



Reliability Analysis Update

Transmission Expansion Advisory
Committee
November 3, 2016



Artificial Island Update



Artificial Island (AI) Comprehensive Analysis Path to February 2017

Protection & Control Team – Technical whitepaper

Cost & Estimate Team – working to understand basis of estimates

Data and Operational Analysis Team – analyzing historical AI plant data and relevant data (e.g. maintenance outages)

Solution Space Team – identifying and analyzing solution alternatives

Conduct detailed analytical review of individual AI solution elements

Analyze combinations and permutations of existing elements and any new “solution space” alternatives

Document expected cost estimates of resulting alternates/options

Select viable Project paths forward

Prepare draft report and team recommendations to PJM Executive Team

Present PJM Board with final PJM Executive **Recommendation(s)**

October

November

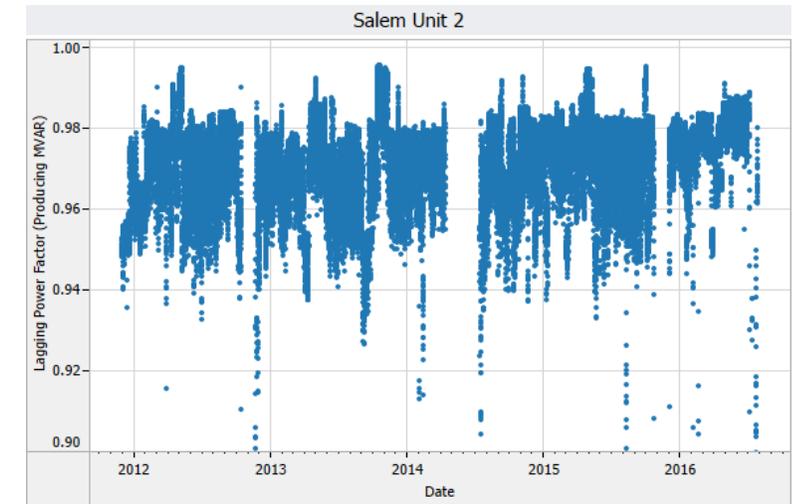
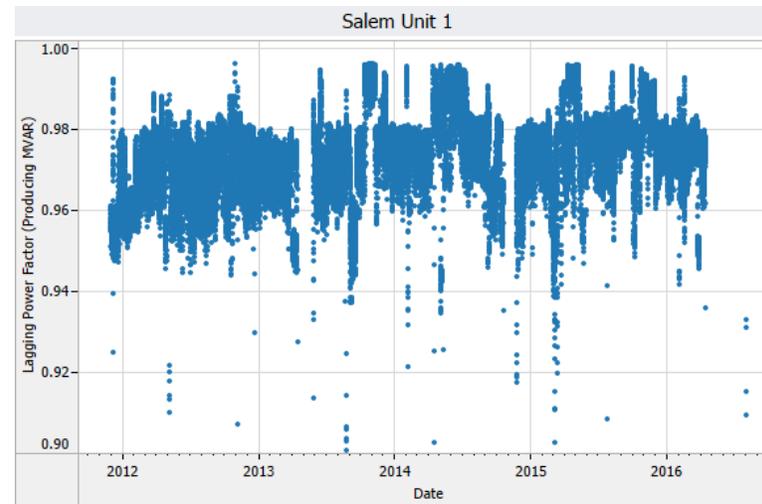
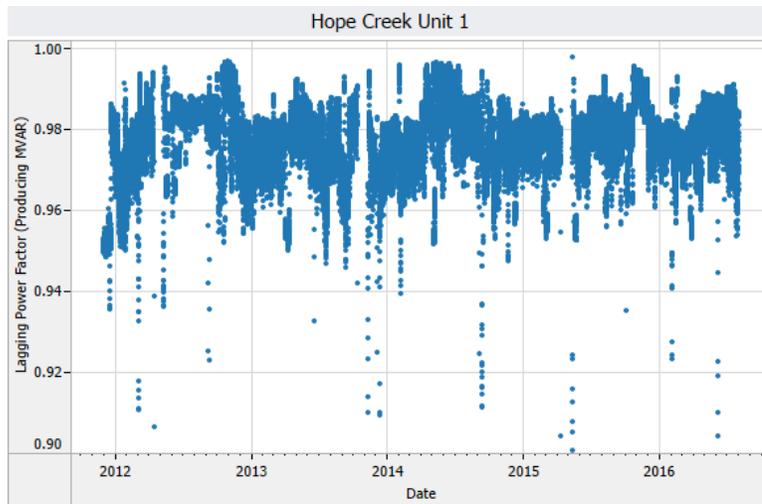
December

January

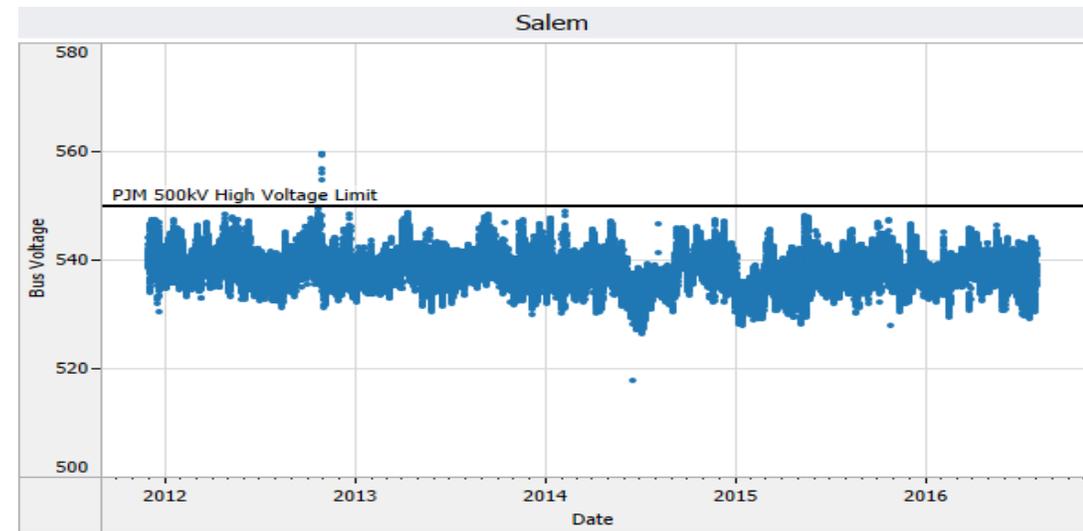
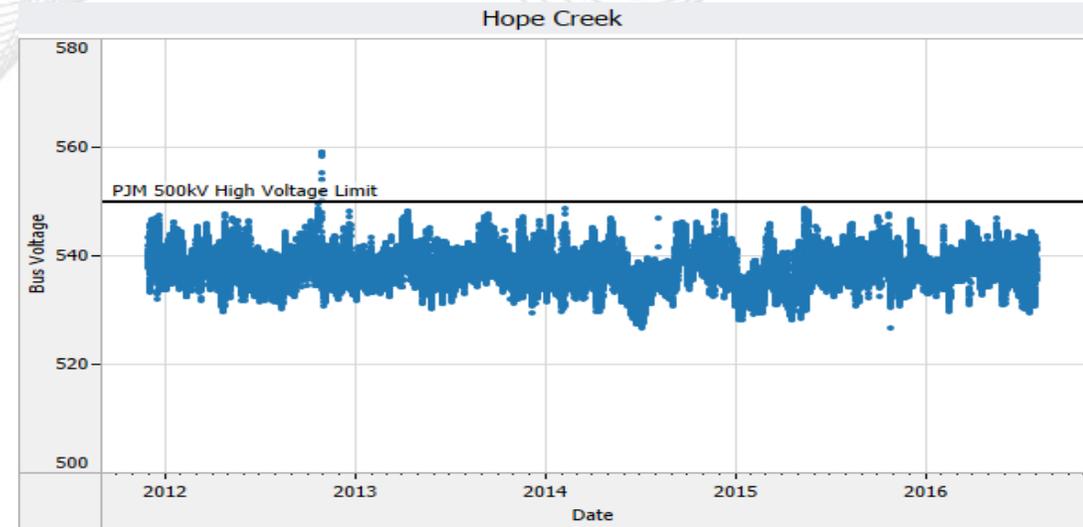
February

- Recent update from PSE&G planning regarding protection system timing at the AI
 - PSE&G provided PJM information about clearing time associated with bus faults with delayed clearing that was not explicitly addressed in the existing operating guide
 - PJM has evaluated the impact of these new fault clearing times
 - With the existing/present configuration, PJM found the bus fault with delayed clearing was less severe than the most critical fault defined in the Artificial Island Operating Guide (AIOG)
 - With the future configuration:
 - The critical outage condition changes
 - The critical contingency changes
 - Given the new information, faster clearing times provided by the new relay systems will not impact the clearing times for the critical contingency with the new/proposed configuration. The benefit of the approved protection upgrade is being re-evaluated

