E-183 115 kV Transmission Line Underground Relocation Project

Evaluation of National Grid's 2014 Underground Estimate

April 10, 2015

Introduction

Ferrucci Russo P.C. contacted Power Delivery Consultants, Inc. (PDC) in regard to an underground transmission line project involving National Grid, the State of Rhode Island, and the cities of Providence and East Providence. This underground transmission line project is related to an agreement between National Grid, the City of Providence, the City of East Providence, and the Rhode Island Attorney General to underground a portion of the existing E-183 transmission line. The engagement of PDC is to review the 2014 project cost estimate submitted by National Grid. PDC worked with Haley & Aldrich (H&A) for this analysis.

This report summarizes the following:

- Review The Narragansett Electric Company E183W – Underground Project Investigation & Estimate Assumptions dated Oct. 29, 2014 by Power Engineers, Inc. to understand the installation it proposes;
- Review of National Grid E183W Underground Relocation, Providence, RI – Design Information Package dated Oct. 21, 2014 by Power Engineers;
- Review of the S.W. Cole Engineering, Inc. report Exploration, Field/Laboratory Testing and Geotechnical Engineering Services – Proposed E183W Underground 115 kV Electric Transmission Cable System, Providence and East Providence, Rhode Island, dated January 20, 2015;
- A walk-through of the proposed route of the relocated underground line, including reviewing the river crossing from the shore ends;
- A determination of the reasonability of the estimate according to common industry practice;
- An opinion on whether or not the estimate submitted by National Grid is reasonable;
- Recommendations on steps that can be taken to reduce the proposed estimated amount;
- A review of the schedule submitted by National Grid with a determination of any steps that can be taken to compress the time allotted for completion of the project;

Analysis

The following sections detail PDC's and H&A's (hereafter PDC) analysis of the National Grid estimate. It also highlights areas of risk, risk factors, and cost escalators.

Walk-through of Proposed Underground Route

On Thursday, Feb. 12, National Grid's Dave Campilii hosted a site walk-through for Rachel Mosier, PDC, and Dennis Doherty, Haley & Aldrich, along with lawyers from both sides.

During the walk-through, we learned that National Grid proposes switches, differential relays, and a control station in order to facilitate fault locating and to allow for isolating one of the two cables in the event of a failure on the cable system. While temporary faults are possible on overhead lines from, say, tree branches, faults on the underground line are almost never temporary. To avoid the risk of a manhole fire or damage to adjacent phases, utilities typically will not reenergize a line with underground portions unless they are certain that a fault was not located on the underground portion. This is common industry practice.

Regarding potential use of the Pointe Street bridge vs a directional drill beneath the river, Mr. Campilii pointed out that the bridge used to be a swing bridge. Because of this, there is a large mechanism in the center of the bridge that would impede the attachment of cables to the underside. Additionally, distribution cables are already attached to the southern sidewalk underside, and the northern sidewalk is obstructed by a 115-kV circuit.

The Fox Point bridge is the only other nearby bridge crossing of the Providence river. This is a new bridge with a flat, smooth underside. National Grid said the bridge was designed this way to discourage pigeons from roosting underneath. Therefore, it is unlikely that suspended ducts would be permitted.

Project Review

In order to fully understand the estimate, PDC first reviewed The Narragansett Electric Company E183W – Underground Project Investigation & Estimate Assumptions dated Oct. 29, 2014 by Power Engineers, Inc. This report described the route between the existing Franklin Square Substation and a new overhead-to-underground transition station on Mauran Avenue in East Providence.

The following is the route proposed by Power Engineers:

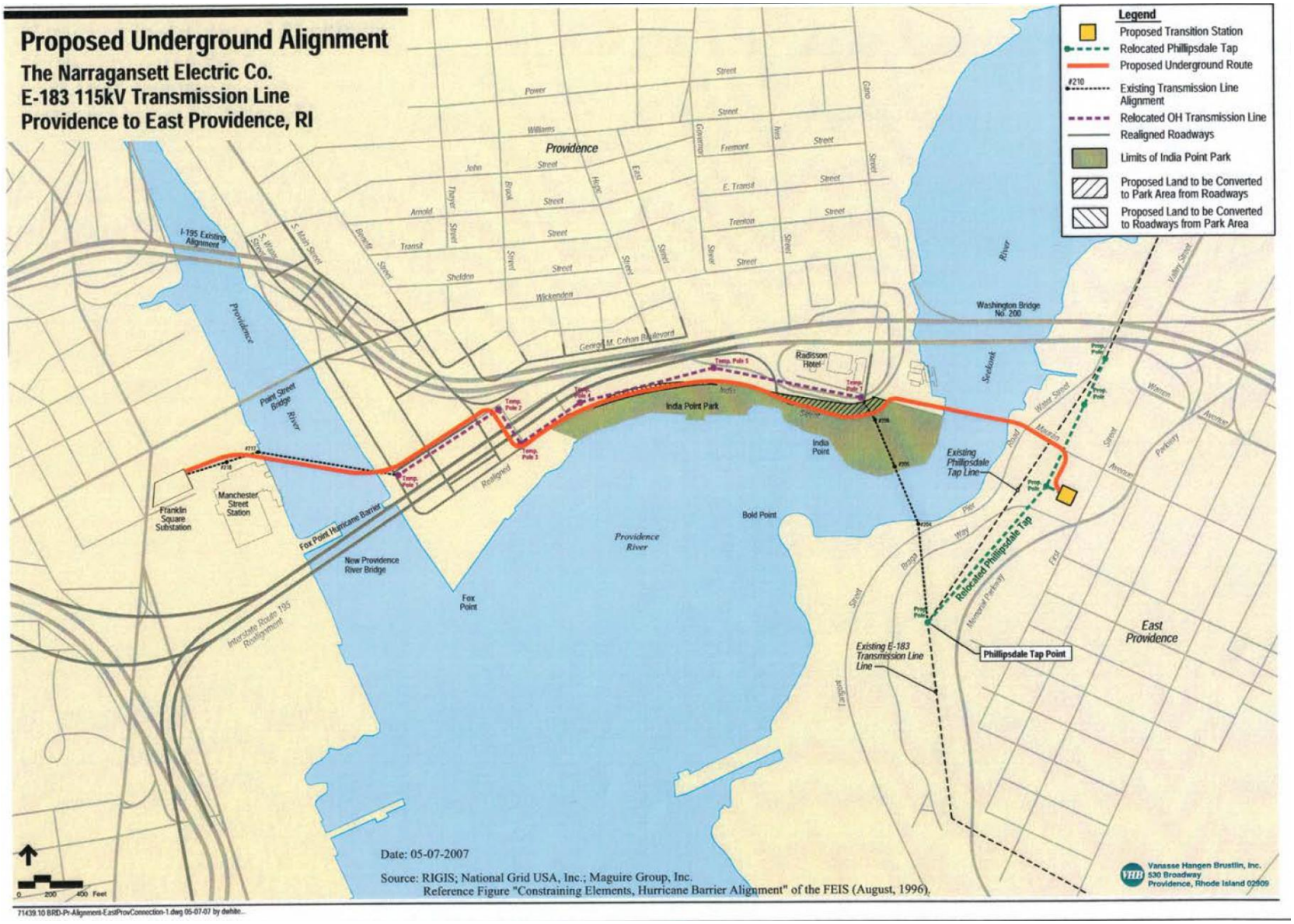

Figure 1. National Grid's Proposed Alignment for the Underground Portion of E-183

According to The Narragansett Electric Company E183W – Underground Project Investigation & Estimate Assumptions dated Oct. 29, this route is approximately 6,330 ft long, includes two horizontal directional drills, one jack-and-bore, with the remainder being installed by open trench excavation. The directional drills are each proposed to include two parallel bores with one cable per phase (i.e., three cables) in each bore. The jack-and-bore is proposed to include two cables per phase in the one bore.

According to the Plan drawings P2-1 through P2-8 dated 8/13/14, Power Engineers is planning on 5 vault locations with 1 vault per phase for a total of 10 vaults.

In addition to undergrounding a portion of the E-183 line, the Phillipsdale tap point will need to shift north to the underground-to-overhead transition point.

