs.

Figure 3-1: Golden-Mars UG Preliminary 230-kV XLPE Duct Bank Cross Section (37'-9" Total ROW)



A summary of the ampacity calculations can be seen in Appendix B of this document.

3.4.2 500-kV Duct Bank

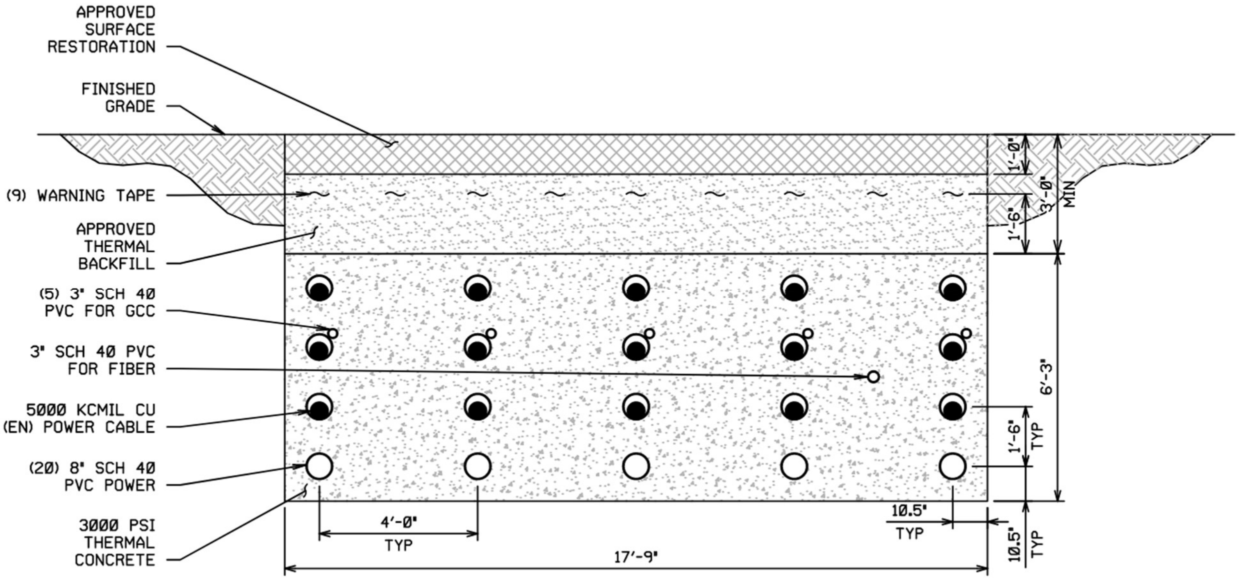
The cross section in Figure 3-2 below represents the anticipated open-cut duct bank configuration for the XLPE cable system, assuming an 85% DLF and including 15 feet at each side for working space. The cross section in Figure 3-3 below represents the anticipated open-cut duct bank configuration for the XLPE cable system, assuming a 100% DLF and including 15 feet at each side for working space. From the ampacity study, it was determined the 100% DLF case would require greater vertical spacing than the 85% DLF case.

The 85% DLF model for the 500-kV circuit was created with the following parameters:

- One (1) UG circuit with (4x5) conduit arrangement
- Five (5) cables per phase
- 8' depth of cover
- 48" center to center horizontal spacing on conduits

- 18” center to center vertical spacing on conduits

Figure 3-2: Golden-Mars UG Preliminary 500-kV XLPE Duct Bank Cross Section, 85% DLF (47’-9” Total ROW)

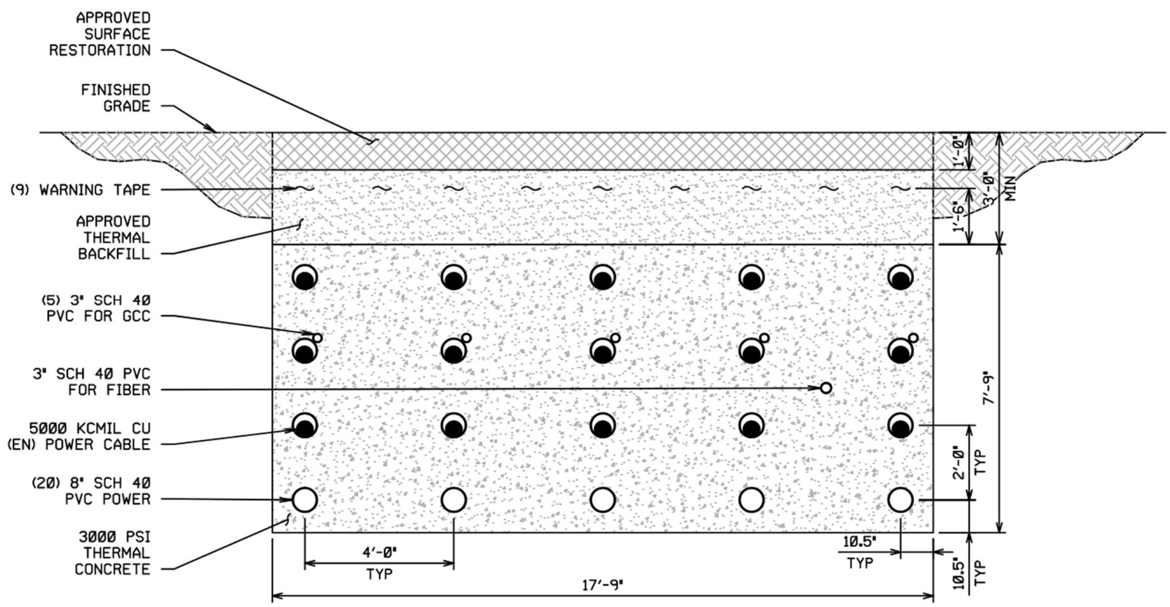


The 100% DLF model for the 500-kV was created with the following parameters:

- One (1) UG circuit with (4x5) conduit arrangement
- Five (5) cables per phase
- 8’ depth of cover
- 48” center to center horizontal spacing on conduits
- 24” center to center vertical spacing on conduits

The ampacity calculations concluded that this configuration of cables could meet the project ampacity requirements with a 100% DLF.

Figure 3-3: Golden-Mars UG Preliminary 500-kV XLPE Duct Bank Cross Section, 100% DLF (47'-9" Total ROW)

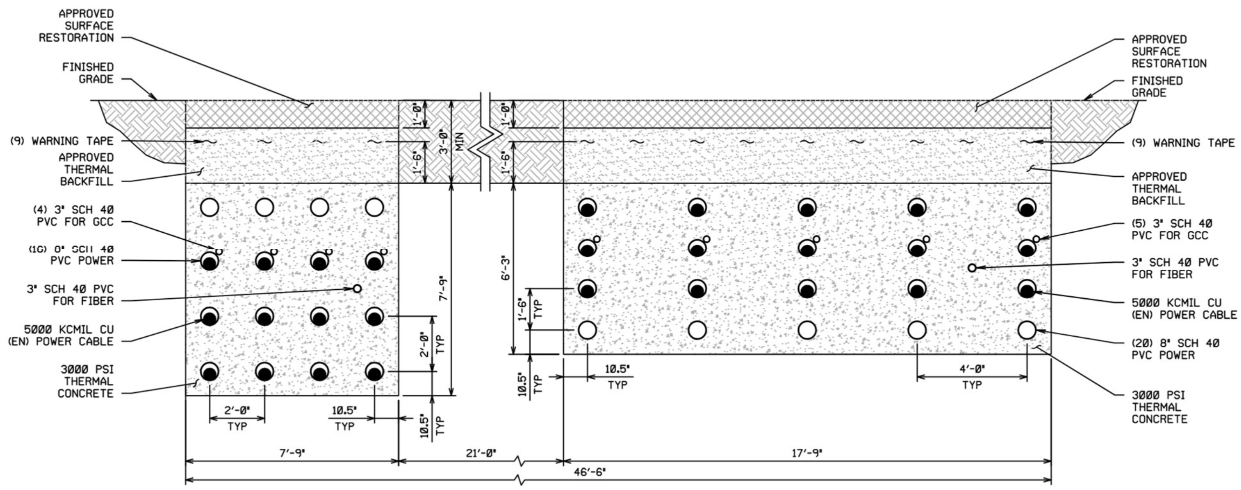


3.4.3 230-kV and 500-kV Duct Banks in Same ROW

The combined circuit route, UG Route 2, will require the 230-kV circuit and the 500-kV to co-exist within the same ROW. The cross section in Figure 3-4 below represents the anticipated open-cut duct bank configuration for the XLPE cable circuit with the 230-kV system and the 500-kV system within the same ROW, at 85% DLF and including 15 feet at each side for working space. The duct bank configuration for the 230-kV circuit is the same as detailed in Section 3.4.1 above. The duct bank configuration for the 500-kV circuit is the same as shown in Figure 3-2 above. The 85% DLF model for the 230-kV and 500-kV circuit within the same ROW was created with a 21-foot edge-to-edge separation between 230-kV and 500-kV duct banks.

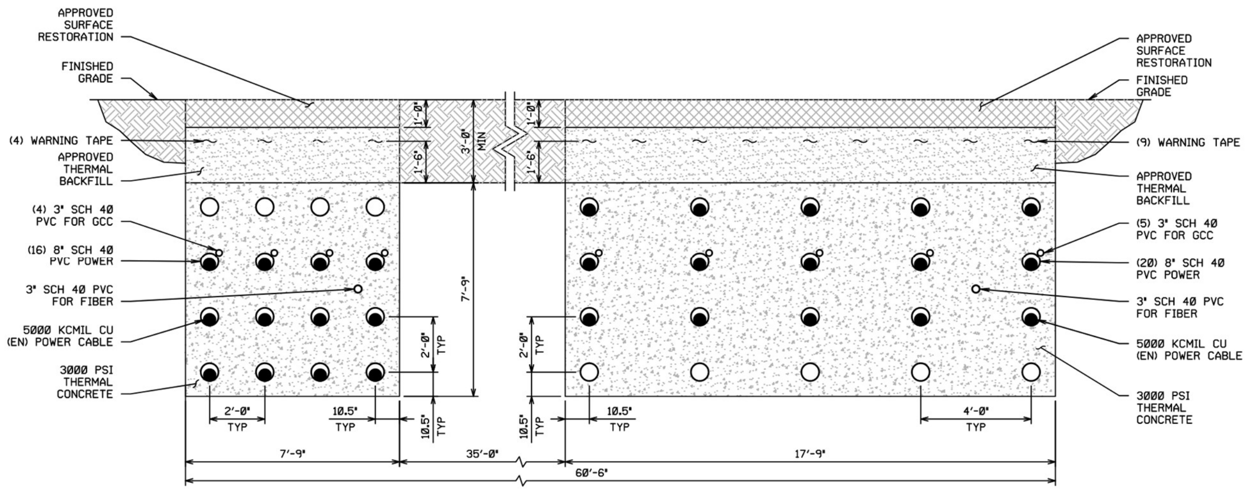
The ampacity calculations concluded that this configuration of cables could meet the project ampacity requirements with an 85% daily load factor.

Figure 3-4: Golden-Mars UG Preliminary 230-kV and 500-kV XLPE Duct Bank Cross Section, 85% DLF (76'-6" Total ROW)



The cross section in Figure 3-5 below represents the anticipated open-cut duct bank configuration for the XLPE cable circuit with the 230-kV system and the 500-kV system within the same ROW, at 100% DLF and including 15 feet at each side for working space. The duct bank configuration for the 230-kV circuit is the same as detailed in Section 3.4.1 above. The duct bank configuration for the 500-kV circuit is the same as detailed in Figure 3-3 above. The 100% DLF model for the 230-kV and 500-kV circuit within the same ROW was created with a 35-foot edge-to-edge separation between 230-kV and 500-kV duct banks. The ampacity calculations concluded that this configuration of cables could meet the project ampacity requirements with a 100% daily load factor. Note that all ampacity scenarios using 100% DLF, require a maximum native soil thermal resistivity of 115 ºC C-cm/watt to meet ampacity requirements.

Figure 3-5: Golden-Mars UG Preliminary 230-kV and 500-kV XLPE Duct Bank Cross Section, 100% DLF (90'-6" Total ROW)



A summary and the CYMCAP executions for all ampacity calculations can be seen in Appendix B of this document.

3.4.4 230-kV and 500-kV Trenchless Installations in Same ROW

The proposed new routes R1 through R4 will require at some specific locations the use of trenchless installations for both, the 230-kV circuit and the 500-kV circuit. Figure 3-6 below represents the anticipated J&B and Microtunneling configuration for the 230-kV XLPE cable system and the 500-kV XLPE cable system within the same ROW, at 100% DLF, assuming 30 feet maximum depth of cover and including 15 feet at each side for working space. Figure 3-7 below represents the anticipated HDD configuration for the 230-kV XLPE cable system and the 500-kV XLPE cable system within the same ROW, at 100% DLF, assuming 45 feet maximum depth of cover and including 15 feet at each side for working space. All the trenchless installations ampacity scenarios, parametric study, bore cross sections and ampacity executions are discussed in detail in Appendix F.

Figure 3-6: Golden-Mars UG Preliminary 230-kV and 500-kV XLPE J&B and Microtunneling Configuration, 100% DLF (270'-0" total ROW). See Appendix F

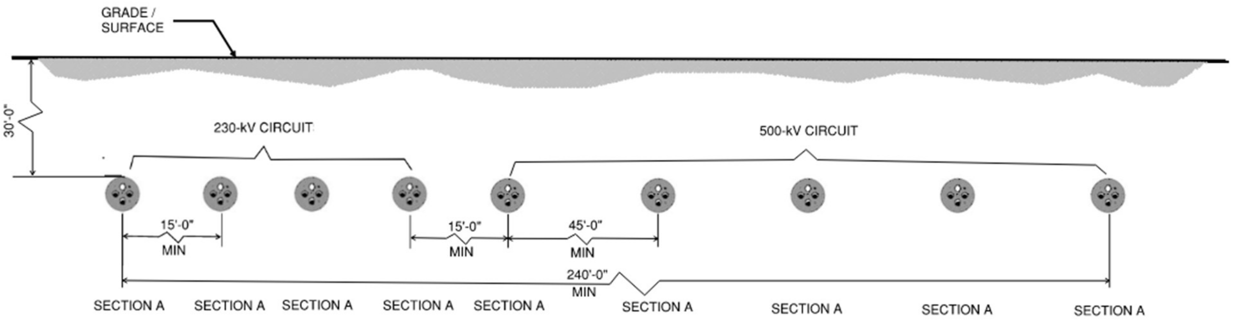
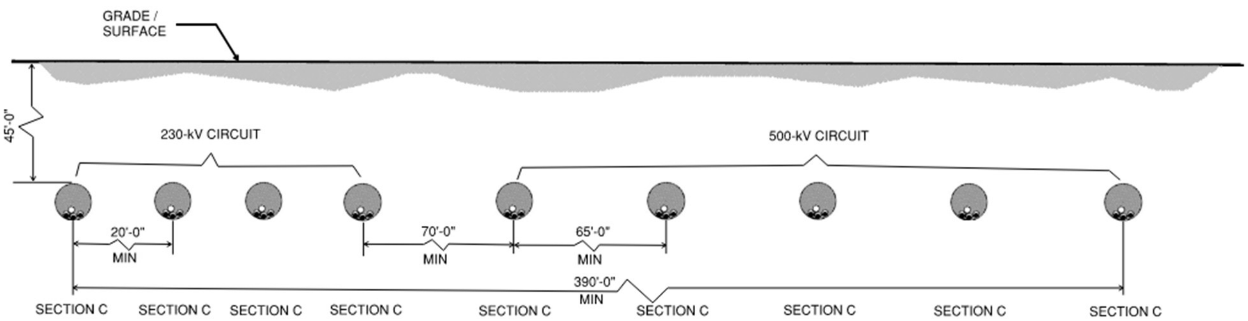


Figure 3-7: Golden-Mars UG Preliminary 230-kV and 500-kV XLPE HDD Configuration, 100% DLF (420'-0" total ROW). See Appendix F



4.0 UNDERGROUND FEASIBILITY REVIEW

BMcD initially evaluated seven (7) UG alignments provided by DEV and ERM (Environmental Resources Management, DEV's consultant) to review the feasibility of these UG routes. Following this initial analysis, ERM and DEV developed four (4) additional UG routes, R1 through R4, which were then submitted to BMcD for further feasibility review.

BMcD performed a desktop review of the routes for the proposed cable system using Google Earth and information provided by DEV and ERM. A site visit was also conducted for the proposed UG Routes 1 through 5. It is important to note that since the additional transition station locations (TS3 through TS8) were provided after the site visit was conducted, the additional routes (UG Routes 6, 7, R1, R2, R3 and R4) were not evaluated during the visit.

This analysis focused on the constructability of the routes based upon route congestion, road or right-of-way width, traffic impacts, and other factors readily available in a desktop level analysis. This report aims to identify any outstanding or unresolved issues that could potentially impact the selected route in the future, such as jurisdictional direction, unknown subsurface environmental conditions, real estate impacts, etc.

A Quality Level C (QL-C) and Quality Level D (QL-D) survey along the paths for the initially proposed routes (UG Routes 1,2 and 3) was provided to BMcD on August 1, 2024. The information on the survey was used to refine the feasibility of each proposed route and their alignments.

4.1 Underground Route Analysis

The objective of the Project routing development process was to identify UG route options from a proposed transition station location (TS1, TS2, TS3, or TS4) to the new Mars Substation (see Figure 4-1) or between proposed transition station locations (TS5 to TS6, or TS7 to TS2). The proposed transition station location and new Mars Substation are discussed in Section 5.0. The proposed underground route will consist of both a 230-kV and 500-kV cable systems. Based on the preliminary substation layout, the proposed 230-kV circuit will enter and terminate on the southeast corner of Mars Substation, while the proposed 500-kV circuit will enter and terminate at the southwest corner.

Figure 4-1: Mars Substation Location

To develop the route alternatives, the proposed UG routes were selected based on potential effects on social and environmental resources. By using multiple data layers within GIS and Google Earth, supplemented by field observations gathered during a site visit, the BMcD engineering team conducted an iterative review of the potential routes. The approach for this study consisted of several main tasks that helped guide the routing study analysis and generate the cost estimates associated with each proposed route.

Finding the preferred transition station location as described in Section 5.0 was the first major step in determining viable route options. In addition, the routing constraints listed in Table 4-1were considered.

Table 4-1 Routing Analysis Constraints

Constraint	Rationale
Existing Subsurface Utility Density & Location of Major Facilities	Pipes, cables, duct banks, manholes, tunnels, foundations, boulders, public utilities, and various other objects installed over time that occupy space under city streets. In urban areas especially, subsurface congestion has become a major obstacle to overcome. Underground duct banks must weave through these utilities while maintaining proper depth for protection and separation from other utilities for heat dissipation. In some cases, existing utilities may be relocated to mitigate conflicts.
Land Acquisition and Private Property Encroachment	The number of parcels crossed provides a general indication of the amount and density of development and potential impacts to landowners that would need to be contacted for temporary construction and/or permanent easements. Easement acquisition requires landowner coordination, which may impact the Project schedule. Generally, minimizing the number of easements required for a Project is preferred.
Road Details	While defining routing criteria, BMcD also considered the road widths. Though the proposed transmission circuit will be installed below grade, it is important to consider the above grade traffic conditions and available lanes during construction. While not determining the physical constructability within a particular corridor, road width can be an indicator of the ease of construction, the work hours allowed for construction, and impact to the traffic in the area.
Impact to Traffic	When trenching on a roadway, typically the traffic pattern will be impacted. Depending on the location of existing underground utilities, the trench could be located anywhere on the road ROW. In areas where the trench will be in the center of the road, additional construction techniques can be used to accommodate traffic patterns. The option to perform the work at night may be feasible and will need to be reviewed at the detailed design phase.

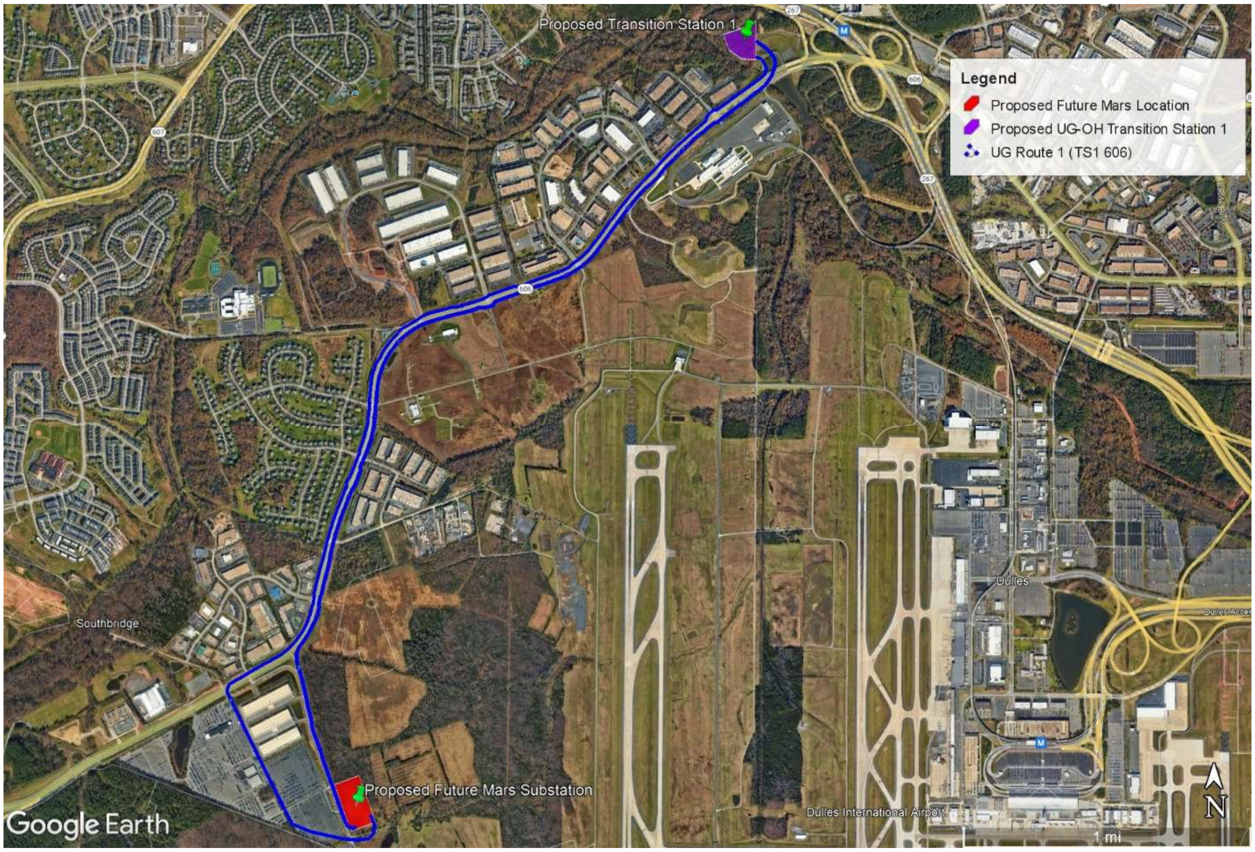
Constraint	Rationale
Sensitive Areas and Facilities	Public relations and public perception are also important characteristics to every project. It is important to maintain a good relationship with the public before, during, and after construction of a project. BMcD recommends evaluating the impact on public facilities such as schools, churches, and hospitals along proposed routes. In addition to public facilities, historically sensitive areas such as cemeteries, parks, wetlands, railroads, and landmarks are also considered when determining and evaluating routing. Open-cut trench activities can also prove challenging in wetlands and other environmentally protected areas both from a construction and a permitting standpoint. For this project a wetland area and highway have been identified.
Constructability	An underground power line ultimately needs to be constructible. Whether the route is in city streets or through a field, there needs to be a way to install the system. Some installation conditions and techniques are more difficult than others. Factors that affect constructability include depth to bedrock, soil conditions, construction work area availability and installation type (concrete encased duct bank system or trenchless). Constructability is also affected by utility density and traffic congestion.

4.1.1 UG Route 1

The proposed UG Route 1 starts from the proposed TS1 location and travels southwest along Route 606 towards Mars Substation. The 230-kV and 500-kV circuits remain in separate ROWs for the entirety of the route. The 500-kV circuit remains on the southern side of Route 606 (Old Ox Road), then diverts south on to Route 857 (Carters School Road) before turning east into the Mars Substation. The 230-kV circuit remains on the northern side of route 606, then diverts through the Amazon Integrated Access Device (IAD) data center parking lot for approximately 3,700 feet towards Mars Substation. The line will then head towards the Mars Substation where the UG circuits will be terminated. The proposed route is approximately 21,300 feet in length for the 230-kV circuit and 19,400 in length for the 500-kV circuit; it is the longest route. An aerial image of the proposed UG Route 1 is shown in Figure 4-2 below.

As an alternate, the proposed UG Route 1 may be routed to the proposed TS3 location if the parcel for TS1 is not acquirable.

Figure 4-2: Golden-Mars UG Route 1



4.1.1.1 Existing Subsurface Utility Density and Location of Major Facilities

Overhead lines run along the majority of the route 606 corridor and a substation was also identified near the intersection of Route 606 and Ladbrook Drive. It is assumed that there will be underground utilities entering and leaving the identified substation. Figure 4-3 below shows the identified substation on Route 606. The UG duct bank will need to avoid foundations of existing overhead poles and any underground utilities along the route.

Based on the provided survey, a number of UG utilities exist along both sides of the Route 606 corridor. Leveraging the survey data, the route alignment has been adjusted to avoid as many subsurface utilities and structures as possible, while staying out of the Route 606 pavement wherever possible. However, due to the high congestion of utilities, UG Route 1 is still expected to cross some existing utilities. The expected utility crossings include UG electrical lines, telecommunication lines, RCPs, and a foundation wall, amongst others as shown in Figure 4-4 through Figure 4-7 and Figure 4-36 through Figure 4-40 below. It is likely that with the footprint of the proposed duct bank, some level of utility relocation will be required to install the duct banks.

Figure 4-3: Substation Identified Along Route 606

Figure 4-4: UG Utility Density Along Route 606 - Near to Overland Drive

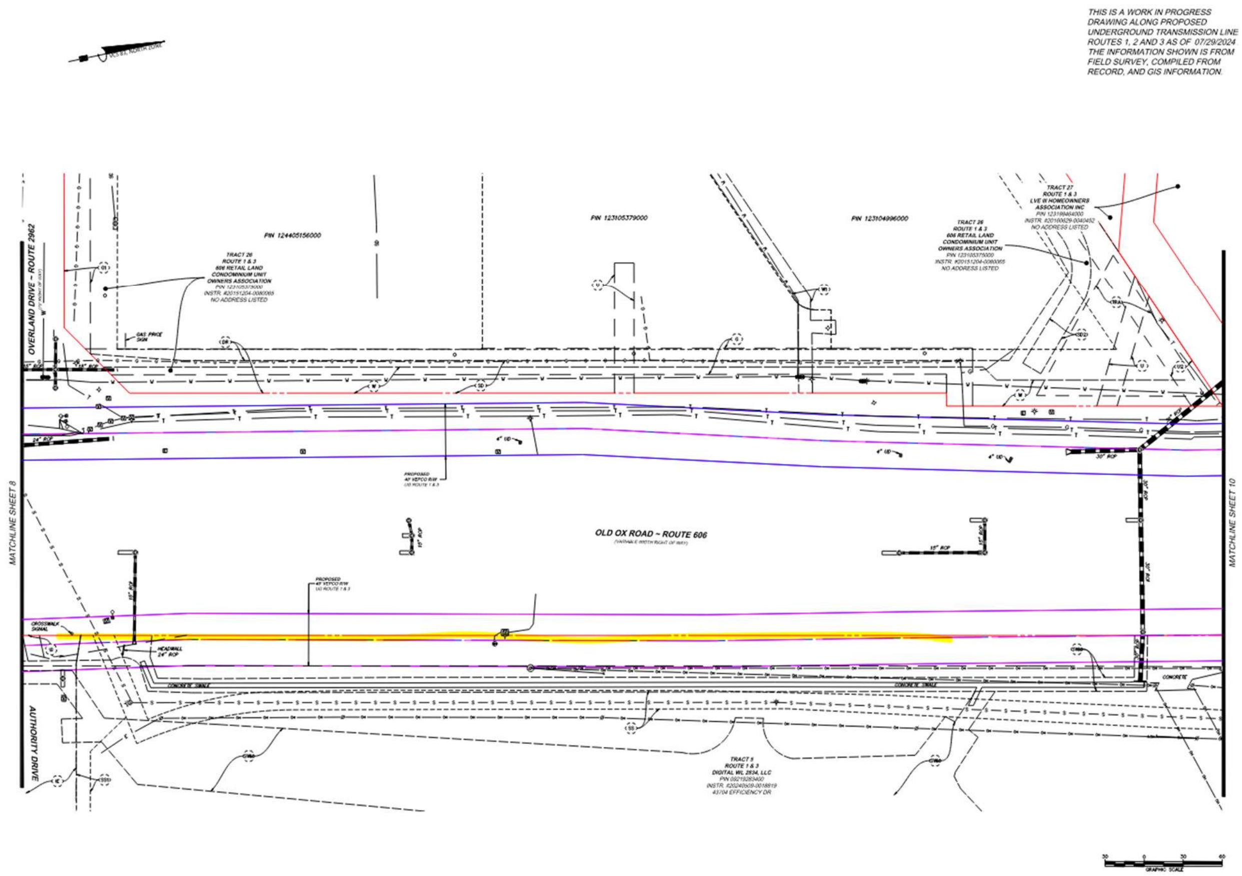


Figure 4-5: UG Utility Density Along Route 606 - Near to Beaver Meadow Road

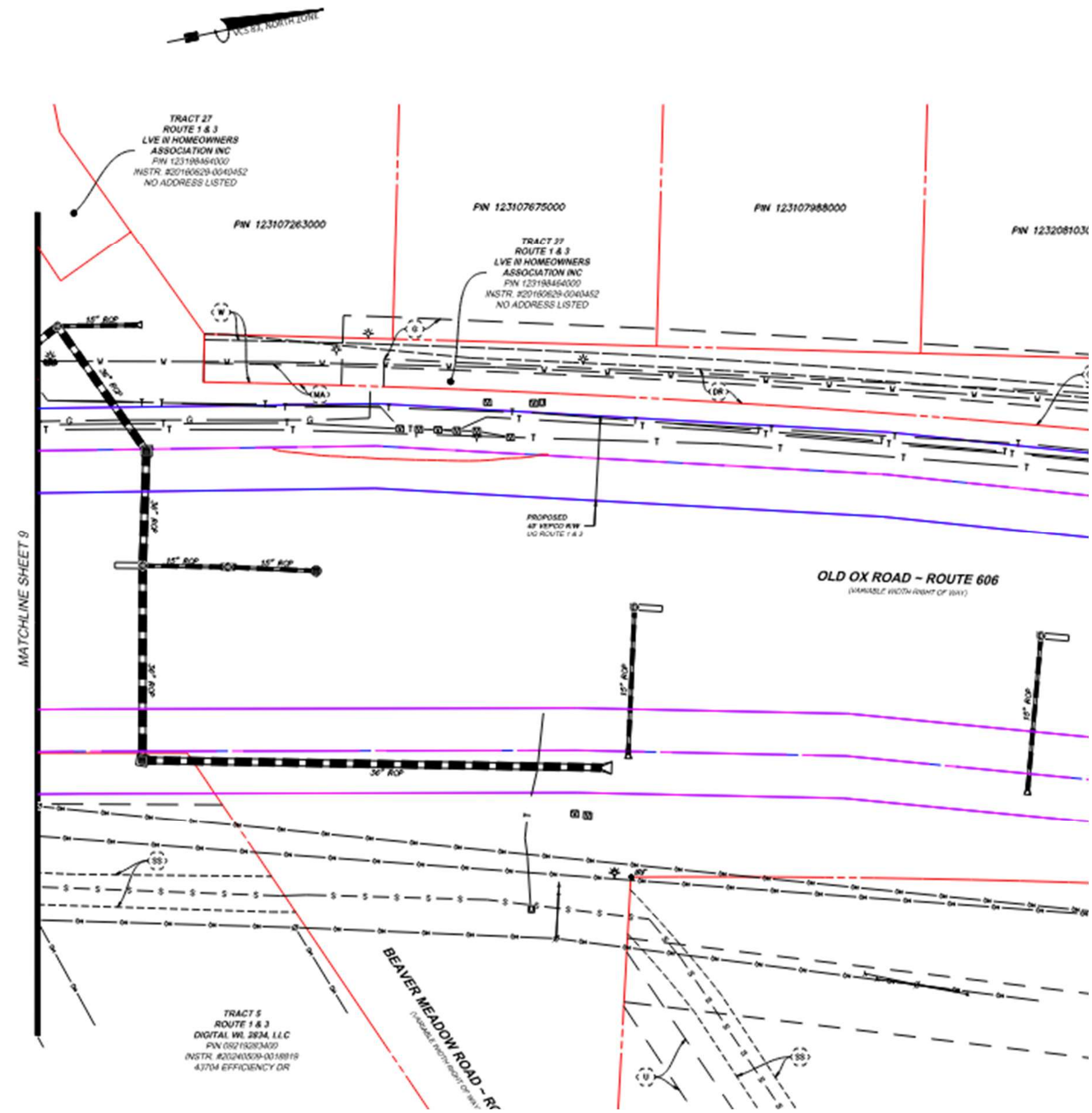


Figure 4-6: UG Utility Density Along Route 606 - Near to Stukely Drive

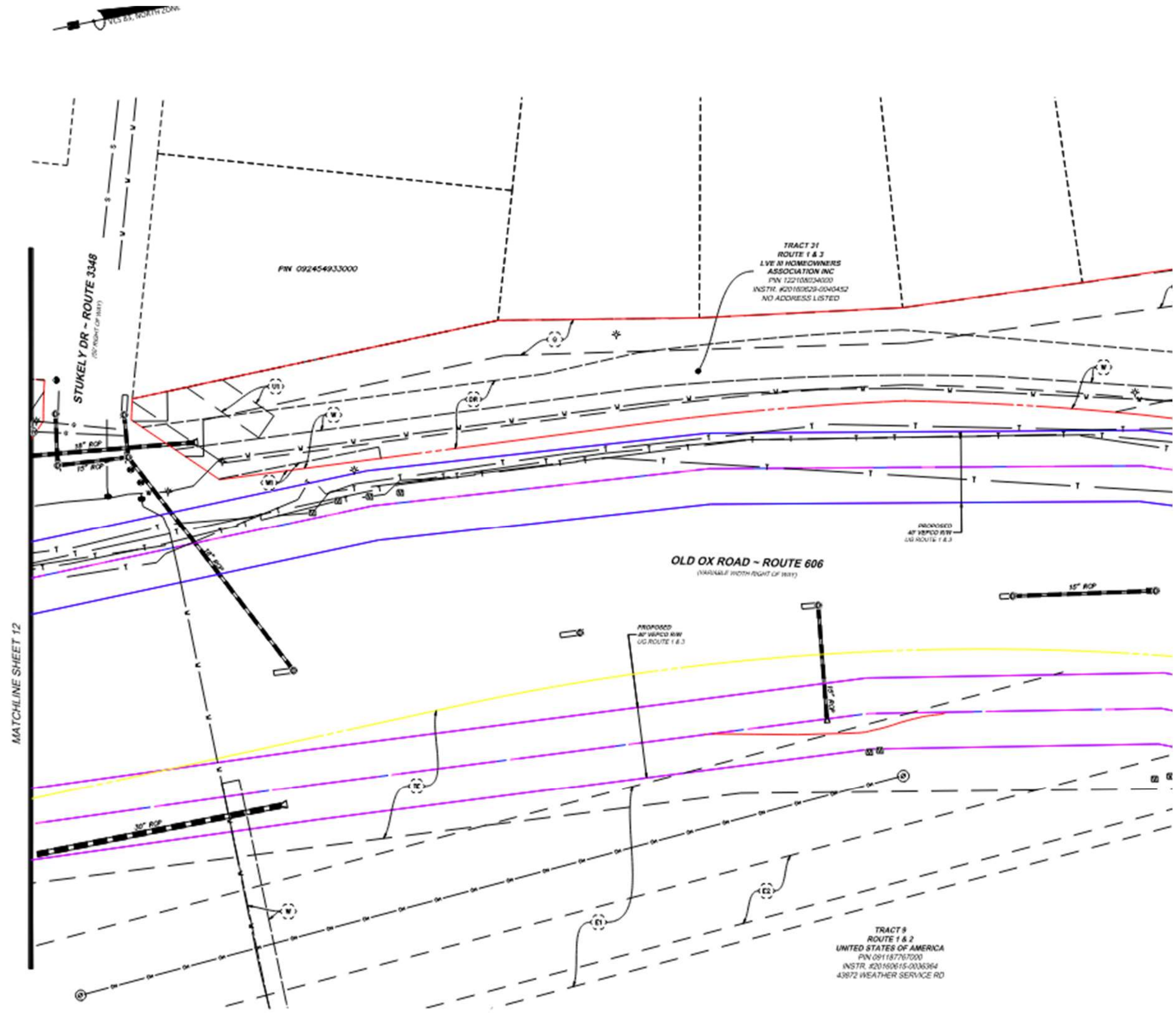
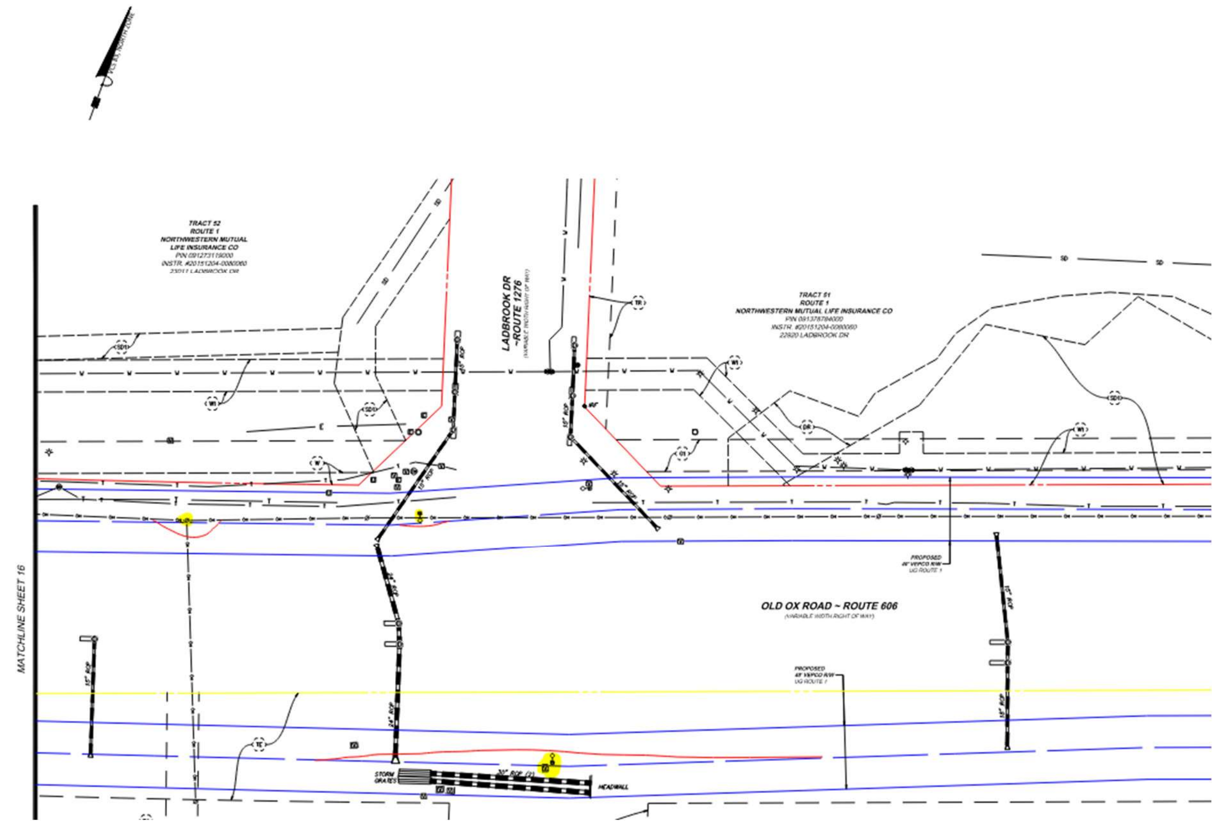


Figure 4-7: UG Utility Density Along Route 606 - Near to Ladbrook Drive



4.1.1.2 Land Acquisition and Private Property Encroachment

UG Route 1 remains in VDOT roads ROW for the majority of the route. However, there are some instances where the UG Route need to divert out of VDOT roads ROW to avoid an existing UG utility and to minimize impact to Route 606.