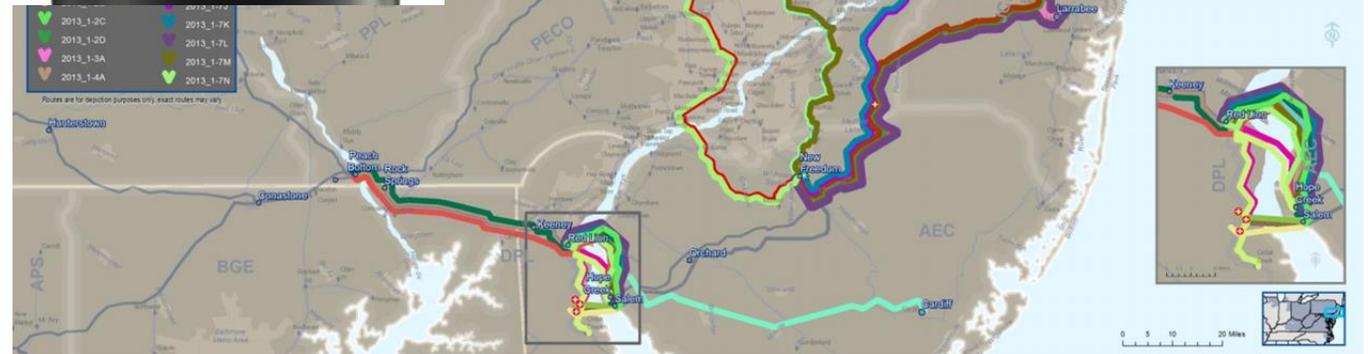
- PJM procedures evaluate generator stability with the unit at unity power factor
- No instances observed in real-time operation where power factor at unity or with a leading (absorbing MVAR) power factor
- Plots below of units with a lagging (producing MVAR) power factor



- One event when Hope Creek and Salem bus voltages exceeded 550 kV in 4.5 years (October 30, 2012 12am-8am)
 - Hurricane Sandy
 - Salem Unit 2 was offline prior to this period and Salem Unit 1 went offline in this window.
- All other measurements were between 525kV and 550kV



- Performing updated analysis with new relay clearing times
- Performing updated analyses of the different configurations (i.e. Salem connection, HC connection) with updated assumptions like transformer impedances
- Evaluating the impact of each of the components of the overall AI solution



Images:

[http://www04.abb.com/global/seitp/seitp202.nsf/0/9feda7f47b15cf1dc1257d3b002b3c72/\\$file/525+kV_copper_0360_.jpg](http://www04.abb.com/global/seitp/seitp202.nsf/0/9feda7f47b15cf1dc1257d3b002b3c72/$file/525+kV_copper_0360_.jpg)

<http://www07.abb.com/images/librariesprovider16/web-pages/about/technology/abb-technologies-that-changed-the-world/facts-svc-technologie.jpg?sfvrsn=1>

- Complete Protection & Control Team review
- Complete Solution Space Team analysis and recommendations
- Finalize documentation
- February 2017 – Staff recommendation to PJM Board



Clean Power Plan Reliability Studies

- Provide a representative overview of the types of reliability issues that can be expected.
- Each scenario has a distinct portfolio of generation additions and retirements derived from the economic studies PJM has performed.
- The starting base case that each of the scenarios will be built from is the 2019/20 RPM power flow model.
- All scenarios will be studied for a 2025 load year

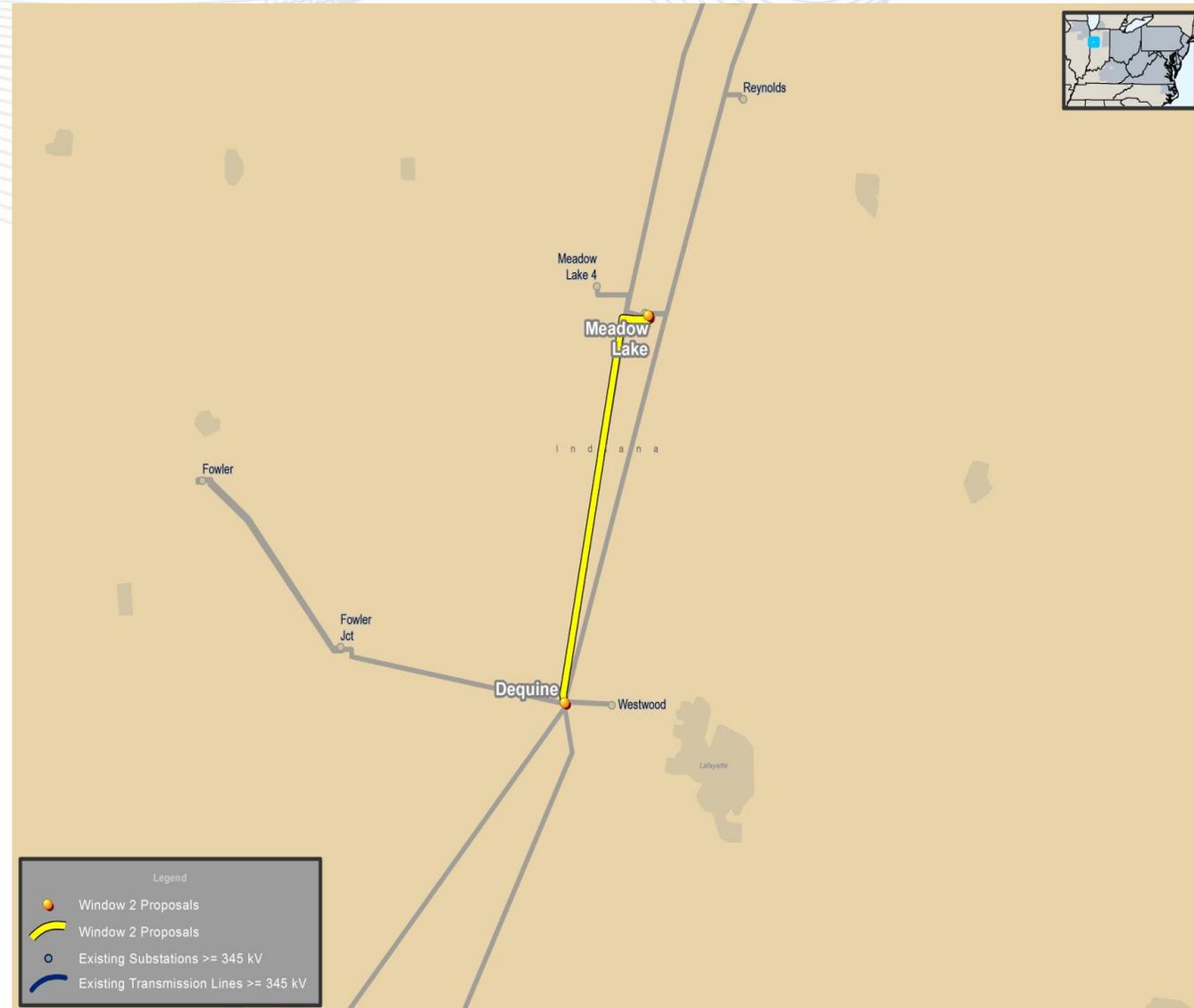
- Generator deliverability will be performed on the following scenarios
 - Reference
 - Trade Ready Mass
 - Trade Ready Rate
- Load deliverability will be performed only on the Reference scenario power flow model, but selected individual LDAs will be updated and examined separately to account for the most severe scenario for that LDA if the LDA's forecast CETO exceeds its forecast CETL
 - Reference: BGE & MAAC
 - Reference 5/20: DLCO & EMAAC
 - State MASS NSC: Dayton
 - Low Natural Gas Price: APS & AEP
- PV analysis will be performed on the following scenarios
 - Reference
 - Trade Ready Mass
 - Trade Ready Rate
 - State Mass
 - State Mass NSC
 - State Rate

- The reliability power flow models for each scenario are currently under construction and expect to be completed in early November.
- The reliability studies will commence once the power flow models are completed and are expected to be completed by early December



2016 RTEP Proposal Window #2 Updates and Recommendations

- Generation Deliverability (FG# 64):
- Dequine to Meadow Lake 345 kV circuit #2 is overloaded for loss of the Dequine to Meadow Lake 345 kV circuit #1.
- **Alternatives considered:**
 - 2016_2-7H (\$33.7 M)
 - 2016_2-7I (\$29.1 M)
 - 2016_2-7K (\$28.1 M)
 - 2016_2-7J (\$6.6 M)
 - 2016_2-7P (\$127.6M)
 - 2016_2-9I (\$80.5 M)
 - 2016_2-11C (\$102.4 M)
 - 2016_2-13G (\$136.9 M)
- **Recommended Solution:**
 - Reconductor the entire Dequine - Meadow Lake 345kV circuit #2. (2016_2-7J) (B2776)
- **Estimated Project Cost:** \$ 6.6 M
- **Required IS Date:** 6/1/2021