Reviewing National Grid E183W Underground Relocation, Providence, RI – Design Information Package dated Oct. 21, 2014 by Power Engineers, we see the assumptions used to perform a preliminary design of the system. The ambient soil temperatures are in line with what we would expect for those depths in Providence, RI. In addition, the native soil thermal resistivity assumed for the trenched section of the route appears correct based on the S.W. Cole Engineering, Inc. report Exploration, Field/Laboratory Testing and Geotechnical Engineering Services – Proposed E183W Underground 115 kV Electric Transmission Cable System, Providence and East Providence, Rhode Island, dated January 20, 2015. However, for the horizontal directional drill (HDD) section beneath the Providence River, Power Engineers' report assumed a native soil thermal resistivity of 90 C°-cm/W, where the S.W. Cole Engineer report indicates an actual thermal resistivity of up to 225 C°-cm/W. This would result in greater heating of the cable, and therefore a larger conductor size or other efforts required to reduce the cable temperature. This will have a cost impact (increase) on the project.

Utility verification of locations has not been performed. This could impact the cost if significant utility conflicts are encountered. Section 3.2.2 of National Grid E183W Underground Relocation, Providence, RI – Design Information Package dated Oct. 21, 2014 by Power Engineers states an obstruction clearance of 25 feet is required. Given a major gas transmission line, waterfront bulkheads, abandoned bridges, etc., this is part of the risk associated with this project.

For the HDD crossing of the Providence River, Power Engineers states that the depth of vertical alignment will be 35 to 60 feet, but data from the new I-195 bridge downstream of the hurricane barrier indicates 29 feet of fill over 30 to 45 feet of organic silt and silty fine sand that would be considered very soft. That data also indicates that there is significant weight of rod material which is detrimental. Based on the S.W. Cole geotechnical data presented, a prudent engineer would install a conductor sleeve (also known as a casing pipe) to an elevation approximately 60 feet bgs to mitigate potential steering issues, borehole stability issues, and the potential inadvertent returns (i.e., frac-out). A vertical curve cannot begin until after this depth since it will be confined by the straight section of conductor sleeve. The total depth of the 60 feet plus additional depth accumulated going through a vertical curve would be between

105 and 165 feet bgs depending on the entry angle. The geotech borings from S.W. Cole only go to about 80 feet bgs. Power Engineers may not have considered the very loose-to-loose or soft-to-medium stiff ground conditions. Below the depth of 50 feet is well-graded dense sand with gravel. H&A believes the alignment should be below this 50-ft depth to reduce risk.

The drawings from Power Engineers also indicate an HDD entry point at the Manchester Street Station to be only 100 feet from the Providence River. This will place a vertical depth at between 15 and 25 feet below ground surface at the top of the bulkhead when crossing the bulkhead assuming an 8- to 14-degree entry angle based on a typical HDD drill rig for this size crossing. This can be problematic given the potential for abandoned piles, the former bridge in the area, and the geology in the river. On the opposite side of the crossing, based on the Power Engineers drawing, the vertical distance to the pipe at the bulkhead will be 28 to 50 feet deep from the ground surface at the top of the bulkhead.

Power Engineers' report notes that costs for environmental permitting and mitigation are not included in the pricing. During the site meeting, National Grid and others noted highly contaminated river sediments, the former rail yard at the now India Point Park, a hazardous material dump site, and the power plant. Contaminated ground could be significant and thus cost to mitigate could also increase significantly.