Per ERM analysis, the route would require new land rights where it deviates from public right-of-way onto a parcel owned by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS). During a September 27, 2024 meeting, NOAA informed Dominion that they would not grant new land rights, citing the existence of viable alternative routes that avoid NWS lands.

Additionally, due to the location of the Mars Substation and TS1 outside of VDOT roads ROW, some private property encroachments are expected near the stations. The 230-kV circuit must route through private property, to avoid co-location with the 500-kV circuit on the Route 285 corridor. In total, easements from three (3) unique parcel owners would need to be required for UG Route 1 (Prologis- Exchange (Location for the Amazon IAD), Digital Realty, and SDH Ashburn I, LLC). Figure 4-8 and Figure 4-9 below shows the location where easements will be needed for duct bank placement.

Figure 4-8: Route 1 Easements Near Mars Substation

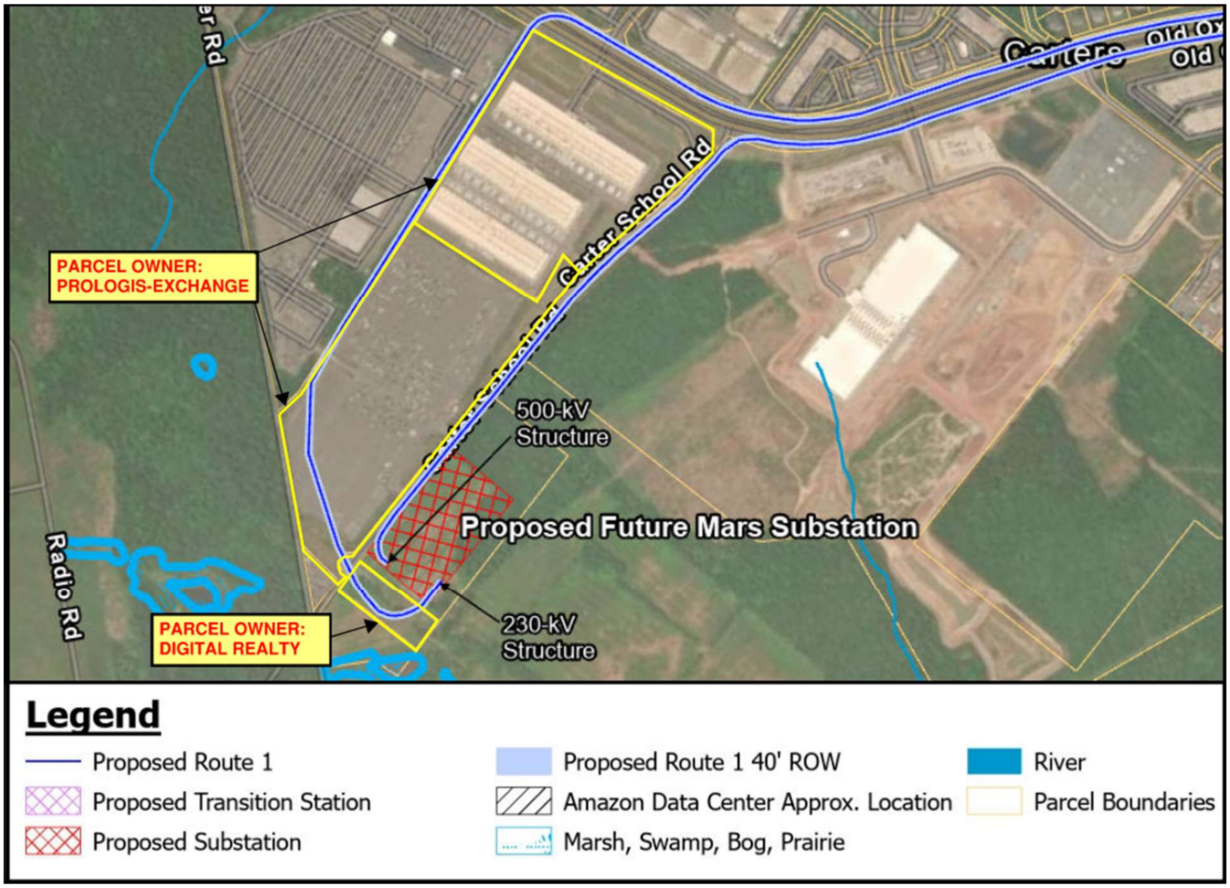
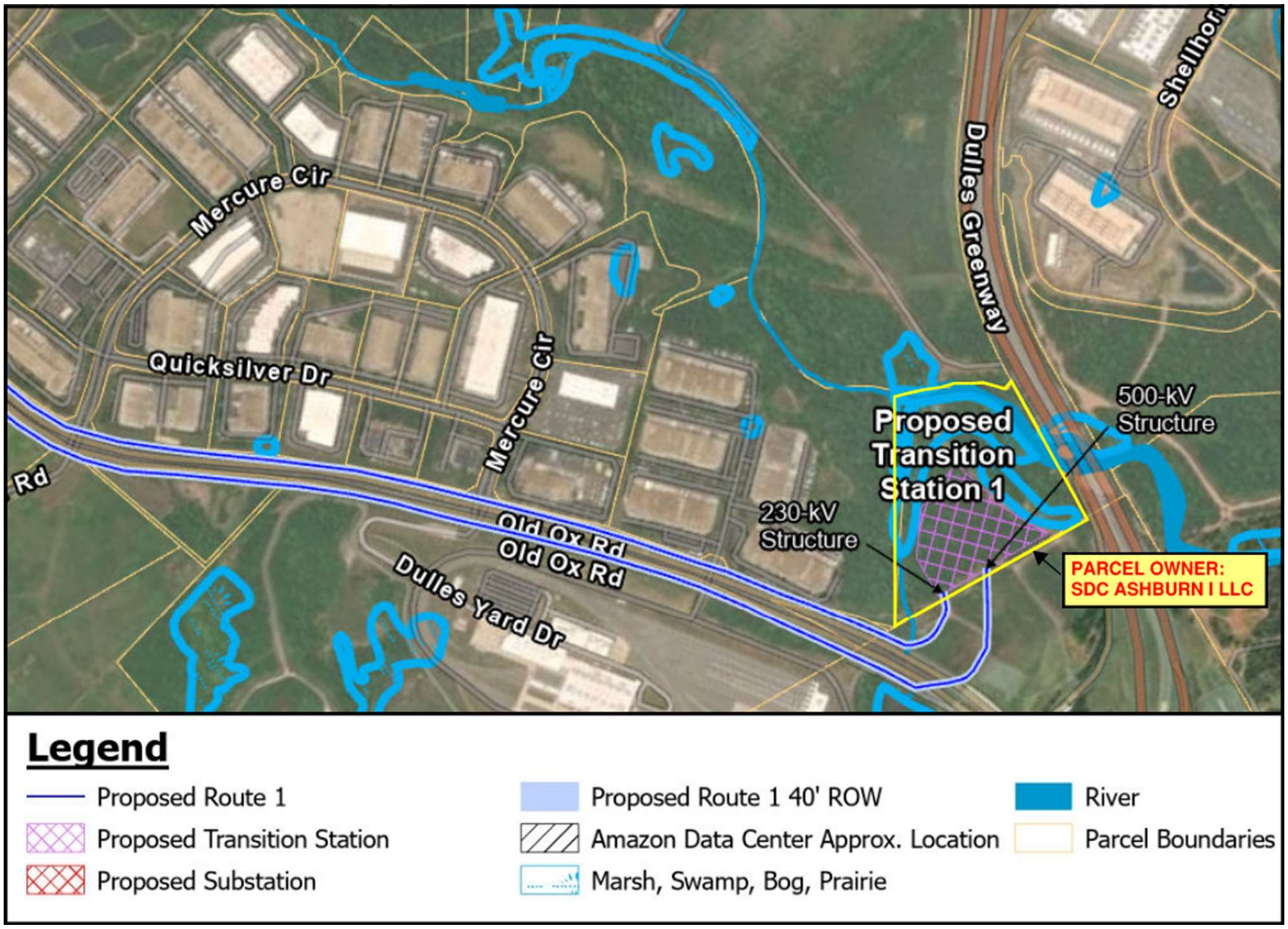


Figure 4-9: Route 1 Easements Near Transition Station 1



4.1.1.3 Road Details

The main corridor for this proposed route is Route 606 which is a four-lane road with a divided median. Route 606 is approximately 100 feet wide, and the duct bank installation can be completed in phases where a couple of lanes can remain open for traffic flow during construction. Figure 4-10 below shows an image of the Route 606 corridor. Since Route 606 is a secondary highway, the proposed UG must minimize impact by avoiding placing trenches on the asphalt where possible and limiting the traffic disturbance during construction to only one (1) lane of traffic. For the proposed UG Route 1, the alignment has been adjusted so the duct bank trench does not require digging into the asphalt on Route 606. At the crossing with Route 606 south of TS1 and at the crossing with Route 606 west of Pebble Run Place open-cut crossing through all traffic lanes is required.

Per ERM analysis, the Virginia Department of Transportation expressed opposition to open-cut installation along or across Route 606 during a September 16, 2024 meeting and in a follow-up email on September 26, 2024. Their concerns include construction-related traffic impacts, conflicts with existing utilities, and potential impacts to road integrity as a result of construction.

For some locations, if splice vaults are stacked adjacently, the vault trenches may need to occupy up to approximately 2 feet of the asphalt on the Route 606 shoulder. At these locations, excavation is only expected on the road shoulder, and no trenching is expected within the ongoing traffic lanes. However, a staggered configuration may be used to minimize impact to Route 606 and avoid excavating the asphalt.

The route crosses a total of eleven (11) other roads where they intersect with Route 606. When crossing these intersections, the duct bank installation will need to be performed in phases to avoid obstruction to the entire intersection. Night work may also be required to reduce obstruction.

For the proposed UG Route 1, 230-kV circuit and 500-kV circuit are installed in separate concrete-encased duct banks, each circuit having its own ROW. The minimum ROW required for the 230-kV circuit is approximately 38 feet in width. At vault locations, the minimum required ROW for the 230-kV circuit is approximately 52 feet. The minimum ROW required for the 500-kV is approximately 48 feet in width. At vault locations, the minimum required ROW is approximately 78 feet. This assumes that 15 feet of working space is required on both sides of the trench limits and outer vault edge.

Figure 4-10: Route 606 Overview

4.1.1.4 Impact to Traffic

Due to the road widths along the route, it appears that sufficient space should exist to allow for effective traffic management. However, the use of alternating lane closures and modified traffic patterns to allow for construction of the proposed duct banks. Only up to a single lane of traffic would be impacted on the Route 606 corridor. It is important to note that splice vaults should not be located in intersections and the preliminary locations have been carefully located using the information on existing utilities included in the survey. For the 230-kV circuit, a total of nine (9) vault locations are required. Since two (2) vaults are required for each 230-kV vault location, a total of eighteen (18) 230-kV splice vaults are required. For the 500-kV circuit, a total of eleven (11) vault locations are required. Since three (3) vaults are required for each 500-kV vault location, per-phase circuit. A total of thirty-three (33) 500-kV splice vaults are required. If needed, splice vaults can be placed in phases to minimize traffic disruptions and lane closures.

4.1.1.5 Sensitive Areas and Facilities

Two (2) water drainage ditch locations were identified along UG Route 1. One (1) at the intersection of Route 857 and Route 606, and one (1) on Route 606 between Ladbrook Drive and Stuckely Drive.

No trenchless crossings are anticipated near these drain ditches, as the circuit paths will avoid the ditches by routing around them. Near TS1, Route 606 is elevated creating a Dam for Horsepen Pond.

As reported by ERM, Dominion consulted with the Virginia Department of Conservation and Recreation (VDCR) about crossing Horsepen Dam. The dam, owned and maintained by the Metropolitan Washington Airports Authority (MWAA) and permitted by VDCR, is classified as 'high-risk' due to its large drainage basin and significant downstream development, including Route 606 and the Dulles Greenway bridge over Broad Run. VDCR highlighted several concerns: significant permitting and operational risks for construction near or within the dam, potential spillway inundation during construction and operation, and the requirement for MWAA's authorization and sponsorship of any dam alterations, which would necessitate hydrologic studies to reassess the inundation zone.

No trenchless crossings are anticipated to cross the pond, as the duct banks will be installed on Route 606, above the water body. Special consideration must be taken near ditches and Horsepen pond to minimize impact on the water bodies by the proposed route. See Figure 4-11 for an image of the drainage ditch on Route 857. Figure 4-12 and Figure 4-13 shows aerial maps views of the drainage ditch locations on UG Route 1.

Figure 4-14 and Figure 4-15 show Horsepen pond located on UG Route 1 near TS1.

Figure 4-11: Drainage Ditch Location on Route 857

Figure 4-12: Drainage Ditch on Route 857, Aerial View

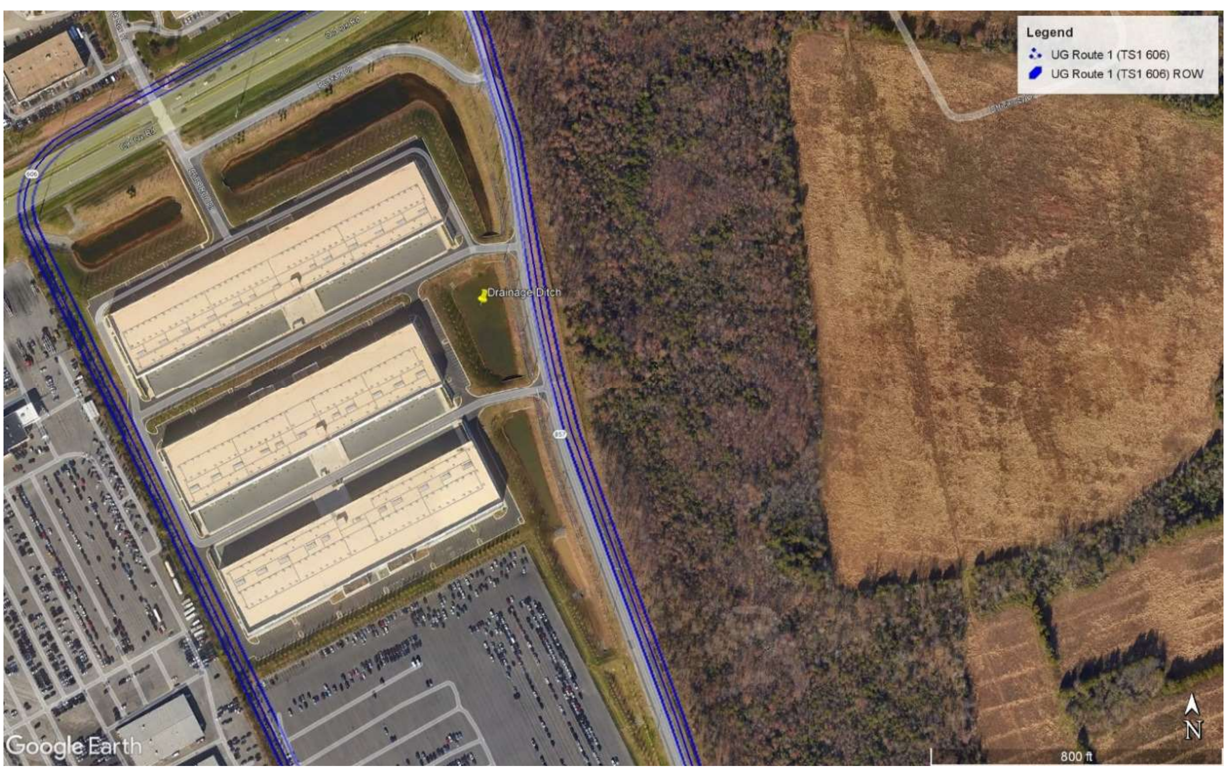


Figure 4-13: Drainage Ditch on Route 606, Aerial View

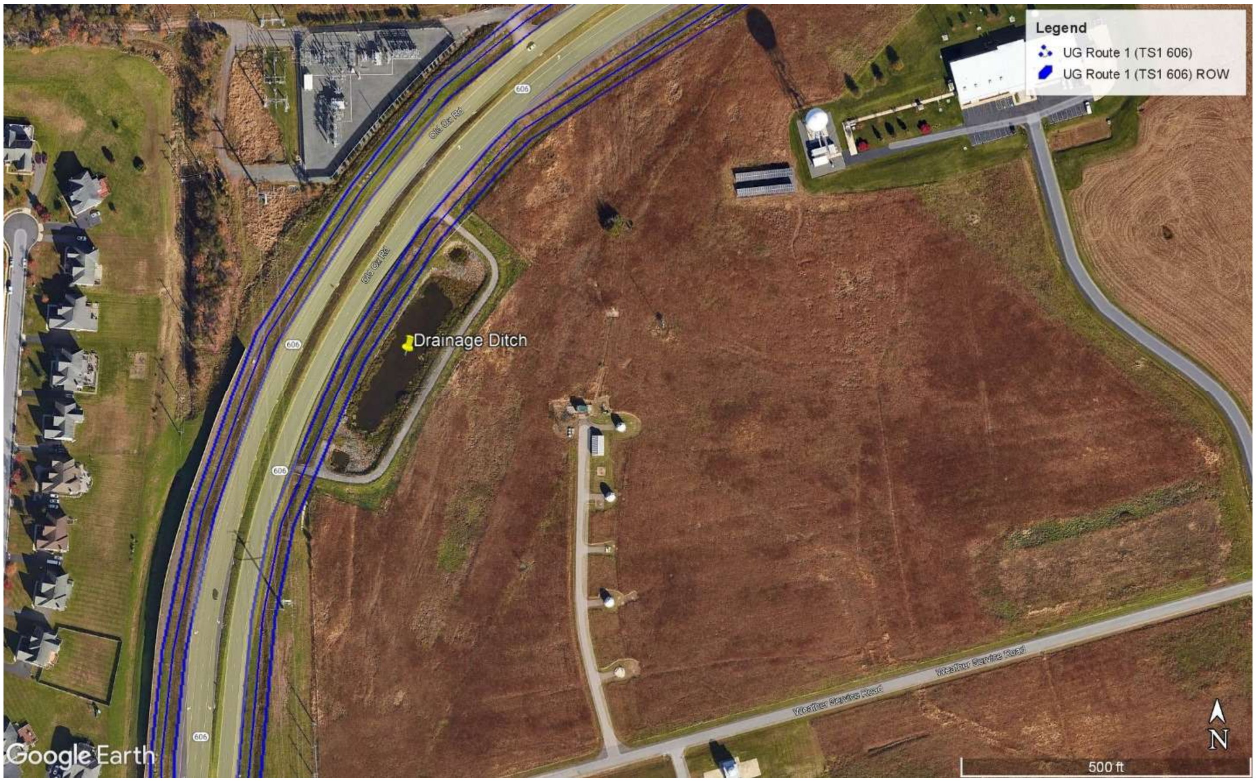
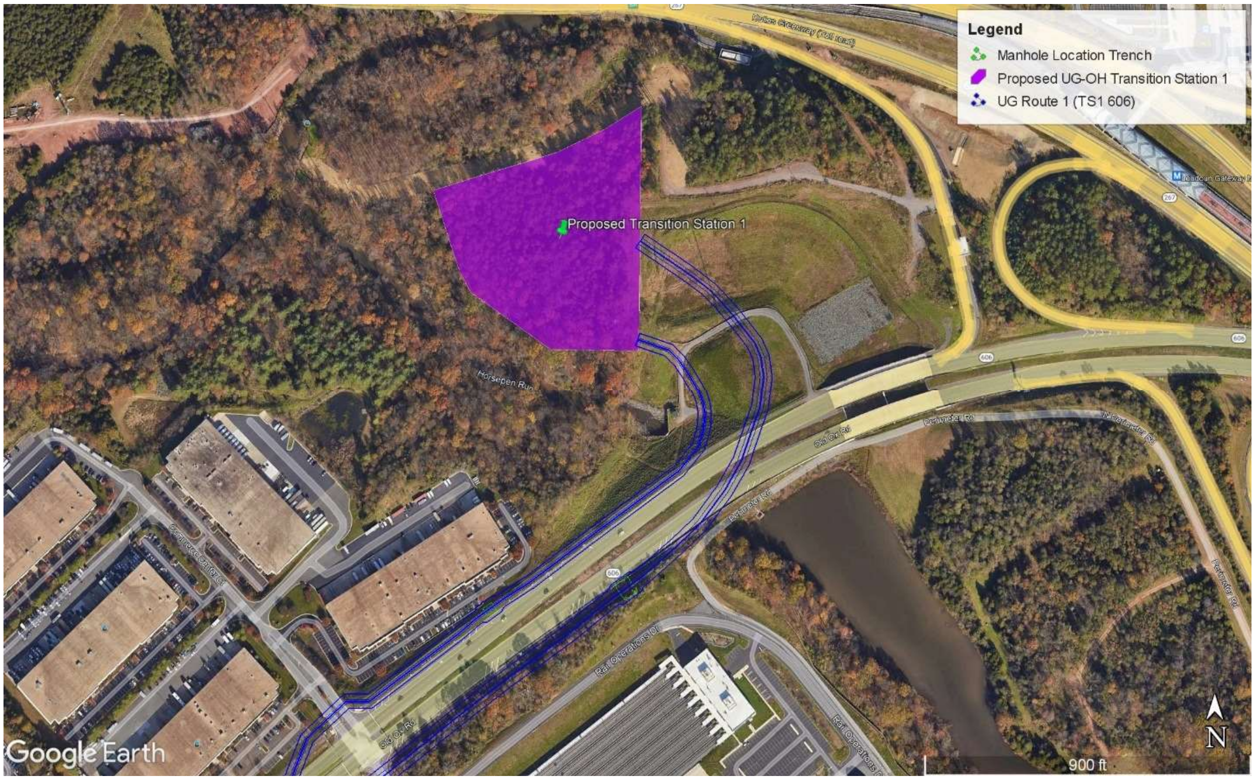


Figure 4-14 Horsepen Pond near TS1

Figure 4-15: Horsepen Pond near TS1, Aerial View

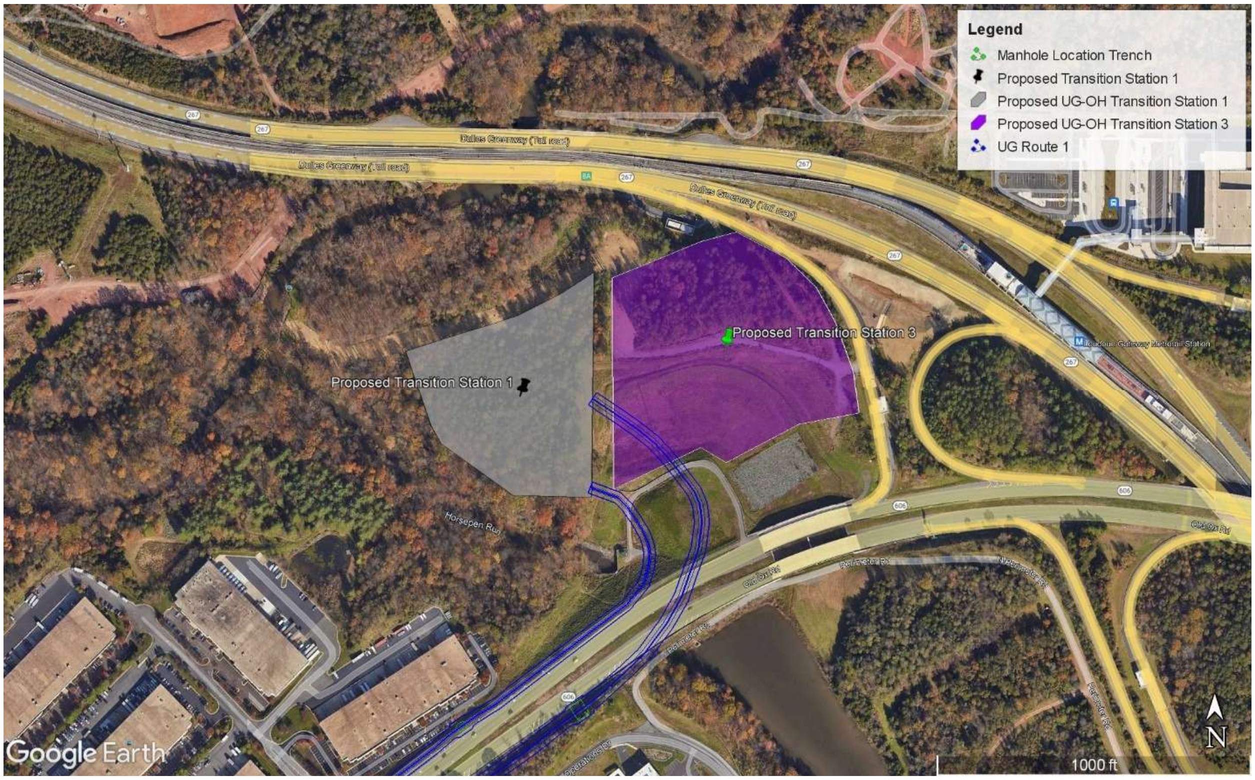


4.1.1.6 Constructability

Factors that affect constructability include utility density and traffic congestion. The utility congestion along Route 606 will add complexity to the proposed UG Route. Constructability is also affected by depth to bedrock, soil conditions, construction work area availability and route installation type. Based off Geotechnical data from a nearby project site provided by DEV, diabase rock has been identified as the main rock formation at the nearby project site. Diabase rock is an igneous rock that is typically hard and abrasive. A detailed site-specific geotechnical investigation along the proposed route must be performed to further define the diabase rock depth variation along the route as well as other soil layer types, thicknesses and mechanical properties.

This analysis assumes that the parcel for transition station can be acquired. If the parcel cannot be obtained, the proposed route would not be feasible and TS3 would need to be considered as the alternate transition station location for UG Route 1. Reference Figure 4-16 below for an aerial overview of the TS3 location that UG Route 1 would need to reroute to.

Figure 4-16 UG Route 1 Alternate Transition Station Location TS3



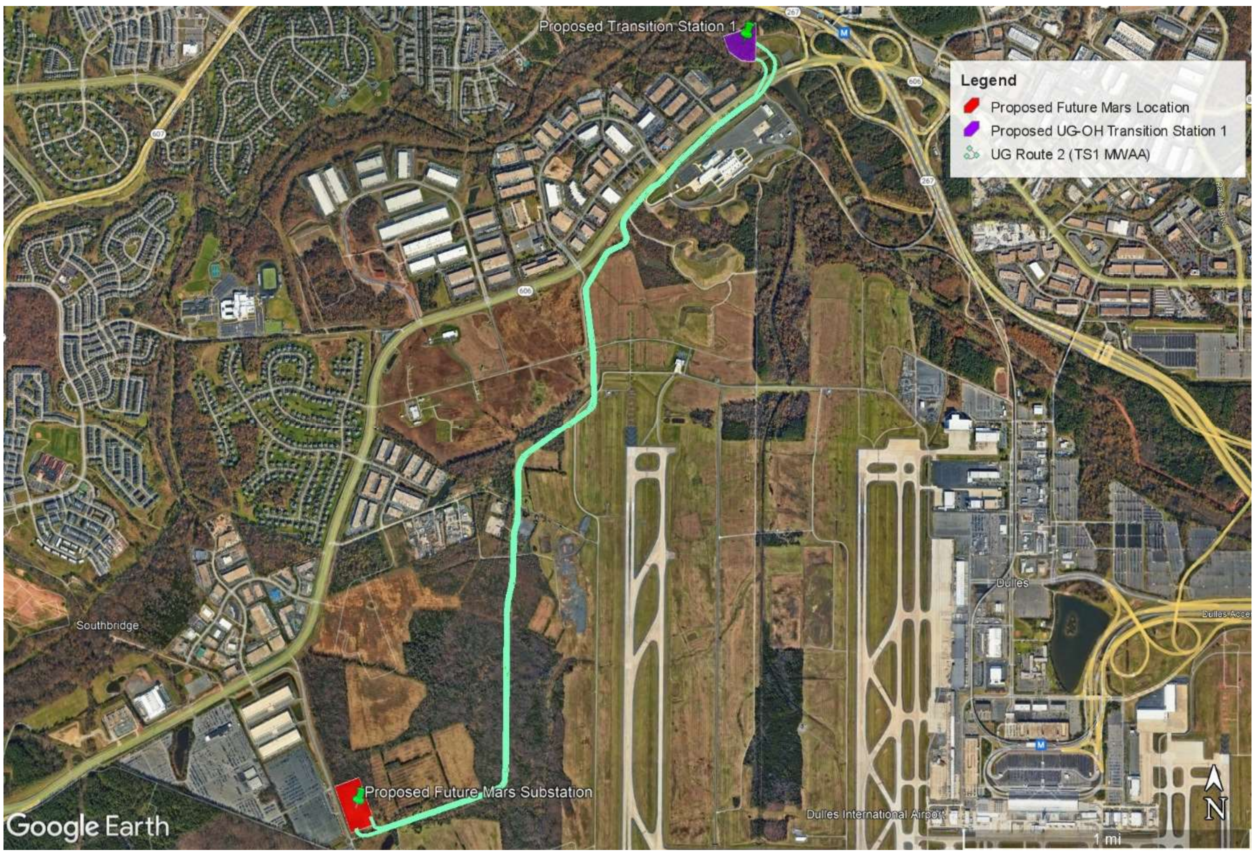
UG Route 1 has been reviewed for constructability and feasibility for this project. Throughout this review different challenges have been identified in the previous Sections: UG utility congestion along Route 606 interfering with the proposed alignment, presence and depth of diabase rock formations, soil conditions, construction work area availability, VDOT limitations on Route 606 and traffic control along Route 606, the significant permitting and operational risk of crossing of Horsepen Dam, and the inability to obtain new land rights across the NOAA parcel. In addition, ERM reported that VDOT indicated to Dominion in writing that they are opposed to any open-cut crossing of Route 606 (which requires permission from VDOT). Based on these factors, the proposed UG Route 1 has been determined to not be constructable for this project.

4.1.2 UG Route 2

The proposed UG Route 2 starts from the proposed TS1 location and travels southwest mainly through private properties towards Mars Substation. The 230-kV and 500-kV UG circuits remain in the same ROW for the majority of the route except near the stations where the circuits separate to tie into the respective transition structures. The proposed route is approximately 18,400 feet in length. UG Route 2 leaves the proposed TS1, travelling southwest along Route 606 briefly before diverting south through private lands (MWAA, Digital Reality). After crossing Route 606, the entire rest of the route remains outside of public ROW, all the way to Mars Substation where the UG circuits will be terminated. An aerial image of the proposed UG Route 2 is shown in Figure 4-17 below.

As an alternate, the proposed UG Route 2 may be routed to the proposed TS3 location if the parcel for TS1 is not acquirable.

Figure 4-17: Golden-Mars UG Route 2



4.1.2.1 Existing Subsurface Utility Density and Location of Major Facilities

Overhead lines run along the majority of the Route 606 corridor and a substation was also identified near the intersection of Route 606 and Ladbrook Drive. UG Route 2 only travels parallel Route 606 for approximately 3,800 feet and avoids the identified overhead lines and substation. UG Route 2 passes though mostly wooded areas and private lots. Future development in these areas could introduce new utilities and infrastructure along the route, that may require future relocation of the proposed UG transmission circuits.

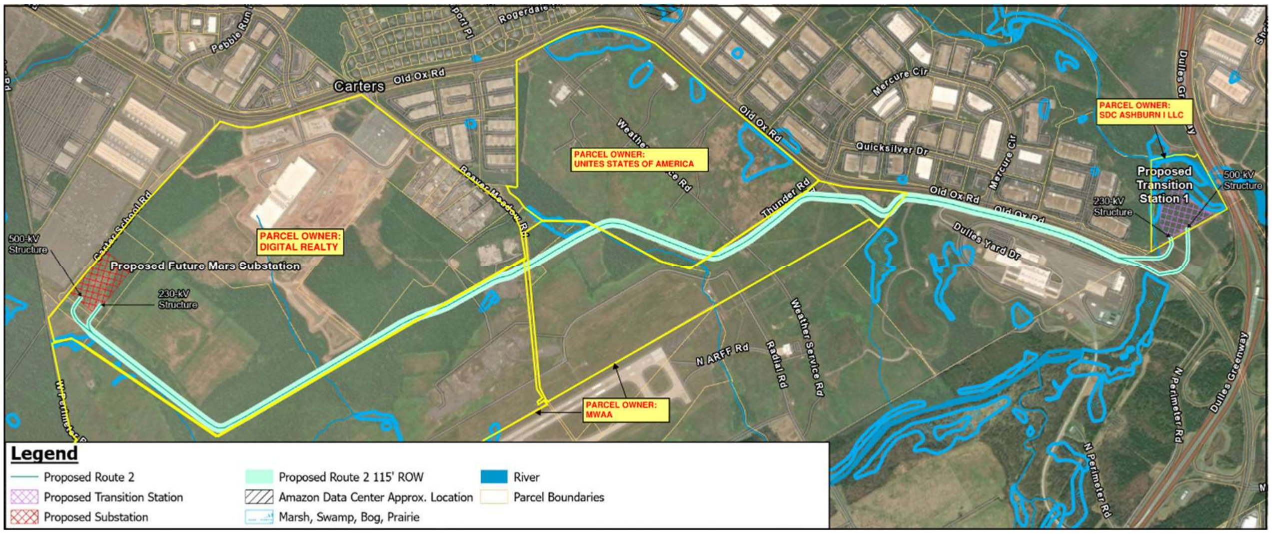
For UG Route 2, existing UG utilities are apparent on the section of the route which travels northeast parallel to Route 606, see Figure 4-36 through Figure 4-40. Based on the survey, several crossing points for different underground utilities (sanitary lines, storm water lines and manholes, water lines) were identified. Therefore, utility relocations are anticipated to be necessary for UG Route 2 in this section.

4.1.2.2 Land Acquisition and Private Property Encroachment

UG Route 2 is located outside of VDOT roads ROW for the majority of the route, so different property encroachments are expected. In total, easements from three (3) unique parcel owners will be required for UG Route 2 (MWAA, Digital Realty, SDH Ashburn I, LLC). Since it is federal land, permanent easements are not an option for the MWAA property and a special license would be required. Initially UG Route 2 travelled on a parcel owned by the United States of America (USA). The USA-owned parcel houses the National Weather Service (NWS) Forecast Office for Baltimore Washington, which is a government office. In general, easements for government property may be more difficult to obtain and duct bank construction must be careful to avoid disruption to the NWS and airport operations. ERM reported that during a September 27, 2024 meeting, NOAA informed Dominion that they would not grant any new land rights, citing the availability of viable alternatives that avoid National Weather Service (NWS) lands.

Figure 4-18 below shows the location where easements will be needed for duct bank placement along UG Route 2. UG Route 2 has been rerouted to avoid the USA property based on the provided survey information.

Figure 4-18: UG Route 2 Parcel Owners



4.1.2.3 Road Details

UG Route 2 travels briefly parallel to Route 606, which is a four-lane road with a separation median. Route 606 is approximately 100 feet wide, from road edge to road edge. The duct bank installation can be completed in phases where a couple of lanes can remain open for traffic flow during construction. At the crossing with Route 606 south of TS1, open-cut crossing through all traffic lanes is required.

ERM reported that during a September 16, 2024 meeting and in a follow-up email on September 26, 2024, VDOT expressed concerns about open-cut installation along Route 606, citing three key issues: traffic disruption, conflicts with existing utilities, and potential impacts to road integrity.

The route crosses a total of two (2) other roads where they intersect with Route 606. When crossing these intersections, the duct bank installation will need to be performed in phases to avoid obstruction to the entire intersection. The rest of the route travels through private lands consisting of private roadways, parking lots, and forestry. For UG Route 2, the 230-kV Circuit and 500-kV Circuit are collocated within the same ROW except near station locations where the circuits must divert to tie into their respective termination or transition structures. The minimum ROWs required for the collocated duct banks is 76.5 feet minimum ROW for the 85% DLF scenario and 90.5 feet at 100% DLF scenario. The spacing between the two circuits must increase to maintain ampacity at a high DLF; reference Section 3.4.3 above for duct bank design details.

At vault locations, the minimum required ROW for the dual circuit is approximately 115 feet in width. This number is determined based on request from DEV assumed design parameters. This assumes that a minimum 15 feet of working space is required on both sides of the trench limits and outer vault edge.

4.1.2.4 Impact to Traffic

UG Route 2 will briefly parallel Route 606 but will remain outside of the public ROW, except where the route crosses Route 606 towards the proposed transition station. Based on the road width for Route 606, it appears that sufficient space should exist to allow for effective traffic management during construction where the route parallels and crosses the roadway. However, is it anticipated that the use of alternating lane closures and modified traffic patterns will be required to allow for construction of the proposed duct banks. It is important to note that splice vaults should not be located in intersections and the preliminary locations have been carefully located using the information on existing utilities included in the survey. For the 230-kV circuit, seven (7) vault locations are required, for a total of fourteen (14) 230-kV splice vaults for UG Route 2. For the 500-kV circuit, eleven (11) vault locations are required, for a total of thirty-three (33) 500-kV splice vaults for UG Route 2. Because both circuits share the same ROW, it may be necessary to co-locate the splice vaults for each circuit within close proximity. This means that at those locations the route will require a larger ROW width for construction. Even though UG Route 2 is out of the public ROW, there are some private roads along the route. If needed, splice vaults can be placed in phases to minimize traffic disruptions and lane closures.

4.1.2.5 Sensitive Areas and Facilities

UG Route 2 avoids the water drainage ditch location within the study area as it diverts from Route 606 on to private property. However, UG Route 2 also crosses the Horsepen Pond as it exits TS1. Near TS1, Route 606 elevated creating a dam for Horsepen pond. No trenchless crossings are anticipated to cross the pond, as the duct banks will be installed on Route 606, above the water body. Special consideration must be taken near Horsepen pond to minimize impact on the water body by the proposed route. ERM stated that VDCR stated that construction along Horsepen Dam presents significant permitting and operational risks.

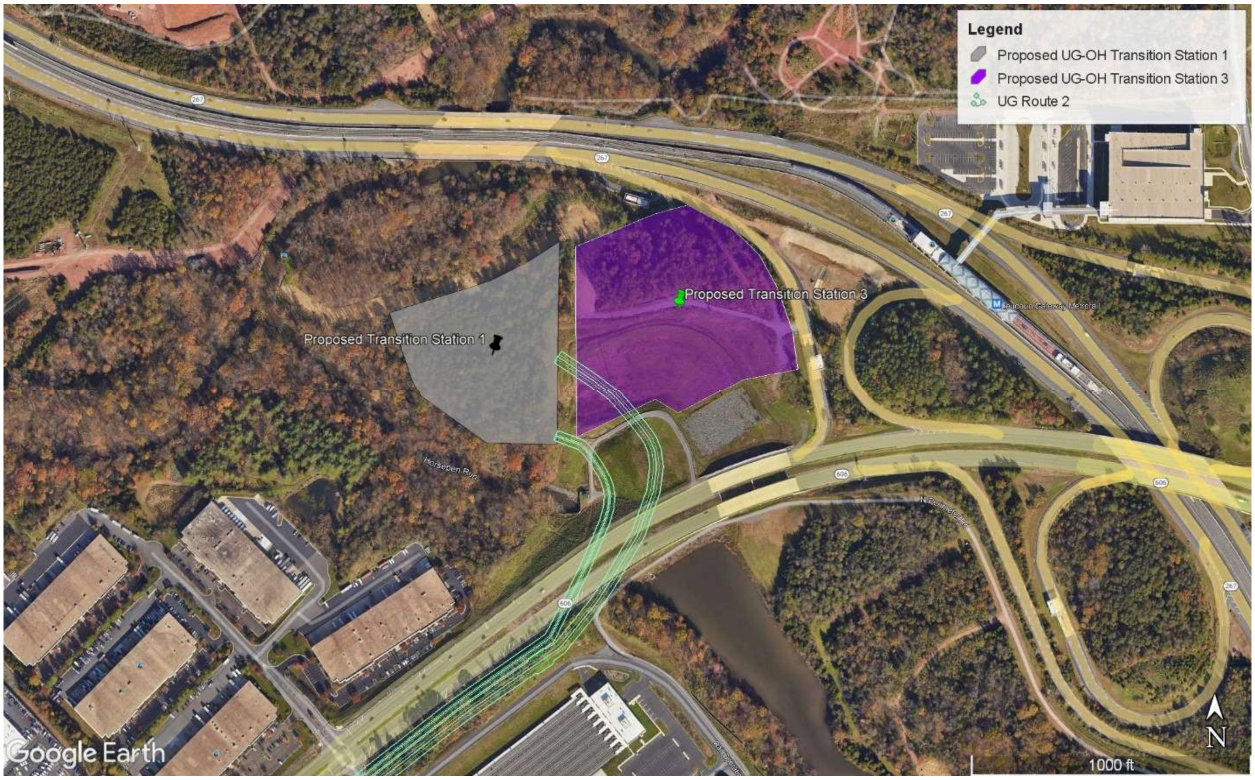
UG Route 2 will pass Fire station 304, located on MWAA property. This fire station is specially placed to protect IAD lands and provide services such as aircraft rescue, firefighting, and emergency services. UG Route may impact unit deployment in and out of the fire station as it crosses the private roadway, Weather Service Road. This roadway provides a path from the fire station to the main road, Route 606. If this route is selected, coordination with the fire station will be required, to minimize impact to public safety. Note that there are also other roadways leaving the fire station that will not be impacted be UG Route 2, and they provide direct paths to IAD. See Figure 4-19 for an overhead view of the location of Fire Station 304 along the UG Route 2.