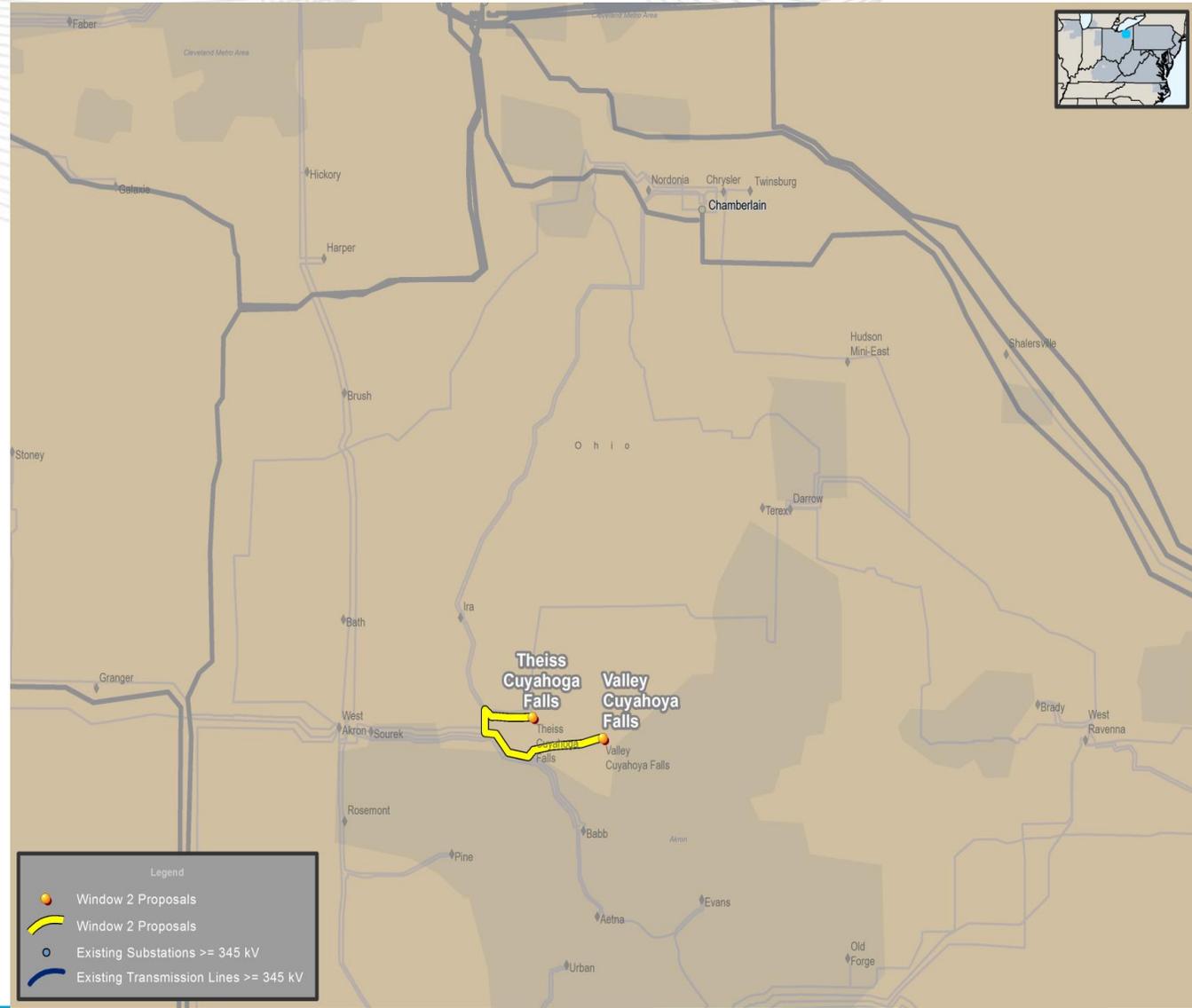
- Baseline and Generation Deliverability (FG# 101, 102 128, 130, 131,134) :
- Eugene to Dequine 345 kV circuit #1 is overloaded for several single contingencies.
- **Alternatives considered:**
 - 2016_2-6B (\$32.5 M)
 - 2016_2-7L (\$113.7 M)
 - 2016_2-7M (\$99.1 M)
 - 2016_2-7N (\$22.19 M)
 - 2016_2-7O (\$99.3M)
 - 2016_2-7P (\$127.6M)
 - 2016_2-9I (\$80.5 M)
 - 2016_2-11C (\$102.4 M)
 - 2016_2-13G (\$136.9 M)
- **Recommended Solution:**
 - Reconductor the entire Dequine - Eugene 345kV circuit #1. (2016_2-7N) (B2777)
- **Estimated Project Cost:** \$ 22.19 M
- **Required IS Date:** 6/1/2021



- N-1-1 Voltage (FG# N2-VM5, N2-VM6) :
- Low voltage violation at Valley and Theiss Road 138 kV stations for the N-1-1 contingency loss of the Chamberlain 345/138 kV transformer and the Valley – Babb 138 kV circuit .

- **Alternatives considered:**
 - 2016_2-8B: Install one 138kV 50MVAR Capacitor Bank, one Capacitor switcher, one MOAB's, three CCVT, one Standard Relay panel, tap on Valley-Theiss 138 kV Line, fiber communication and associated relay revisions at Valley & Theiss Substations.

 - 2016_2-8C: Add 2nd 345/138kV transformer at Chamberlin substation

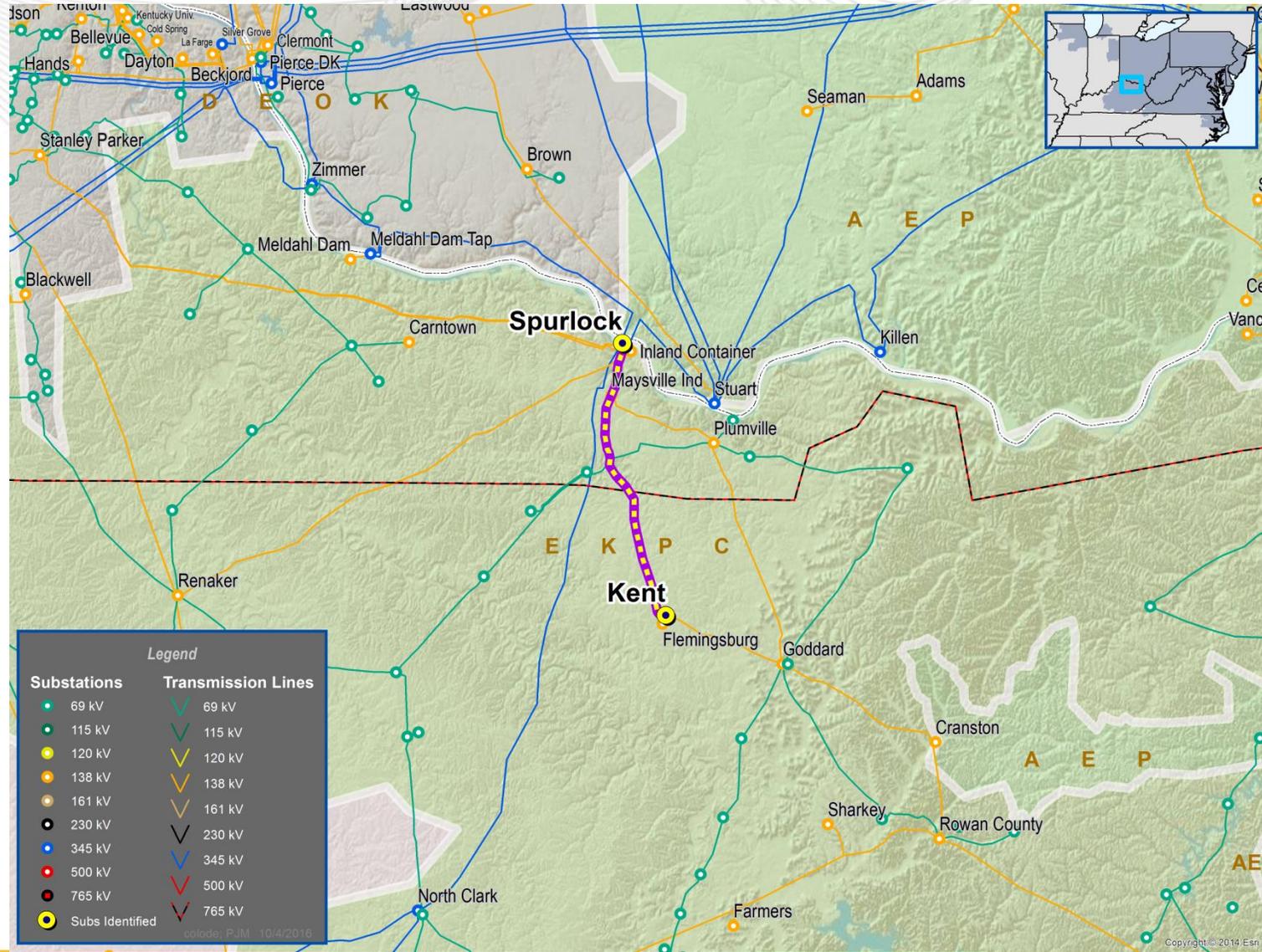


- Comparison of two Options**

	Estimated Cost (M)	Solved the issue?	Equipment availability	New site	Operational Flexibility Benefit	Reliability Improvement for the boarder area
2016_2-8B	\$ 1.8	Y	Purchase new	Yes	No	No
2016_2-8C	\$3.8	Y	A previously purchased system spare transformer already has been placed at the Chamberlin site at the open bay position.	No; Brownfield site; no additional land purchase required	Increased Operational Flexibility including transformer and breaker maintenance.	Yes; Provide additional source for the area