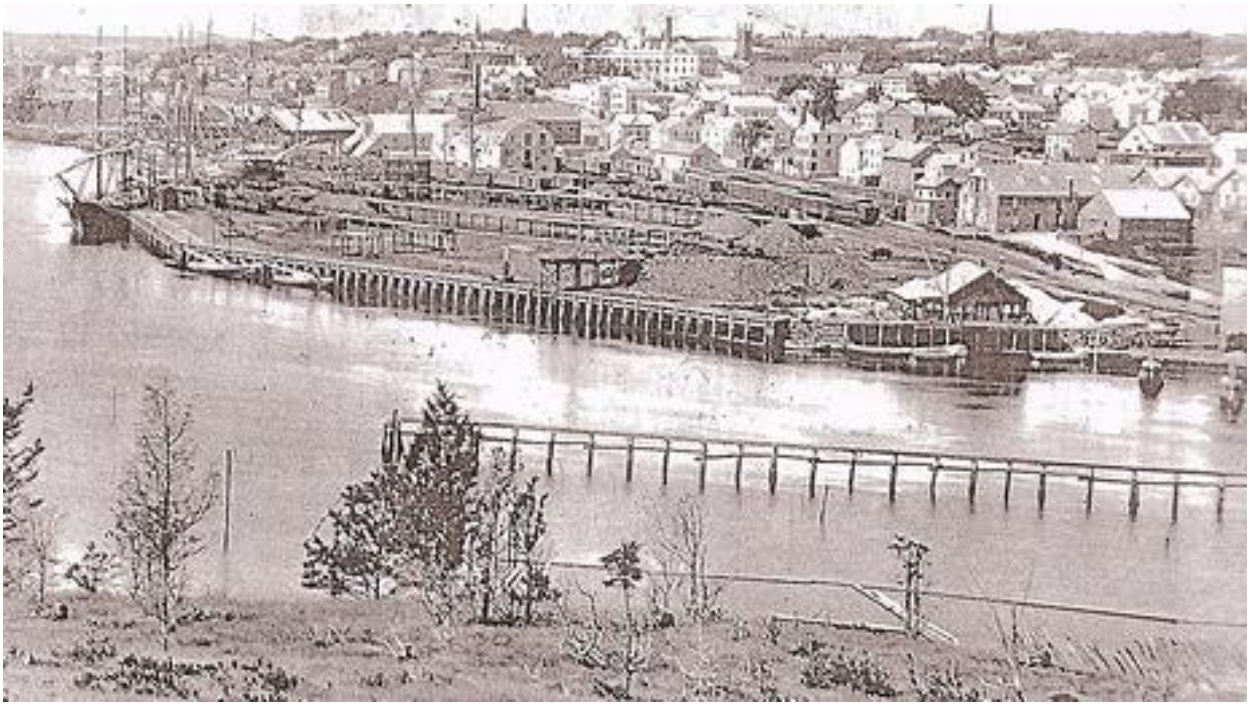

Figure 2. View of India Point from East Providence circa early 1880's
https://www.flickr.com/photos/25521239@N06/2774059277/lightbox/

Power Engineers used a 25% Civil Contingency. This civil contingency appeared to include the HDDs and jack-and-bore. Typically in HDD, contractors may add an additional contingency

factor of upwards of 40 to 60% of base construction cost depending on the perceived risk, especially when the risks are perceived to be high. Given the contaminated ground, the urban setting, the old waterfront, and the potential buried building foundations, unmapped utilities, filled land, poor geology, etc., H&A considers this project to be high risk which warrants a higher risk factor.

The jack-and-bore under I-195 is believed to be under the jurisdiction of the U.S. Army Corps of Engineers (USACE) since it is technically a levee being part of the hurricane barrier protecting the economic value of downtown Providence. Jurisdiction of the I-195 hurricane barrier needs to be confirmed. The USACE generally does not allow penetration of levees; this is to protect the integrity of the levee. Generally the USACE requires utilities to go deep underneath the levees in natural ground. This could increase cost. In addition, the USACE permitting costs would increase cost or may even prevent the crossing from being allowed without substantial redesign.

Section 3.2.3 of National Grid E183W Underground Relocation, Providence, RI – Design Information Package states possible use of Hobas pipe. Hobas pipe cannot be used in a jack-and-bore application without an internal steel casing or as a double jack. Otherwise the augers will severely damage the HOBAS pipe.

With respect to the jack-and-bore proposed by Power Engineers, it may be difficult to install a 10-ft x 10-ft shaft at the top of the highway embankment. While this requirement may be driven by the Rhode Island Department of Transportation, the expense to build a deep, quality shaft to prevent highway movement may be higher than estimated.

The Seekonk River HDD has a slight horizontal bend in the alignment. It also most likely passes under a former rail bridge that appeared to be a swing bridge. The foundation for that bridge will be extensive and possibly deep, adding risk to project. Although Power Engineers did conduct a side scan sonar investigation of the Seekonk River in the area of the proposed crossing, and the report identifies submerged structures that may be former bridge foundations, it is uncertain of the exact location. Figure 3 below is a picture showing the former railroad crossing.