Figure 4-19: Fire Station 304 Along UG Route 2

4.1.2.6 Constructability

Factors that affect constructability include depth to bedrock, soil conditions, construction work area availability and route installation type. Constructability is also affected by utility density and traffic congestion. Similarly to UG Route 1, if parcel for TS1 is not able to be obtained, the proposed UG Route would need to be re-routed to the TS3 location. Reference Figure 4-20 below for an aerial overview of the TS3 location that UG Route 1 would need to reroute to. Additionally, a large portion of UG Route 2 the 230-kV and 500-kV circuits share a ROW. This may impact construction for future circuit repairs.

Figure 4-20 UG Route 2 Alternate Transition Station Location TS3

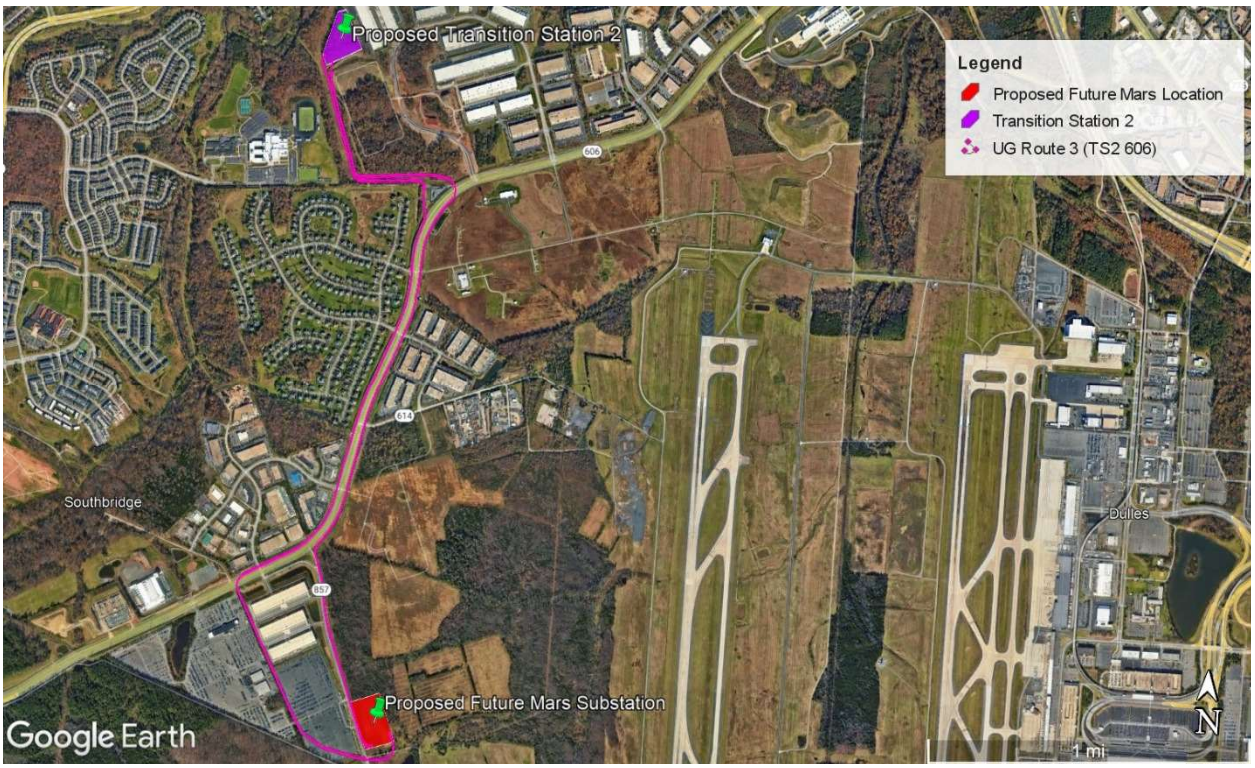


UG Route 2 has been reviewed for constructability and feasibility for this project. Throughout this review different challenges have been identified in the previous Sections: UG utility congestion along the segment paralleling Route 606, presence and depth of diabase rock formations, soil conditions, construction work area availability, VDOT limitations on Route 606 and traffic control along Route 606, encroachments into private property and federal lands, and circuits sharing the same ROW impacting construction for future circuit repairs. In addition, ERM stated that VDOT provided written confirmation of their opposition to any open-cut crossing of Route 606, for which their permission is required. Additionally, crossing Horsepen Dam presents significant permitting and operational risks as detailed by VDCR. Based on these factors, the UG Route 2 has been determined to not be constructable for this project.

4.1.3 UG Route 3

The proposed UG Route 3 starts from the proposed TS2 location and travels southwest along Route 606 towards Mars Substation. Directly leaving proposed TS2, the 230-kV and 500-kV circuits run parallel in close proximity to pass between an existing OH line on the west and private property to the east before entering Route 606. Note that even though the circuits come within close proximity, they are still considered within separate ROWs and will maintain the minimum spacing required between the duct banks to meet the ampacity requirements. The two duct banks will be separated by 40 feet from duct bank edge to duct bank edge. The 500-kV circuit remains on the southern side of Route 606, then diverts south to Route 857 before turning east into the Mars Substation. The 230-kV circuit remains on the northern side of route 606, then diverts through the Amazon IAD data center parking lot for approximately 3700 feet towards Mars Substation. The line will then head towards the proposed transition station where the UG circuits will be terminated. The proposed route is approximately 15,500 feet in length for the 230-kV circuit and 13,400 in length for the 500-kV circuit; it is the shortest route. An aerial image of the proposed UG Route 3 is shown in Figure 4-21 below.

Figure 4-21: Golden-Mars UG Route 3



4.1.3.1 Existing Subsurface Utility Density and Location of Major Facilities

The route consists of two circuits installed in separate concrete encased duct banks, each circuit having its own ROW. The minimum ROW required for the 230-kV is approximately 38 feet in width. At vault locations, the minimum required ROW is approximately 52 feet. This assumes that 15 feet of working space is required on both sides of the trench limits and outer vault edge. Overhead lines run along the majority of the route 606 corridor with a substation near the intersection of Route 606 and Ladbrook drive.

Based on the utility survey received from DEV, a few number of UG utilities exist along the north side of the Route 606 corridor. Leveraging the survey data, the route alignment has been adjusted to avoid as many subsurface utilities and structures as possible, while staying out of the Route 606 pavement. However, due to the high congestion of utilities, the proposed UG Route 3 is expected to cross a number of the existing utilities. The expected utility crossings include UG electrical lines, telecommunication lines, RCPs, and a foundation wall, amongst others as shown in Figure 4-4 through Figure 4-7 above. It is likely that with the footprint of the proposed duct bank, some level of utility relocation will be required to install the duct banks.

4.1.3.2 Land Acquisition and Private Property Encroachment

UG Route 3 remains in VDOT roads ROW for the majority of the route. However, there are some instances where the UG Route need to divert out of VDOT roads ROW to avoid an existing UG utility and to minimize impacts to Route 606. One location where the route leaves public ROW would require new land rights on the NOAA NWS parcel. ERM reported that during a September 27, 2024 meeting, NOAA informed Dominion that they would not grant new land rights, citing viable alternative routes that avoid NWS lands. Additionally, due to the location of Mars Substation and TS2 outside of public ROW, some private property encroachments are expected near the stations. Near TS2, the route travels briefly through the Amazon IAD property where the two circuits were brought as close together as possible to minimize the width of the encroachment. While the 500-kV circuit leaves Mars Substation on Route 857, the 230-kV routes travels briefly through Prologis-Exchange property. In total, easements from three (3) unique parcel owners will be required for UG Route 3 (Prologis- Exchange and Digital Realty, and Amazon IAD). Figure 4-22 and Figure 4-23 below shows the location where easements will be needed for duct bank placement.

Figure 4-22: Route 3 Easements near Mars Substation

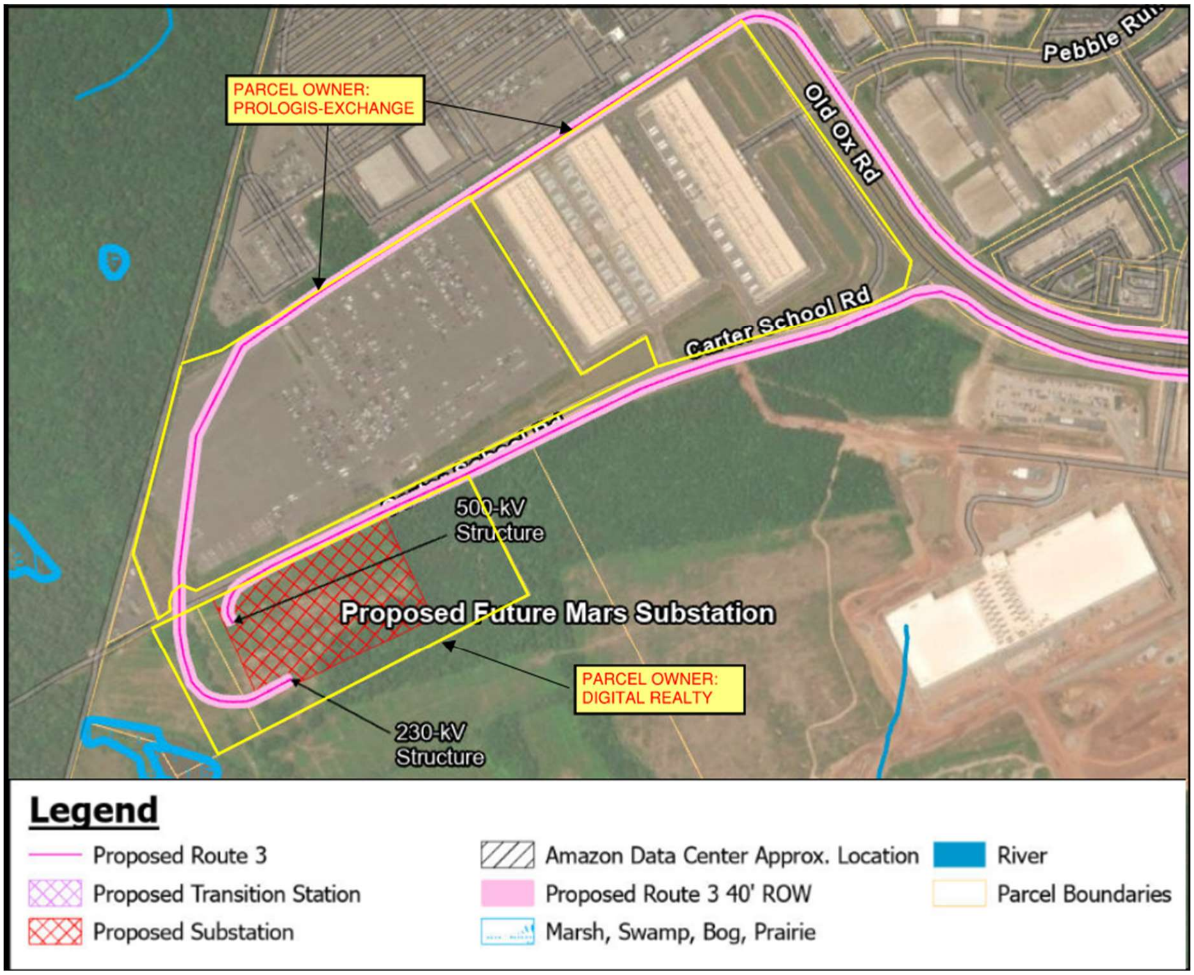
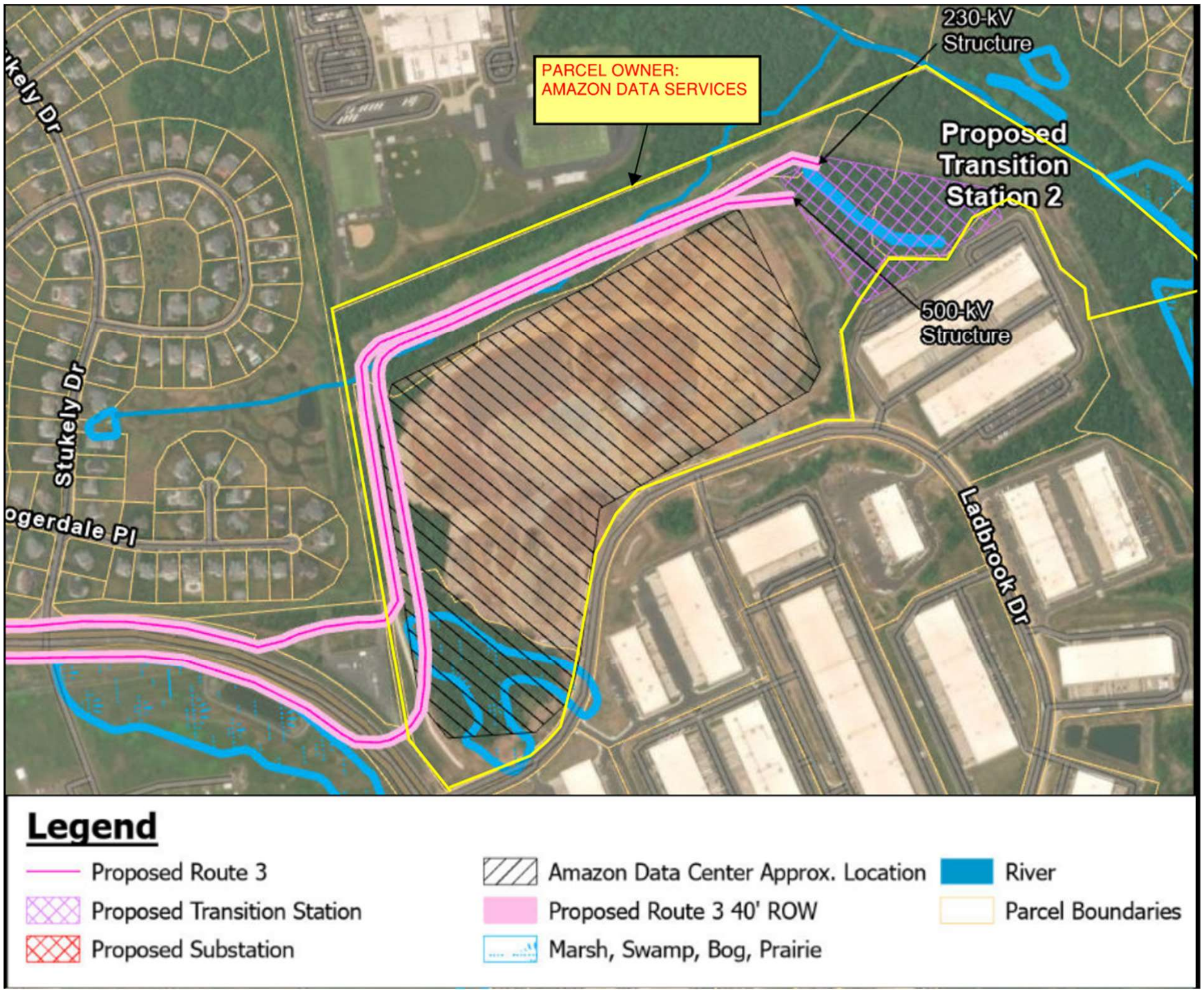


Figure 4-23 Route 3 Easements near Transition Station



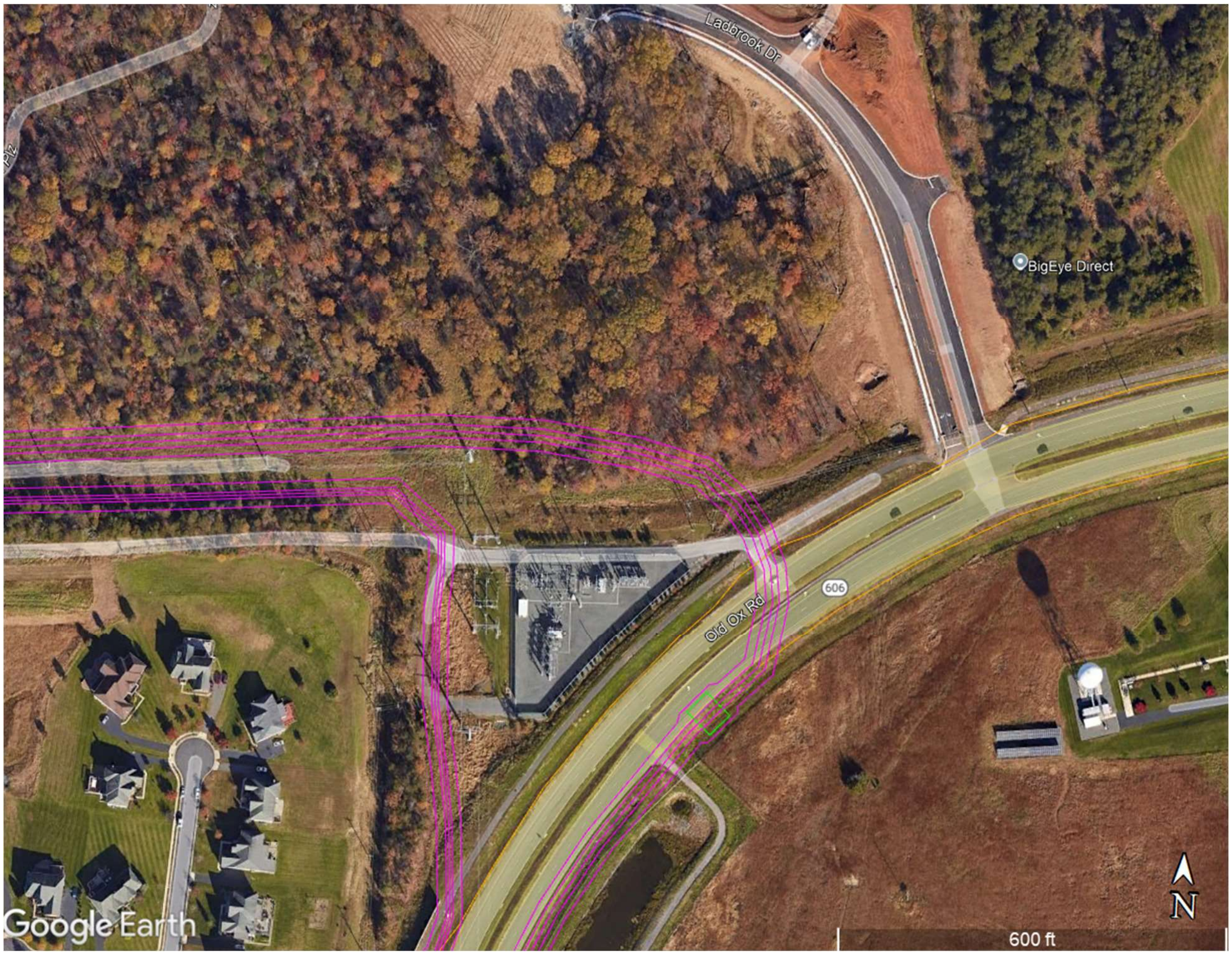
4.1.3.3 Road Details

The main corridor for this route is Route 606 which is a four-lane road with a separation median. Route 606 is approximately 100 feet wide, and the duct bank installation can be completed in phases where a couple of lanes can remain open for traffic flow during construction. Reference Figure 4-10 above for an image of the Route 606 corridor. Since Route 606 is a secondary highway, the proposed UG must minimize impact by avoiding placing trenches on the asphalt where possible and limiting the traffic disturbance during construction to only one (1) lane of traffic. For the proposed UG Route 3, the alignment has been adjusted so the duct bank trench does not require digging into the asphalt on Route 606. At the crossings with Route 606 west of Ladbrook Drive shown in Figure 4-24 below and at the crossing with Route 606 west of Pebble Run Place open-cut crossing through all traffic lanes is required.

ERM reported that during a September 16, 2024 meeting and in a follow-up email on September 26, 2024, VDOT expressed concerns about open-cut installation along Route 606, citing three key issues: traffic disruption, conflicts with existing utilities, and potential impacts to road integrity.

For some locations, if splice vaults are stacked adjacently, the vault trenches may need to occupy up to approximately 2 feet of the asphalt on the Route 606 shoulder. At these locations, excavation is only expected on the road shoulder, and no trenching is expected within the ongoing traffic lanes. However, a staggered configuration may be used to minimize impact to Route 606 and avoid excavating the asphalt. The route crosses a total of six (6) other roads where they intersect with Route 606. When crossing these intersections, the duct bank installation will need to be performed in phases to avoid obstruction to the entire intersection. Night work may also be required to reduce obstruction. For UG Route 3, the 230-kV circuit and 500-kV circuit are installed in separate concrete encased duct banks, each circuit having its own ROW. The minimum ROW required for the 230-kV circuit is approximately 38 feet in width. At vault locations, the minimum required ROW for the 230-kV circuit is approximately 52 feet. The minimum ROW required for the 500-kV is approximately 48 feet in width. At vault locations, the minimum required ROW is approximately 78 feet. This assumes that 15 feet of working space is required on both sides of the trench limits and outer vault edge.

Figure 4-24: UG Route 3 Crossings with Route 606 at Existing Substation West of Ladbrook Drive



4.1.3.4 Impact to Traffic

Due to the road widths along the route, it appears that sufficient space should exist to allow for effective traffic management. At this stage of the design, it would be anticipated alternating lane closures and modified traffic patterns would be required to allow for construction of the proposed duct banks. Only up to a single lane of traffic would be impacted on the Route 606 corridor. It is important to note that splice vaults should not be located in intersections and the preliminary locations have been carefully located using the information on existing utilities included in the survey. For the 230-kV circuit, a total of six (6) splice vault locations are required. Since two (2) vaults are required for each location along the 230-kV circuit a total of twelve (12) 230-kV splice vaults are proposed. For the 500-kV circuit, a total of eight (8) vault locations are required. Since three (3) vaults are required for each location along the 500-kV circuit, a total of twenty-four (24)

500-kV splice vaults are needed for UG Route 3. If needed, splice vaults can be placed in phases to minimize traffic disruptions and lane closures.

4.1.3.5 Sensitive Areas and Facilities

Just like UG Route 1, two (2) water drainage ditch locations were identified along crossings along UG Route 3. One (1) at the intersection of Route 857 and Route 606, and one (1) on Route 606 between Ladbrook Drive and Stuckely Drive. No trenchless crossings are anticipated near these drain ditches, as the circuit paths will avoid the ditches by routing around them. Special consideration must be taken near ditches to minimize impact on the water bodies by the proposed route. See Figure 4-11 above for an image of the drainage ditch on Route 857. Figure 4-12 and Figure 4-13 above shows aerial maps views of the drainage ditch locations on UG Route 3.

4.1.3.6 Constructability

UG Route 3 uses transition station location TS2, which is situated upon a flood plain. See section 5.2.2 below for more details on the flood plain effects on TS2. On the way to TS2, UG Route 3 runs above a riverine for approximately 1,700 feet, a National Wetland Inventory (NWI) identified wetland. According to the US Fish and Wildlife Service, the riverine may be subject to seasonal flooding. It is unknown how the wetland and seasonal flooding may affect soil conditions. Construction activities will need to be coordinated to avoid times where high-water levels are present.

One major issue affecting the constructability of one segment of the UG Route 3 is the crossing with Route 606 around the existing substation west of Ladbrook Drive shown in Figure 4-24. The proposed UG Route will be passing through different OH distribution lines dead-end structures from where the OH conductor enter the substation, will be encroaching partially into different OH high-voltage transmission lines power corridors and traveling through a narrow path between existing OH power corridors. To build this segment, DEV would need to acquire permits to plan phased outages, demolish and relocate different OH line support structures and their foundations, which may impact the substation yard design receiving those OH lines. These challenges amplify the risk of redesigning up to some extent the existing substation.

UG Route 3 has been reviewed for constructability and feasibility for this project. Throughout this review different challenges have been identified in the previous Sections: UG utility congestion along Route 606, presence and depth of diabase rock formations, soil conditions, construction work area availability, VDOT limitations on Route 606 and traffic control along Route 606, encroachments into private property, water drainage ditches located close to the proposed alignment, crossings through OH distribution lines dead-end structures from existing substation on Route 606, and ERM noted that VDOT indicated to Dominion in writing their opposition to any open-cut crossing of Route 606 as well as the inability to obtain new land rights across the NOAA parcel. Based on these factors, the UG Route 3 has been determined to not be constructable for this project.

4.1.4 UG Route 4

UG Route 4 begins at TS2 and travels south on the western side of Loudoun Valley Estates towards the new Mars Substation as shown in Figure 4-25. In this route both circuits are coexisting in the same ROW. The proposed route is approximately 15,900 feet in length. Through this desktop analysis BMcD has detected a number of constructability disadvantages greater than those of the other proposed routes. The disadvantages of the proposed UG Route 4 are as follows:

- Majority of route is outside of public ROW, and easements will be required from four (4) separate parcel owners: MWAA, Amazon Data Services, United States of America, and Digital Realty LLC
- Proximity to Broad Run Creek, parallels a riverine, and within the floodplain area at TS2, where there is increased risk for rocky soil and karst topography.
- 230-kV and 500-kV circuits share a ROW which may impact construction for future circuit repairs
- Constructability concerns such as utility congestion along Old Ox Road
- Requirements of open-cut trenching across Old Ox Road. VDOT will not allow open cut trenching through Old Ox Road and trenchless crossings will be required.
- The existing stormwater pond on NOAA property and the impact to NOAA's security perimeter.

UG Route 4 passes Dulles International Airport (IAD) as it travels southwest toward Mars Substation and thereby encroaches on property owned by the Metropolitan Washington Airports Authority (MWAA) and the National Oceanic and Atmospheric Administration (NOAA). As these are federal lands, permanent easements are not possible without consent of those respective agencies and alternative land rights agreements would be required. NOAA has informed Dominion that such agreements would not be granted for a crossing of their property.

Given the significant and cumulative construction drawbacks outlined above, the UG Route 4 has been determined to not be constructable for this project and further in-depth analysis of this UG route was not performed.

4.1.5 UG Route 5

UG Route 5 travels south from TS2 on the eastern side of Loudoun Valley Estates towards the new Mars Substation as shown in Figure 4-25. In this route both circuits are coexisting in the same ROW. The proposed route is approximately 15,850 feet in length. Similarly to the proposed UG Route 4, through this desktop analysis BMcD has detected a number of constructability disadvantages greater than those of the other proposed routes. The disadvantages of the proposed UG Route 5 are as follows:

- Majority of route is outside of public ROW, and easements will be required from eleven (11) separate parcel owners including seven (7) limited liability companies (LLCs), Loudoun County Board of Supervisors, LVE III Homeowners Association, Microsoft Corporation, Loudoun County Public Schools and Amazon Data Services

- Parallels Broad Run Creek for approximately 4,322 feet placing approximately 30% of the route within a flood plain.

- 230-kV and 500-kV circuits share a ROW which may impact construction for future circuit repairs

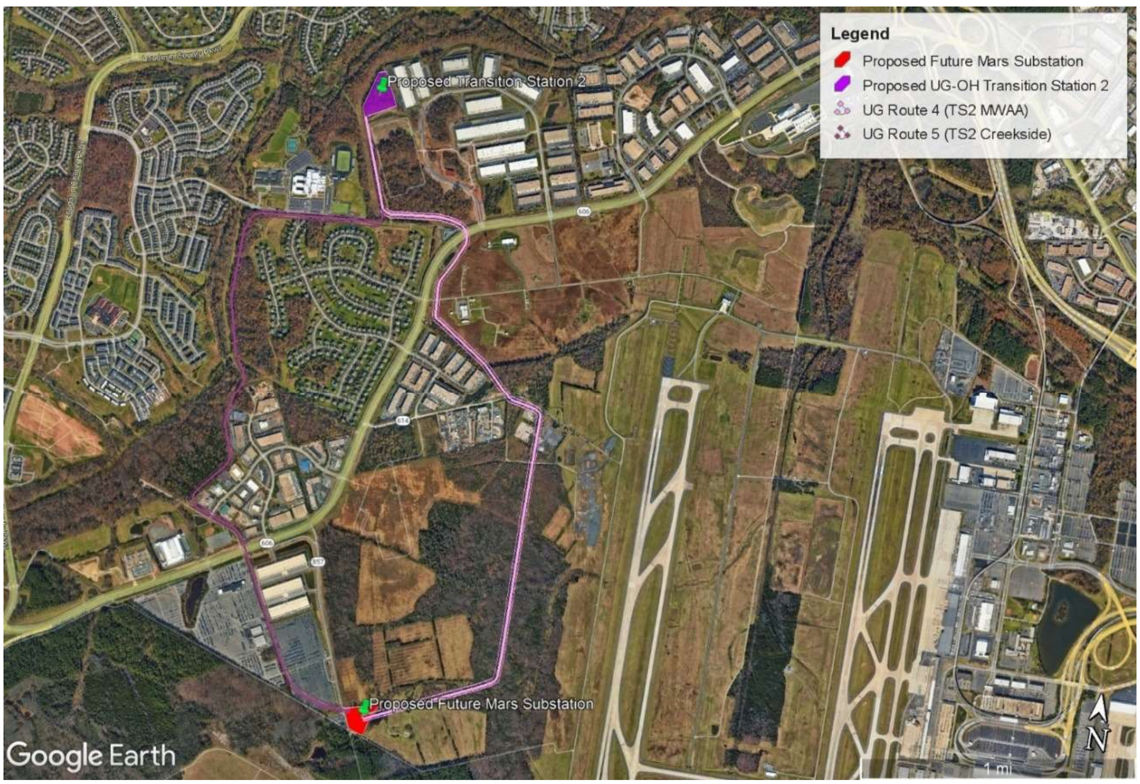
- Constructability concerns such as utility congestion along Old Ox Road

- Requirements of open-cut trenching across Old Ox Road. VDOT will not allow open cut trenching through Old Ox Road and trenchless crossings will be required.

Any route crossing Loudoun County Public Schools (LCPS) property would require approval from the LCPS Board. During discussions, LCPS staff expressed opposition to any construction affecting the access road to Rosa Lee Carter Elementary School and Rock Ridge High School, as it provides the only entry point for both schools. Consequently, LCPS does not support any route that would require closing this access drive.

Given the significant and cumulative construction drawbacks outlined above, the UG Route 5 has been determined to not be constructable for this project and further in-depth analysis of this UG route was not performed.

Figure 4-25: Golden - Mars UG Routes 4 and 5 to TS2



4.1.6 UG Route 6

The proposed UG Route 6 starts from the proposed TS4 location. The 230-kV circuit travels west around the Ladbrook Drive loop, while the 500-kV Route travels south around the Ladbrook Drive Loop. Leaving Ladbrook Drivee, each circuit then travels southwest along Route 606 towards Mars Substation. The 230-kV and 500-kV circuits remain in separate ROWs for the entirety of the route. The 500-kV circuit remains on the southern side of route 606, then diverts south on to Route 857 before turning east into the Mars Substation. The 230-kV circuit remains on the northern side of route 606, then diverts through the Amazon Integrated Access Device (IAD) data center parking lot for approximately 3,700 feet towards Mars Substation. The line will then head towards the Mars Substation where the UG circuits will be terminated. The proposed route is approximately 21,300 feet in length for the 230-kV circuit and 19,400 in length for the 500-kV circuit. An aerial image of the proposed UG Route 6 is shown in Figure 4-26 below.

Figure 4-26: Golden-Mars UG Route 6

4.1.6.1 Existing Subsurface Utility Density and Location of Major Facilities

Overhead lines run along the majority of the route 606 corridor and a substation was also identified near the intersection of Route 606 and Ladbrook Drive. It is assumed that there will be underground utilities entering and leaving the identified substation. Figure 4-3 above shows the identified substation on Route 606. The UG duct bank will need to avoid foundation of existing overhead poles and any UG utilities along the route.

Based on the utility survey provided by DEV, a number of UG utilities exist along the north side of the Route 606 corridor. Leveraging the survey data, the route alignment has been adjusted to avoid as many subsurface utilities and structures as possible, while staying out of the Route 606 pavement. However, due to the high congestion of utilities, the proposed UG Route 6 is expected to cross a number of them.. The expected utility crossings include UG electrical lines, telecommunication lines, RCPs, and a foundation wall, amongst others as shown in Figure 4-4 through Figure 4-7 above. It is likely that with the footprint of the proposed duct bank, some level of utility relocation will be required to install the duct banks.

4.1.6.2 Land Acquisition and Private Property Encroachment

UG Route 6 remains in VDOT roads ROW for the majority of the route. However, there are some instances where the UG routes need to divert out of VDOT roads ROW to avoid an existing UG utility and to minimize impact to Route 606. Per ERM's review, the route would require new land rights where it deviates from public ROW onto a parcel owned by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS). During a September 27, 2024 meeting, NOAA informed Dominion that they would not grant new land rights, citing the existence of viable alternative routes that avoid NWS lands.

Additionally, due to the location of the Mars Substation and TS4 outside of public ROW, some private property encroachments are expected near the stations. In addition, 230-kV circuit must route through private property, to avoid collocation with the 500-kV circuit on the Route 285 corridor. In total, easements from three (3) unique parcel owners will be required for UG Route 1 (Prologis- Exchange (Location for the Amazon IAD), Digital Realty, and Minalter Incorporated (Inc.)). Figure 4-8 and Figure 4-9 above shows the location where easements will be needed for duct bank placement near Mars Substation. These locations are the same as the easement locations for UG

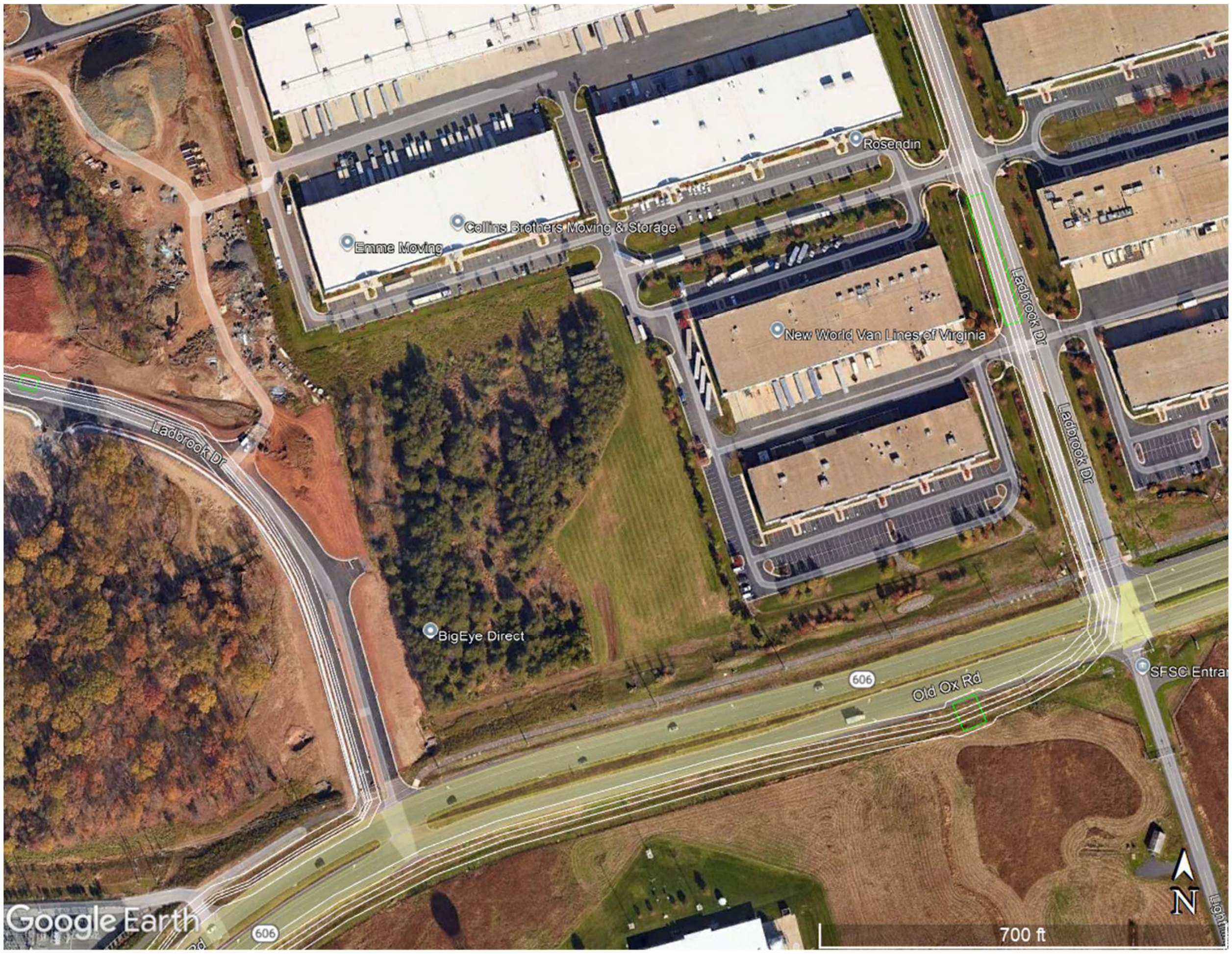
Route 1. Minalter Inc. owns the parcel which TS4 is located, and this land would have to be acquired if UG Route 6 is selected for detailed design.

4.1.6.3 Road Details

The main corridor for this route is Route 606 which is a four-lane road with a separation median. Route 606 is approximately 100 feet wide, and the duct bank installation can be completed in phases where a couple of lanes can remain open for traffic flow during construction. Figure 4-10 below shows an image of the Route 606 corridor. Since Route 606 is a secondary highway, the proposed UG must minimize impact by avoiding placing trenches on the asphalt where possible and limiting the traffic disturbance during construction to only one (1) lane of traffic. For UG Route 6, the alignment has been adjusted so the duct bank trench does not require digging into the asphalt on Route 606. The crossing with Route 606 at Ladbrook Drive shown in Figure 4-27 below and the crossing with Route 606 west of Pebble Run Place will require open-cut trenching throughout all Route 606 traffic lanes. ERM reported that during a September 16, 2024 meeting and in a follow-up email on September 26, 2024, VDOT expressed concerns about open-cut installation along Route 606, citing three key issues: traffic disruption, conflicts with existing utilities, and potential impacts to road integrity.

For some locations, if splice vaults are stacked adjacently, the vault trenches may need to occupy up to approximately 2 feet of the asphalt on the Route 606 shoulder. At these locations, excavation is only expected on the road shoulder, and no trenching is expected within the ongoing traffic lanes. However, a staggered configuration may be used to minimize impact to Route 606 and avoid excavating the asphalt. The route crosses a total of eight (8) other roads where they intersect with Route 606. When crossing these intersections, the duct bank installation will need to be performed in phases to avoid obstruction to the entire intersection. Night work may also be required to reduce obstruction.

Figure 4-27: UG Route 6 Crossings with Route 606 at Ladbrook Drive



As mentioned above, the Ladbrook Drive corridor leading to TS4 may only be considered for single duct bank at a time. On the side of the loop which the 500-kV Route takes, the existing utilities running parallel on the corridor do not leave enough room for the 500-kV manhole location. The existing storm drainage and gravity sewer lines would need to be relocated if UG Route 6 is selected. To minimize impact on the existing utilities, a staggered configuration is proposed for the 500-kV splice vault location on Ladbrook Drive. Figure 4-28 and Figure 4-29 below shows the 500-kV splice vault to be utilized on the Ladbrook Drive corridor. For UG Route 6, 230-kV circuit and 500-kV circuit are installed in separate concrete-encased duct banks, each circuit having its own ROW. The minimum ROW required for the 230-kV circuit is approximately 38 feet in width. At vault locations, the minimum required ROW for the 230-kV circuit is approximately 52 feet. The minimum ROW required for the 500-kV is approximately 48 feet in width. At vault locations, the minimum required ROW is approximately 78 feet. This assumes that 15 feet of working space is required on both sides of the trench limits and outer vault edge.