- Recommended Solution:** Add 2nd 345/138kV transformer at Chamberlin substation (2016_2-8C) (B2778)
- Estimate Cost:** \$3.8M
- Required IS Date:** 6/1/2021

- Common Mode Outage (FG# 905, 906):
- Spurlock – Kenton 138 kV circuit is overloaded for loss of the tower lines of the Spurlock – Stuart 345KV and the Spurlock- Meldahl 345kV
- **Alternatives considered:**
 - 2016_2-3C (\$19.0 M)
 - 2016_2-3F (\$63.0 M)
 - 2016_2-5A (\$2.5 M)
- **Status:**
 - Evaluation is in progress



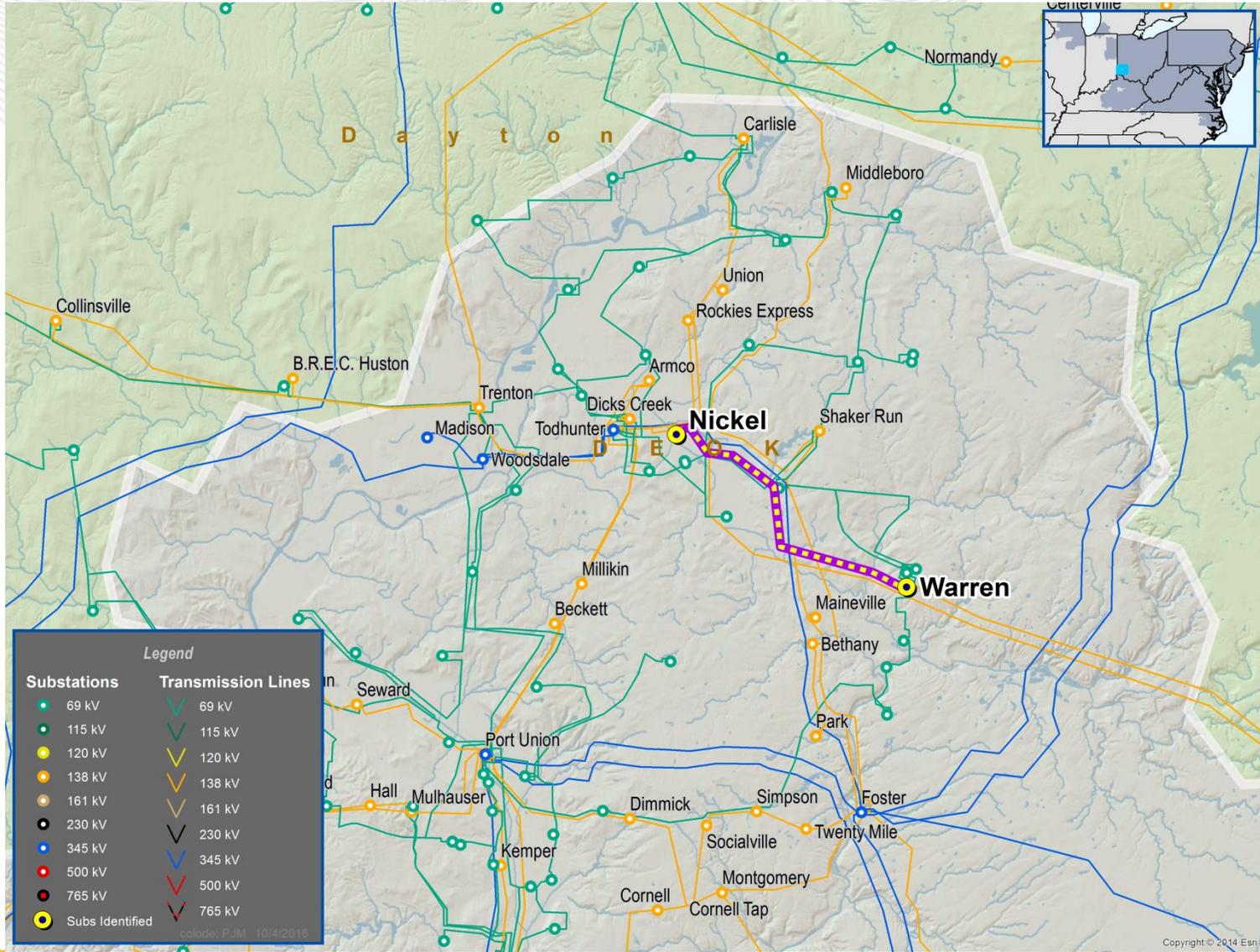
- Common Mode Outage (FG# 907):
- Nickel – Warren 138 kV circuit is overloaded for loss of the tower lines of the Todhunter – Rockies Express 138kV and the Foster- Garver 345kV

• **Alternatives considered:**

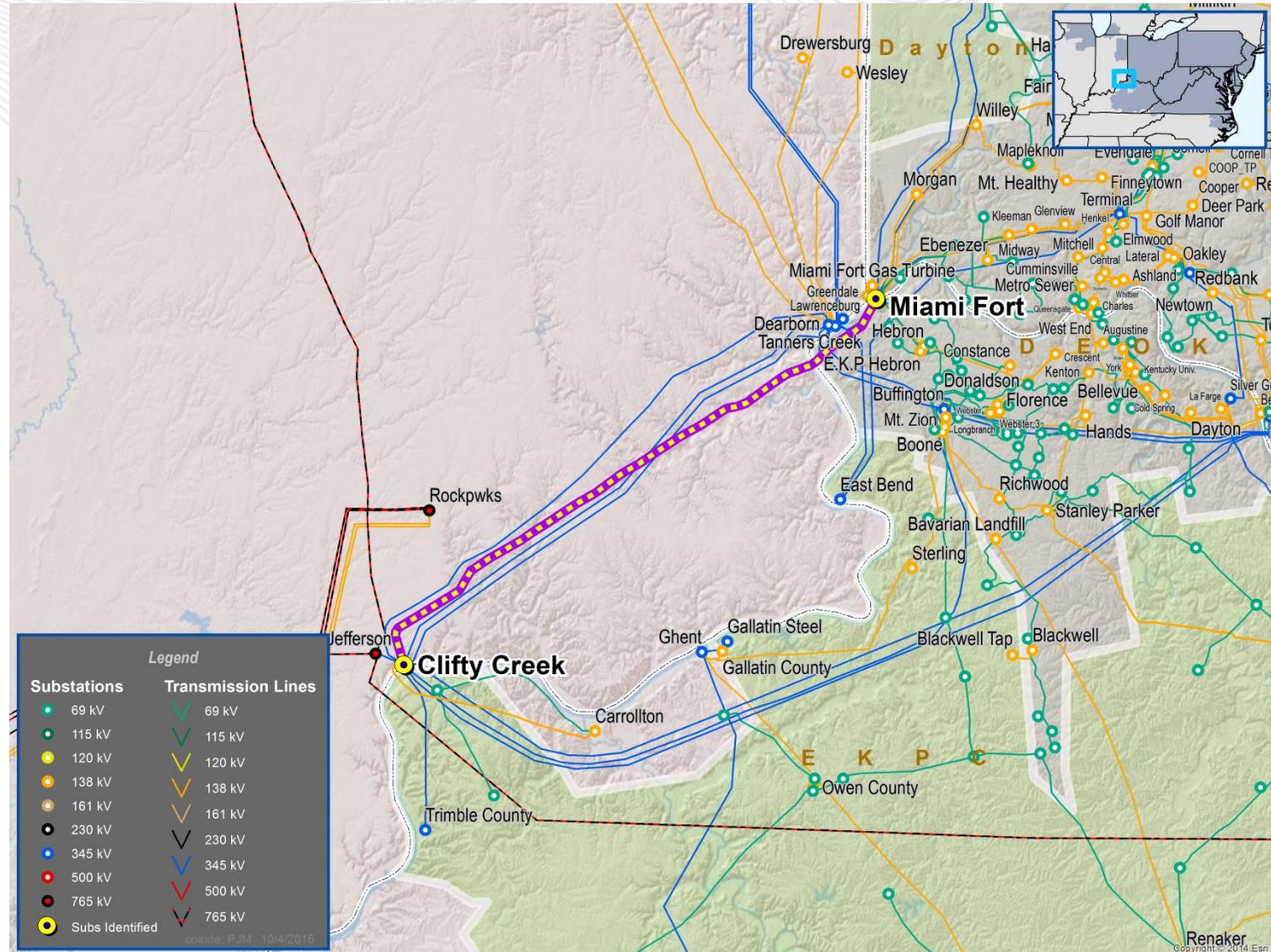
- 2016_2-1C (\$10.5 M)
- 2016_2-13I (\$11.19 M)
- 2016_2- 13J (\$14.27M)
- 2016_2-3C (\$19.0 M)
- 2016_2-3F (\$63.0 M)
- 2016_2- 6A (\$17.1M)
- 2016_2_9J (\$17.0M)
- 2016_2-10B (\$29.5M)