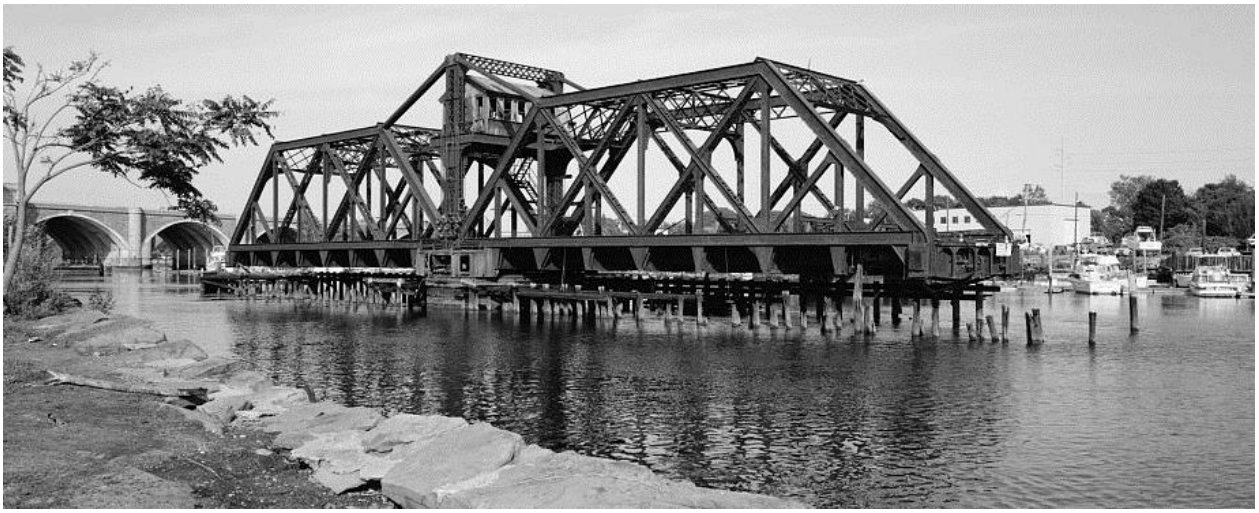

Figure 3. Former railroad crossing of Seekonk River

There are several conflicts in the S.W. Cole Engineering, Inc. report Exploration, Field/Laboratory Testing and Geotechnical Engineering Services – Proposed E183W Underground 115 kV Electric Transmission Cable System, Providence and East Providence, Rhode Island, dated January 20, 2015.

- S.W. Cole states that ground water is 14 feet below ground surface (bgs) at borings near the Pipe Jack under I-195. They acknowledge fine sands and that, with ground water, these could flow and lose stability. Then on page 10 of the same report, S.W. Cole calls for dewatering of jacking pits and again acknowledges potential for flowing sand (also called piping). The report does not address soil under I-195 that H&A suspects to be different because it is assumed to be a levee as previously noted.
- With respect to the HDD crossing of the Providence River and using the S.W. Cole geotechnical data presented, the borings from S.W. Cole only go to about 80 feet bgs. Power Engineers may not have considered the very loose-to-loose or soft-to-medium stiff ground conditions. Yet the S.W. Cole report acknowledges HDD steering issues in these types of ground conditions. S.W. Cole does not mention borehole stability issues that should also be of concern in the geotechnical conditions presented. Using the S.W. Cole geotechnical data, the combination of the longer conductor sleeves and vertical curves equates to a total horizontal distance of approximately 2,100 feet for the HDD. This could be longer or shorter depending on the size of the conduit bundle and entry angle. The S.W. Cole boring on the opposite side of the river does indicate more favorable geotechnical conditions, but the first boring noted above will determine the total depth and thus length. The Power Engineers report calls for a 1,200-ft long HDD. This certainly presents a cost impact as well as a design impact.
- With respect to the HDD across the Seekonk River, the S.W. Cole report notes that they were instructed by Power Engineers to assume a 60-ft depth of the HDD below the river.

The S.W. Cole borings at this crossing go to about 75 to 80 feet bgs. The geotechnical borings provided by S.W. Cole for this crossing indicate a more favorable geotechnical condition for HDD installation. The Power Engineers report calls for a 950-ft long HDD. This may work, but needs further consideration based on the conduit configuration.

Underground Estimate Evaluation

PDC reviewed Power Engineers' National Grid Providence E183 Summary of Cost dated 10/3/2014, as well as the detailed cost estimate which supported the summarized cost. In addition to the risk and additional cost factors stated above, the following is our analysis of the estimate.

Per Power Engineers, costs include the installation of temperature monitoring equipment for the cable system. While the embedded fiber optics in the power cable will add minimal cost, the temperature monitoring instrumentation can cost about $70,000 installed. Since the earth has a very long thermal time constant, and since most utilities build their transmission systems for the need 20 years out, it is generally many years before the cable system will register temperatures higher than ambient. Therefore, many utilities instead opt to rent the equipment whenever they would like to take a reading.