Figure 4-28 Staggered 500-kV Splice Vault Layout

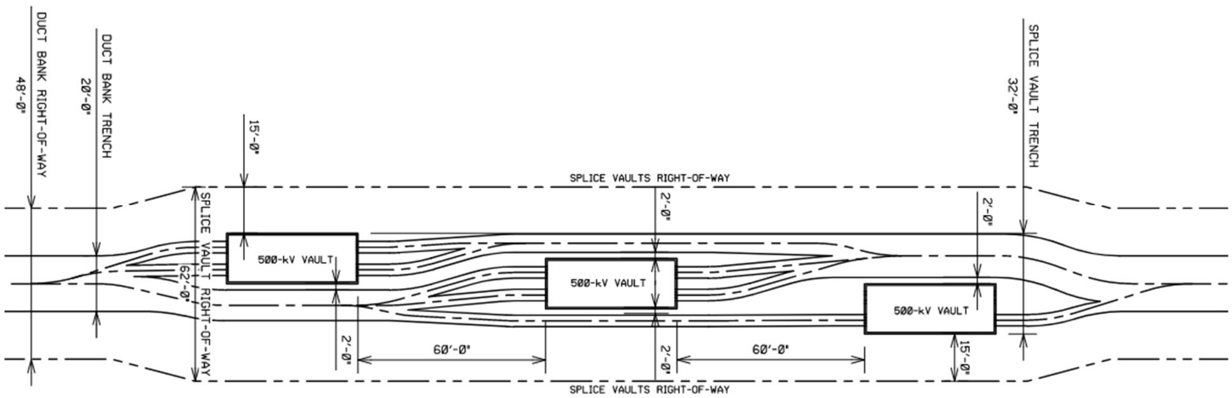
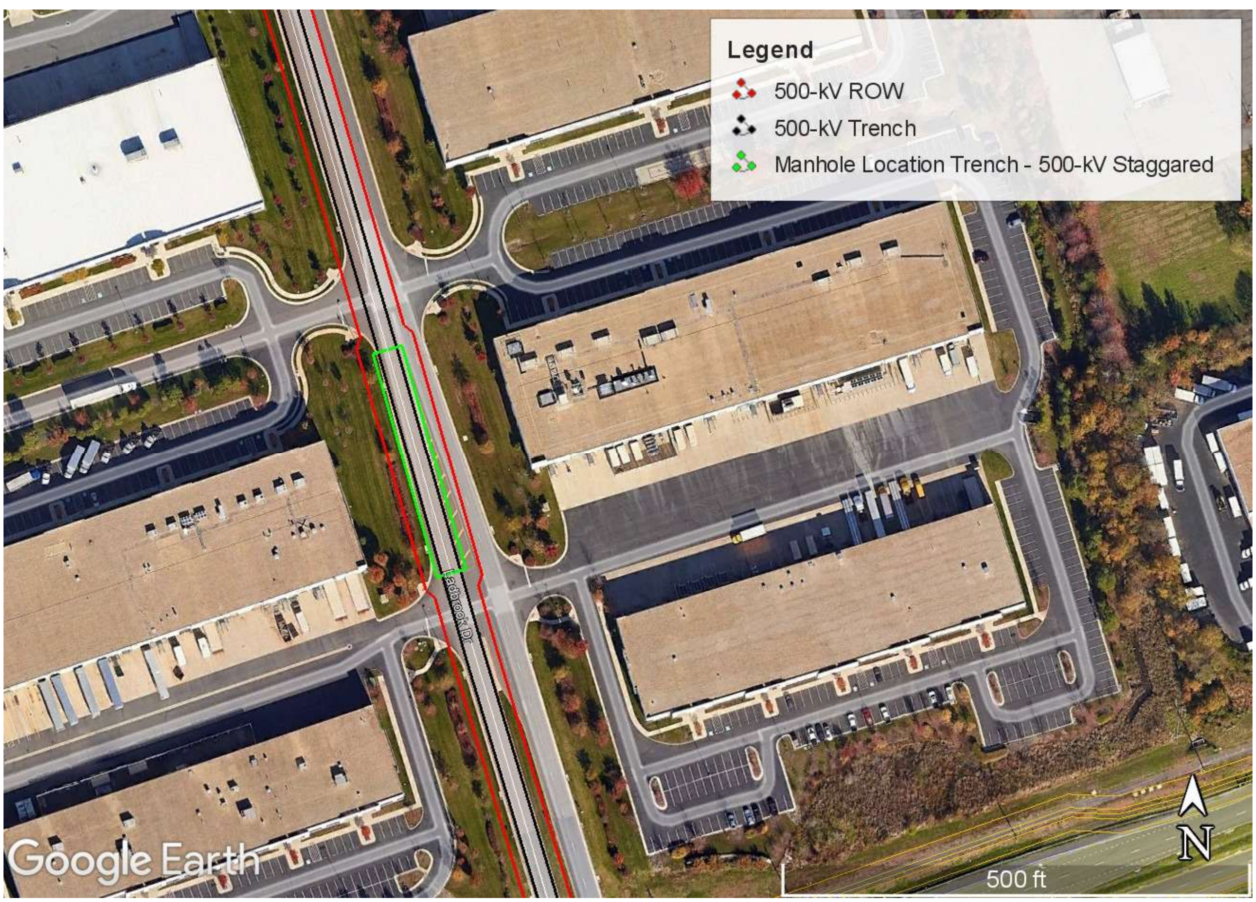


Figure 4-29: Staggered 500-kV Splice Vault Location



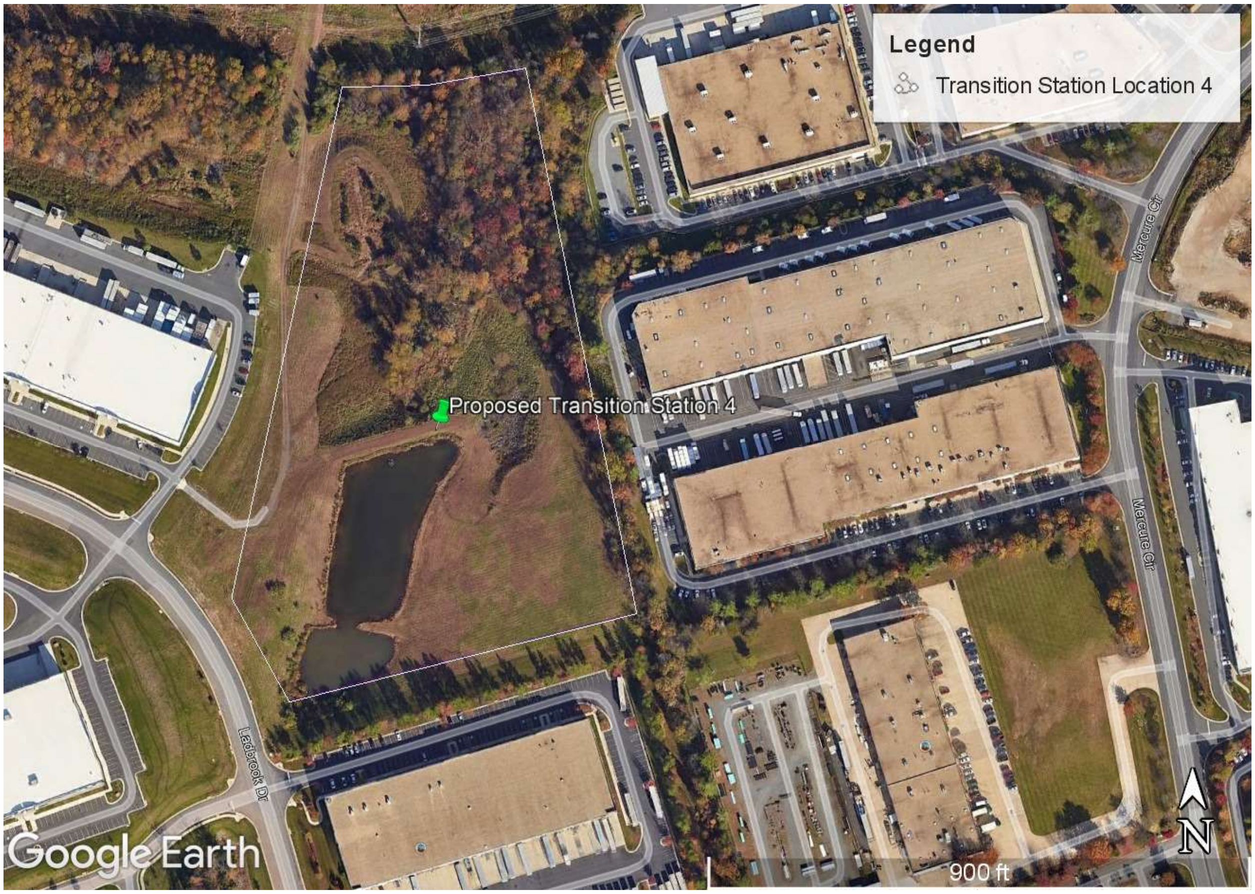
4.1.6.4 Impact to Traffic

Due to the road widths along the route, it appears that sufficient space should exist to allow for effective traffic management. However, it would be anticipated alternating lane closures and modified traffic patterns would be required to allow for construction of the proposed duct banks. Only up to a single lane of traffic would be impacted on the Route 606 corridor. On the Ladbrook Drive Corridor, it will be necessary to occupy at least two (2) of the four (4) lanes of traffic during construction. It is important to note that splice vaults should not be located in intersections and the preliminary locations have been carefully located using the information on existing utilities included in the survey. For the 230-kV circuit, a splice vault location will be placed every 2,400 feet, for a total of seven (7) vault locations. Based on the 230-kV system requirement, two (2) vaults are required for each vault location to splice the four (4) cables-per-phase circuit. For the 500-kV circuit, a splice vault location will be placed every 1,700 feet, for a total of eight (8) vault locations. Based on the 500-kV system requirement, three (3) vaults are required for each vault location, to splice the five (5) cables-per-phase circuit. A total of fourteen (14) 230-kV splice vaults and twenty-four (24) 500-kV splice vaults will be needed for UG Route 6. If needed, splice vaults can be placed in phases to minimize traffic disruptions and lane closures.

4.1.6.5 Sensitive Areas and Facilities

Two (2) water drainage ditch locations were identified along UG Route 6. One (1) at the intersection of Route 857 and Route 606, and one (1) on Route 606 between Ladbrook Drive and Stuckely Drive. No trenchless crossings are anticipated near these drain ditches, as the circuit paths will avoid the ditches by routing around them. There is an existing stormwater retention basin/pond in the middle of the TS4 site. If UG Route 6 is selected for detailed design, the retention basin/pond would need to be relocated before construction of the transition station can begin. See Figure 4-11 above for an image of the drainage ditch on Route 857. Figure 4-12 and Figure 4-13 above shows aerial maps views of the drainage ditch locations on UG Route 6. Figure 4-30 below shows an aerial view of the retention basin/pond located at the TS4 site.

Figure 4-30: Pond at the TS4 Site



4.1.6.6 Constructability

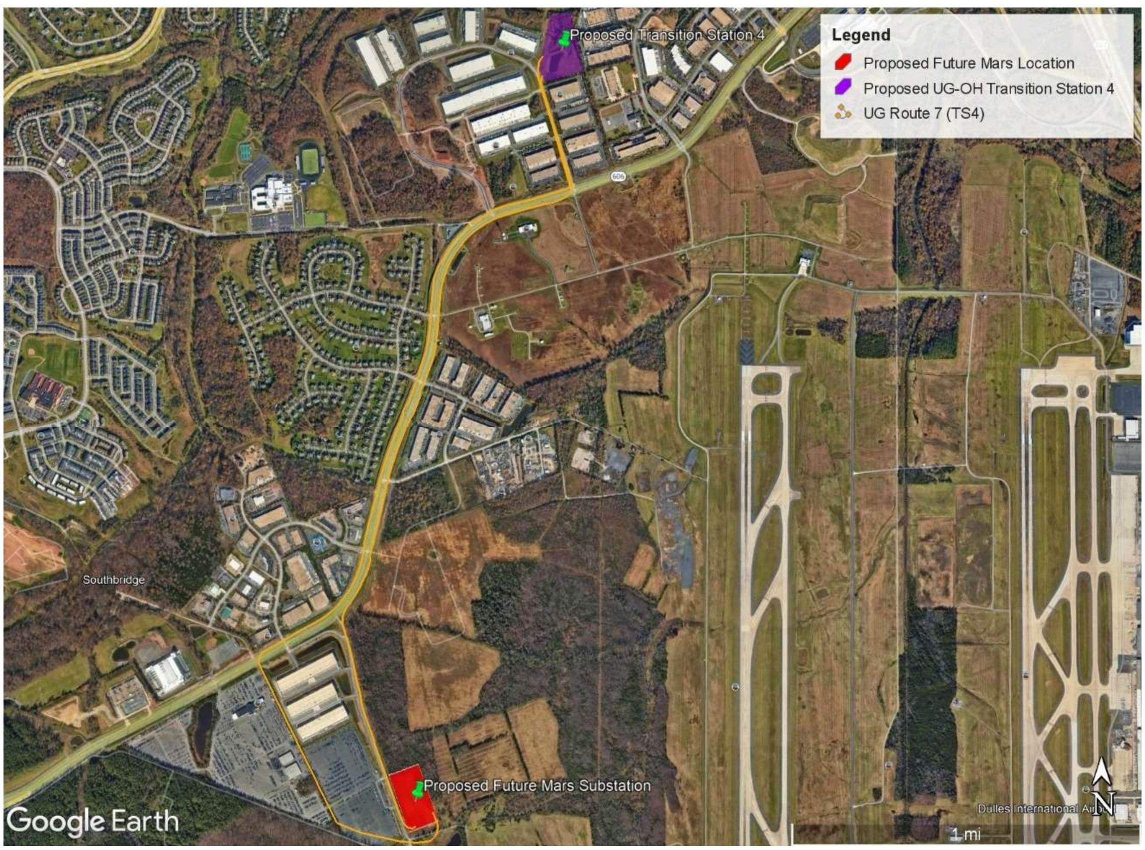
Factors that affect constructability include depth to bedrock, soil conditions, construction work area availability and route installation type. Constructability is also affected by utility density and traffic congestion. The utility congestion along the Route 606 and Ladbrook Drive corridors will add complexity to the UG route.

UG Route 6 has been reviewed for constructability and feasibility for this project. Throughout this review different challenges have been identified in the previous Sections: UG utility congestion along Route 606 and Ladbrook Drive, presence and depth of diabase rock formations, soil conditions, construction work area availability, VDOT limitations on Route 606, traffic control along Route 606 and Ladbrook Drive, encroachments into private property, water drainage ditches located close to the proposed alignment, existing pond in the transition station area, and the inability to obtain new land rights across the NOAA parcel. Based on these factors, the UG Route 6 has been determined to not be constructable for this project.

4.1.7 UG Route 7

UG Route 7 travels south from TS4 with both the 230-kV and 500-kV duct banks occupying the eastern side of the Ladbrook Drive Loop. The circuits split on Route 606, placing each circuit on opposite sides of the median, travelling southwest towards the new Mars Substation as shown in Figure 4-31 below. The proposed route is approximately 16,200 feet in length for the 230-kV circuit and 13,330 in length for the 500-kV circuit. The public ROW width on Ladbrook Drive is approximately 70 feet. This is not wide enough to fit both the 230-kV and 500-kV duct banks, reference Figure 3-5 above. However, due to the route's length of run on the corridor, a splice vault will need to be placed on Ladbrook drive for both circuits. The ROW is not wide enough to house all the splice vaults, as the minimum required width for vault locations is 115-feet.

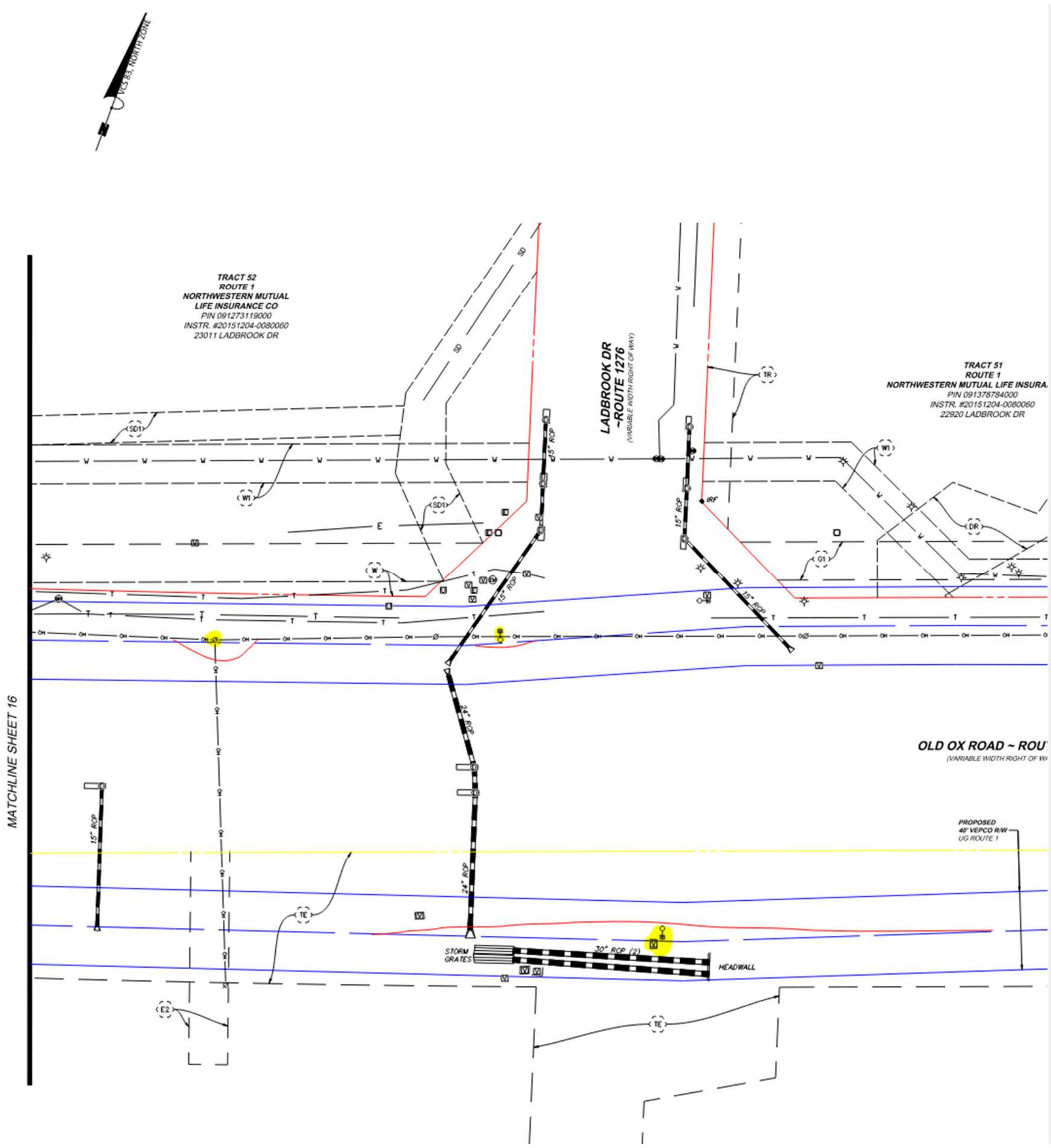
Figure 4-31 Golden - Mars UG Route 7 to TS4



Another constraint for this route is that installing both circuits in this corridor would take the entire road out of operation and will affect traffic in this corridor thus impacting all the nearby businesses. Additionally, based on the provided survey there are three (3) existing utilities that run parallel on Ladbrook Drive as indicated in Figure 4-32 below, a storm drainage system, a gravity sewer system and a water line system. This reduces the working width for placement of the proposed UG Route to approximately 28-feet, which is inadequate spacing for the two duct banks. Installing both circuit duct banks along this corridor would not be possible without relocating these utilities along the entire length of route on Ladbrook Drive.

Per ERM analysis, a significant constraint for Underground Route 7 is the requirement for new land rights on the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) parcel. During a September 27, 2024 meeting, NOAA informed Dominion that they would not grant new land rights, citing the availability of viable alternative routes that avoid NWS lands.

Figure 4-32 Existing Utilities on Ladbrook Drive



The summary of constructability disadvantages of the proposed UG Route 7 are as follows:

- Three (3) existing utilities running parallel on Ladbrook Drive limit space for placement of both 230-kV and 500-kV duct banks within corridor
- Survey data incomplete on Ladbrook Drive and other unidentified existing utilities are expected in the study area
- At splice vault locations, route would need to exist partially outside of public ROW

- Constructability concerns such as utility congestion along Old Ox Road
- VDOT will not allow open cut trenching on Old Ox Road
- NOAA has confirmed they will not grant land rights for this project.

Given the significant and cumulative construction drawbacks outlined above, the UG Route 7 has been determined to not be constructable for this project and further in-depth analysis of this UG route was not performed.

4.1.8 UG Route R1 – (MWAA Route) Loudoun Water Sewer Route

The proposed UG Route R1 has been defined by DEV and ERM and starts from the proposed future Mars Substation located northeast of Carters School Road and Perimeter Road intersection, traveling then northeast through forested lands (MWAA, Digital Reality), until Route 606 (Old Ox Road) where proposed UG Route R1 turns northwest towards the proposed TS1 location. The 230-kV and 500-kV circuits remain in the same ROW for the entirety of the route.

Both circuits exit the Mars Station south paralleling Carters School Road until the existing freshwater pond north of W Perimeter Road, where they turn northeast after crossing the pond via trenchless technology. The proposed UG line continues northeast for approximately 1,780 feet where other trenchless crossing may be required to traverse the stream north of Hellcat Drive. The proposed UG line will continue northeast and then turn north following the east side of the existing fence in the MWAA land until crossing another stream located south of Beaver Meadow Road. Both circuits continue north paralleling that existing fence until the intersection with Beaver Meadow Road, where they head north paralleling the permanent ROW of a future sewer line project crossing a freshwater forested wetland. The proposed UG line heads northeast parallel to the future sewer line crossing an existing stream and pond system at the west exit of Instrument Road culverts. The proposed route keeps going northeast paralleling the future sewer line where it crosses a stream connecting two freshwater forested wetland systems located on east and west sides of Operations Road. Then, both circuits divert north parallel to Operations Road and the future sewer line until south of WMATA Dulles Rail Yard, where they head northeast crossing through the Horsepen Pond, the future sewer line pond and the railway overpass where large trenchless crossings are anticipated. The line will head then northwest through a forested area until the intersection with Route 606 where it crosses the road overpass. Finally, the UG Route continues toward the proposed transition station where the UG circuits will be terminated. The proposed route is approximately 22,090 feet in length for both, 230-kV and 500-kV circuits. The preliminary trenchless crossings identified through this desktop analysis are listed in Table 4-2 below and the feasibility analysis of each crossing is detailed in Appendix E. Some route alternatives and installation options are also outlined in Table 4-3 for crossings where trenchless installations could be avoided, provided site-specific conditions, environmental and permitting constrains allow that. An aerial image of the proposed UG Route R1 is shown in Figure 4-33 below.

Figure 4-33: Golden-Mars UG Route R1 – (MWAA Route) Loudoun Water Sewer Route

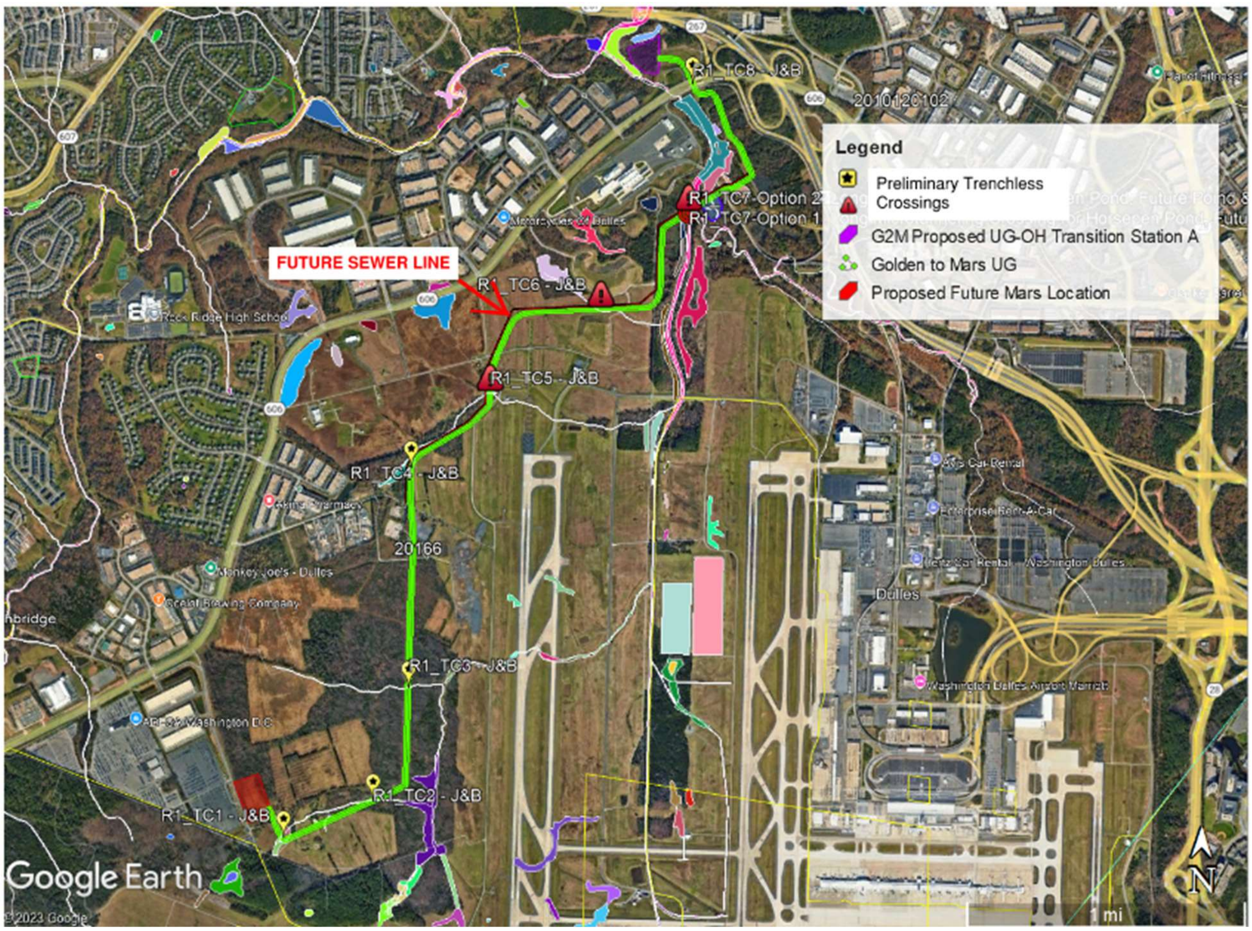


Table 4-2 UG Route R1 - Preliminary Trenchless Crossings List

Trenchless Crossing	Description
R1_TC1	Crossing through existing pond northwest of W Perimeter Road.

Trenchless Crossing	Description
R1_TC7	Crossing through Horsepen pond, future sewer line pond and railway overpass.

Table 4-3 UG Route R1 – Potential Open-Cut Crossings List

Crossing	Description
R1_TC2	Crossing through small stream west of freshwater wetland area north of Hellcat Drive. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment is shifted north to avoid crossing the stream. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.
R1_TC3	Crossing through small stream south of Beaver Meadow road. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.
R1_TC4	Crossing through wetland north of Beaver Meadow road. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment is shifted east to avoid crossing the wetland area.

Crossing	Description
R1_TC5	Crossing through existing pond west of a group of existing culverts below Instrument Road. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route can be shifted east to avoid crossing the ponds.
R1_TC6	Crossing through stream south of Operations Drive. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.
R1_TC8	Crossing through highway 606 overpass. Crossing below highway 606 overpass: pending on the type of overpass foundation (raft mat or piles, etc.) and upon permission from VDOT, open-cut installation may be feasible

4.1.8.1 Existing Subsurface Utility Density and Location of Major Facilities

Survey along route R1 was not provided to BMcD for this assessment, therefore it is not possible to identify in this desktop analysis the existing UG utilities along the proposed route. However, since the proposed Route R1 runs almost entirely through private lands of the Metropolitan Washington Airport Authority and due to the proximity of Dulles International Airport it can be inferred that some UG telecommunication, electrical, water and sewer lines, amongst other existing utilities may run near or through portions of the proposed route. Future development in these areas could introduce new utilities and infrastructure along the route, that may require future relocation of the proposed UG transmission circuits.

4.1.8.2 Land Acquisition and Private Property Encroachment

The proposed Route R1 is located outside of VDOT roads ROW for all the route, therefore different property easements are expected. In total, easements from two (2) unique parcel owners will be required for the proposed Route R1 (MWAA and Digital Realty). Since it is federal land, permanent easements are not an option for MWAA property, and a special license would be required. In general, easements for government property may be more difficult to obtain and duct bank construction as well as trenchless installations must be careful to avoid disruption to the airport operations, this is a factor weighing heavily at trenchless crossings where the preliminary ROW minimum widths range from 270 feet up to 420 feet requiring larger easements than the open-cut segments. The map book developed in Appendix A for R1 shows the location where easements will be needed for 230-kV and 500-kV duct banks and trenchless crossings placement along the UG route.

4.1.8.3 Road Details

The UG route travels through private lands consisting of private roadways, parking lots, and forestry. There is just a single instance where the proposed UG Route R2 crosses a public road, it happens south of TS1 where the UG line passes below Route 606 overpass. To define the impact on this overpass existing VDOT bridge foundations and details will need to be reviewed. In this route, the 230-kV Circuit and 500-kV Circuit are collocated within the same ROW. The minimum ROW required for the collocated duct banks is 90.5 feet at 100% DLF, see Section 3.4.3 for details. At vault locations, the minimum required ROW for the dual circuit is approximately 115 feet in width. For trenchless installations identified through this alignment, the minimum ROW required varies from 270 feet up to 420 feet in width depending on the location and anticipated trenchless technology required, see Appendix F for details. This assumes that a minimum 15 feet of working space is required on both sides of the trench limits and outer vault edge.

4.1.8.4 Impact to Traffic

As described in previous sections, since the proposed Route R1 travels through private lands consisting of private roadways, parking lots, and forestry, impacts to public traffic and roads is not anticipated. Even though the proposed UG Route R1 is out of the public ROW, there are some private roads and parking lots along the route, and they may be affected by the location of splice vaults depending on trenchless final lengths and site-specific conditions which are factors determining the proposed splice vault final locations. For the proposed 230-kV Circuit nine (9) preliminary vault locations are required and for the proposed 500-kV Circuit thirteen (13) preliminary vault locations are required. If needed, splice vaults can be placed in phases to minimize traffic disruptions and lane closures of those private roads.

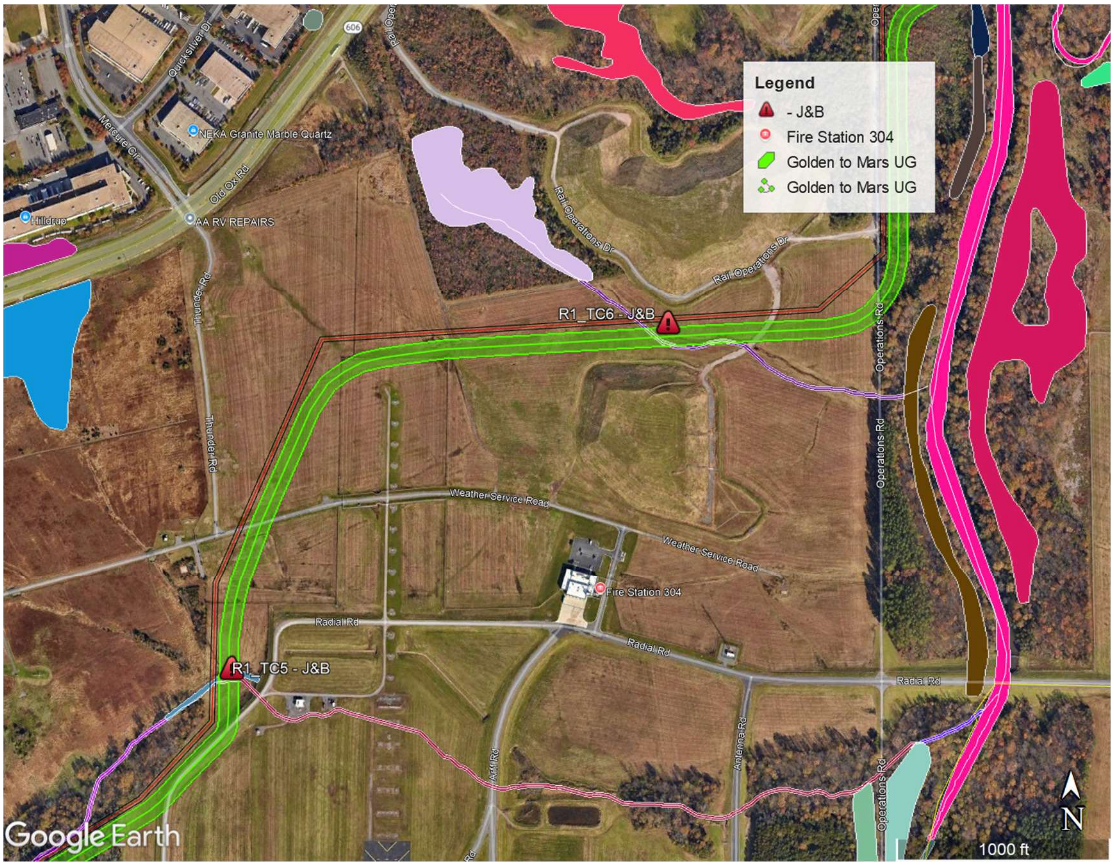
4.1.8.5 Sensitive Areas and Facilities

South of WMATA Dulles Rail Yard, the proposed UG Route R1 crosses the Horsepen Pond and the future sewer line pond, as well as other crossing through an existing pond that have been preliminary identified in Table 4-2 and studied in Appendix E, requiring trenchless crossings to minimize impacts on these water bodies.

Per ERM's permitting review, the proposed underground Route R1 would cross the Horsepen Dam spillway both north and south of Route 606. VDCR has classified this as a high-risk dam. Any spillway crossing, regardless of construction method, would require inundation preparedness measures and pose significant operational risks. Additionally, the crossing would require permits from MWAA, which may not grant such approvals.

The proposed UG Route R1 will pass Fire station 304, located on MWAA property. This fire station is specially placed to protect IAD property and provides services such as aircraft rescue, firefighting, and emergency services. UG Route R1 may impact unit deployment in and out of the fire station as it crosses the private roadway, Weather Service Road. This roadway provides a path from the fire station to the main road, Route 606. If this route is selected, coordination with the fire station will be required, to minimize the impact on public safety. Note that there are also other roadways leaving the fire station that will not be impacted by the proposed UG Route R1, and they provide direct paths to IAD. See Figure 4-34 for an aerial view of the location of Fire Station 304 along the proposed UG Route R1.

Figure 4-34 Fire Station 304 Along UG Route R1



4.1.8.6 Constructability

Factors that affect constructability include depth to bedrock, soil conditions, construction work area availability, and utility density amongst other factors. These factors are unknown for this feasibility study since site-specific geotechnical studies and survey have not been performed for the segments outside the public ROW, which comprise most of the route, and therefore cannot be assessed at this moment with certainty. Additionally, the proposed 230-kV and 500-kV circuits share the same ROW. This may impact construction for future circuit repairs.

UG Route R1 has been reviewed for constructability and feasibility for this project. Throughout this review different challenges have been identified in the previous Sections: UG utility congestion along Route 606, presence and depth of diabase rock formations, soil conditions, construction work area availability, trenchless crossings through hard and abrasive rock, encroachments into private property and federal lands, water drainage ditches located close to the proposed alignment, crossings through streams and the significant permitting, construction, and operational risk of crossing of Horsepen Dam and spillway. Based on these factors, the UG Route R1 has been determined to not be constructable for this project.

4.1.9 UG Route R2 – MWAA Perimeter Road Route

The proposed UG Route R2 starts from the proposed future Mars Substation located northeast of Carters School Road and Perimeter Road intersection, traveling then northeast through forested lands (MWAA, Digital Reality), until the intersection with the future sewer line where the alignment turns north until Route 606 (Old Ox Road) where the proposed Route R2 runs northeast parallel to the southeast side of Route 606 turning then northwest towards the transition station TS1.

The 230-kV and 500-kV circuits remain in the same ROWs for the entirety of the route. The proposed Route R2 shares the same segment of Route R1 option from the Mars Substation up to the intersection between Thunder Road and Weather Service Road, where the proposed UG Route crosses the future sewer line, at this location a trenchless crossing is anticipated. The proposed UG line proceeds northward up to the southeast side of Route 606 roadway to continue traveling northeast between WMATA Dulles Rail Yard northwest side and Route 606. Throughout this segment, the proposed UG Route passes through private ROW. The proposed UG line will then cross Route 606 over the Horsepen Run culvert, and since VDOT prohibits having any lane closure, a trenchless crossing is warranted to cross below the culvert to exit at the north side of Route 606. Finally, the proposed UG Route continues toward the proposed transition station where the UG circuits will be terminated. The proposed route is approximately 19,013 feet in length for both 230-kV and 500-kV circuits. The preliminary trenchless crossings identified through this desktop analysis are listed in Table 4-4 below and the feasibility analysis of each crossing is detailed in Appendix E. Some route alternatives and installation options are also outlined in

Table 4-5 for crossings where trenchless installations could be avoided, provided site-specific conditions, environmental and permitting constraints allow that. An aerial image of the proposed UG Route R2 is shown in Figure 4-35 below.

Figure 4-35 Golden-Mars UG Route R2 - MWAA Perimeter Road Route

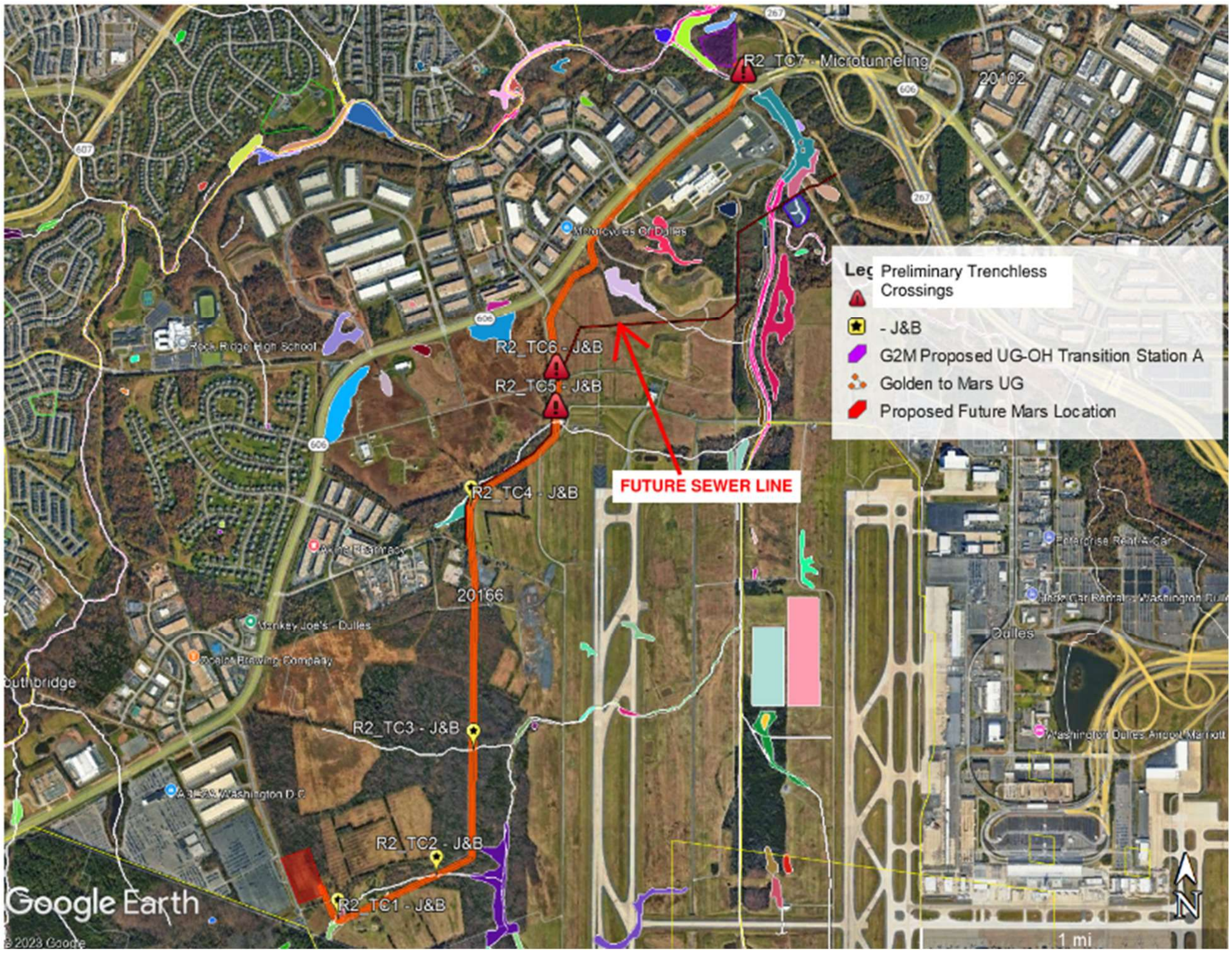


Table 4-4 UG Route R2 - Preliminary Trenchless Crossings List

Trenchless Crossing	Description
R2_TC1	It is the same R1_TC1 crossing from Route R1 crossing list table. Crossing through existing pond northwest of W Perimeter Road. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment is shifted north to avoid crossing the pond.
R2_TC6	Crossing through future 24” PVC DR-25 sewer line and future permanent sanitary sewer easement.
R2_TC7	Crossing through highway 606 and existing Horsepen Run culvert below 606.