• **Status:**

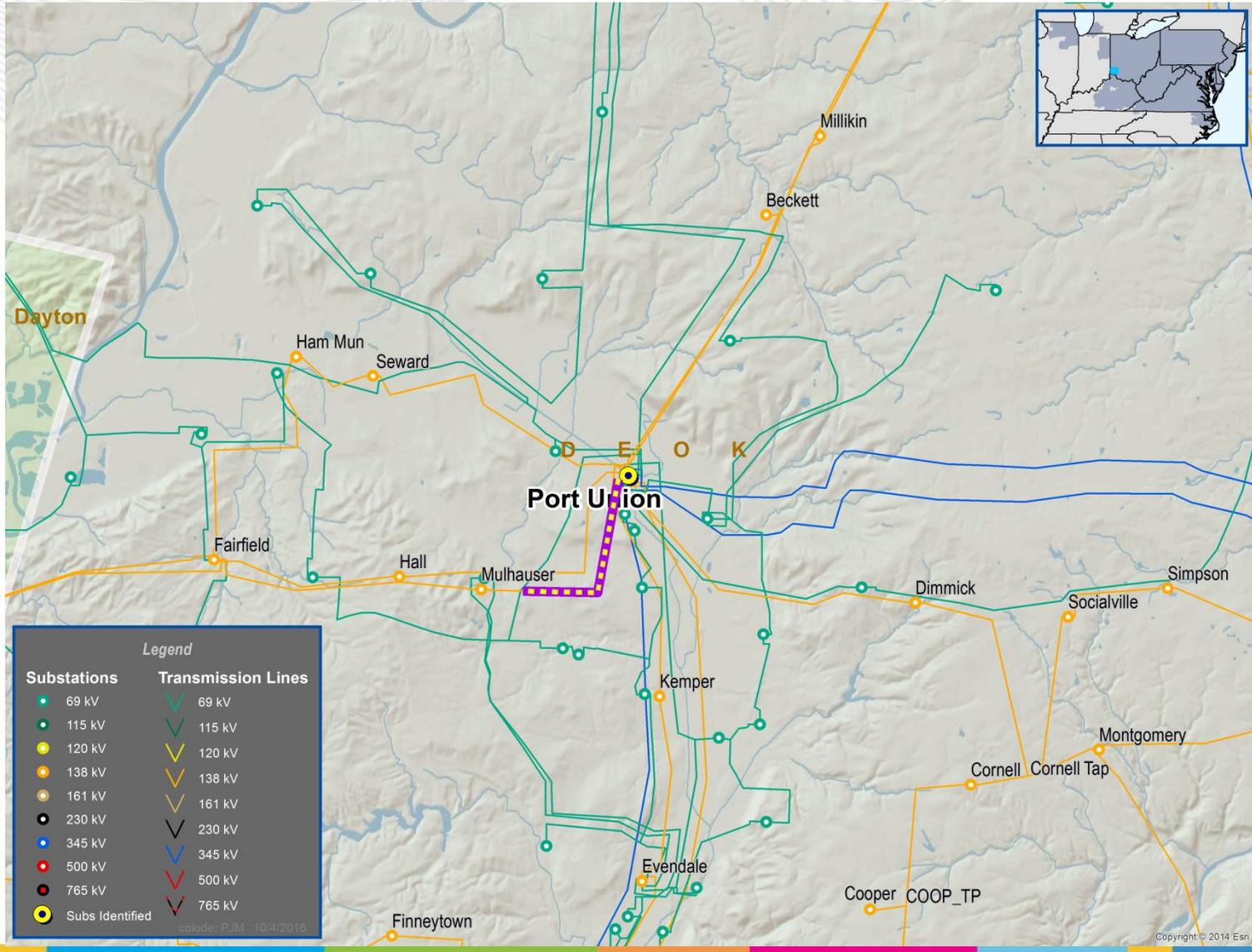
- Evaluation is in progress



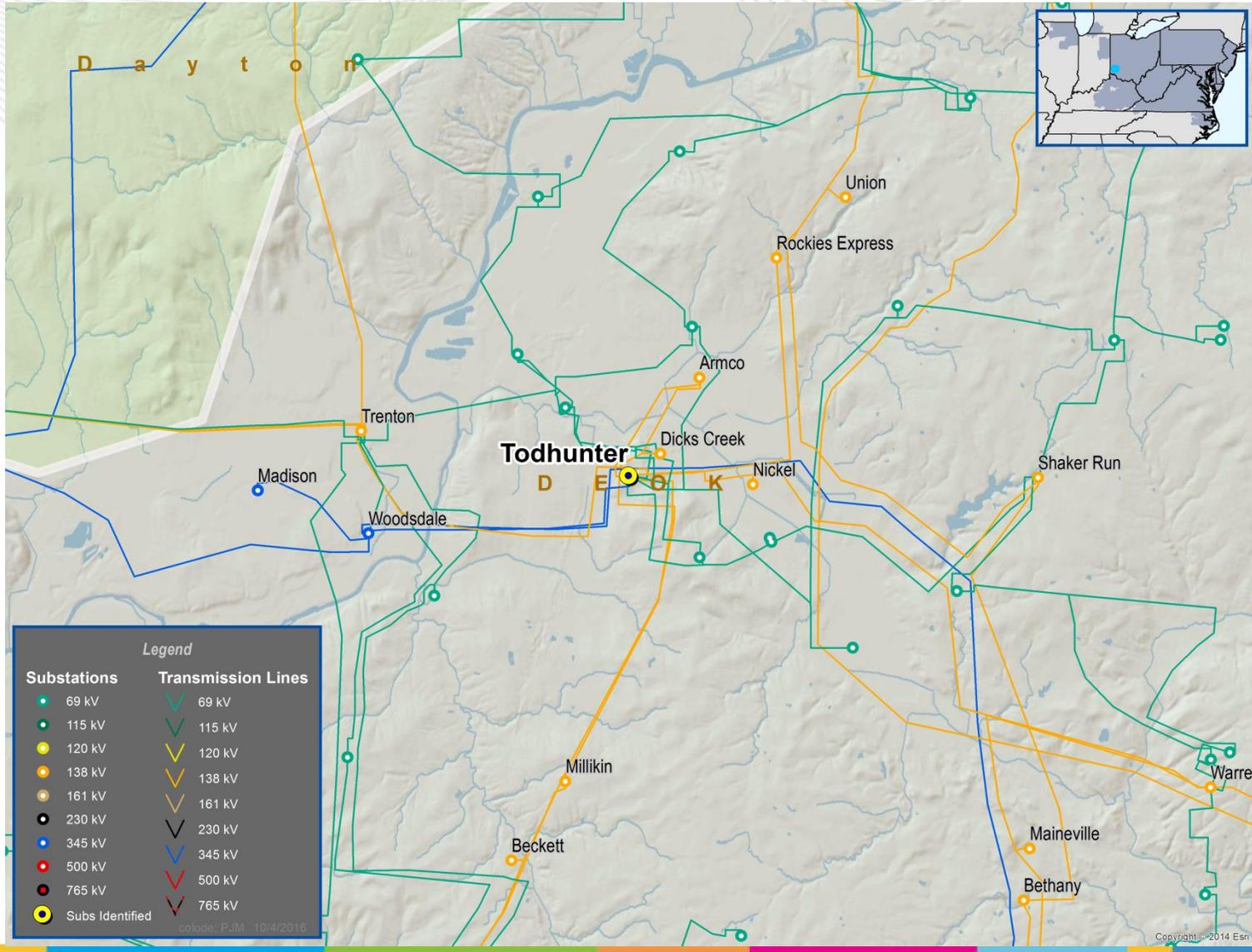
- Common Mode Outage (FG# 897, 1137):
- The Clifty Creek– Miami Fort 138 kV circuit is overloaded for multiple common model Contingencies
- **Alternatives considered:**
 - 2016_2-1B (\$1.0M)
 - 2016_2-3C (\$19.0 M)
 - 2016_2-3F (\$63.0 M)
 - 2016_2-7S (\$0.82M)
 - 2016_2-9R (\$18.7M)
 - 2016_2-9T (\$6.1M)
 - 2016_2-11D (\$44.3M)
 - 2016_2-11E (\$85.7M)
 - 2016_2-13F (\$12.4M)
- **Status:**
 - Evaluation is in progress