As described in National Grid E183W Underground Relocation, Providence, RI – Design Information Package dated Oct. 21, 2014 by Power Engineers and confirmed during the walk-through, the design incorporates disconnect switches at each transition station end. While disconnect switches will help facilitate taking one of the cables out of service in the event of failure or required maintenance, other utilities have achieved this by installing a jumper instead. Northeast Utilities installed a hybrid line (i.e., a transmission line with overhead and underground portions) in 2006 using a jumper and transition pole rather than a larger transition structure with a switch and control station. This can have a modest effect on cost, albeit at the expense of outage time.

Regarding the potential difficulties of the jack-and-bore beneath I-195 combined with the possibility of having to bore deeper and longer across the Providence River, H&A has analyzed a new alignment. See Figure 4.

Figure 4. Alternate HDD Beneath Providence River

The red alignment introduces a slight horizontal curve to avoid passing under the restaurant next to the original exit point. The green line is the shortest alignment at about 2,050 feet. If National Grid does not want to acquire additional easement, then the red line is recommended which is about 2,100 feet long. This would replace about 625 feet of open trenching on the east side of the river and north of I-195, as well as the jack-and-bore. Rough prices below are based on RSMeans Cost Data for comparison purposes:

New HDD Cost = 2,100 ft x 2 pipes x $720/ft =	$3,024,000
Elimination of 625 ft of open trenching =	-$93,900
(Includes excavation, hauling, soil, FTB, concrete.)	
Elimination of jack-and-bore =	-$607,000
(Includes bore, grout, and spacers.)	
Elimination of original HDD (1,200 ft x 2) =	-$1,728,000

The cost increase is estimated to be $595,100. However, this does not take into account that a 2,100-ft HDD may be required regardless due to the bottom conditions as discussed earlier. Other benefits: this will allow for easier permitting from USACE, shorter construction time, fewer disturbances to traffic access to I-195 East at the South Main Street on ramp, and less impact to parking at the restaurant.

Even though line-by-line PDC's estimate differs fairly substantially from Power Engineers' detailed estimate, the bottom line is within 7%. See Table 1.

Table 1. Comparison of Power Engineers' and PDC's Estimate

Power Engineers' Estimate			
SUMMARY	XLPE Cable System Costs		
	Material Costs	Labor & Equipment	Total Cost
Duct Bank	$1,139,858	$2,530,888	$3,670,745
Trenchless Installations	$1,855,660	$3,842,240	$5,697,900
Manholes	$250,000	$300,000	$550,000
Cable	$3,357,500	$790,000	$4,147,500
Splices	$300,000	$360,000	$660,000
Terminations	$120,000	$144,000	$264,000
Arresters	$0	$0	$0
Spare Material	$200,000	$0	$200,000
Additional Cable Accessories	$248,250	$206,500	$454,750
Communication System	$76,000	$81,800	$157,800
Temperature Monitoring System	$98,300	$90,200	$188,500
Termination Structures	$0	$0	$0
Mob/Demob	$0	$502,000	$502,000
Real Estate/Permitting	$0	$0	$0
Engineering and Construction Management	$0	$1,600,000	$1,600,000
SUBTOTAL	$7,645,568	$10,447,628	$18,093,195
15% Contingency - Electrical Construction	$660,008	$566,175	$1,226,183
25% Contingency - Civil Construction	$747,380	$1,476,282	$2,223,662
TOTAL	$9,052,956	$12,490,085	$21,543,040

Notes:

1. Additional Cable Accessories consist of the following components: Grounding system for vaults, Link boxes, Cable clamps, Continuity conductor, Jacket Integrity Test
2. Temperature Monitoring or Communication System consists of the following: Terminal equipment, Fiber-optic cable, 2-in conduit
3. Due to the volatility of metal costs, the cable material prices could increase.