Table 4-5 UG Route R2 - Potential Open-Cut Crossings List

Crossing	Description
R2_TC2	It is the same R1_TC2 crossing from Route R1 crossing list table. Crossing through small stream west of freshwater wetland area north of Hellcat Drive. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment is shifted north to avoid crossing the stream. As an alternative, if temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.

Crossing	Description
R2_TC3	It is the same R1_TC3 crossing from Route R1 crossing list table. Crossing through small stream south of Beaver Meadow road. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.
R2_TC4	It is the same R1_TC4 crossing from Route R1 crossing list table. Crossing through wetland north of Beaver Meadow road. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment is shifted east to avoid crossing the wetland area. As an alternative, if the agencies with jurisdiction provide a permit to cut through the freshwater forested wetland, then open-cut installation may be feasible.
R2_TC5	It is the same R1_TC5 crossing from Route R1 crossing list table. Crossing through existing pond west of a group of existing culverts below Instrument Road. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.

4.1.9.1 Existing Subsurface Utility Density and Location of Major Facilities

Survey of existing UG utilities for the segment between Mars Station and Route 606 traveling through private ROW belonging to MWAA and Digital Reality is not available at the time of this report, therefore similar to the analysis in Section 4.1.8.1, a desktop analysis of the existing UG utilities along this portion of proposed Route R2 was not conducted. In contrast, for the UG route portion between Route 606 northeast side and WMATA Dulles Rail Yard northwest side, QL-C and QL-D survey were provided to BMcD on July 29th, 2024. This survey shows moderate density of existing UG utilities with unknown elevations to be expected from Route 606 and Mercure Circle intersection all the way up to the UG line crossing through Route 606 towards TS1, see Figure 4-36 through Figure 4-40. Two (2) important clusters of existing UG utilities are identified in this desktop analysis, one at the intersection of R2 and Route 606 other at R2 and Commerce Center Court intersection, according to Figure 4-36 and Figure 4-39 correspondingly. The first one consists of water and sanitary sewer lines, the latter corresponds to water lines, storm water lines ranging from 15" reinforced concrete pipe (RCP) to 30" RCP and manholes. Additional information will be required to determine if trenchless crossings will be required in these areas. Additional congested UG utilities are found before the UG line starts crossing Route 606 where manholes, water lines and storm water lines with sizes up to 36" RCP are identified in Figure 4-40. The congested utility density in this area could introduce challenges during detailed design and extend the anticipated Route 606 trenchless crossing underneath the congested utility area. In any scenario, it will be challenging to collocate all the nine (9) bore pits without relocating some of the longer UG utilities as discussed in Appendix E.

This desktop analysis anticipates approximately 3,700 feet of electrical chain-link fence at the north of WMATA Dulles Rail Yard will need to be demolished and reconstructed for the proposed Route R2 open-cut installation of 230-kV Circuit and 500-kV Circuit coexisting in the same ROW. The typical electrical chain-link fence is shown in Figure 4-41.

Installing the proposed UG route via open-cut trenching between Route 606 and Rail Operations Drive requires challenging measures. These measures are derived from the restriction imposed by VDOT, which prohibits the use of Route 606 roadway, and from the congestion of existing UG utilities described above. These measures include: relocation of some of the major existing UG utilities, acquisition of permanent easements from WMATA Dulles Rail Yard, which may not be possible or may take a prohibitively long time to obtain, getting all 230-kV and 500-kV splice vaults staggered, and in some areas where the existing utilities are deep, the duct banks ampacity may need to be revised if the depth of cover (DOC) exceeds the limits indicated in Sections 3.4.1 and 3.4.2.

Figure 4-36 Existing Subsurface Utility Density at Route R2 and Route 606 Intersection

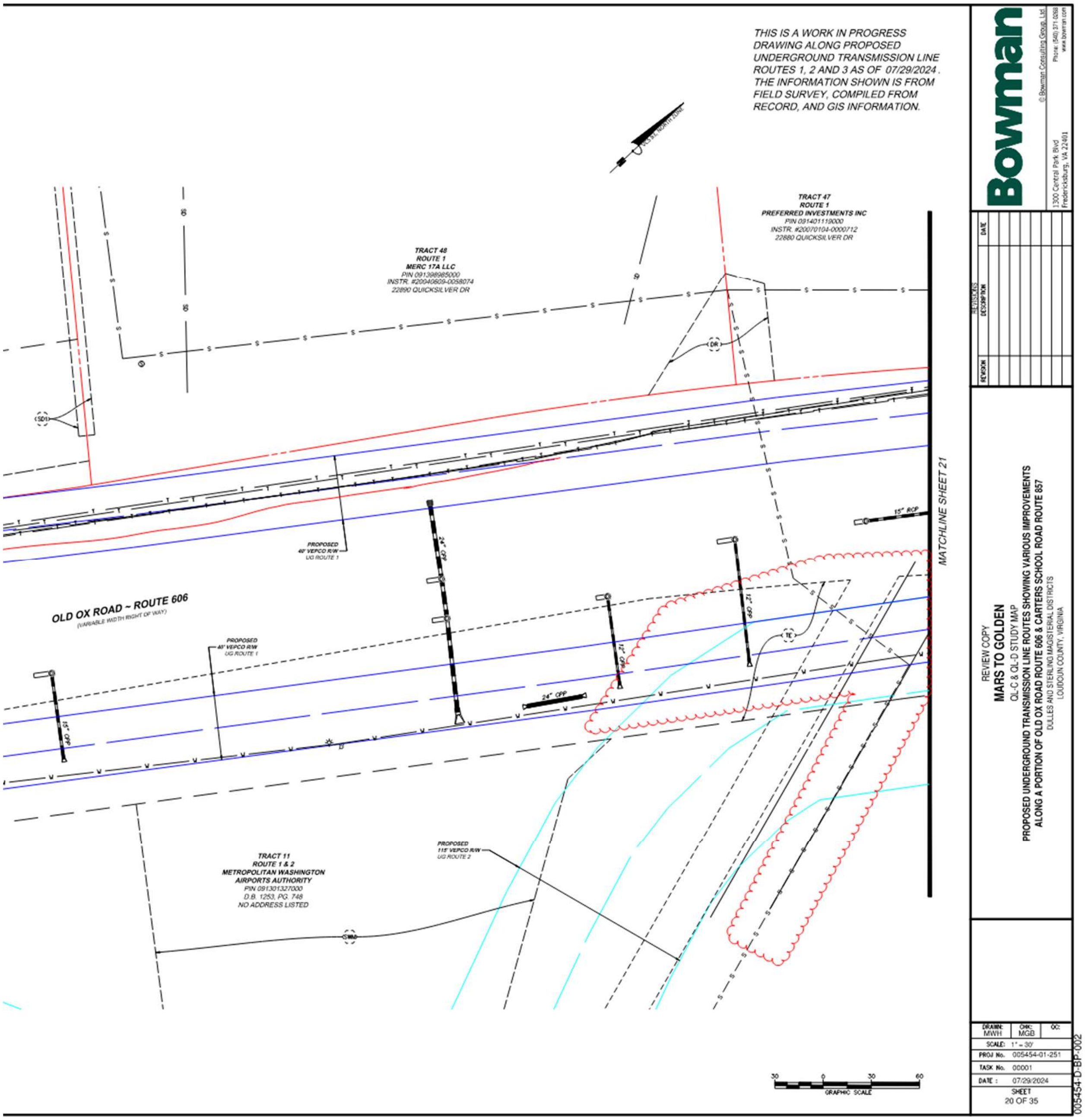


Figure 4-37 Existing Subsurface Utility Density Along Northeast Side of Route 606. 1 of 4

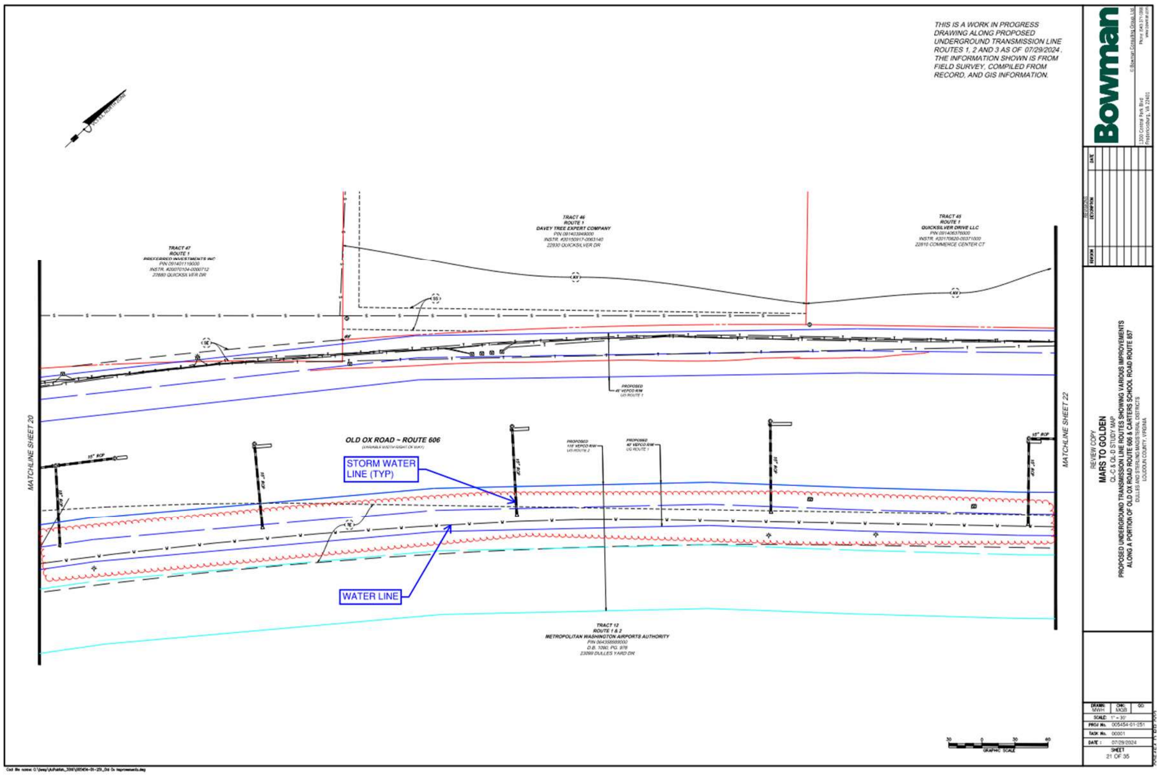


Figure 4-38 Existing Subsurface Utility Density Along Northeast Side of Route 606 (Mercure Circle and Route 606 Intersection). 2 of 4

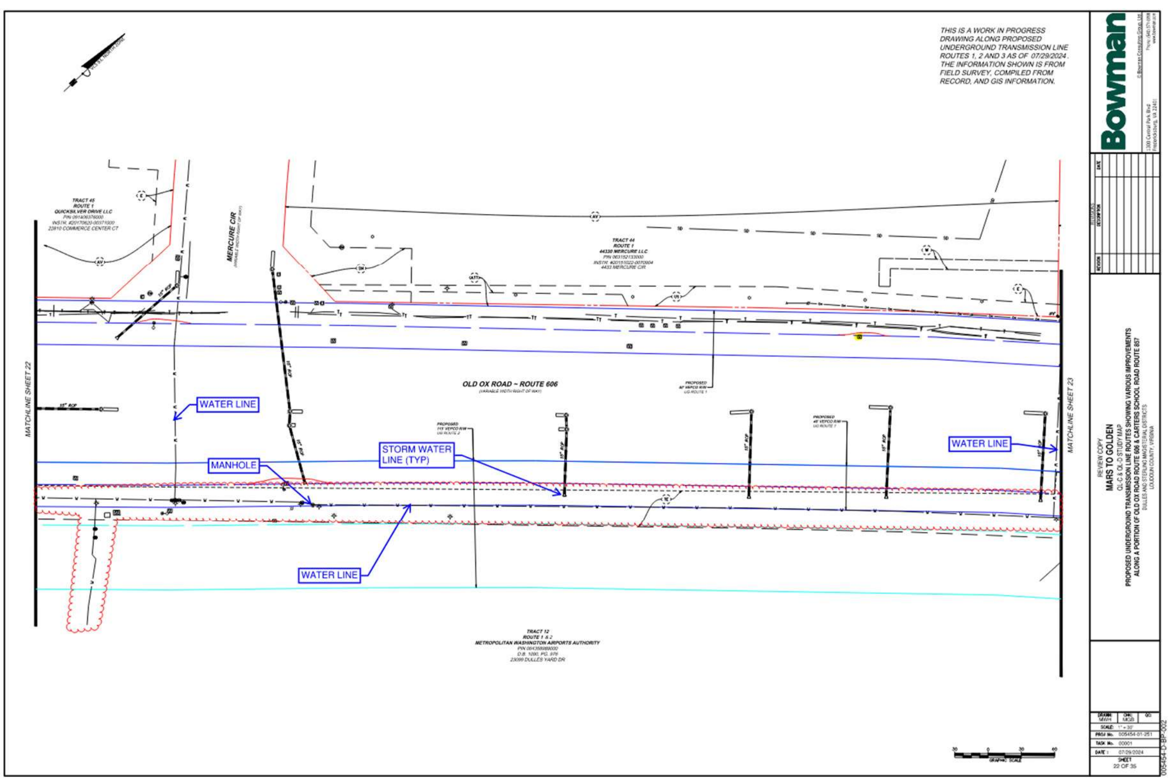


Figure 4-39 Existing Subsurface Utility Density Along Northeast Side of Route 606 (Commerce Center Court and Route 606 Intersection). 3 of 4

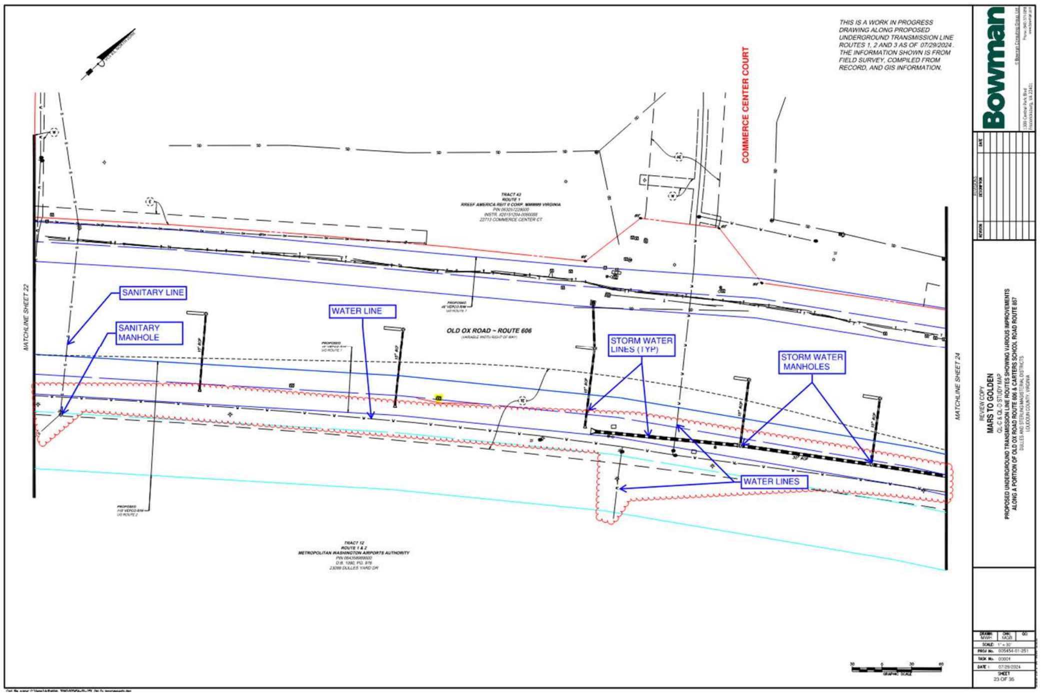


Figure 4-40 Existing Subsurface Utility Density Along Northeast Side of Route 606. 4 of 4

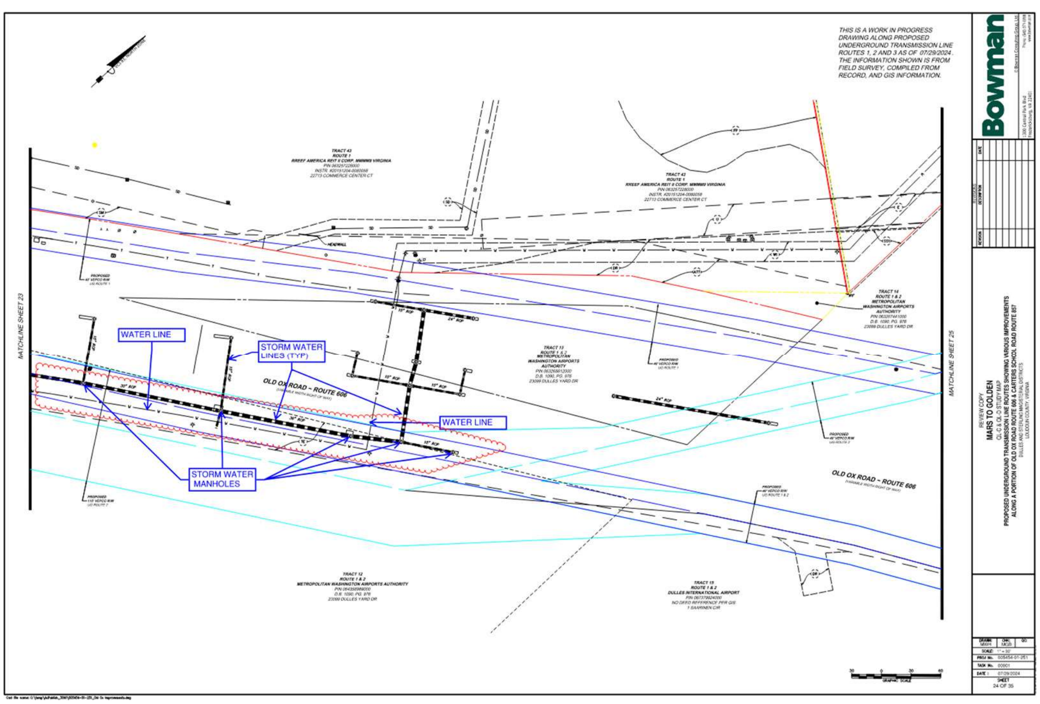


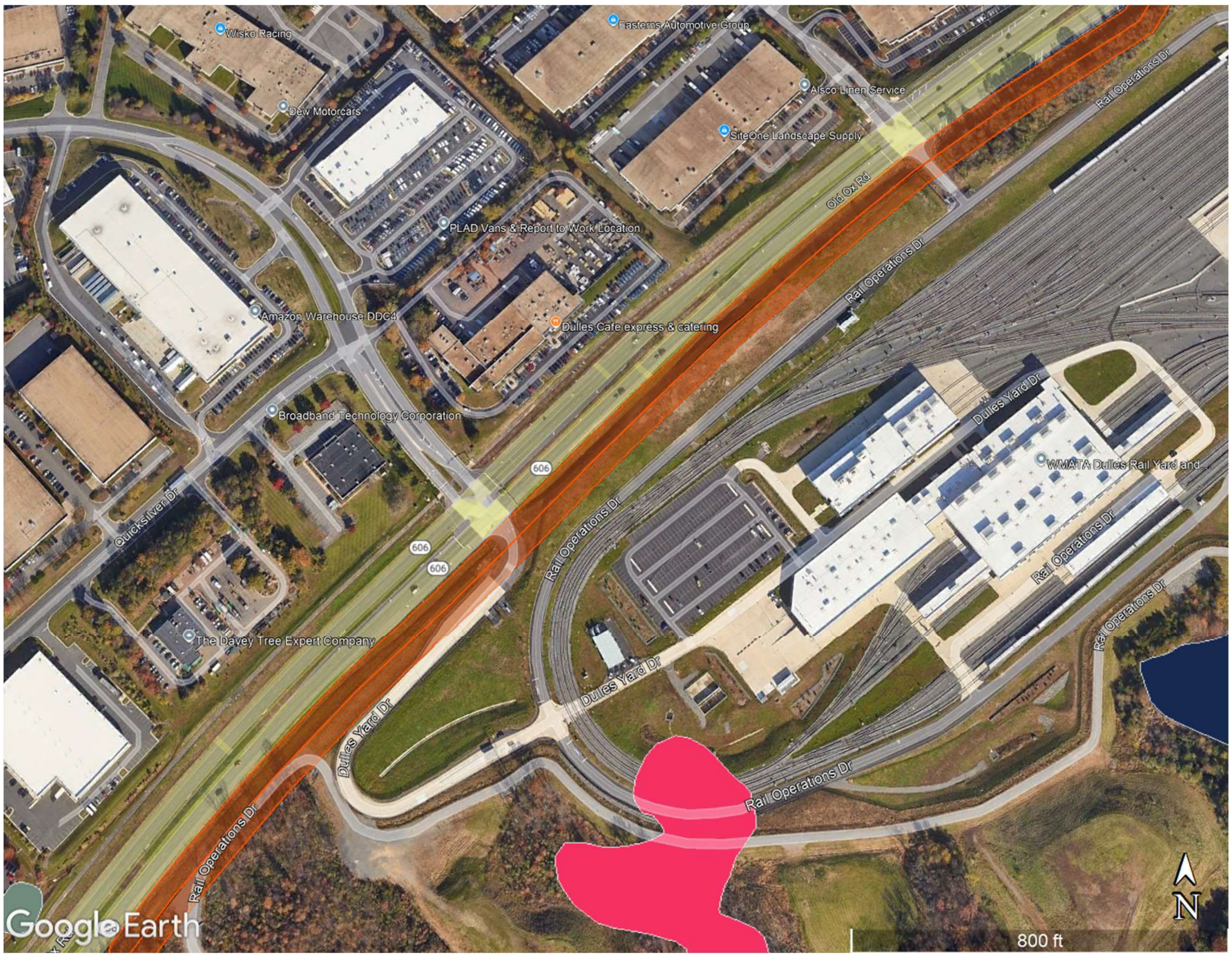
Figure 4-41 WMATA Dulles Rail Yard North Electrical Chain-Link Fence

4.1.9.2 Land Acquisition and Private Property Encroachment

The analysis performed in Section 4.1.8.2 is applicable to the proposed Route R2 segment between Mars Substation and Route 606 intersection. Due to VDOT's restriction of not using open-cut trenching in Route 606 lanes, it is anticipated that 230-kV Circuit and 500-kV Circuit installations on northeast side of Route 606, will require property easement from MWAA for the power corridor running on the north side of WMATA Dulles Rail Yard as shown on Figure 4-42 below. Permanent easement may not be attainable due to being government owned, therefore special permit will likely be required.

ERM stated that, WMATA informed Dominion that while crossing their rail yard facility might be possible in principle, they oppose any crossing of their lease area that would require facility relocations, including the perimeter fence. Given the uncertain timeline for obtaining such agreements, WMATA recommended avoiding any crossing between their rail yard facility and Route 606.

Figure 4-42 Route R2 Segment Inside the Metropolitan Wash Airport Authority Property



4.1.9.3 Road Details

The UG line segment length parallel to Route 606 shown on Figure 4-42 is 3,355 feet long approximately. Although Route 606 has a large corridor width, around 100 feet, and four (4) traffic lanes, VDOT prevents to use any of the lanes for open-cut installation nor to close any traffic lane. Therefore, the UG line duct banks and anticipated splice vaults in this segment will need to be installed entirely in private property allowing all Route 606 lanes to remain open during construction. This route will impact the traffic lights located on the northeast side of Route 606 at intersections with Mercure Circle and Commerce Center Court. The lights will need to be removed during the UG line installation and then replaced with new foundations and structures.

4.1.9.4 Impact to Traffic

As indicated above, the Route 606 is anticipated to remain open during the UG line installation and the ductbank crossings at Mercure Circle and Commerce Center Court requiring temporary removal and replacement of traffic lights shown on Figure 4-43 and Figure 4-44 correspondingly. It should be anticipated that alternating lane closures for the incoming traffic to WMATA Dulles Rail Yard through Mercure Circle and Commerce Center Court will be required for construction of the proposed duct banks. It is important to note that splice vaults should not be located in these intersections.

The impact to traffic analysis performed in Section 4.1.8.4 is applicable as well to R2 segment between Mars Substation and Route 606 intersection.

Figure 4-43 Route 606 (Old Ox Road) and Mercure Circle Intersection

Figure 4-44 Route 606 (Old Ox Road) and Commerce Center Court Intersection

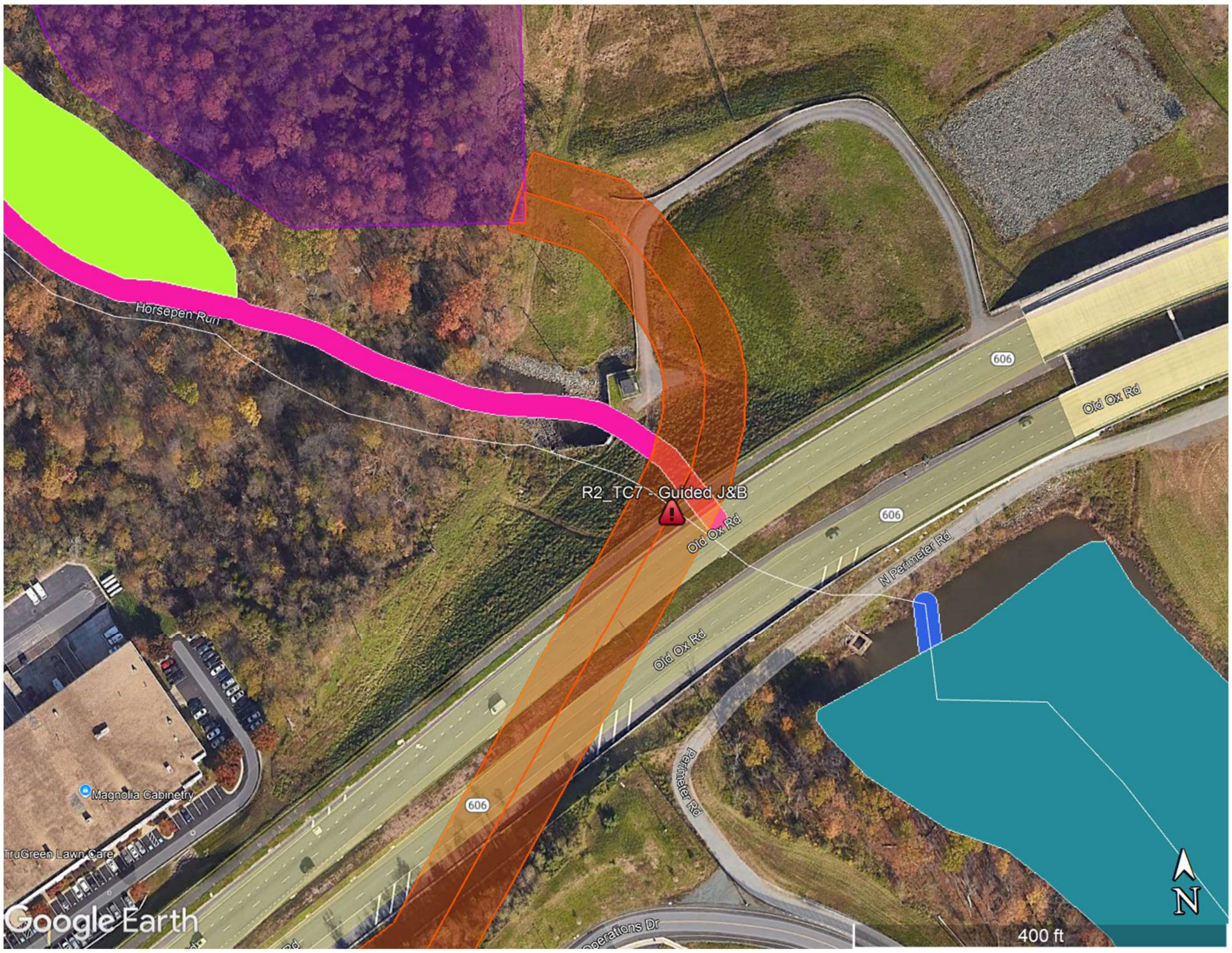
4.1.9.5 Sensitive Areas and Facilities

The UG line crosses Route 606 as it reaches TSA. As shown in Figure 4-45, Route 606 crosses over an existing concrete culvert that is part of Horsepen Dam. Due to VDOT's restrictions, a trenchless crossing is anticipated at this location, as detailed in Appendix E. Careful settlement monitoring shall be implemented during bore drilling processes to reduce the risk of differential settlement affecting the culvert and road. Per ERM analysis, a trenchless crossing of Horsepen Dam would pose significant operational risks and may not receive permitting approval from MWAA and VDCR.

Along the Route 606 northeast side there are existing fire hydrants inside the minimum ROW width required for the duct bank. Fire protection needs to be maintained in the area during construction and coordination with the municipality will need to occur to ensure the public's safety.

The sensitive areas and facilities analysis done in Section 4.1.8.5 is applicable to proposed Route R2 segment between the Mars Substation and Route 606 intersection.

Figure 4-45 Route 606 Existing Concrete Culvert North of WMATA Dulles Rail Yard



4.1.9.6 Constructability

Factors such as depth of bedrock, soil conditions and construction work area are key factors affecting the Constructability of the UG Route trenchless crossings, as well as the Constructability of the open-cut installation where utility density becomes another important consideration for the segment paralleling Route 606. All the UG line uses private ROW, therefore the land availability is a key factor weighing against the Constructability of the proposed Route R2.

On the other hand, VDOT restrictions and the location of the existing WMATA Dulles Rail Yard play a detrimental factor against the robustness of the proposed 230-kV and 500-kV cable systems since maintenance and future expansions will be limited.

UG Route R2 has been reviewed for constructability and feasibility for this project. Throughout this review different challenges have been identified in the previous Sections: UG utility congestion along the Route 606 segment, presence and depth of diabase rock formations, soil conditions, construction work area availability, traffic control along Route 606, trenchless crossings through hard and abrasive rock, encroachments into private property and federal lands, water drainage ditches located close to the proposed alignment, and crossings through streams. Additionally per ERM's review, timing of land acquisition and relocation of facilities on the WMATA Dulles Rail Yard lease area, and the significant permitting and operational risk of crossing of Horsepen Dam. Based on these factors, the UG Route R2 has been determined to not be constructable for this project.

4.1.10 UG Route R3 – Loudoun County Parkway Route

The proposed UG Route R3 starts from the proposed transition station TS5 located southeast of the Route 607 (Loudoun County Parkway) and Winterday Drive intersection, traveling north and then northeast paralleling Route 607 on the roadway's edge always through private lands (multiple owners), until Route 607 and Barrister Street intersection where the proposed UG Route turns southeast towards the proposed transition station TS6.

The 230-kV and 500-kV circuits remain in the same ROW, and parallel Loudoun County Parkway for the majority of the route. Both circuits exit the proposed transition station TS5 paralleling the south side of Route 607 crossing the freshwater pond located north of Greeley Square. The proposed UG line continues north crossing two (2) manmade ponds located west of Madison Heights Terrace until Route 607 and Evergreen Ridge Drive intersection. The proposed route turns east crossing a freshwater pond and a freshwater forested wetland with streams. This group of waterbodies is located northwest of Addlestone Place and Caterham Drive intersection. The proposed UG line continues traveling east and then northeast parallel to Route 607 until the intersection with Gleedsville Manor Drive. In this segment, the alignment crosses two (2) Route 607 culverts. After Gleedsville Manor Drive, the 230-kV and 500-kV circuits turn northwest crossing the west shore of a pond and Route 607 to be collocated on the north side of that road. The UG line keeps traveling east parallel to Route 607 up to the intersection with Centergate Drive, crossing three (3) culverts below Route 607 along the way. Before crossing Centergate Drive, the alignment crosses a freshwater pond, and after Centergate Drive the UG line turns south to pass through Route 607. Then, the proposed UG line keeps traveling south between Barrister Street and The Ashburn Healthplex Emergency parking lot crossing a set of concrete culverts, one of them parallels Barrister Street. The alignment continues south for another 700 feet approximately. Finally, the proposed UG Route turns east towards the proposed transition station TS6 where the UG circuits will be terminated.

The proposed route is approximately 23,990 feet in length for both, 230-kV and 500-kV circuits. The preliminary trenchless crossings identified through this desktop analysis are listed in Table 4-6 below and the feasibility analysis of each crossing is detailed in Appendix E. Some route alternatives and installation options are also outlined in Table 4-7 for crossings where trenchless installations could be avoided, provided that site-specific conditions as well as environmental and permitting constraints allow that. An aerial image of the proposed UG Route 3 is shown in Figure 4-46 below.

Figure 4-46 Golden-Mars UG Route R3 - Loudoun County Parkway Route

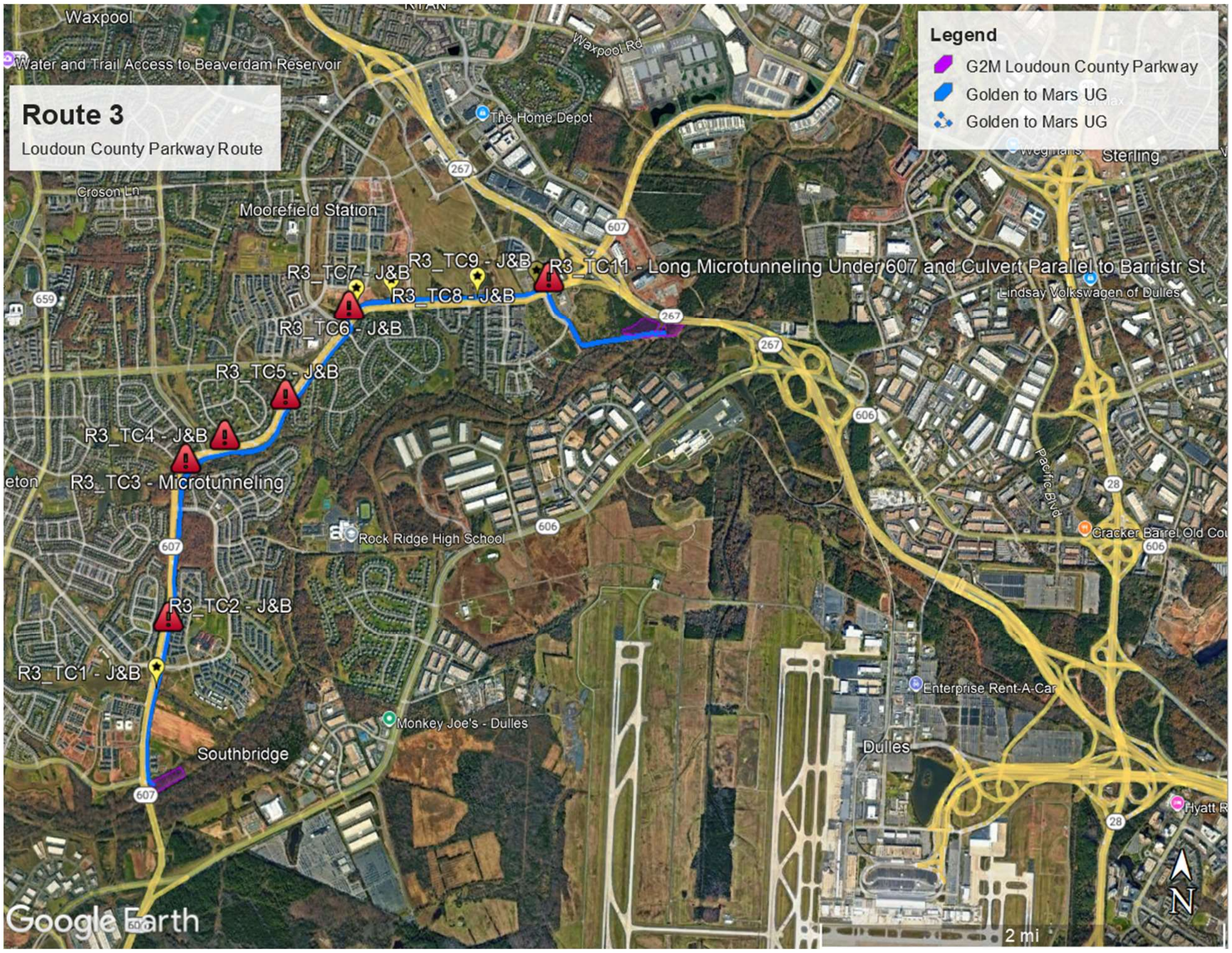


Table 4-6 UG Route R3 - Preliminary Trenchless Crossings List

Trenchless Crossing	Description
R3_TC2	Crossing through existing ponds between Route 607 and Madison Heights Terrace.
R3_TC3	Crossing through existing pond, stream and forested wetland between Route 607 and Addlestone Place.
R3_TC5	Crossing through existing concrete culvert exit on east side of Route 607 and stream between Route 607 and Zulla Chase Place.

Trenchless Crossing	Description
R3_TC6	Crossing through Route 607 and west margin of existing pond. Crossing located north of Route 607 and Gleedsville Manor Drive intersection.
R3_TC10	Crossing through existing pond at northwest side of Centergate Drive and Route 607 intersection.
R3_TC11	Crossing through Route 607 and existing concrete culvert parallel to Barrister Street.

Table 4-7 UG Route R3 - Potential Open-Cut Crossings List

Crossing	Description
R3_TC1	Crossing through existing Lake Birchwood Dock pond and wetland pond east of Route 607. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment can be shifted east to avoid crossing the pond and emergent wetland. Pond and wetland drain to Lake Birchwood Dock
R3_TC4	Crossing through existing Route 607 concrete culvert exit on south side of Route 607, stream and forested wetland between Route 607 and Addlestone Place. Pending site visit, site specific information, permitting and environmental assessment, open-cut installation may be feasible if the route segment can be shifted south to avoid crossing the Route 607 concrete culvert exit, and provided temporary stream water deviation is feasible and allowed

Crossing	Description
	to be used by the agencies with jurisdiction during installation.
R3_TC7	Crossing through the existing stream between Goshen Run Square and north side of Route 607. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.
R3_TC8	Crossing through existing stream draining to Duck Pond Walk and north discharge slope of concrete culvert below Route 607. If upon consultation with VDOT they allow open-cut at this location impacting Route 607 concrete culvert, and if temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible. If VDOT prevents open-cut trenching close to the culvert, then the UG route may need to be shifted north which may impact the pond concrete retention wall.
R3_TC9	Crossing through existing stream draining to pond between Centergate Drive and Route 607, and north discharge slope of concrete culvert below Route 607. If upon consultation with VDOT they allow open-cut at this location impacting Route 607 concrete culvert, and if temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible. If VDOT prevents open-cut trenching close to the culvert,

Crossing	Description
	then the UG route may need to be shifted north which may impact the pond concrete retention wall.