- N-1-1 Thermal Violation (FG# N2-T4, N2-T5):
- The Port Union – EPROV 138 kV circuit is overloaded for loss of the Todhunter – Rockies Express 138kV and the Foster-Garver 345kV
- **Alternatives considered:**
 - 2016_2-1D (\$2.2M)
 - 2016_2-3F (\$63.0 M)
 - 2016_2-9R (\$18.7M)
- **Status:**
 - Evaluation is in progress



- N-1-1 Thermal Violation (FG# N2-T6, N2-T7, N2-T8, N2-T9, N2-T10):
- The left one of the three Todhunter 345/138kV transformers is overloaded for loss of the any two of them
- **Alternatives considered:**
 - 2016_2-1A (\$18.7M)
 - 2016_2-3C (\$19.0M)
 - 2016_2-3F (\$63.0 M)
 - 2016_2-6A (\$17.1 M)
 - 2016_2-9J (\$17.0 M)
 - 2016_2-9R (\$18.7M)
 - 2016_2-10B (\$29.5M)
- **Status:**
 - Evaluation is in progress





2016 RTEP Proposal Window #3 Update

- Status: 30 Day Portion closed 10/31/2016, Final details due 11/15/2016
- Scope:
 - 2016 RTEP Winter Analysis
 - Baseline N-1 (thermal and Voltage)
 - Generation Deliverability and Common Mode Outage
 - N-1-1 (thermal and Voltage)
 - Load Deliverability (thermal and voltage)
 - 2016 RTEP Light Load Analysis
 - Baseline N-1 (thermal and voltage)
 - Generation Deliverability and Common Mode Outage
 - Short Circuit Analysis

- **Timeline**
 - Window Opened: 9/30/2016
 - Window Closed: 10/31/2016
 - Proposal definitions, simulation data and planning cost estimate due
 - Detailed Cost due: 11/15/2016
 - Additional 15 days to develop and provide detailed cost data
 - See the window documentation for additional information

- 25 total flowgates

Test/kV Level*	<200 kV	230 kV	345 kV	500 kV	765 kV	Total
Short Circuit	2		1			3
Winter Baseline N-1						0
Winter Gen Deliv/CMO	17		3			20
Winter N-1-1						0
Winter Load Deliv						0
Light Load N-1						0
Light Load Gen Deliv						0
Gen Deliv	1					1
Winter Baseline Thermal	1					1
Total	21	0	4	0	0	25

*xfmr are categorized based on low side kV

- 25 flowgates recommended for proposals
- 29 Proposals Received from 7 entities addressing 6 Target Zones
 - 17 Greenfield
 - 12 Transmission Owner Upgrade
- Next Steps
 - Begin Analysis



Immediate Need Reliability Project

- Solution Option Comparison**

	Estimated Cost (M)	Right of way Width (feet)	Additional ROW (miles)	Addresses Local Area Needs?	Ease of future area Outage Scheduling?
Option 1 (345kV double circuit)	\$ 76.5	150	~17	No	No
Option 2 (138 kV solution)	\$107.7	100	~7	Yes*	Yes

- * Local 69Kv lines built in the 1950s with wood pole construction with distribution class cross arms
- * The existing 69 kV line passes through an industrial zone and continued area industrial growth is anticipated.
- * Local wholesale distribution cooperative is also served from the 69 kV line of similar vintage and construction. This cooperative just West of this area has experienced multiple forced and momentary outages in the recent past.

- **Recommended Solution:**

- Construction a new 138 kV station, Campbell Road, tapping into the Grabill – South Hicksville 138kV line (B2779.1)
- Reconstruct sections of the Butler-N.Hicksville and Auburn-Butler 69kV circuits as 138kV double circuit and extend 138kV from Campbell Road station (B2779.2)
- Construct a new 345/138kV SDI Wilmington Station which will be sourced from Collingwood 345KV and serve the SDI load at 345KV and 138 kV respectively; (B2779.3)
- 138Kv circuits will be looped in-out of the new SDI Willington station resulting in a direct circuit to Auburn and in direct circuit to Auburn and Rob Park via Dunton Lake, and a circuit to Campbell Road; Reconnector 138kV line section between Dunton Lake – SDI Wilmington; (B2779.4)
- Expand 138kV bus at Auburn (B2779.5)

- **Estimated Project Cost: \$107.7M**

- **Required IS Date: Immediate Need**

- **Expected IS Date: 6/1/2019**

Supplemental

Supplemental Upgrade:

Install Stop Joints on 345 KV circuit J-3410, South Mahwah – Waldwick

Problem Statement:

- J-3410 is a 5.45mi fluid-filled 345kV cable.
- Today, a breach in the pipe or termination will result in a significant loss of insulating fluid.

Proposed Solution:

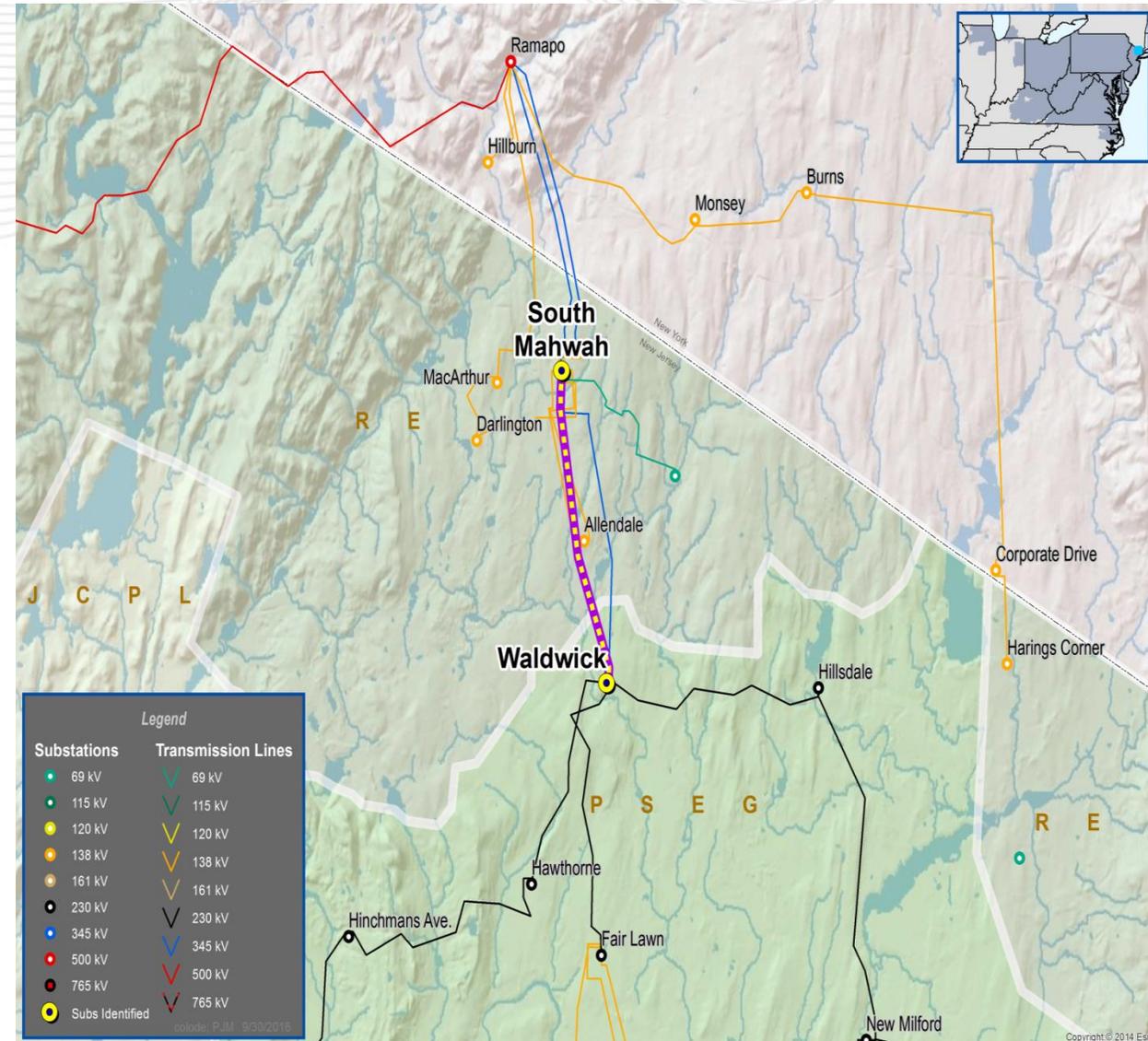
- Install two stop joints to limit the amount of fluid loss in the event of a breach.