PDC's Estimate			
SUMMARY	XLPE Cable System Costs		
	Material Costs	Labor & Equipment	Total Cost
Duct Bank	$1,316,693	$1,828,079	$3,144,771
Trenchless Installations	$433,570	$3,258,885	$3,692,455
Manholes	$750,000	$700,000	$1,450,000
Cable	$3,357,500	$1,818,700	$5,176,200
Splices	$678,000	$789,000	$1,467,000
Terminations	$452,400	$615,600	$1,068,000
Arresters	$0	$0	$0
Spare Material	$252,900	$0	$252,900
Additional Cable Accessories	$373,190	$274,400	$647,590
Communication System	$130,600	$63,800	$194,400
Temperature Monitoring System	$98,300	$90,200	$188,500
Termination Structures	$0	$0	$0
Mob/Demob	$0	$485,000	$485,000
Real Estate/Permitting	$0	$0	$0
Engineering and Construction	$0	$1,730,000	$1,730,000
SUBTOTAL	$7,843,153	$11,653,663	$19,496,816
15% Contingency - Electrical Construction	$89,706	$1,349,189	$1,438,895
25% Contingency - Civil Construction	$18,219	$2,071,806	$2,090,025
TOTAL	$7,951,078	$15,074,658	$23,025,736

Notes:

1. Mob/Demob for the HDD is included in Trenchless Installations.
2. Cable includes AC Hi-Pot and PD commissioning tests.

Schedule Review

The schedule provided to the State of Rhode Island Energy Facility Siting Board (Docket No. SB-2003-01) shows the following:

- **August 15, 2014 – September 30, 2014**
  - National Grid to receive underground component cost estimates from consultant on or before September 1, 2014.
  - National Grid to receive cost estimates for other project components from internal project teams on or before September 1, 2014.
  - National Grid to present project cost estimate to parties for review on or before September 30, 2014.
  - Municipalities and Attorney General to make preparations to engage consultant for peer review.
  - Municipalities to advance negotiations for acquisition of property rights.
- **September 30, 2014 – November 15, 2014**
  - Municipalities and Attorney General to determine whether to engage consultant for peer review.
  - Attorney General and Municipalities to peer review cost estimate if consultant engaged.
  - Attorney General and Municipalities to advise National Grid and EFSB whether all support proceeding with underground project.
- **November 15, 2014 – April 1, 2015**
  - Municipalities to acquire necessary property rights.
- **April 1, 2015 – October 1, 2016**
  - National Grid to commence and complete project permitting, subject to agency schedules.
- **December 1, 2016**
  - National Grid to award EPC contract.
- **Spring, 2017**
  - National Grid to commence construction.

Reviewing the schedule, there is an obvious difference (i.e., this peer review was delayed 5 months from Sept-Nov 2014 to Feb-Apr 2015). Regarding the permitting, the schedule shows 18 months. Experience has shown that permitting can take at least 12 months, especially when dealing with the USACE. That said, National Grid could compress the schedule by beginning the bid process prior to obtaining all of the permits, with work contingent upon receiving the permits. This would give the manufacturer an opportunity to begin making the cable and accessories, and possibly commence construction as early as July 2016.

National Grid shows that it will be awarding an EPC contract. EPC contracts have gained popularity in the electric transmission industry because they provide for accelerated schedules while managing project risk early in the process. Many of these risks are not technical, but may be a result of stakeholder input and regulatory requirements. Regardless, non-technical risks may lead to or exacerbate technical risk during construction. National Grid should also consider Design-Build or EPCM to make sure they select the most optimal project delivery method.

Conclusion

After reviewing Power Engineers' assumptions and design information, SW Cole's geotechnical and geophysical data, and Ocean Surveys' marine geophysical survey, PDC has determined that the proposed project is aligned with standard industry practice. That said, PDC believes there are minor adjustments that can be made to save some cost. For example, transition poles with jumpers can be employed at either end of the line vs. a pole with disconnect switches. In addition, it may be more cost-effective considering permitting cost and schedule delays to install a longer HDD beneath the Providence River vs. a shorter HDD in addition to a jack-and-bore beneath I-195. This can be sorted out during detailed engineering.

PDC has identified several areas of risk that will very likely increase project cost. Costs for environmental permitting and mitigation are not included in the pricing. Contaminated ground could be significant given the history of the location, and thus cost to mitigate could also be significant.

PDC is in general agreement with the work Power Engineers has done to date on this project, and we are in relatively close agreement with their cost estimate, barring the unknowns (e.g., utility obstacles, contaminated ground, old bridge footings, etc.).

Regarding the schedule, PDC believes there are opportunities to compress the schedule to award and begin construction in 2016 rather than 2017. This would need to be looked at more closely to optimize the project delivery method.