4.1.10.1 Existing Subsurface Utility Density and Location of Major Facilities

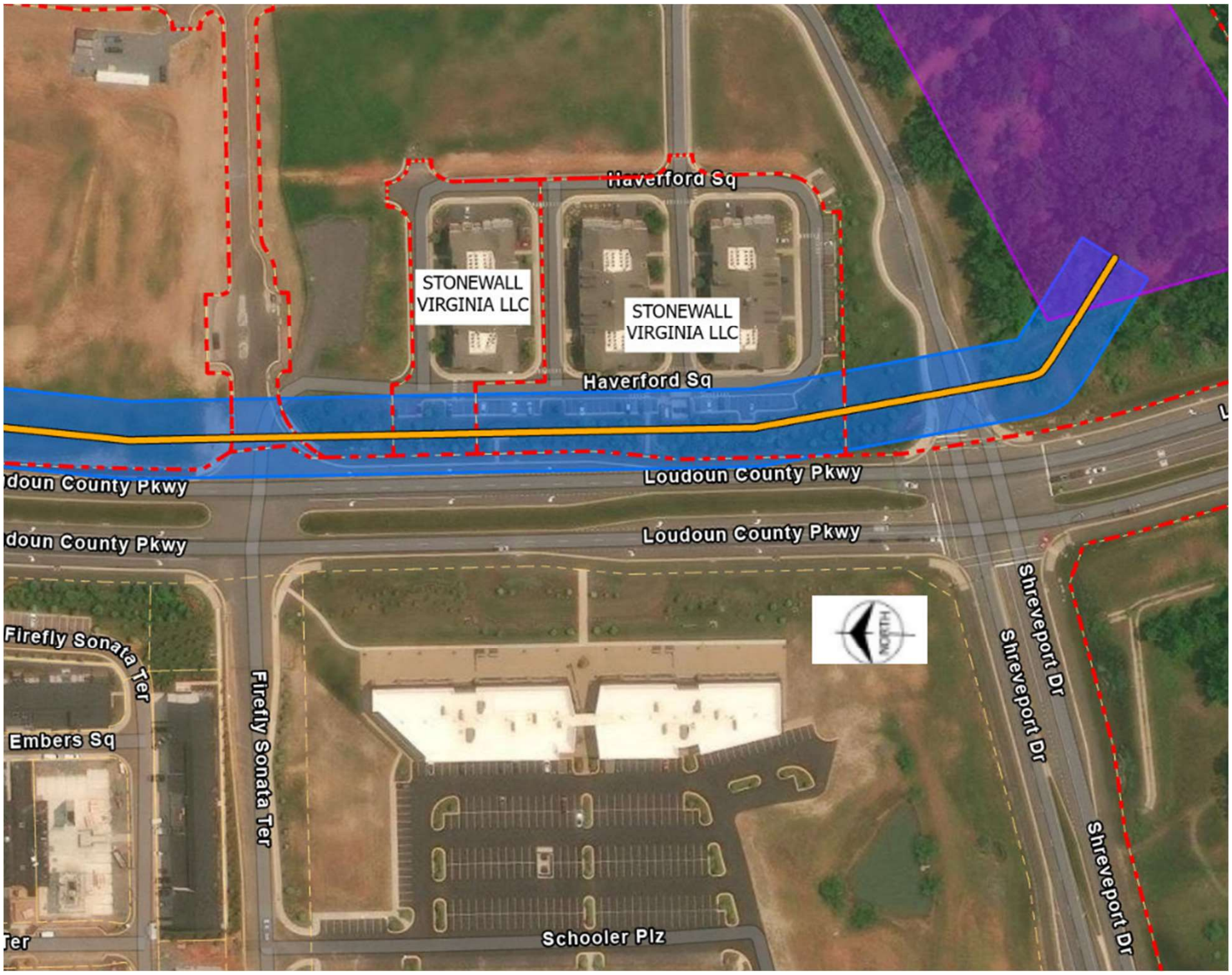
QL-C and QL-D surveys have not been performed for this route to date. However, due to the residential density along both sides of Route 607 roadway, a high existing UG utilities density is expected along Route 607 corridor, especially at intersections with other roads. Depending on the size, nature and depth of cover of these unknown existing UG utilities, relocation of some of them is anticipated and trenchless crossings may be required at some specially congested locations.

Several overhead lines are identified along the UG line, therefore relocation of them is anticipated since it may not be possible to thread with large duct banks through existing overhead line structures and their foundations while maintaining the minimum duct bank separation and the ROW width.

4.1.10.2 Land Acquisition and Private Property Encroachment

The majority of the proposed UG line travels through private lands, therefore permanent easements from landowners are anticipated along the majority of the alignment. However, there is a segment north of Transition station TS5 between Shreveport Drive and Firefly Sonata Terrace encroaching into Route 607 corridor as shown on Figure 4-47. VDOT has restricted the use of Route 607 and will not allow for any of 230-kV Circuit and 500-kV Circuit open-cut installation in the roadway or to close traffic lanes, therefore this route would need to be shifted east completely into private lands requiring permanent easements from the landowner (Stonewall Virginia LLC).

Figure 4-47 UG Line Power Corridor Encroachment Into Route 607 (Loudoun County Parkway) Roadway



South of the intersection between Route 607 and Barrister Street, the UG line installation will require permanent easement from a private owner (Inova Health Care Services) to install 920 feet of duct bank approximately through a facility providing emergency care services to the public, see Figure 4-48. It is anticipated that acquiring these easements may not be possible due to the nature of the facility's services.

Figure 4-48 UG Line Power Corridor Encroachment Into Ashburn Health Plex Emergency Center Lands

Installing the parallel 230-kV and 500-kV UG circuits in the same ROW using proposed Route R3 will have alignment locked in between VDOT's restrictions of using any portion of Route 607 roadway and several private landlords. This will make any future UG cable system expansion more difficult. Overall, this will play a detrimental factor on the UG system robustness.

4.1.10.3 Road Details

The proposed UG 230-kV Circuit and 500-kV Circuit follow Route 607 throughout most of the alignment. Route 607 has an average corridor width between 110 feet and 120 feet approximately with four (4) to seven (7) traffic lanes. The proposed UG line crosses several two (2) and four (4) lane roadways perpendicular to Route 607 and most of these routes are public roadways. Phased open-cut installation could be used through them (unless crossing Route 607) to maintain traffic flow at these intersections. However, this may change upon future DEV's consultations with VDOT.

Most of the proposed UG line crossings with these roads have traffic signs and traffic lights that will require removal and replacement for open-cut installations. It is anticipated that splice vault locations can be set to avoid these intersections, and if necessary, staggered splice vaults can be considered.

4.1.10.4 Impact to Traffic

As described above, the proposed UG Route passes through several Route 607 and other secondary public roads intersections. It is anticipated that traffic flow can be maintained at these crossings while doing open-cut installation of 230-kV Circuit and 500-kV Circuit coexisting on the same ROW since a phased-construction method can be used to maintain at least one traffic lane open all the time. A comprehensive traffic management plan in conjunction with this phased-construction will be required to accommodate the traffic flow in the area during the UG line installation. The traffic management plan will also need to incorporate temporary traffic signals and temporary traffic detours during work at these intersections.

4.1.10.5 Sensitive Areas and Facilities

One (1) school has been identified on the west side of Route 607 and Mooreview Parkway intersection, whose main access is through Mooreview Parkway, see Figure 4-49. The proposed UG line runs parallel to the opposite side of Route 607 and then crosses the road via trenchless installation with entry and receiving pits off the roadway, therefore it is not anticipated that construction works will be impacting the school normal operations.

Along Route 607 fire hydrants are located on both sides of the roadway and some of them fall within the minimum ROW width required for the duct bank. Fire protection needs to be maintained in the area during construction and coordination with the municipality will need to occur to ensure the public’s safety.

In addition, at least eight (8) different freshwater ponds are discovered throughout the alignment as shown on Figure 4-49 through Figure 4-54. The proposed UG line installation plan must minimize detrimental repercussions on these waterbodies, for such purpose some route strategies may be implemented during detailed design:

1. Trenchless installations to cross: the freshwater ponds close to Gleedsville Manor Drive and Route 607 intersection (Figure 4-49), between Route 607 and Madison Heights

Terrace (Figure 4-51), between Route 607 & Addlestone Place (Figure 4-52), and at northwest side of Centergate Drive and Route 607 intersection (Figure 4-53, & Figure 4-54).

2. Shifting the route to avoid the pond located south of Evergreen ridge Drive & Route 607 intersection (Figure 4-50).

Nevertheless, as detailed in the trenchless feasibility analysis (Appendix E) for the crossings listed above in bullet point 1, due the minimum bore center-to-center separation dictated by the ampacity ratings required for each circuit, some of the bores would need to be installed below private residences, yielding these segments not constructible. At the location of these crossings the alignment will need to be rerouted to avoid private residences conflicts.

Figure 4-49 Primrose School at Moorefield Station & Freshwater Pond

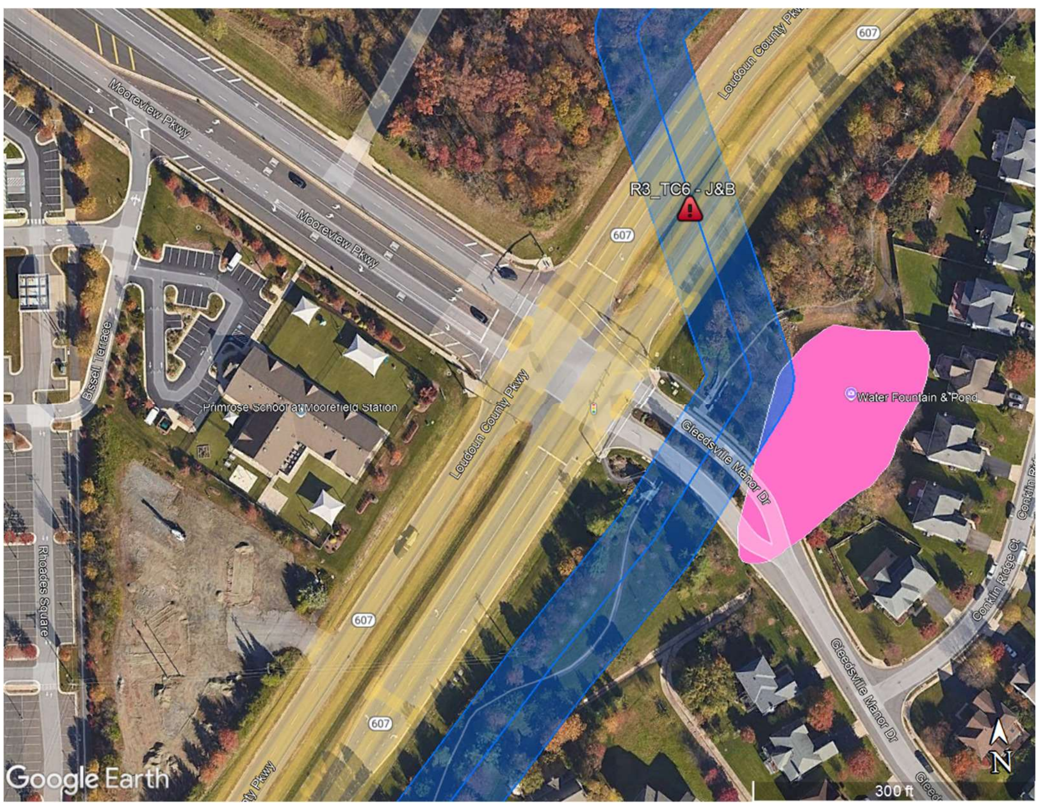


Figure 4-50 Lake Birchwood Dock Pond and Wetland Pond East of Route 607

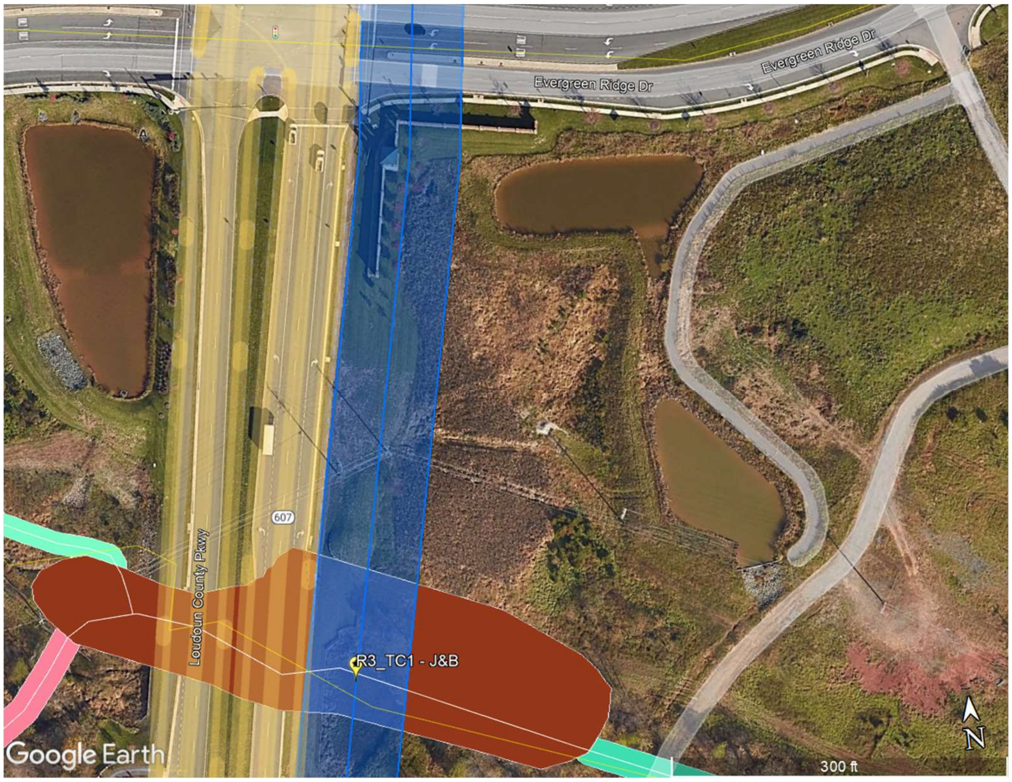


Figure 4-51 Freshwater Ponds Between Route 607 and Madison Heights Terrace

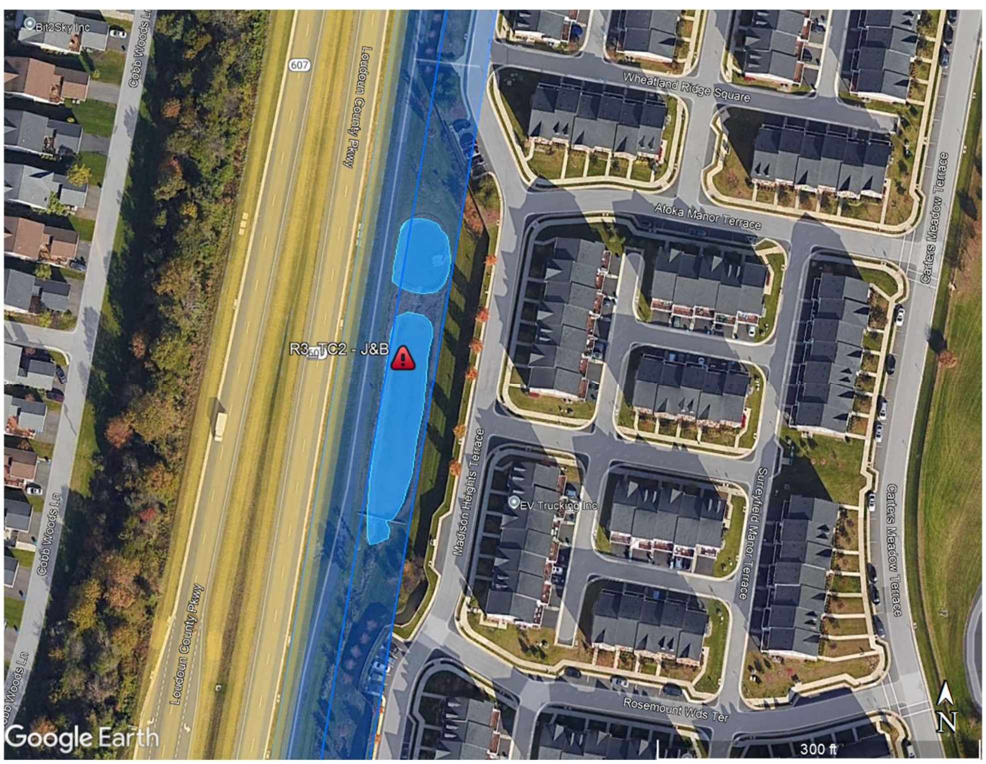


Figure 4-52 Freshwater Pond, Stream and Forested Wetland between Route 607 and Addlestone Place

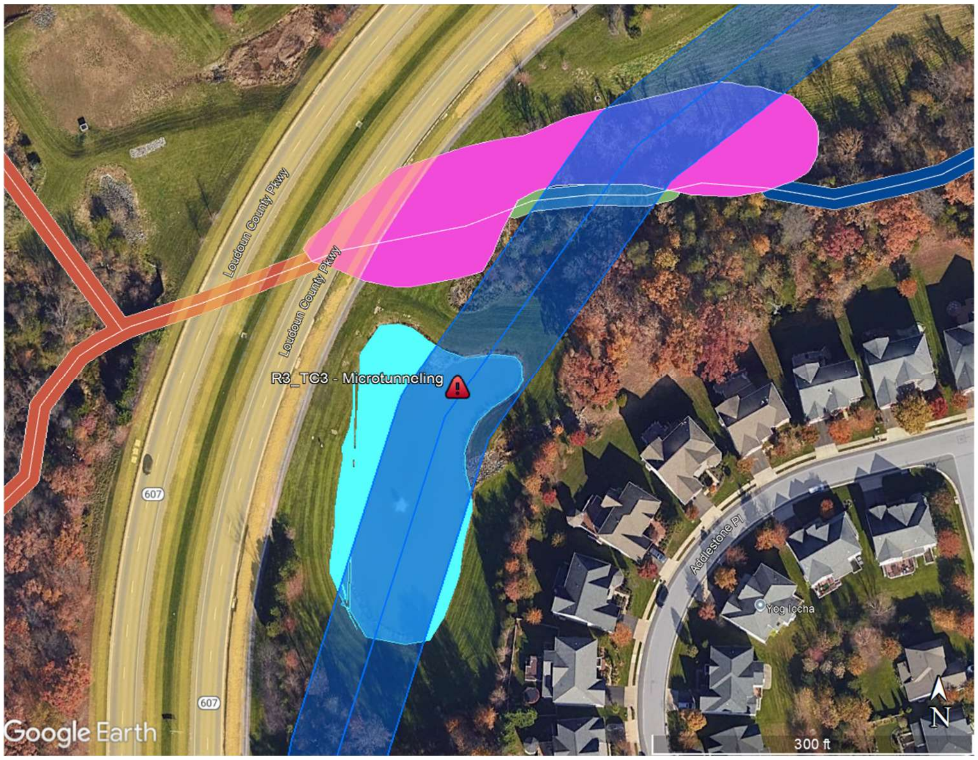


Figure 4-53 Freshwater Pond at Northwest Side of Centergate Drive and Route 607 Intersection – Aerial View

Figure 4-54 Freshwater Pond at Northwest Side of Centergate Drive and Route 607 Intersection – Street View

In the case of the Duck Pond Walk identified on Figure 4-55 and the pond between Centergate Drive and Route 607 identified on Figure 4-56 below, the proposed UG alignment would likely need to be shifted north such as to prevent encroaching into the north section of the existing culverts under Route 607 draining streams to these ponds. However, while this proposed UG alignment shift reduces the need of trenchless crossings, getting the open-cut installation closer to the ponds may affect the concrete retaining walls located on the south shore of these ponds. Figure 4-57 shows a street view of these typical concrete retaining walls.

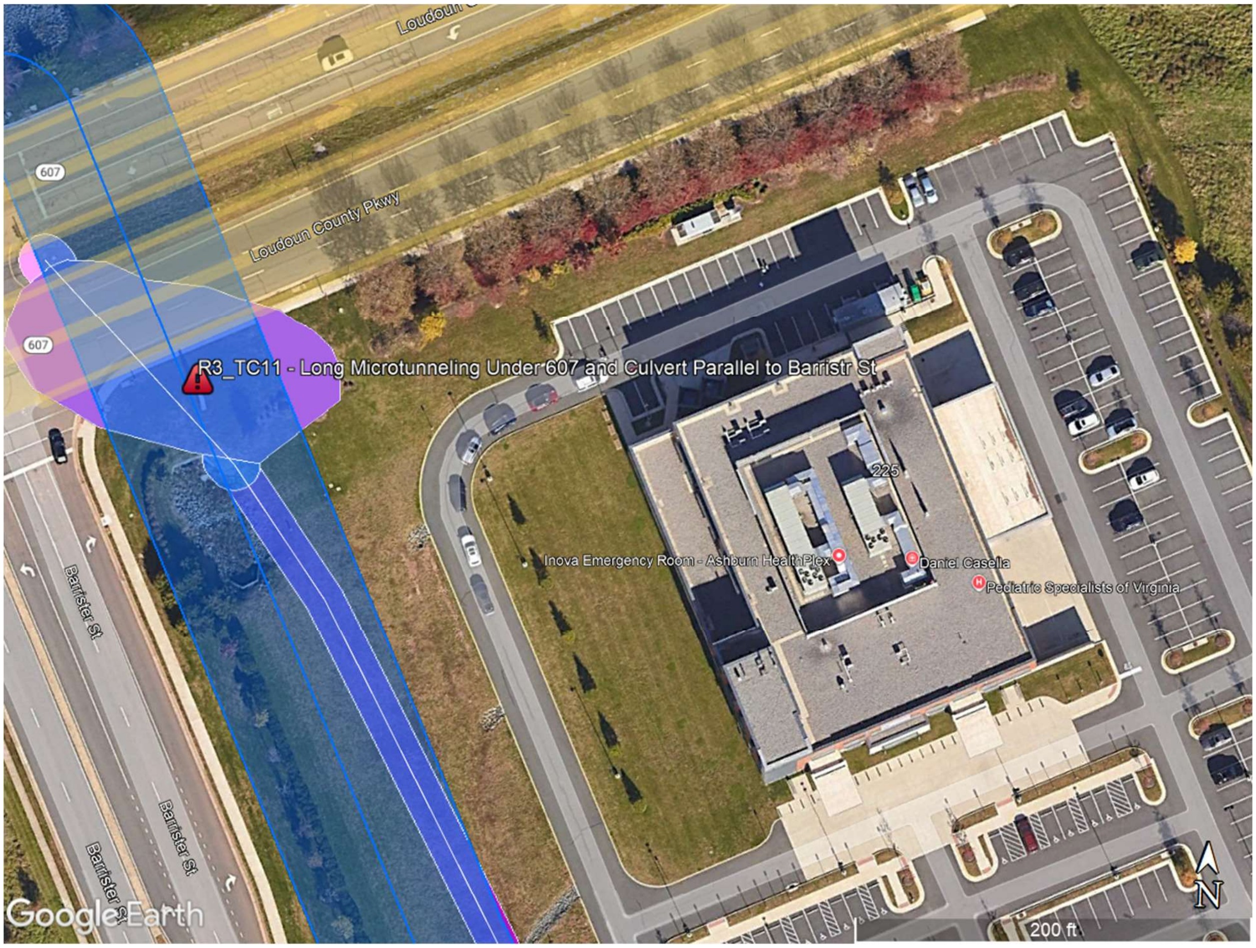
Figure 4-55 Duck Pond Walk

Figure 4-56 Freshwater Pond Between Centergate Drive and Route 607 – Aerial View

Figure 4-57 Freshwater Pond Between Centergate Drive and Route 607 – Street View

In addition to the group of waterbodies described above, a sensitive facility providing health emergency services has been identified on the east side of the UG line, parallel to Barrister Street as indicated on Figure 4-58 below. As the proposed UG Route travels south parallel to this emergency center, it crosses an existing concrete culvert, it is anticipated then that a long trenchless installation would be required to pass underneath the existing culvert and to avoid any impact on Barrister Street and Landmark Court that may affect the traffic flow. These are the only roads providing access to this facility. However, as detailed in the feasibility analysis of Appendix E for trenchless crossing, due to the high ampacity requirements imposed over 230-kV Circuit and 500-kV Circuit, some of the bores would be passing underneath the emergency center. Therefore, this segment is not constructible and will need to be rerouted to avoid this facility altogether.

Figure 4-58 Ashburn Health Plex Emergency Center



4.1.10.6 Constructability

The proposed UG Route R3 faces several challenges as described in previous sections such as: VDOT restrictions to use Route 607 roadway, VDOT restrictions on Route 607 lane closures during installation and maintenance operations, the need to acquire permanent easements from private land owners and sensitive facilities along the UG Route, the need to shift and reroute several segments of the alignment due to open-cut installation requirements as well as trenchless crossing feasibility risks detailed in Appendix E. These challenges for the proposed Route R3 alignment make the risks of the UG system constructability increase, and inhibit any future expansion works over both 230-kV Circuit and 500-kV Circuit.

Although a review of existing utilities was conducted along Route 607, which identified water, sewer, and fiber utilities that both cross and run parallel to the road. This infrastructure would require significant service disruption and relocations for both open-cut and trenchless construction methods assuming that the incumbent utilities and landowners were willing to accommodate a new UG transmission ROW. Based on these factors, the UG Route R3 has been determined to not be constructable for this project.

4.1.11 UG Route R4 – Rock Ridge Route

The proposed UG Route R4 starts from the proposed transition station TS7 located northwest of Route 606 and Overland Drive intersection, traveling northwest paralleling the Broad Run waterway up to the intersection with Loudoun Reserve Drive, there it turns east up to an existing overhead transition line power corridor trough private lands (different owners), diverting then north towards the proposed transition station TS2 using Amazon Data Services Inc. lands. The 230-kV and 500-kV circuits remain in the same ROW, and parallel Broad Run and the existing overhead transmission line ROW for the majority of the route. Both circuits exit the proposed transition station TS7 northwest through the forested area between Broad Run waterway and Meadowvale Glen Court up to the intersection with Loudoun Reserve Drive, which is the access road to Rosa Lee Carter Elementary School and Rock Ridge High School, property of Loudoun County School Board. The proposed UG line diverts east through Loudoun Reserve Drive and then along the south side of the High Scholl's soccer and baseball fields up to the existing overhead transmission line ROW between the High School and Light Speed Plaza. The proposed UG circuits turn north paralleling the east side of the existing overhead transmission line power corridor throughout 1,400 feet approximately of streams carrying water from the Broad Run waterway to Loudoun Valley Estates' freshwater pond system. Finally, the proposed UG Route turns northeast to the proposed transition station TS2 where the UG circuits will be terminated. The proposed UG Route is approximately 8,290 feet in length for both, 230-kV and 500-kV circuits. The preliminary trenchless crossing identified through this desktop analysis is listed in Table 4-8 below and the feasibility analysis of this crossing is detailed in Appendix E. An aerial image of the proposed UG Route R4 is shown in Figure 4-59 below.

Figure 4-59 Golden-Mars UG Route R4 (Alternative Route) – Rock Ridge Route

Table 4-8 UG Route R4 - Preliminary Trenchless Crossings List

Trenchless Crossing	Description
R4_TC1	Crossing through existing stream between Rock Ridge High School football field and Light Speed Plaza. If temporary stream water deviation is feasible and allowed to be used by the agencies with jurisdiction during installation, then open-cut installation may be feasible.

4.1.11.1 Existing Subsurface Utility Density and Location of Major Facilities

Utility survey along the proposed power corridor is not available at the moment to assess the existing UG utilities density, especially along the segment through the private forested lands. However, Loudoun Reserve Drive is the only access road to the Rock Ridge High School complex, and it may be expected to encounter water, sanitary and electrical UG lines amongst others along the road corridor to serve the school. Therefore some relocation may be required to install both circuits in the same ROW and depending on the site specific utility density, shifting the UG line ROW completely south of the roadway may be necessary.

The proposed UG line parallels the east side of an existing overhead transmission line power corridor for 1,400 feet approximately. This overhead transmission line comes from the northwest H-frame of the Substation located southwest of Route 606 and Ladbrook Drive intersection, and from the line support pole configuration it may correspond to a 115-kV or 230-kV overhead transmission line system, see Figure 4-60 through Figure 4-62 below. After exiting the High-School area, the route crosses this existing overhead line corridor when turning north towards the transition station TS2. At that specific crossing, there is an existing heavy-angle overhead transmission line structure as shown on Figure 4-63. It is anticipated then this heavy-angle overhead transmission line structure may need to be relocated due to the size of the UG duct banks. This relocation would imply modifications on the transmission line structures and overhead conductors at ahead and behind spans from that particular heavy-angle transmission structure. Placing splice vaults in this UG line segment would introduce the risk of working with heavy lifts near or below existing overhead high-voltage conductors.

Figure 4-60 Existing Substation and Overhead Transmission Line Corridor

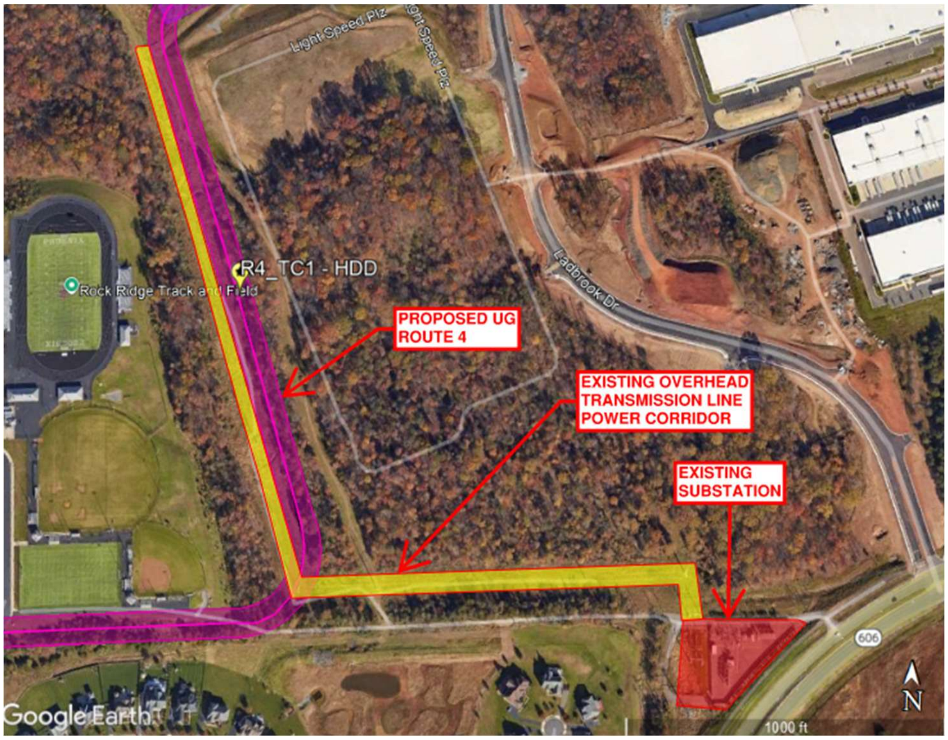


Figure 4-61 Existing Substation and Overhead Transmission Line Exiting the Substation Connection Yard – Aerial View

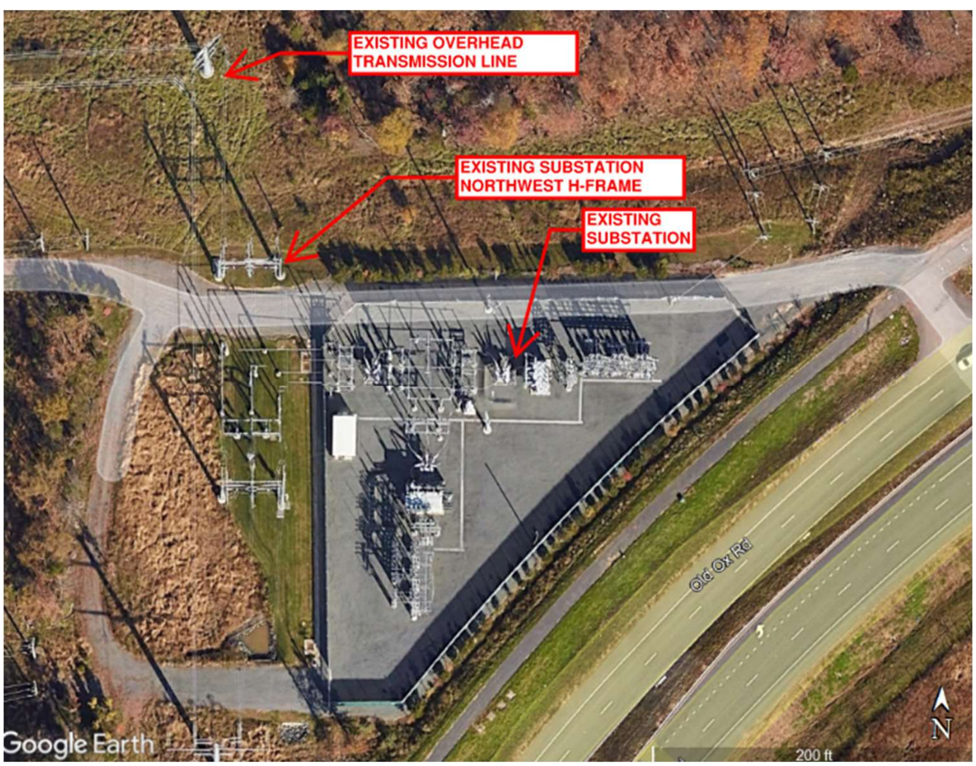
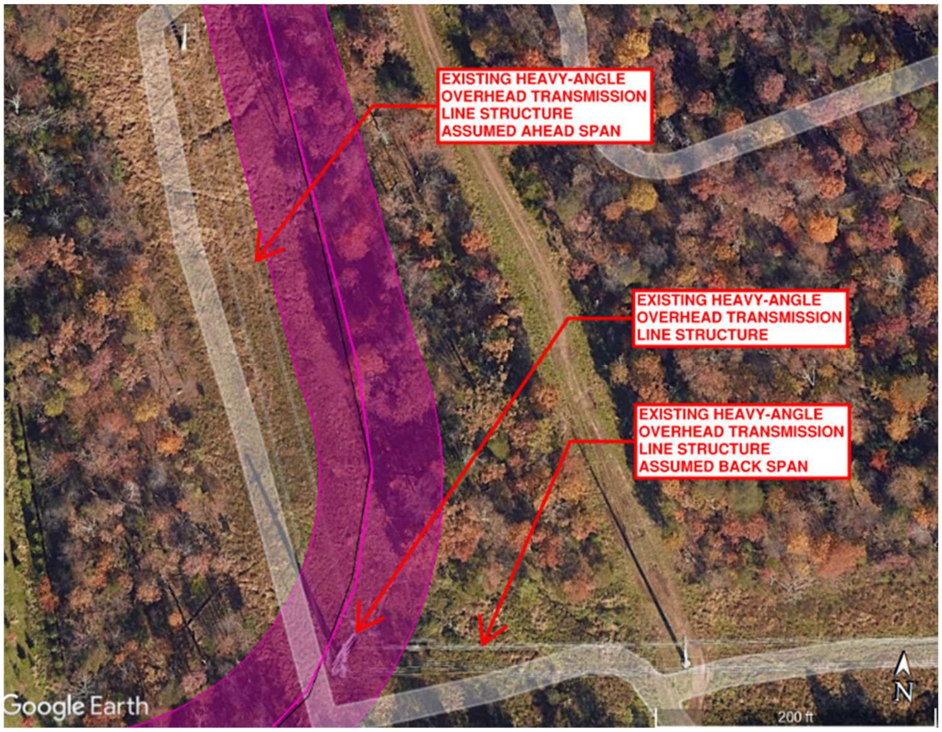


Figure 4-62 Existing Substation and Overhead Transmission Line Exiting the Substation Connection Yard – Street View

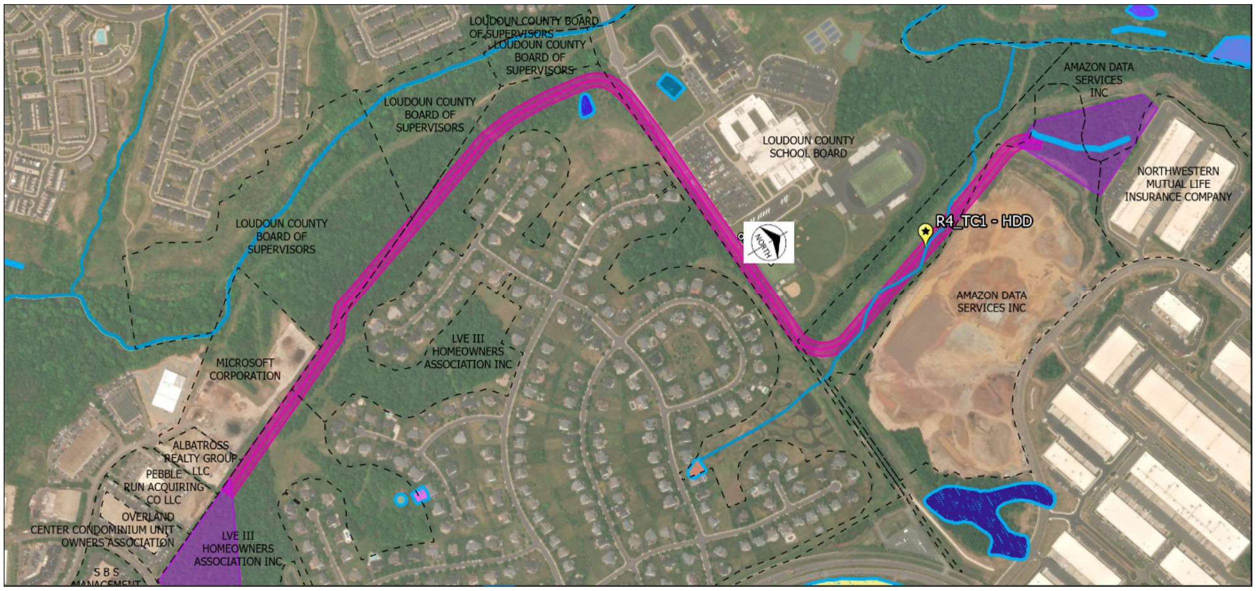
Figure 4-63 UG Route R4 Crossing with Existing Heavy-Angle Overhead Transmission Line Structure



4.1.11.2 Land Acquisition and Private Property Encroachment

Most of the proposed UG Route R4 travels through private forested lands and encroaches onto Loudoun County School Board property when using the same roadway of Loudoun Reserve Drive as shown on Figure 4-64 below. Therefore, the installation of 230-kV and 500-kV UG Circuits coexisting on the same ROW will require permanent leases from different private landowners and the School Board. LCPS property cannot be avoided at this location due to existing homes situated approximately 70 feet from the southern parcel boundary. ERM has stated that LCPS staff has opposed underground construction along Loudoun Reserve Drive because it provides the only access to both school buildings, and significant construction-related road closures would severely impact school operations.

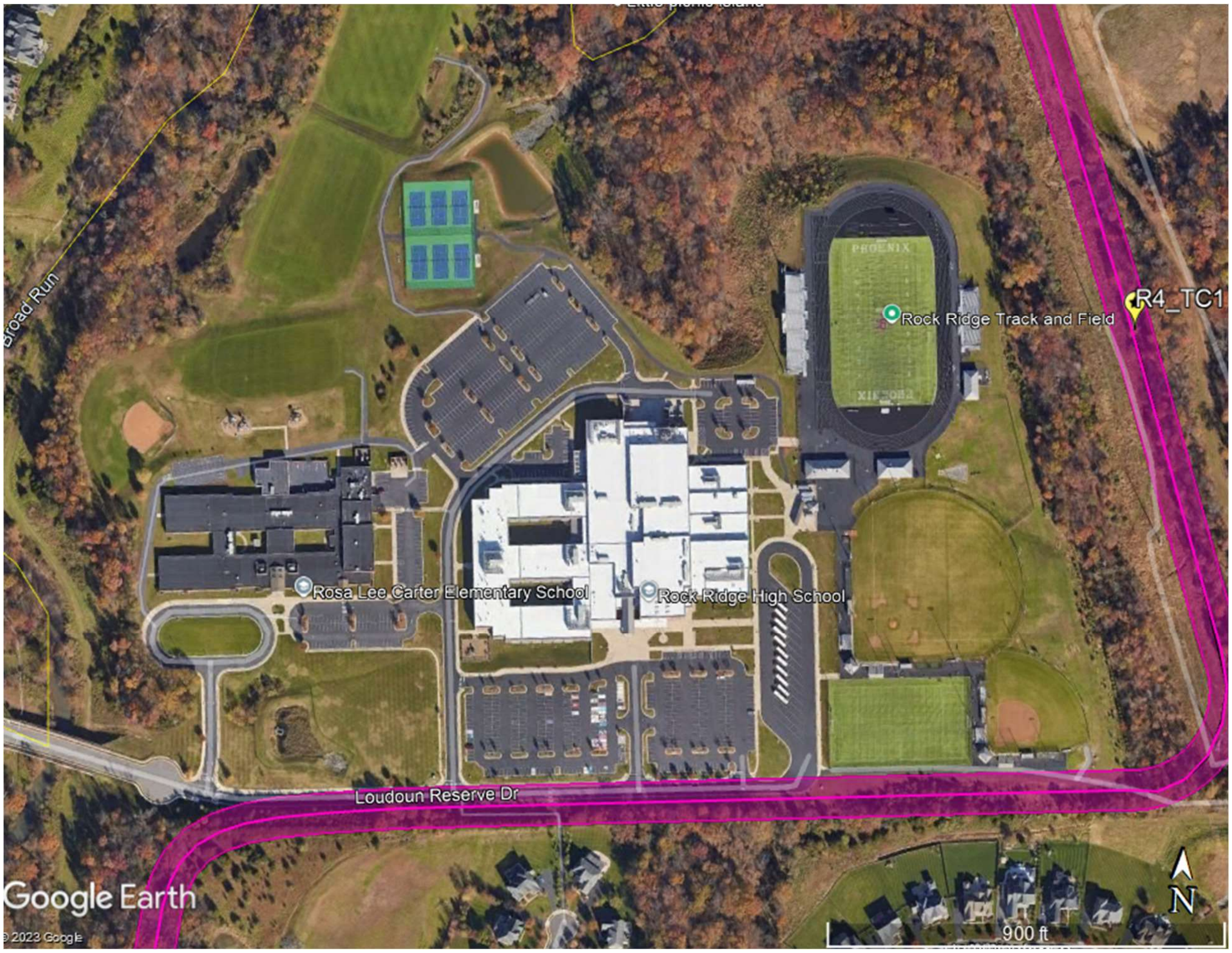
Figure 4-64 UG Route R4 Property Encroachment



4.1.11.3 Road Details

The only roadway this proposed UG line would be impacting is the Loudoun Reserve Drive, Figure 4-65 below. With only two (2) traffic lanes and an average roadway width 26 feet, this road is the only access to and from Rosa Lee Carter Elementary School and Rock Ridge High School. Therefore, both UG circuits will not be able to coexist in the same roadway for this segment.