Alternatives:

- No action. This alternative was eliminated because of the environmental risk of a breach.
- Remove 5.45 miles of pipe-type cable and replace with XLPE cable. Because no dielectric fluid is used with XLPE, it eliminates the environmental risk; however, it is significantly more expensive. It would require remove of the existing cable, widening of the trench through street openings, installation of new cable and replacement of potheads.

Estimated Cost: \$6 M

Scheduled IS Date: 5/23/2017



Previously Reviewed Baseline Upgrades for the December 2016 PJM Board Recommendation

Common Mode Outage (FG# 1026):

- The Homer City 345/230 kV transformer “S” is overloaded for a line fault stuck breaker contingency loss of the Homer City – Armstrong 345 kV circuit and Homer City 345/230 kV transformer #N.

Alternatives considered:

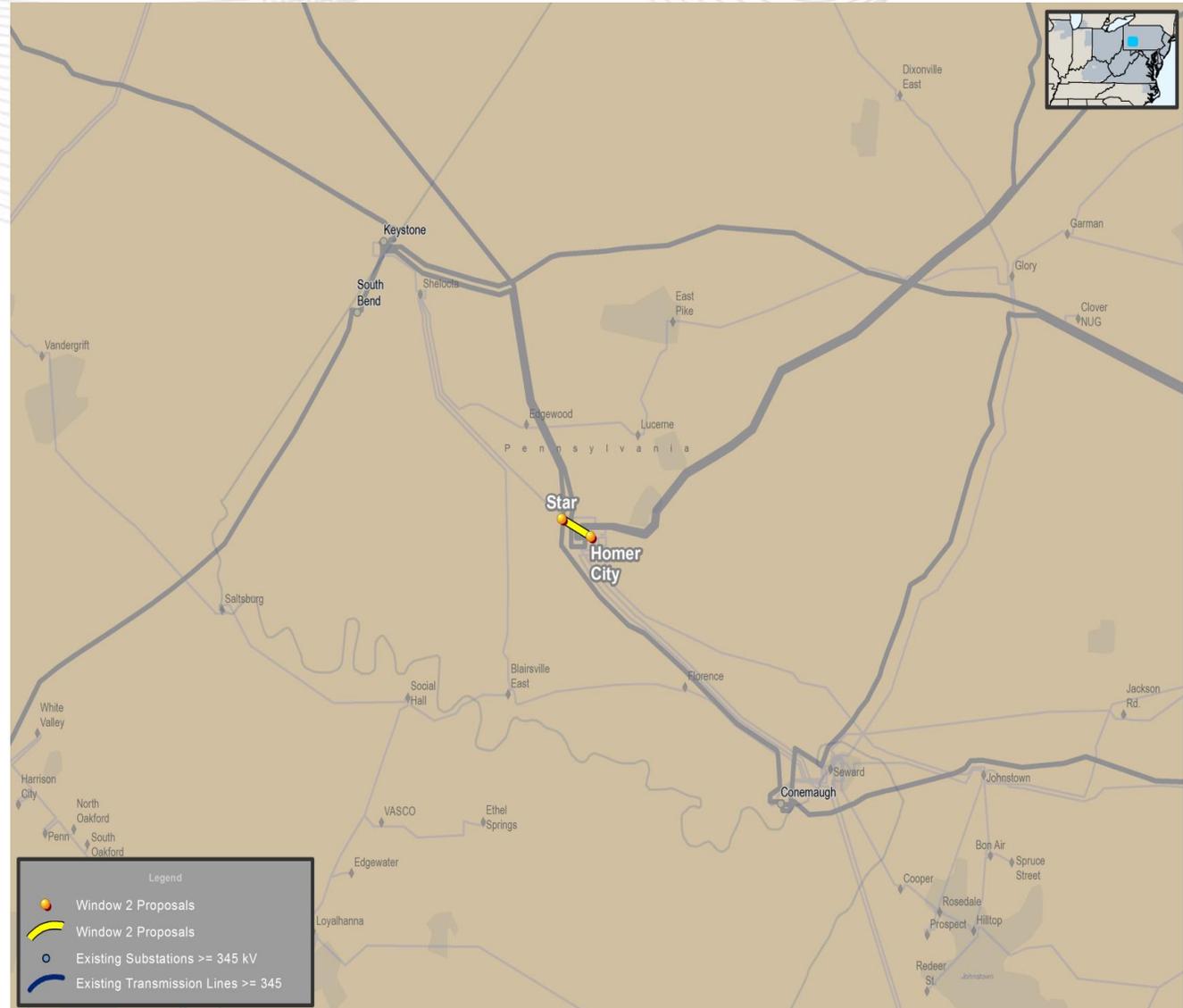
- 2016_2-3B (\$36 M)
- 2016_2-8G (\$6.6 M)
- 2016_2-9D (\$23 M)

Recommendation:

- Construct a new 345kV breaker string with three (3) 345kV breakers at Homer City and move the North autotransformer connection to this new breaker string. (b2767)

Estimated Project Cost: \$ 6.6 M

Required IS Date: 6/1/2021



Short Circuit:

- The Warren 115kV breakers are overstressed.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

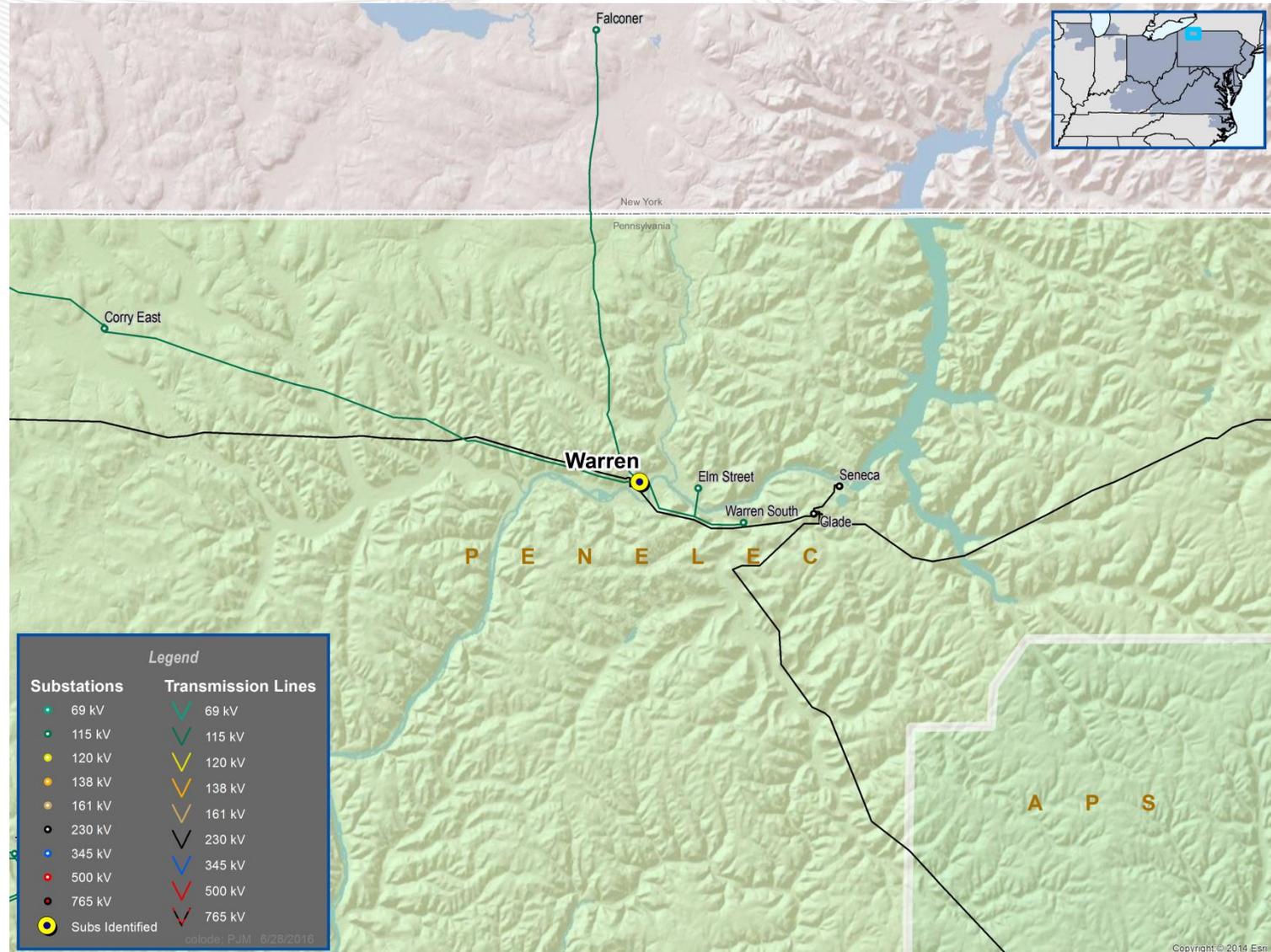
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace the Warren 115kV breakers (b2735 – b2739)