Figure 4-65 UG Route Segment Trough Rosa Lee Carter Elementary School and Rock Ridge High School Access Road



4.1.11.4 Impact to Traffic

It is anticipated that the impact to traffic will occur when installing the proposed Route R4 segment along Loudoun Reserve Drive. As described above, this road only has two traffic lanes and provides the only access to the school complex located on the north side of the roadway. Therefore, due to the size of the duct banks the route segment will need to be shifted south such that the reminder portion of the UG ROW staying on the roadway allows to maintain a traffic lane open always. In addition, splice vaults cannot be located along this segment due to the size and quantity of vaults needed at each UG line splicing location.

4.1.11.5 Sensitive Areas and Facilities

As described in Sections 4.1.11.1 through 4.1.11.4, one portion of the proposed UG Route will pass through the only access to and from Rosa Lee Carter Elementary School and Rock Ridge High

School. ERM has stated that LCPS staff has stated their opposition to any construction that would significantly impact access to either school. Installing this route segment is likely to impact existing UG utilities serving the school complex and to close one of the two available traffic lanes permanently during construction works. In addition to this school complex, 1,400 feet approximately of streams carrying water from the Broad Run waterway to Loudoun Valley Estates' freshwater pond system are identified along the proposed Route R4 ROW. To cross below this waterbody, a large HDD through shallow diabase is anticipated according to the trenchless crossing assessment from Appendix E.

4.1.11.6 Constructability

The need to acquire permanent easements from private landowners and sensitive facilities owners along the proposed UG line increases the challenges to the constructability of the proposed UG system. Furthermore, the proposed route as it stands would require a reroute of more than half of the segments due to the challenges described in previous sections such as:

- Encroaching entirely over the High-School only access road
- Crossing through high-voltage transmission line corridor
- The need of a large HDD to cross below the stream system drilling through potential shallow diabase as detailed in Appendix E, Section E.6.1.1
- The splice vaults long distances to avoid the School Board lands and the existing overhead line corridor

Based on these factors, the UG Route R4 has been determined to not be constructable for this project.

5.0 TRANSITION STATION

The primary purpose of the transition station is to provide a point where the overhead transmission lines can be converted to underground. This conceptual layout follows DEV standard substation design requirements for the 230-kV, 3,950 Amp rated line and for the 500-kV, 5,000 Amp rated line. The general arrangement for transition stations TS1 and TS2 is shown in Figure 5-1 and Figure 5-2. It is assumed the general arrangement proposed for either TS1 or TS2 may be utilized for TS3, TS4, TS5, and TS6 locations. After this general arrangement was developed, DEV requested to create a new arrangement for transition station TS7 as shown in Figure 5-3. The transition station layouts can also be seen in Appendix D. If an UG Route to TS3, TS4, TS5, TS6 or TS7 is selected, a detailed transition station layout will be developed to accommodate the respective areas. For each transition station location, it is assumed that a minimum of approximately seven (7) acres of land is required to locate all of the 230-kV and 500-kV equipment excluding the area for SWM pond, county required setbacks and buffer.

5.1 General Design Considerations

The equipment layout and overall footprint of the transition stations are intended to provide a balance between flexibility and conservatism. To accommodate the entry of the overhead lines from multiple directions, independent of the yard orientation, the backbones can be shifted lengthwise along the long main bus runs with minimal impact to the overall design. If the backbones were to be rotated 90 degrees, both the parcels would not have enough space to accommodate station equipment considering the limitation of UG cables routing into the station. Utilization of single and double cable per phase termination structures, with dedicated switches for each cable set, allows for faster isolation of a compromised cable and operation of the line at a reduced capacity, should it be required. Two (2) drive gates plus a full turnaround inside the yard provide sufficient space for vehicular access and maintenance activities. Gates can be shifted around the perimeter near any corner with little to no impact to accessibility or cost.

It is assumed that the station will have security design level one fence and integrator package. A power voltage transformer (PVT) is connected to the tubular bus runs of Phase A and C and provides dual, independent sources for station service. The fence will be 20 feet in height with Level 1 Security requirements.

The shunt reactor sizing study and vendor prints were not available during the transition station parcel evaluation. A conservative approach was taken into consideration for the sizing of these equipment. For 230 kV shunt reactors, a previously installed 100MVAR fixed shunt reactor was assumed for a footprint approximation. Three (3) single phase and a spare reactor was assumed for 500 kV shunt reactor. The sizing of these 500 kV reactors was assumed to be approximately 52'x40'each phase per the discussion with Dominion Shunt Reactor Equipment team. It is assumed that the actual reactors may fit into the space allotted for these reactors in this study.

Additional land outside the station fence would likely need to be acquired to meet storm water, permitting buffer, and any additional changes per system protection philosophy. It is assumed for the purposes of this study that the area required is approximately equivalent to the area inside the station fence.

The presence of high-risk flood plains designated by the Federal Emergency Management Agency (FEMA) as well as the system of streams and ponds around Route 267, Route 606, Route 607 and other secondary roads in the general project area are stressors increasing the risks over detailed site-preparation and civil designs for transition stations located in this area. Furthermore, there are different existing overhead lines ramifying from existing substations on Route 606 and existing distribution lines along secondary roads. These existing overhead structures and foundations will become a factor to account for the transition station construction planning and relocation of some of them may be warranted. In addition, a number of existing UG utilities (stormwater lines, sewer lines, water lines, concrete culverts below roads or between ponds, etc.) serving the parcels around Route 267, Route 606, Route 607 and secondary roads are likely to be encountered, therefore relocation of these existing utilities must be factored in the design and construction planning of the transition station.

Figure 5-1: Transition Station 1 Arrangement (Parcel 1)

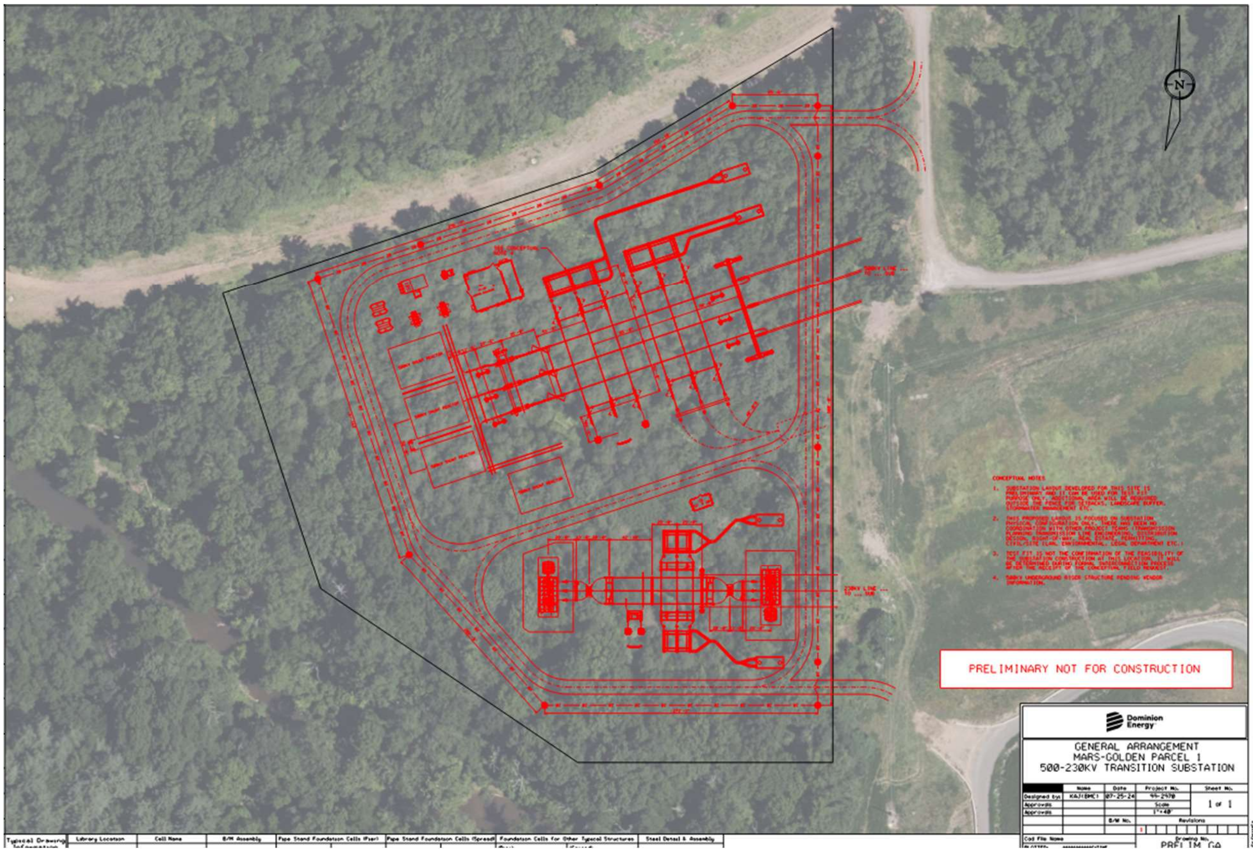


Figure 5-2: Transition Station 2 Arrangement (Parcel 2)

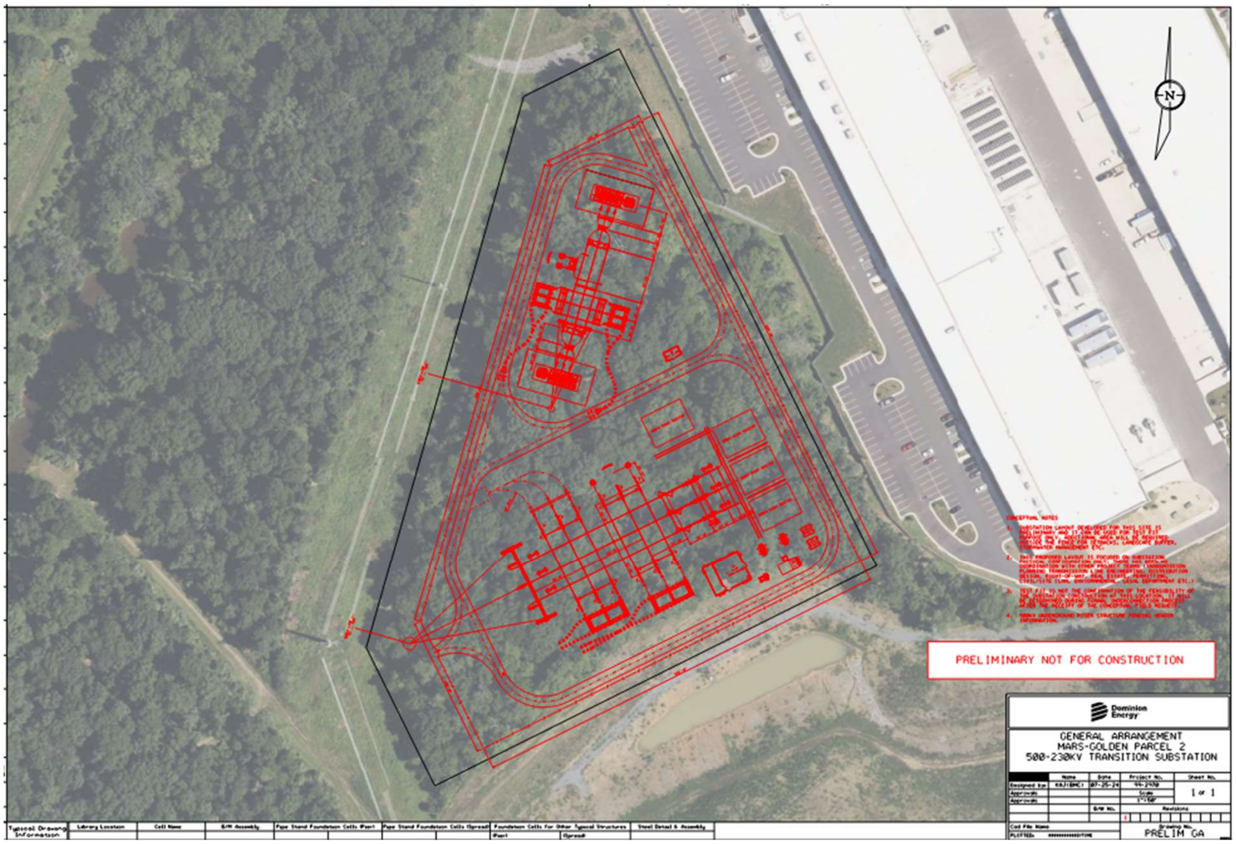
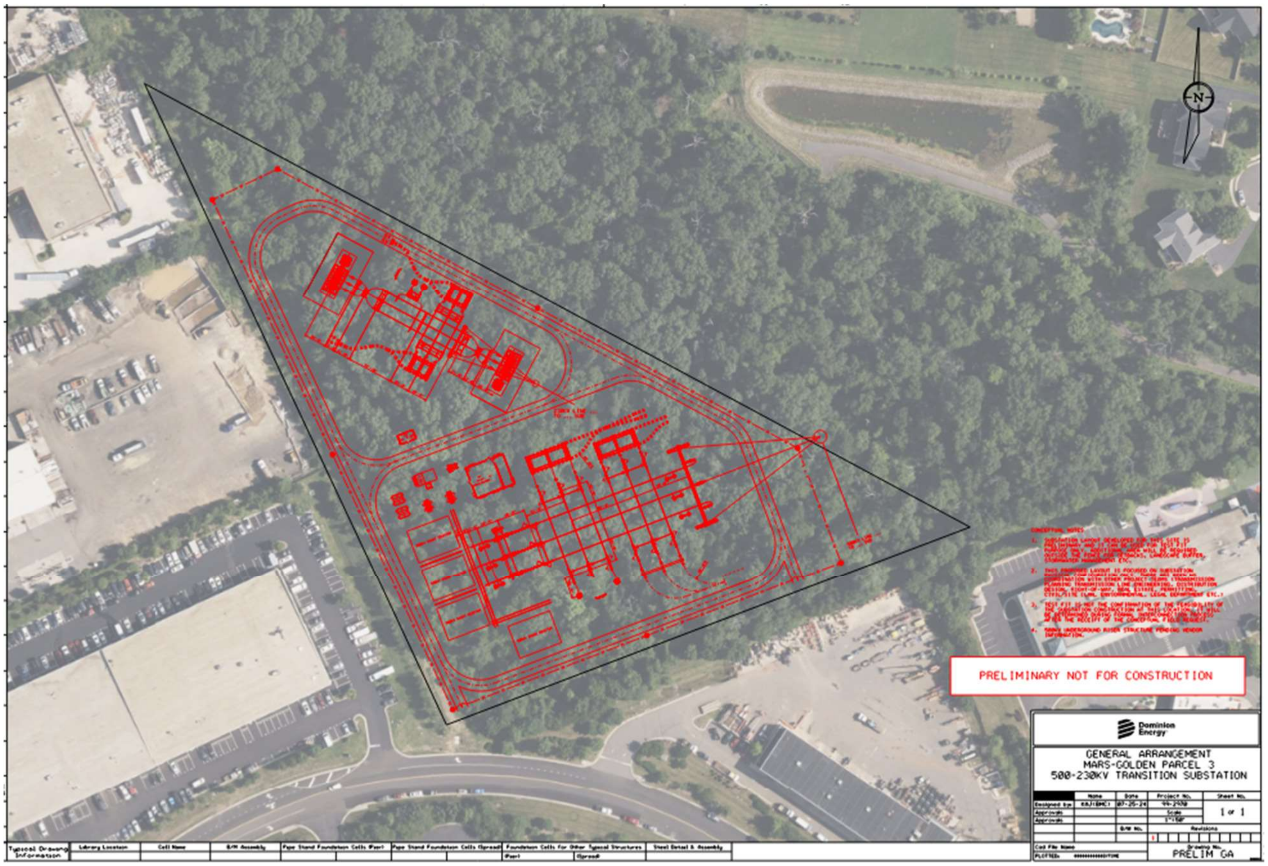


Figure 5-3: Transition Station 7 Arrangement (Parcel 3)



5.2 Proposed Transition Station Locations

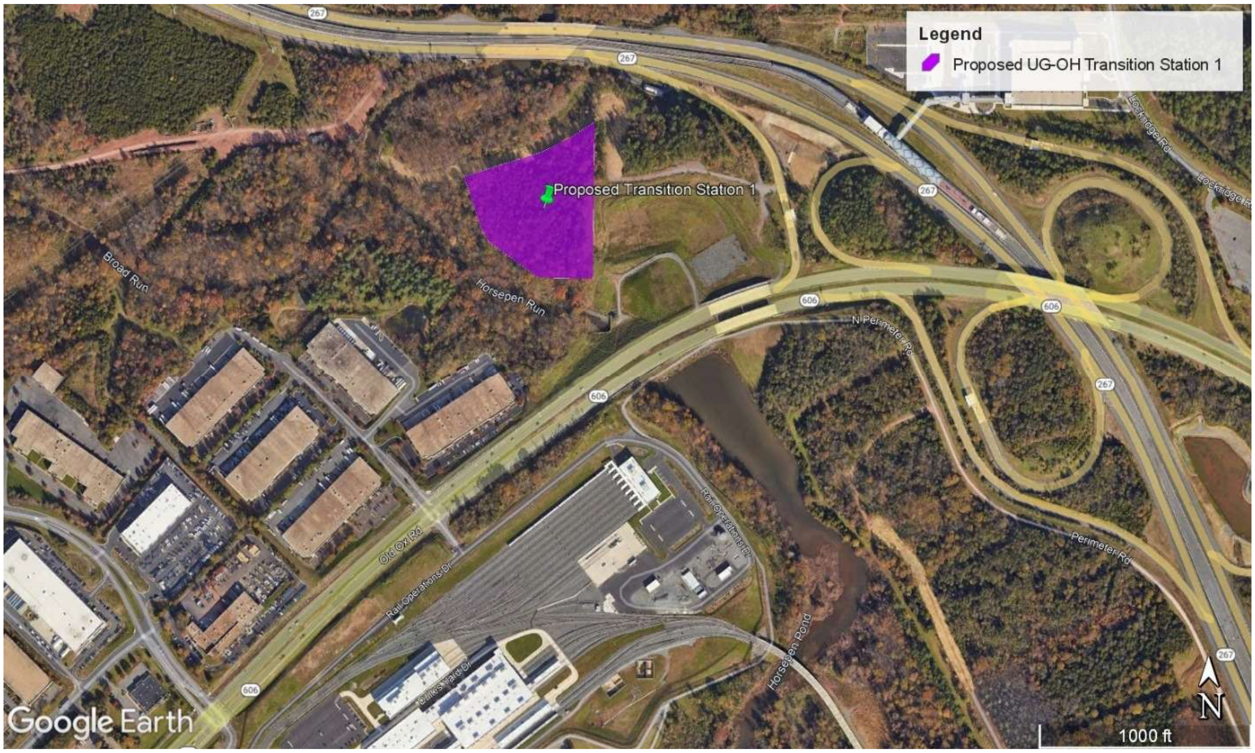
All proposed transition station locations have been provided by DEV for BMcD route evaluations.

5.2.1 Proposed Transition Station 1

Proposed TS1 is located north of Route 606 and west of Route 267 as shown on the route map where the OH line will transition to UG, see Figure 5-4 below. The area for TS1 is approximately 7.0 acres. TS1 is further away in distance from the Mars Substation than TS2 and TS4, and as a result the routes to TS1 are longer than the routes to the other proposed transition station locations.

The TS1 site is located at the Horsepen Run spillway outfall. Due to its position relative to Horsepen Run, Route 606, and MWAA property, any route from TS1 would require crossing Horsepen Run dam. As detailed in Section 4, such a crossing presents significant operational and permitting risks. Additionally, the site's location makes it vulnerable to major flood events, creating further risks for infrastructure critical to grid reliability

Figure 5-4: Proposed Transition Station #1 Location - Amazon



5.2.1.1 Land Acquisition

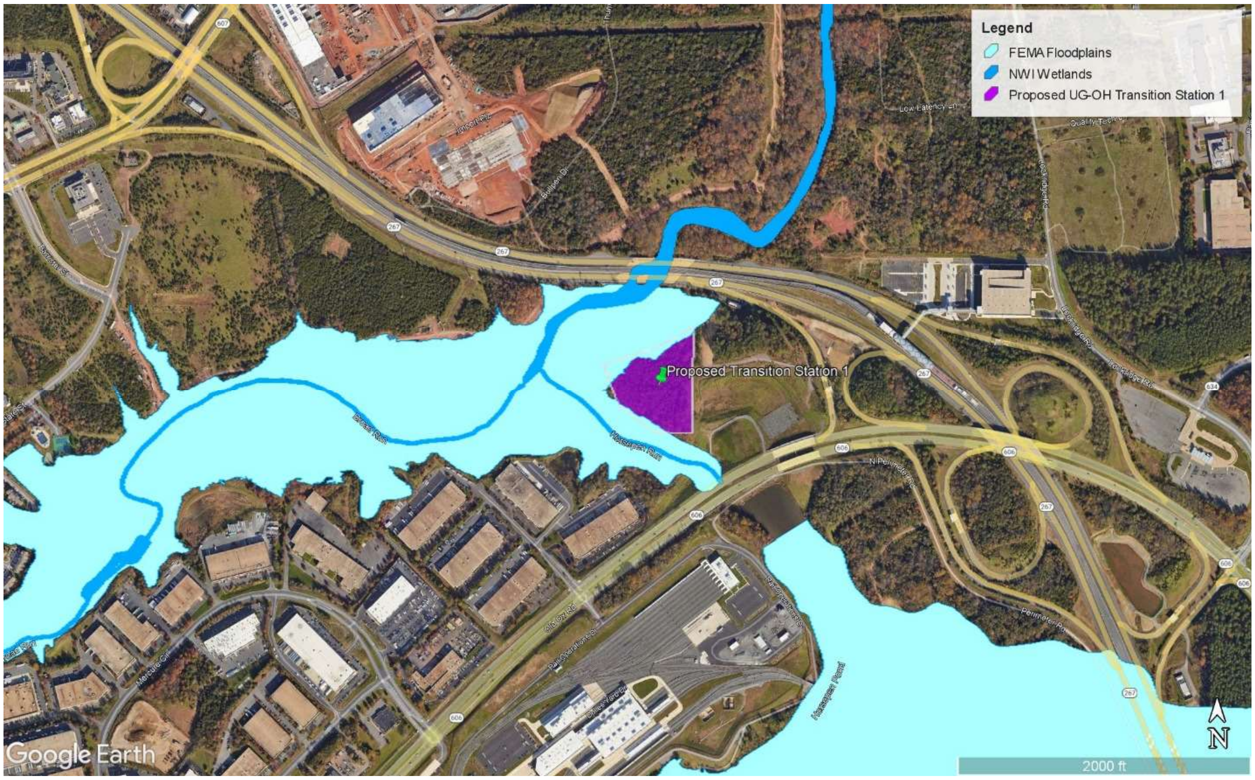
The TS1 site cannot accommodate both a transition station and the planned substation needed to serve the landowner's data center development. DEV and the landowner have been unable to identify suitable alternative sites, as adjacent areas are constrained by floodplains, public lands, and planned development. Consequently, this parcel is not viable for a transition station location.

5.2.1.2 Sensitive Areas and Environmental Impacts

There is sufficient area on the parcel for placement of the new transition station, however a portion of it is occupied by the flood plain areas and the Horsepen Run water body that is on the property. There is a large concrete culvert below Route 606 connecting Horsepen Pond and Horsepen Run located near the southeast corner of this parcel. TS1 sits just barely outside of the flood plain area and there is enough room on the parcel property to adjust the transition station during detailed design to avoid impact accordingly. The rest of the area is primarily covered with heavy foliage and would likely require major clearing efforts during construction. Due to the surrounding foliage, the transition station would have minimal line of sight visibility from the highway. In addition, another substation already exists on Route 606 so the visual impact would not be inconsistent with existing surroundings. The identified water bodies lie on the southwest side of the station location, but the station will likely be able to avoid impacting those areas. Access roads to the Parcel already exist, from Highway 267 on the east, and from Route 606 on the south. See Figure 5-5 below for an image of the site location for TS1. See Figure 5-6 below for the wetlands and flood plains near TS1.

Figure 5-5 Transition Station 1 Location

Figure 5-6: Wetland and Flood Plains near TS1



5.2.2 Proposed Transition Station 2

TS2 is located north of Route 606 and west of Ladbrook Drive as shown in Figure 5-7 below. The area for TS2 is approximately 7.4 acres. This transition station is closer to the Mars Substation site than TS1, therefore the routes are shorter and provide a more direct path to Mars Substation The TS2 site, while currently undeveloped forested land, lies almost entirely within the Broad Run floodplain. This location cannot be permitted due to restrictions on floodplain development.

Figure 5-7: Transition Station 2 Location

5.2.2.1 Land Acquisition

TS2 is also located on a parcel owned by a data center company, Amazon Web Services (AWS). There is sufficient area on the parcel, however, the transition station placement is limited by existing infrastructure and planned future development. AWS is planning to build a new data center on the same parcel that will take up the majority of the south side of property space. This leaves only the northern side of the parcel for TS2. While it may be possible to obtain this land, the only undeveloped land in the area is located within the Broad Run floodplain and would not be permittable based on ERMs experience.

5.2.2.2 Sensitive Areas and Environmental Impacts

The west side of TS2 parcel is parallel to an existing high-voltage overhead line stemming from Shellhorn Substation located east of Highway 267 and Route 607 intersection as shown in Figure 5-8 below. Construction planning may need to consider and synchronize with Shellhorn Substation stakeholders a phased outage of that existing line along with probable relocation of some of the existing transmission poles to build TS2. A large portion of the northern side of the parcel lies within a floodplain. Because of the area needed for the placement of the transition station, TS2 must be built primarily upon the flood plain. There is a shrub wetland passing directly through the transition station area, which may impact construction on the site. The rest of the area is primarily covered with heavy foliage and would likely require major clearing efforts. Due to the surrounding foliage and location, the station would have no line-of-sight visibility from the highway. New access roads will likely be required and will need to be placed in coordination with the planned future development by AWS on the same parcel. See Figure 5-9 below for an image of the site location for TS2. See Figure 5-10 below for the wetlands and flood plains near TS2.

Summarizing, TS2 location is being affected by the main constructability stressors listed below. They increase the risk level over TS2 detailed design and execution.

- Planned future development of a large data center on the same parcel which TS2 will occupy
- Development of the parcel is unlikely to be permitted due to County floodplain regulations
- Wetland at the center of the transition station location driving concerns for permitting and construction
- Existing high-voltage overhead transmission line adjacent to TS2 parcel would require outages and relocations.

Figure 5-8: Existing Overhead Transmission Line Alongside Transition Station 2 Location

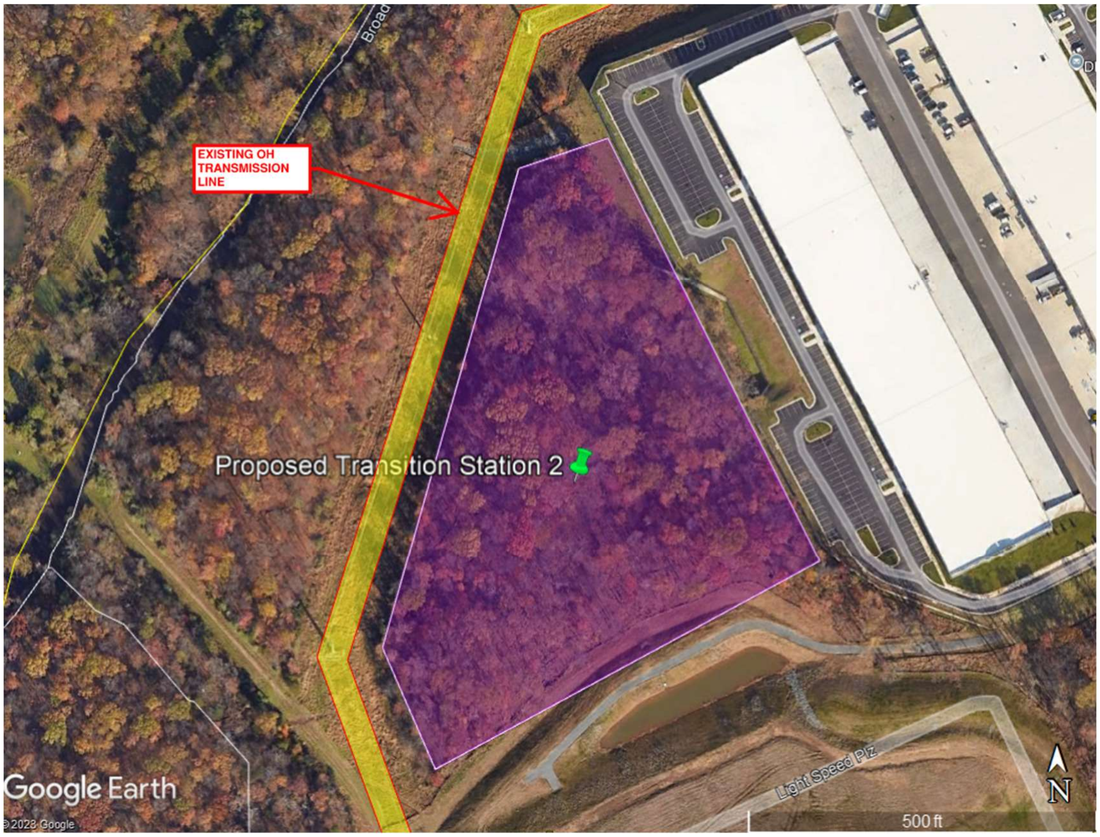
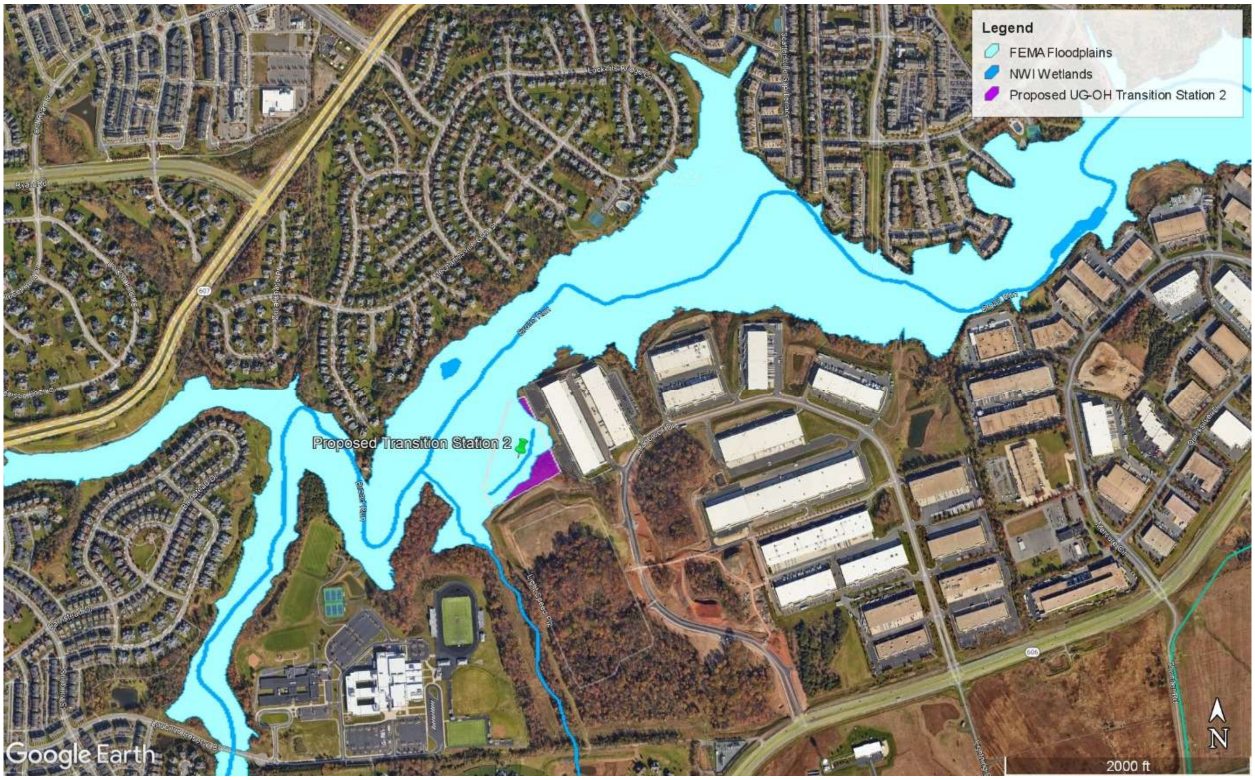


Figure 5-9: Transition Station 2 Location, Facing Northwest

Figure 5-10: Wetlands and Floodplains Near TS2



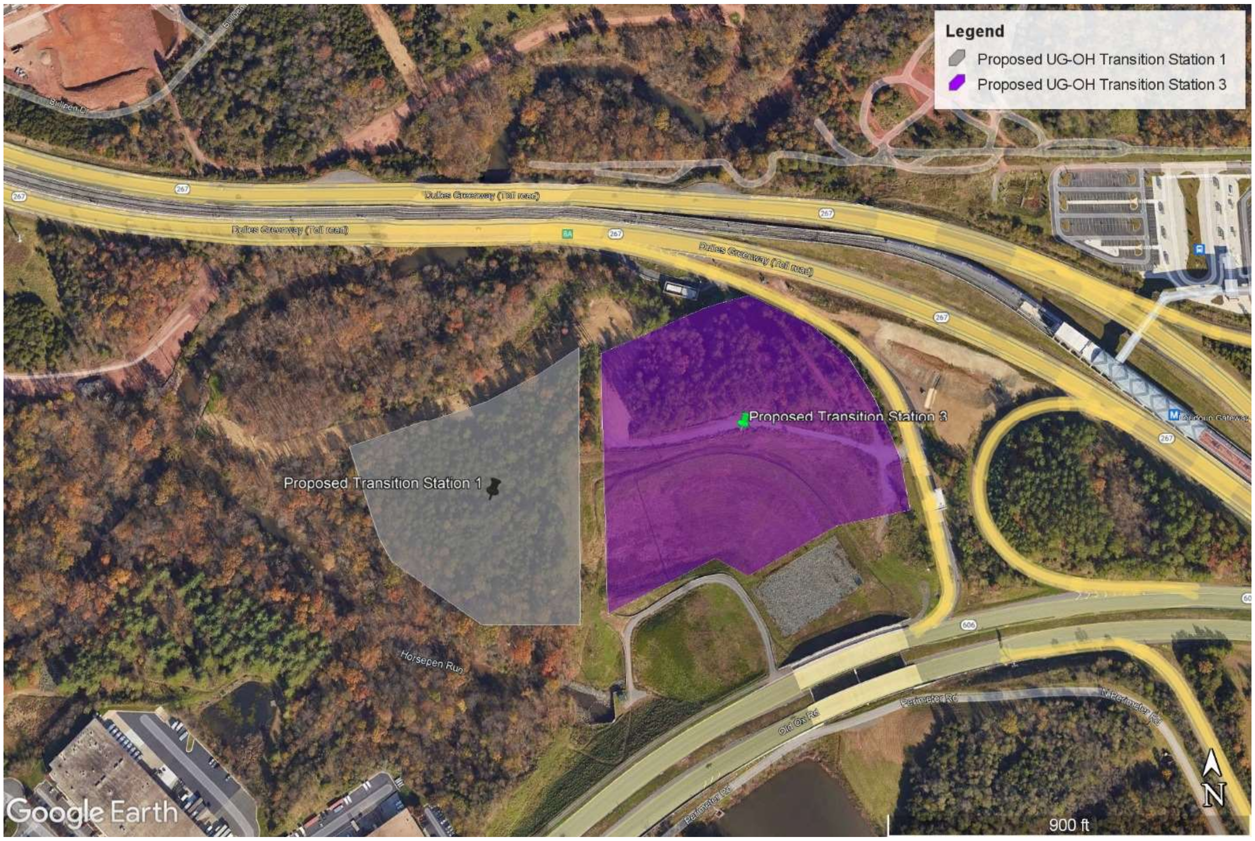
5.2.3 Proposed Transition Station 3

The proposed TS3 is located directly adjacent to TS1 on the east side of the route map. It is considered as an alternate location to TS1 location if the TS1 parcel cannot be acquired. TS3 is to be located north of Route 606 and west of Route 267 as shown on the route map in Figure 5-11 below. TS1 is also pictured as a reference. TS3 is further away in distance from the Mars Substation than TS2 and TS4. Like the routes to TS1, the route to TS3 is longer than the other proposed routes.

TS3 was incorporated into this study after the site visit was performed. Information on the station locations was pulled using Google Earth analysis, the provided survey data, and publicly available information.

TS3 is located entirely on public land owned by MWAA, and the site is bisected by the Horsepen Run dam spillway, which crosses under Route 606. Site grading and installation of transition station equipment would compromise the spillway's essential function. Furthermore, modifying the dam and constructing the transition station would require MWAA approval, introducing significant permitting delays and uncertainties. Additionally, any route from TS3 would need to cross either the dam or spillway, creating substantial construction, operational, and permitting risks.

Figure 5-11 Transition Station 3 Location- MWAA



5.2.3.1 Land Acquisition

TS3 is located on a parcel that is owned by MWAA and the area is approximately 10.7 acres. There is sufficient area on the parcel for placement of the new transition station. Access roads to the Parcel already exist, from Highway 267 on the east, and from Route 606 on the south. However, it is unclear if this parcel can be acquired due to the complex permitting process with MWWA. ERM reported that , although MWAA expressed willingness to coordinate with Dominion on the Project, they were not responsive to specific questions about their permitting process or approval timelines, including NEPA permitting. This uncertainty creates significant risk for both acquiring land rights and obtaining necessary permits within the Project schedule.

5.2.3.2 Sensitive Areas and Environmental Impacts

Around 1,200 feet of existing overhead distribution lines traverse the parcel and will need to be demolished and relocated, if this parcel is used to build TS3. This overhead line demolition includes support structures, foundations and phased outages.

Unlike the other transition station locations, no portion of TS3 area is occupied by the flood plains or water bodies. The rest of the area is occupied by minimal foliage when compared to the other TS1 and TS2. Some clearing efforts would be required during construction. A large portion of the TS3 site lies within the Horsepen Run dam spillway. ERM stated that altering this area would require MWAA permission and would introduce significant operational and permitting risks to the Project.

5.2.4 Proposed Transition Station 4

TS4 is located just northeast of the Ladbrook Drive loop off Route 606, as shown in Figure 5-12 below. TS4 is closer to the Mars Substation site than TS1 and TS3, but farther away than TS2. TS4 was evaluated due to its adjacency to the existing overhead route corridor and its lack of buildings. However, the site contains a large stormwater pond that provides required stormwater management for surrounding development.

TS4 was incorporated into this study after the site visit was performed. Information on the station locations was pulled using Google Earth analysis, the provided survey data, and publicly available information.

Figure 5-12 Transition Station 4 Location - Minalter Inc.

5.2.4.1 Land Acquisition

TS4 is located on a parcel that is owned by Minalter Inc and the area is approximately 11.5 acres, which is estimated to be sufficient for placement of the new transition station. Ladbrook Drive is the only public ROW corridor leading to the TS4 location from Route 606, and as outlined in Section 4.1.7 above, there is minimal spacing on this corridor due to existing sewer and storm lines. Therefore, the routing of both UG circuits into the TS4 location may need additional private easements. There is an alternate path to TS4 on the station location east side that was reviewed. However, most of the path width is within existing natural gas and storm water easements.

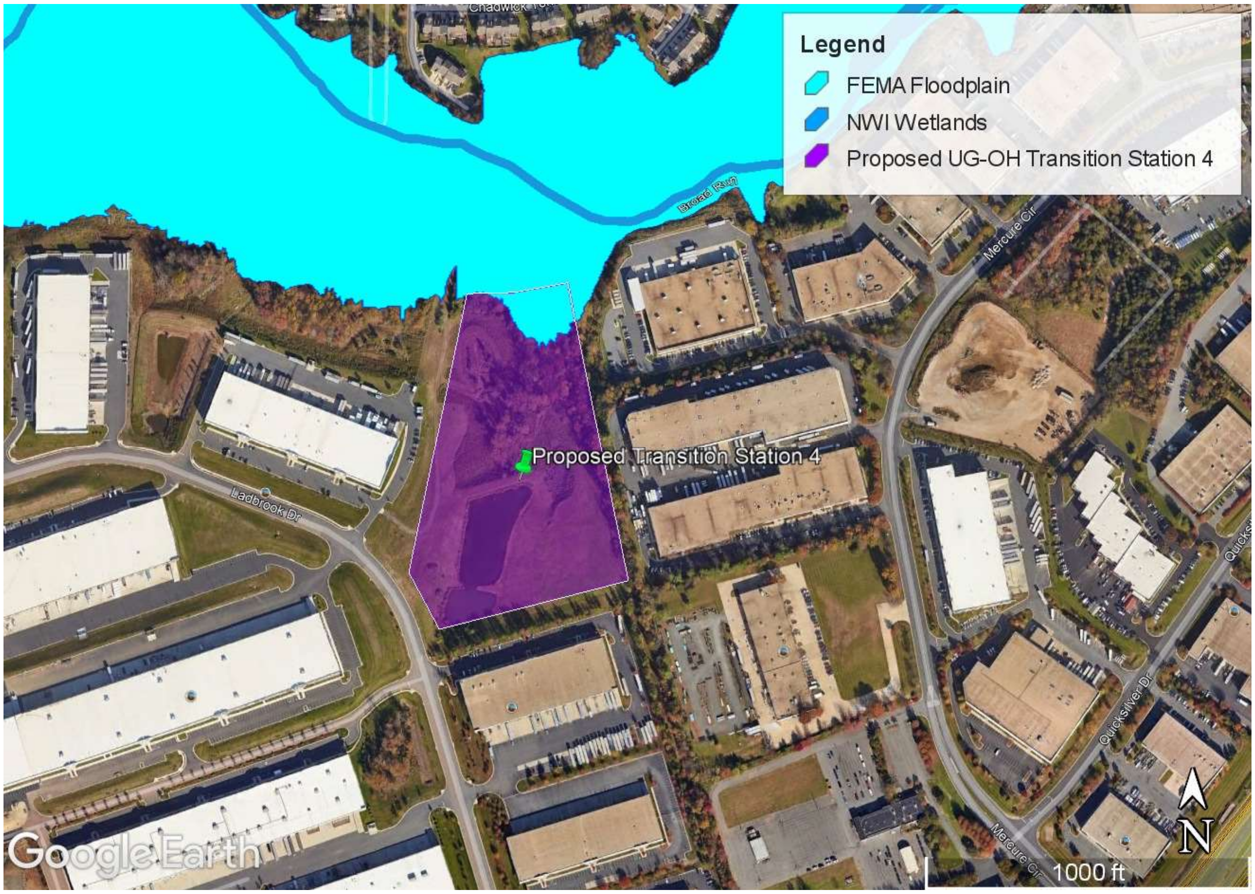
5.2.4.2 Sensitive Areas and Environmental Impacts

A portion of TS4 is occupied by the flood plain areas and there is an existing water retention basin/pond at the site. This retention basin/pond at the site would need to be relocated and resurfaced during construction of the transition station. TS4 sits just barely outside of the flood plain area and there is enough room on the parcel property to adjust the transition station during detailed design to avoid impact accordingly. The rest of the area is occupied by minimal foliage when compared to TS1 and TS2. Some clearing efforts would be required during construction. Since the TS4 site is off Ladbrook Drive, the transition station would have minimal line of sight visibility from Route 606 highway. In addition, another substation already exists on Route 606 so the visual impact would not be inconsistent with existing surroundings. The only existing access road to the parcel is on Ladbrook Drive to the west. An additional access road may be required if a route to TS4 is selected for detailed design. See Figure 5-13 below for the wetlands and flood plains near TS4.

Summarizing, TS4 location is being affected by the main constructability stressors listed below. They increase the risk level over TS4 detailed design and execution.

- Existing storm water retention basin/pond at the transition station location would introduce additional time for permitting as well as during construction for relocating the retention basin/pond, if it is even possible to relocate the stormwater pond to meet the needs of the adjacent developed areas and TS4 entirely within the site.
- The biggest challenge with TS4 is routing both circuits into the TS4 location. The Ladbrook Drive corridor may only be considered for the single circuit duct bank configuration.
- Landbrook Drive is congested with UG structures (reinforced concrete pipes (RCPs), an overhead pole foundation, utility vaults, a storm structure, a utility pedestal, and light poles) near the entrance of alternate path where the proposed UG Route would need to cross Route 606.

Figure 5-13 Wetlands and Flood Plains Near TS4

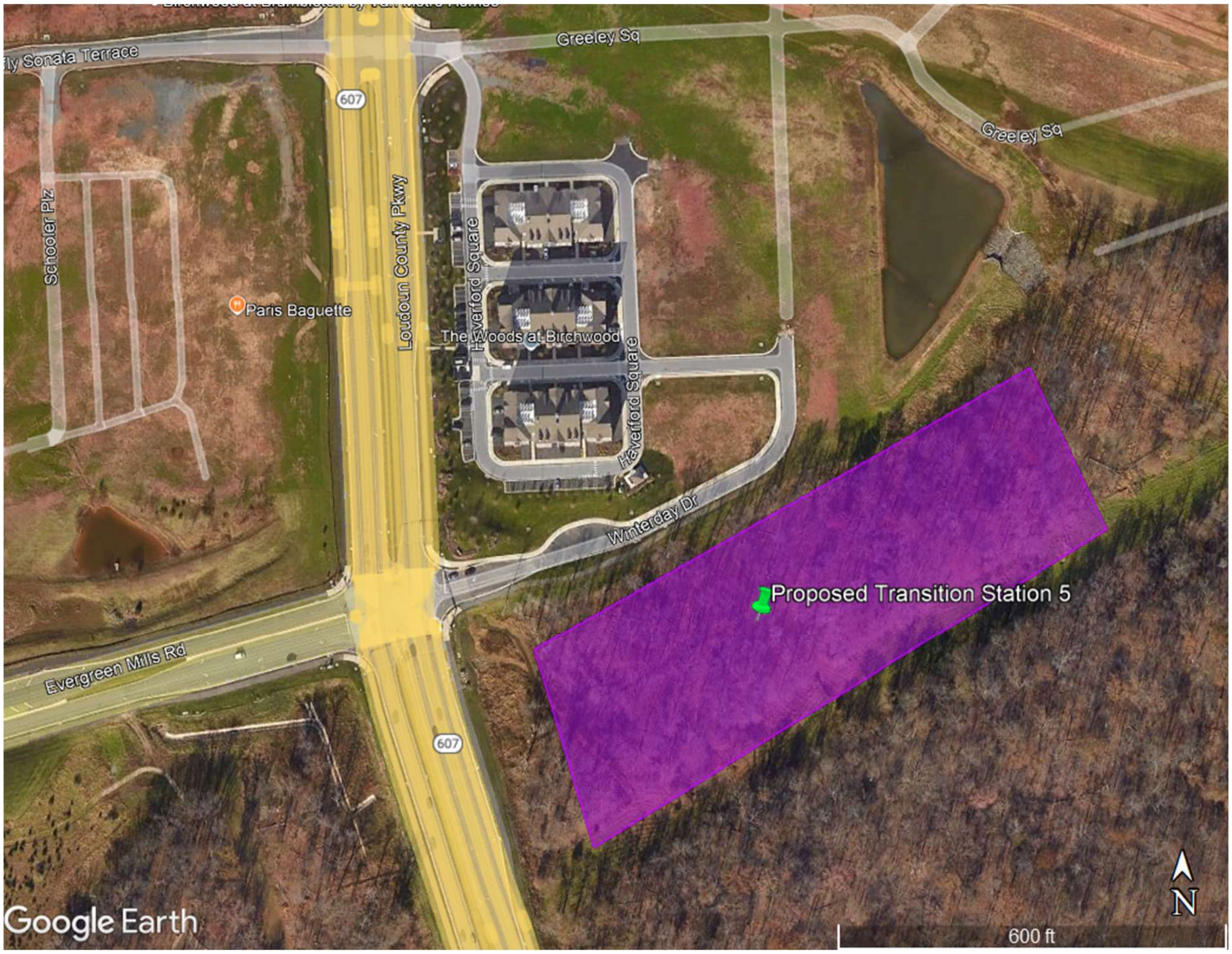


5.2.5 Proposed Transition Station 5

TS5 is located southeast off Evergreen Mills Road and Route 607 intersection, as shown in Figure 5-14 below. TS5 was developed for DEV by ERM as an intermediate location to have both, 230-kV and 500-kV circuits, in OH installation instead of UG installation from the Mars Substation up to where TS5 is. At TS5, both OH circuits will transition to UG installation following the Route R3 described above in Section 4.1.3 up to transition station TS6. Although TS5 is closer to the Mars Substation than TS2, any routing option considering TS5 will involve an OH segment with two (2) circuits carrying large loads. TS5's location was selected because it lies south of residential areas and could connect to TS6 without requiring a trenchless crossing of Broad Run, enabling use of Loudoun County Parkway as an underground route.

TS5 was incorporated into this study after the site visit was performed. Information on the station locations was pulled using Google Earth analysis, and publicly available information.

Figure 5-14: Transition Station 5 Location (Crestnet 2 LLC)



5.2.5.1 Land Acquisition

TS5 parcel is owned by Crestnet 2 LLC and the area is 6 acres which may not be sufficient for placement of the new transition station. Access roads to the Parcel would need to be developed stemming from Route 607 on the west, or Winterday Drive on the north. Available space is further constrained by a large sewer main south and the Broad Run floodplain.

5.2.5.2 Sensitive Areas and Environmental Impacts

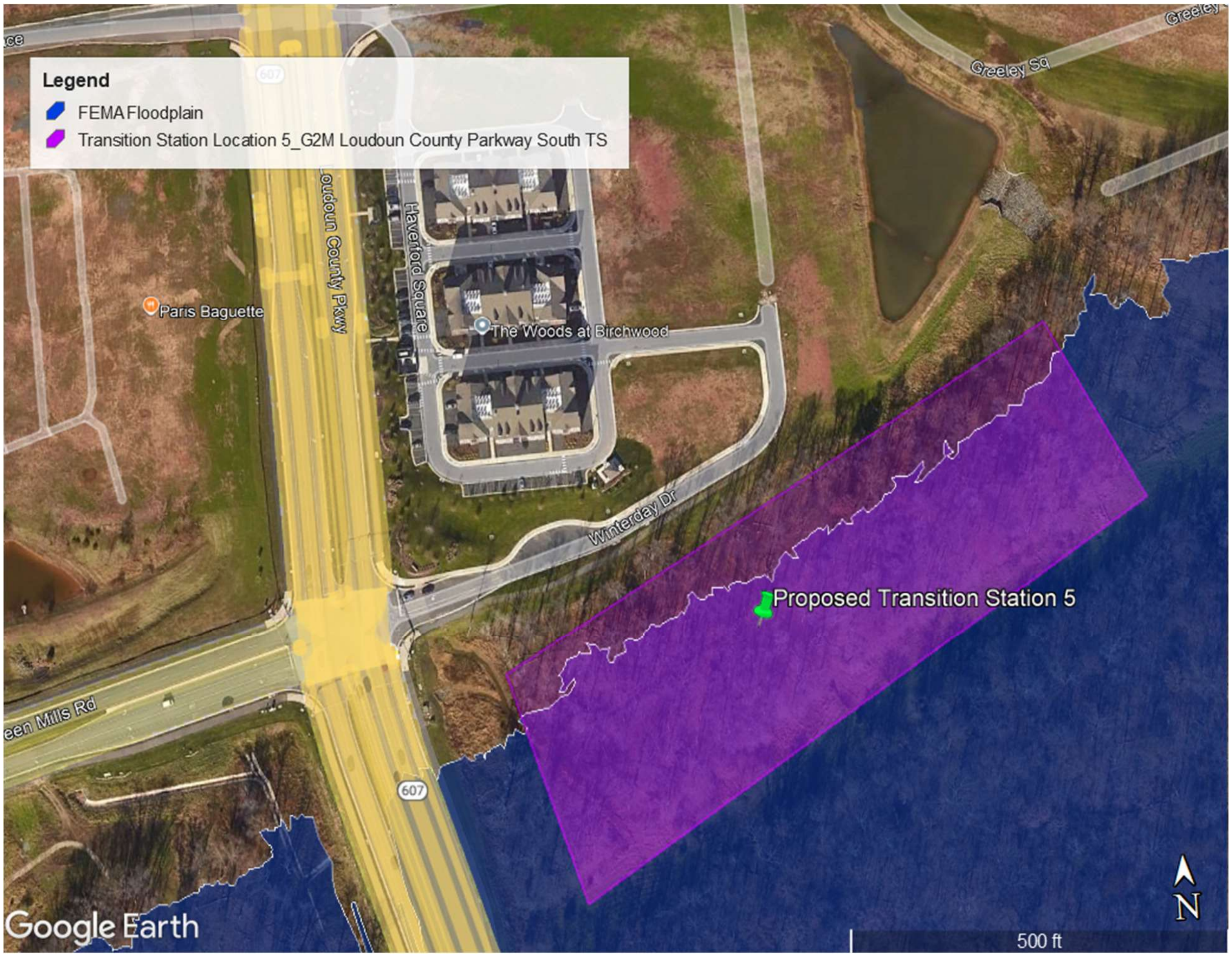
Almost all the parcel lies within a floodplain as shown in Figure 5-16. Because of the area needed for the placement of the transition station, TS5 must be built primarily upon the flood plain. The rest of the area is primarily covered with heavy foliage and would likely require major clearing efforts. There is a pond near to the northwest corner of the Parcel which will need to be considered during the site preparation and earthworks design. Due to the surrounding foliage and location, the station would have no line-of-sight visibility from the highway. New access roads will be required and will need to be placed in coordination with the planned future development by Crestnet 2 LLC around TS5 Parcel. See Figure 5-15 below for an image of the site location for TS5. Subsurface survey is not available for this Parcel, therefore it is unknown if existing UG utilities traverse TS5 area.

Summarizing, TS5 location is being affected by the main constructability stressors listed below. They increase the risk level over TS5 detailed design and execution.

- Parcel size may be inadequate for TS5 installation. Additional land may need to be acquired but location of additional land is limited by a large diameter existing sewer main and floodplain.
- Parcel is located within a flood plain, which would require a complex permitting process for construction which is not permittable.
- Unknow UG utilities may be present in the Parcel and would need relocation impacting the station construction schedule. Overall transition station design may be affected if relocation is not allowed by stakeholders.

Figure 5-15: Transition Station 5 Location, Facing Northwest

Figure 5-16: Wetlands and Floodplains Near TS5



5.2.6 Proposed Transition Station 6

Figure 5-17 shows the transition station TS6 located northwest of Route 606 and Highway 267 intersection, further west from TS1 location described in Section 5.2.1 above. TS6 was developed for DEV by ERM as the transition station for the UG Route originated from TS5 in the southwest, see Section 5.2.5. At TS6, both UG circuits will transition from UG installation to OH installation towards Golden Substation. Any routing option leading to TS6 will have a greater length compared to those leading to TS1, TS2, TS3 and TS4. TS6 was evaluated as a potential route option along Loudoun County Parkway that would connect to TS5 without requiring a trenchless crossing of Broad Run.

TS6 was incorporated into this study after the site visit was performed. Information on the station locations was pulled using Google Earth analysis, and publicly available information.

Figure 5-17: Transition Station 6 Location (SA Associates South LLC)

5.2.6.1 Land Acquisition

TS6 parcel is owned by SA Associates South LLC and the area is 3.6 acres which may not be sufficient for placement of the new transition station. Access roads to the Parcel would need to be developed stemming from Highway 267 to the north. Based on EEM's discussions,, the landowner indicated that the TS6 site will be dedicated to Loudoun County as an open space easement as part of the adjacent Silver District West development. Once dedicated, the site would not be viable location for a transition station.

5.2.6.2 Sensitive Areas and Environmental Impacts

The west side of TS6 parcel is parallel to an existing high-voltage overhead line stemming from Shellhorn Substation located east of Highway 267 and Route 607 intersection as shown in Figure 5-18 below. Based off the pole configuration of the existing OH line shown in Figure 5-19, at a minimum a double-circuit OH structure and foundation can be anticipated. Construction planning may need to consider and synchronize with Shellhorn Substation stakeholders a phased outage of that existing line along with probable relocation of some of the existing transmission poles to build TS6. TS6 sits just barely outside of the flood plain area. Since the Parcel may not have enough area to install the transition station, additional land may be required for the placement of TS6. If the additional area that can be acquired is on the east side of the current location, TS6 would be built primarily upon the flood plain which may impact the permitting process. In contrast, if the additional area is on the west side, TS6 would be built mostly outside of the flood plain. The area is primarily covered with heavy foliage and would likely require major clearing efforts. Due to the surrounding foliage and location, the station would have no line-of-sight visibility from the highway. New access roads will be required and will need to be placed in coordination with the planned future development by SA Associates South LLC on the same parcel. See Figure 5-19 below for an image of the site location for TS6. See Figure 5-20 below for the wetlands and flood plains near TS6. Subsurface survey is not available for this Parcel, therefore it is unknown if existing UG utilities traverse TS6 area.

Summarizing, TS6 location is being affected by the main constructability stressors listed below. They increase the risk level over TS6 detailed design and execution.

- Parcel size may be inadequate for TS6 installation. Additional land may need to be acquired. Since this parcel is planned for dedication as an open space easement to Loudoun County, a transition station would likely not be permittable.
- If the additional land is located in a floodplain, it would increase the permitting process complexity.
- Existing high-voltage overhead transmission line adjacent to TS6 parcel would require outages and relocations.
- Unknow UG utilities may be present in the Parcel and would need relocation impacting the station construction schedule. Overall transition station design may be affected if relocation is not allowed by stakeholders.

Figure 5-18: Existing Overhead Transmission Line Alongside Transition Station 6 Location

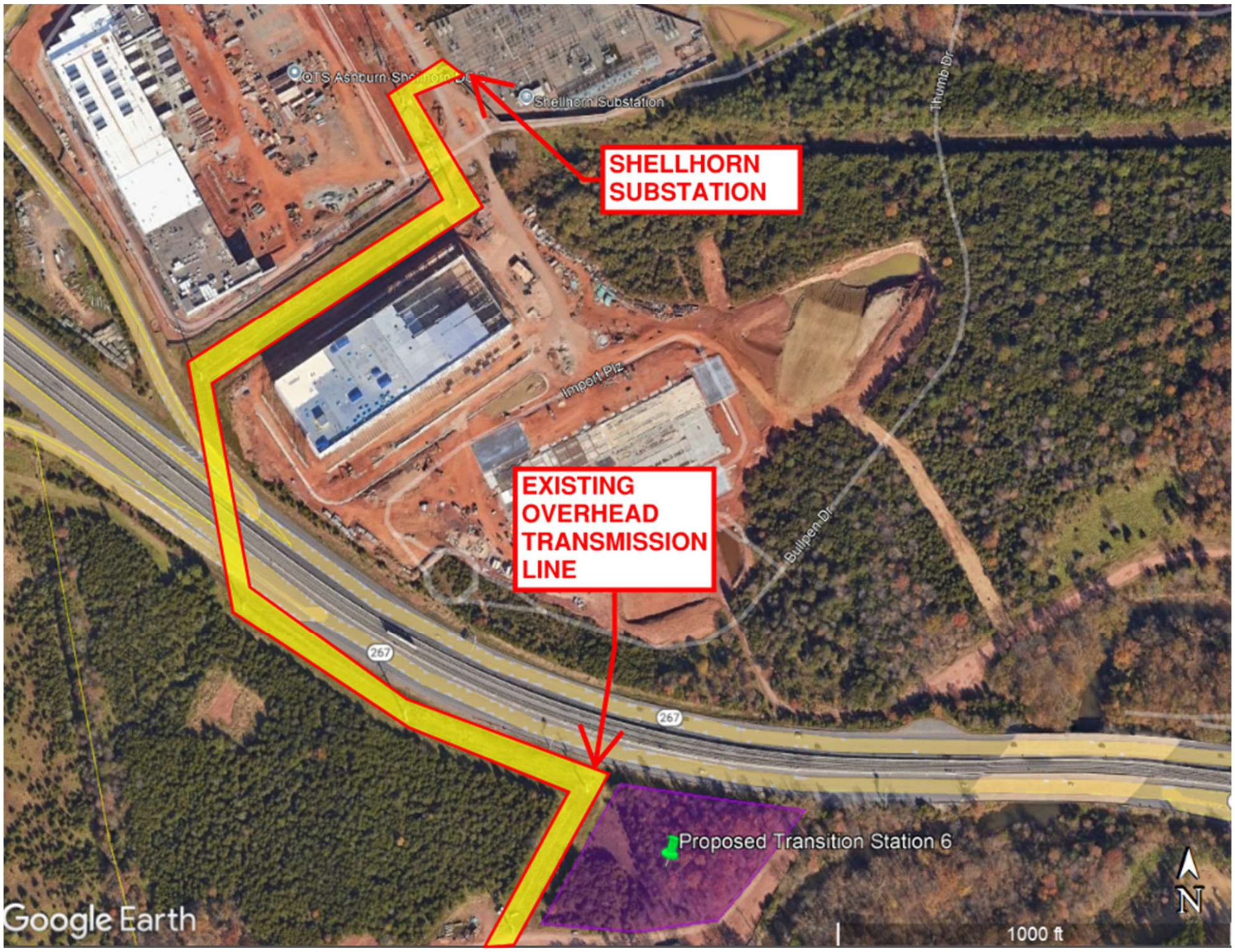


Figure 5-19: Transition Station 6 Location, Facing Southeast

Figure 5-20: Wetlands and Floodplains Near TS6

5.2.7 Proposed Transition Station 7

The proposed TS7 is located northwest of Route 606 and Overland Drive intersection between residential and industrial areas, as shown in

Figure 5-21 below. Similar to TS5, TS7 was developed for DEV by ERM as an intermediate location to have both, 230-kV and 500-kV circuits, in OH installation instead of UG installation from the Mars Substation up to where TS7 is. At TS7, both OH circuits will transition to UG installation following the proposed Route R4 described above in Section 4.1.11 up to transition station TS2. Although TS7 is closer to the Mars Substation than TS2, any routing option considering TS7 will involve an OH segment with two (2) circuits carrying large loads. TS7 was evaluated because it would provide the shortest underground route across Loudoun County Public School land to connect with TS2.

TS7 was incorporated into this study after the site visit was performed. Information on the station locations was pulled using Google Earth analysis, the provided survey data, and publicly available information.

Figure 5-21: Transition Station 7 Location (Loudoun Valley Estates III (LVE III) Homeowners Association Inc.)

5.2.7.1 Land Acquisition

TS7 parcel is owned by Loudoun Valley Estates III (LVE III) Homeowners Association Inc. and the area is 7.0 acres which is estimated to be sufficient for placement of the new transition station. Access roads to the Parcel would need to be developed stemming from Overland Drive in the south or from the pond road in the east stemming from Route 606, see Figure 5-22. ERM's review found that, the area lies within an existing open space easement dedicated to Loudoun County and owned by LVE III. Permitting TS7 would require approval from both Loudoun County and the landowner, which is unlikely to be obtained. Additionally, placing a transition station in a residential zone would require a special use permit, introducing significant schedule risk.

5.2.7.2 Sensitive Areas and Environmental Impacts

All the Parcel is primarily covered with heavy foliage and would likely require major clearing efforts. There is a pond near to the northeast corner of TS7 location which will need to be considered during the site preparation and earthworks design. Due to the surrounding foliage and location, initially the station would have no line-of-sight visibility from the Route 606 and the existing residential area, however the station west and south fences would be visible from the industrial area, see

Figure 5-21 above. The transition station would be clearly visible from the future residential developments on the north and east sides of the Parcel planned by the current landowner. New access roads will be required and will need to be placed in coordination with the planned future development by LVE III Homeowners Association Inc. around TS7 Parcel. See Figure 5-22 below for an image of the site location for TS7. Subsurface survey along Route 606 is available, however the surveyed area does not cover Overland Drive and this Parcel. Nevertheless, from the Route 606 surveyed segment east of TS7 shown in Figure 5-23, existing UG utilities (storm drainage lines, water lines and gas lines) are derived from Route 606 into the industrial area and LVE III Homeowners Association Inc. Parcel, therefore permitting and construction planning must take into account potential UG utilities relocation to build the transition station in this location.

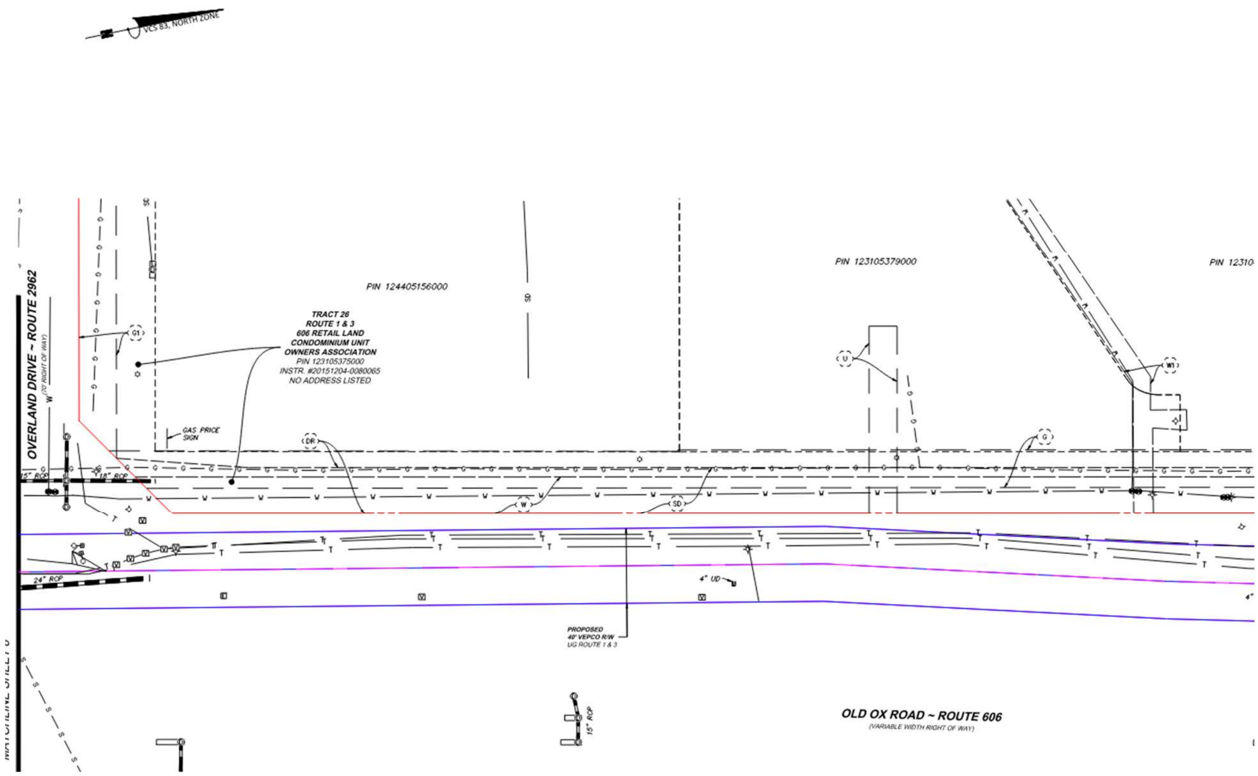
Summarizing, TS7 location is being affected by the main constructability stressors listed below. They increase the risk level over TS7 detailed design and execution.

- Parcel location would make TS7 visible from future residential developments planned by the current landlord.
- Access roads would need to use the existing pond road conflicting with the future residential developments planned by the current landlord.
- UG utilities may be present in the Parcel and would need relocation impacting the station construction schedule. Overall transition station design may be affected if relocation is not allowed by stakeholders.

- The site lies within an existing open space easement and residential zone district, both of which are land uses generally considered incompatible with major utility infrastructure based on discussions with ERM.

Figure 5-22: Transition Station 7 Location, Facing West

Figure 5-23: Route 606 Surveyed Segment East of TS7 Between Overland Drive and Beaver Meadow Road



5.3 Mars Substation Location

During a site visit to project area, the proposed location of Mars Substation was observed, pictured in Figure 5-24 below. The terrain appears largely flat with some trees and shrubbery coverage. Additionally, new constructions south of the proposed substation location were noted that did not appear in Google Earth. As a result, there is introduced high tuck traffic along Route 857, pictured in Figure 5-25 below. Given the UG 500-kV and 230-kV cables, it was not possible to develop an appropriate configuration for the Mars Substation, including switches, that would meet Dominion's reliability standards.

Figure 5-24: Mars Substation Location

Figure 5-25: New Construction Truck Traffic Near Mars Substation

5.3.1 Land Acquisition

ERM's review found that while Dominion has obtained the Mars Substation land, additional space would be needed to accommodate transition station equipment beyond the existing footprint. This expansion is constrained by planned transmission lines, existing ponds, and MWAA property to the south. Consequently, sufficient space for transition station equipment may not be available or obtainable.

5.3.1.1 Sensitive Areas and Environmental Impacts

ERM found that the area directly south of Mars Substation contains an existing pond, an unnamed waterbody, and planned transmission lines, with MWAA property further south. The pond likely cannot be relocated, and acquiring MWAA land would introduce uncertain schedule and permitting risks.

6.0 COST ESTIMATE ANALYSIS

A conceptual cost estimate was developed for all the proposed routes. See Appendix C for the detailed summary of the estimates.

6.1 Cost Estimate Assumptions

At this stage of design, assumptions have been made to obtain preliminary cost estimates. These assumptions are organized by major project area.

6.1.1 Underground Assumptions

Major assumptions for establishing the civil and electrical cost estimates under consideration are as follows:

6.1.1.1 230-kV UG Assumptions

1. Based upon the ampacity calculation results, the cables to be procured for the 230-kV circuit would be a 5,000 kcmil XLPE copper cable with insulated conductor wires.
2. For the 230-kV circuit, one (1) circuit installation with four (4) cables per phase.
3. Two (2) vaults will be needed for each 230-kV vault location.
4. It is assumed that the duct bank will consist of 8-inch Schedule 40 PVC conduits with four (4) spare conduits.

6.1.1.2 500-kV UG Assumptions

1. Based upon the ampacity calculation results, the cables to be procured for the 500-kV circuit would be a 5,000 kcmil XLPE copper cable with insulated conductor wires.
2. For the 500-kV circuit, one (1) circuit installation with five (5) cables per phase.
3. Three (3) vaults will be needed for each 500-kV vault location.
4. It is assumed that the duct bank will consist of 8-inch Schedule 40 PVC conduits with five (5) spare conduits.

6.1.1.3 General UG Assumptions

1. Three percent (3%) escalation over one year assuming 2024-dollars and assuming construction to start in 2026.
2. FTB Backfill 100% throughout entire open-cut trench installation length.
3. One (1) communication handhole required at each vault location and one (1) at each station.
4. Groundwater elevation has been assumed to be 5 feet below grade.
5. Contaminated Material Disposal based upon 5% of total Civil Cost.
6. Utility relocation based upon 5% of total Civil Cost.
7. Rock removal based upon 5% of Civil Excavation length for UG Route 2.
8. Rock removal based upon 10% of Civil Excavation length for UG Routes 1, 3, 4, 5, 6, 7, R1, R2, R3 and R4.
9. Traffic Control assumed to be two (2) crew, per circuit.
10. It is assumed that sheath grounding shall be single point bonded.
11. Estimates based on combined city cost index of (0.926) for Sterling, Virginia from the 2024 RSMeans.
12. Tax rate of 6.0%
13. Project contingency of twenty percent (20%) assumed.
14. Permitting and land acquisition costs have not been included in the estimate.

6.1.2 Transition Station Assumptions

The transition station cost estimate was developed using DEV's Success Enterprise estimating tool. All costs have been developed in alignment with typical estimating processes for DEV internal projects. Other major assumptions are:

1. Security design level 1 fencing and integrators
2. 15’ average spacing of ground grid conductors
3. Spread footers and raised control enclosure foundations
4. The cost and design for 230 kV series reactors is assumed from Dominion Equipment group per the recent projects.
5. The 500 kV series reactors cost is assumed from Dominion Equipment group per their discussion with the vendors. The cost and design to be provided by the vendors once the project is going for AFE approval

The transition station and substation costs provided in Section 6.2 do not include the following items:

1. Real Estate
2. Permitting
3. Site prep (Grading, clearing, E&S controls, storm water management facilities, etc.)
4. Survey
5. Public Communications & Outreach

6.2 Summary of Cost Estimates - Including Engineering and Construction Management

This section contains a summary of the cost estimate for all of the proposed UG routes and stations. See Table 6-1 and Table 6-2 below for the cost estimate summaries which include engineering and construction management support. See Appendix C for the detailed cost estimate reports.

Table 6-1: UG Route Total Project Cost Estimate Summary, 85% DLF

Circuit Route	Transition Station Cost(1)(2)	Mars Substation Cost(1)(2)	230-kV Cost(1)(2)	500-kV Cost(1)(2)	TOTAL COST ($USD)(1)(2)
UG Route 1	$52,273,000	$21,891,000	$239,445,000	$320,041,000	$633,650,000
UG Route 2	$52,273,000	$21,891,000	$200,824,000	$302,279,000	$577,266,000
UG Route 3	$52,273,000	$21,891,000	$290,278,000	$229,405,000	$593,847,000
UG Route 4	$52,273,000	$21,891,000	$175,832,000	$264,723,000	$514,719,000
UG Route 5	$52,273,000	$21,891,000	$176,853,000	$268,766,000	$519,783,000
UG Route 6	$52,273,000	$21,891,000	$203,787,000	$228,195,000	$506,146,000
UG Route 7	$52,273,000	$21,891,000	$185,046,000	$231,947,000	$491,157,000

Notes: 1. Cost estimates displayed are rounded to the nearest $1,000.
2. Cost estimates do not include any trenchless crossings along UG Route 1 through UG Route 7.

Table 6-2: UG Route Total Project Cost Estimate Summary, 100% DLF

Circuit Route	Transition Station Cost(1)	Mars Substation Cost(1)	230-kV Cost(1)	500-kV Cost(1)	TOTAL COST ($USD)(1)
UG Route 1(4)	$52,273,000	$21,891,000	$239,445,000	$328,591,000	$642,200,000
UG Route 2(4)	$52,273,000	$21,891,000	$200,824,000	$320,981,000	$595,969,000
UG Route 3(4)	$52,273,000	$21,891,000	$290,278,000	$235,882,000	$600,324,000
UG Route 4(4)	$52,273,000	$21,891,000	$175,832,000	$272,016,000	$522,012,000
UG Route 5(4)	$52,273,000	$21,891,000	$176,853,000	$276,070,000	$527,087,000
UG Route 6(4)	$52,273,000	$21,891,000	$203,787,000	$235,694,000	$513,645,000
UG Route 7(4)	$52,273,000	$21,891,000	$185,046,000	$238,016,000	$497,226,000
UG Route R1(2)	$52,273,000	$21,891,000	$241,355,000	$370,087,000	$685,606,000
UG Route R2(2)	$52,273,000	$21,891,000	$211,809,000	$321,561,000	$607,534,000
UG Route R3(2)	$52,273,000	$21,891,000	$280,670,000(3)	$438,796,000(3)	$793,630,000(3)
UG Route R4(2)	$52,273,000	$21,891,000	$96,927,000(3)	$152,211,000(3)	$323,302,000(3)

Notes: 1. Cost estimates displayed are rounded to the nearest $1,000.
2. Cost estimates for UG Route R1 through UG Route R4 were developed for 100%DLF.
3. The trenchless crossings identified along this route are not constructible, see Appendix E. Therefore, this cost does not include trenchless construction cost, does not consider the re-routing cost required to avoid those crossings, nor the cost of other trenchless crossings derived from the new alignment.
4. Cost estimates do not include any trenchless crossings along UG Route 1 through UG Route 7.

7.0 NEXT STEPS

The following steps should be taken during detailed design phase if an underground route is required.

7.1 Perform Field Investigation

The following sections provide further detail of the specific investigations that would be required to begin design of the underground installation of this project.

7.1.1 Survey

Even though DEV has recently provided a preliminary survey on certain segments of the project area, BMcD recommends that additional survey be acquired during detailed engineering to account for any new existing utilities that may have been added between now and the time detailed engineering starts. A survey of Quality Level B or Level C is recommended to present a more accurate depiction of the existing utilities along the alternative route and determine any additional project constraints. This level of survey would include field verifying of utility locations and would provide additional information up to and including vertical elevations, sizes, and materials of the utilities.

7.1.2 Geotechnical & Thermal Resistivity Testing

A detailed geotechnical investigation is recommended prior to further design. A geotechnical investigation is recommended to include the following:

- Thermal resistivity testing to confirm cable system parameters.
    - Laboratory testing shall be completed on samples taken from the depths as indicated in the project specifications. Testing shall include a description of the soils, moisture content, density and thermal dryout curves (thermal resistivity versus moisture content).
- Soil characterization for the proposed trench and trenchless portions to identify soil and bedrock conditions for the installation, operation of the facilities and to determine groundwater depth. For the proposed UG route(s), a test boring can be taken every 500 feet along the alignment or as project budget or risk tolerance

allow. Borings should be advanced to a depth of at least 10 feet below the bottom of the proposed UG installation depth.

- Laboratory Testing
    - Laboratory tests shall be assigned and performed to classify soils and obtain geotechnical physical characteristics for soils and rock such as strength, compressibility, and compaction characteristics. The quantity of tests to be performed shall be determined by the Engineer and will be dependent upon type of soil and/or rock encountered during drilling. Testing shall be in consideration of foundation types that may be required for proposed structures as required. Laboratory tests may include, but are not limited to, the tests listed below:
        - Moisture Content
        - Dry Unit Weight
        - Sieve Analysis
        - Percent Finer than No. 200 Sieve
        - Atterberg Limits
        - Organic Content
        - Unconfined Compression – Soil or Rock
        - Compaction Characteristics (Standard Proctor Test)
        - Thermal Testing (By Geotherm, Inc.)
        - Chemical Analyses
            - pH
            - Soluble Sulfates
            - Chloride Ion
            - Electrical Resistivity
            - Redox Potential
            - Sulfides

7.2 Further Stakeholder Involvement

DEV has established lines of communication with the entities that will be potentially impacted by the project and will continue to facilitate ongoing dialogue to ensure concerns are addressed and expectations are managed.

7.2.1 Permitting Coordination

- City of Dulles, Virginia
- Virginia Department of Transportation (VDOT)
- Local utility owners
- Local stakeholder groups that may include clubs, churches, businesses, and other organizations. Stakeholder identification will be required as per regulations.

7.2.2 Third Party Utility Coordination

Generally, in urbanized areas, such as the project area described above, coordination with third-party utilities on location and condition of existing facilities as well as future projects and plans along the proposed routes will be vital to confirm adequate space is available for the planned work.

7.2.3 Future Improvement Projects within Study Area

It will be beneficial for the design process to identify any future improvement projects that are being considered inside of the project study area to finalize routing.

7.2.4 Real Estate Acquisition

The need for real estate acquisition should be confirmed based on the above activities and preliminary investigations should be conducted to determine any potential risks for securing critical properties or easements. As required, real estate options should be obtained at critical locations along the route.

8.0 CONCLUSION

8.1 Feasibility Summary

Burns & McDonnell has reviewed the eleven (11) proposed underground routes developed by DEV and ERM for the proposed UG transmission line and identified various constructability challenges associated with each proposed UG route option. The challenges include:

- Construction through flood plains, wetlands, and ponds.
- Construction through existing concrete culverts below Routes 606 and 607.
- The need of significant number of easements since most of the routes will need to be installed outside of the public ROW.
- Permanent easements from sensitive facilities and federal lands probably not possible to obtain.
- Spacing concerns for duct bank and splice vault placement as well as impacts to traffic for proposed alignments paralleling Routes 606 and 607 roadways.
- Parcel acquisition issues for some of the transition station options.
- Potential relocation of existing UG utilities at congested areas.
- Relocation of existing overhead distribution and transmission lines foundations and supporting structures.
- Trenchless crossings with large ROW widths require demolishing existing private infrastructure to accommodate working spaces at launching/receiving pits.
- The probable presence of diabase rock, which is an abrasive and hard material to drill through at trenchless crossings, implying the need of large rigs and potential schedule risks due to the slow drilling process.

Based on the number and complexity of the identified constructability constraints, all of the studied UG routes are no longer considered constructable options for Golden to Mars project.