Estimated Project Cost: \$1.15 M

Required IS Date: June 1, 2018



Short Circuit:

- The Hooversville 115kV breakers 'Ralphton' & 'Statler Hill' are overstressed.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

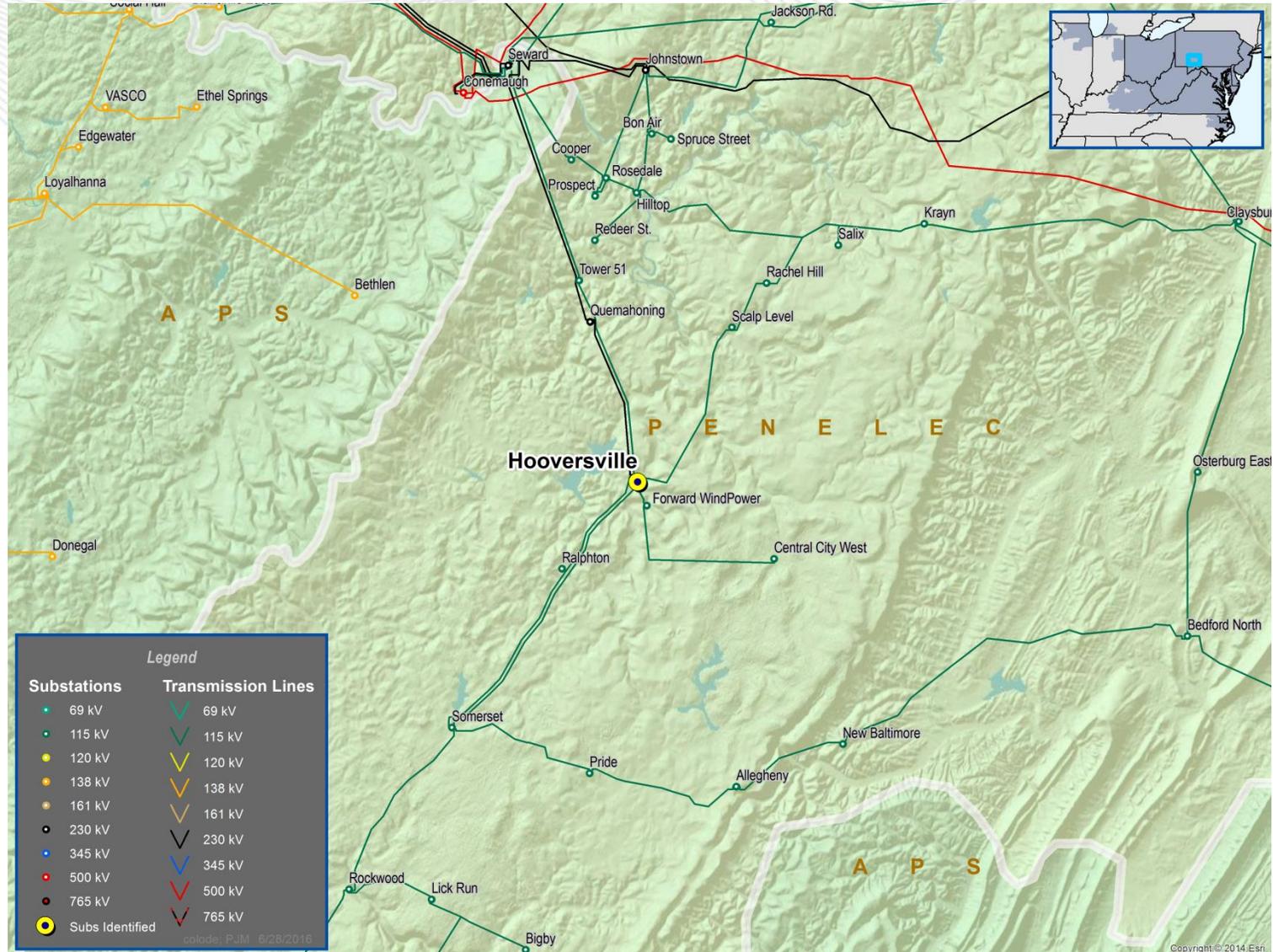
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Revise the reclosing of the Hooversville 115 kV 'Ralphton' & 'Statler Hill' (b2740 - b2741)

Estimated Project Cost: \$10 K per breaker

Required IS Date: June 1, 2018



N-1 First Energy Planning Criteria (FERC Form 715):

- Voltage violation in the Tiffany 115 kV vicinity for several contingencies.

Immediate Need:

- Due to the time – sensitive nature and current issue this problem presents, PenElec (Local TO) will be the Designated Entity

Alternatives Considered:

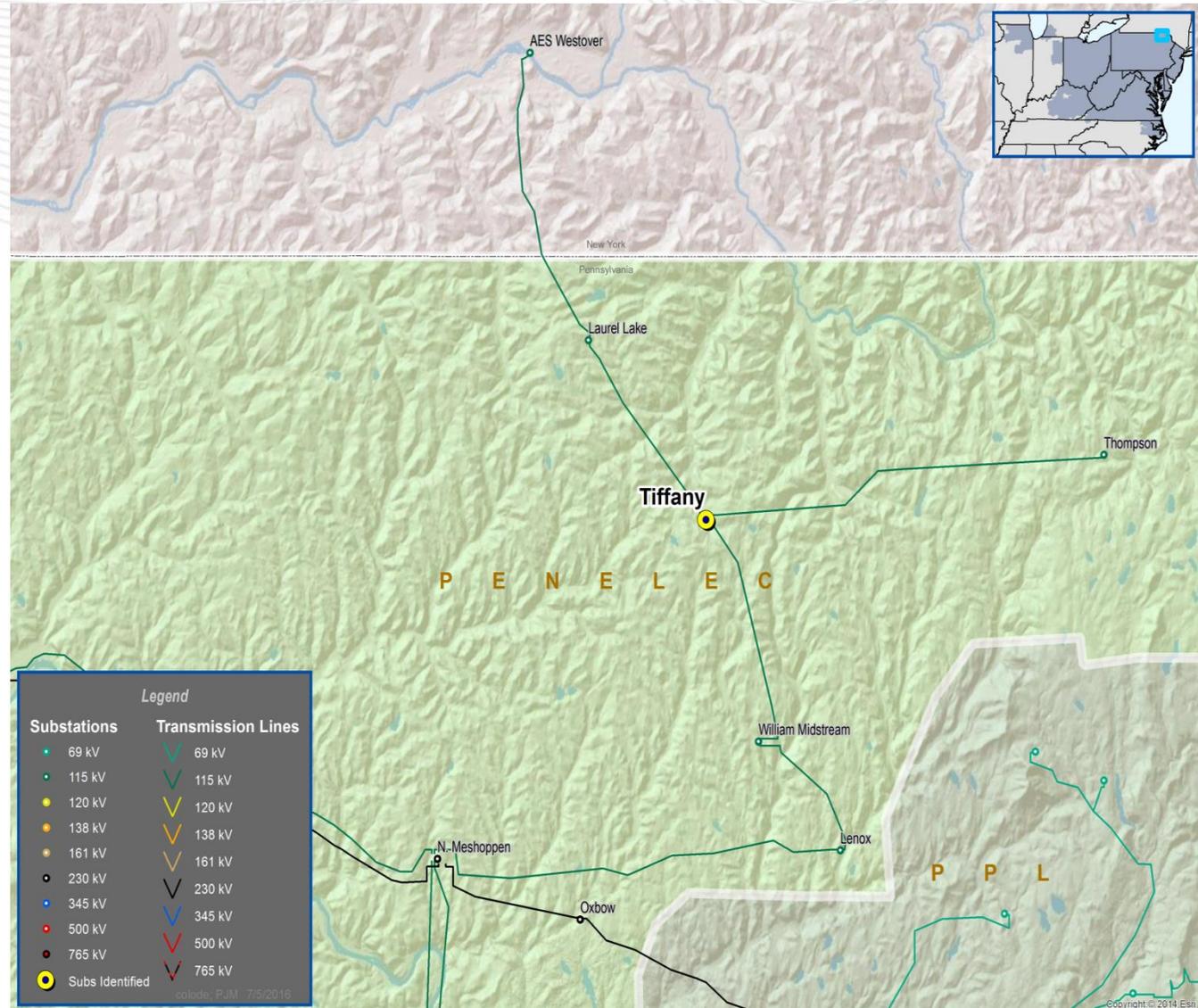
- Do to the immediate need of the project, no alternative solution was considered.

Recommendation:

- Install 2 - 28 MVAR capacitors at Tiffany 115 kV substation. (B2748)

Estimated Project Cost: \$ 2.5 M

Projected IS Date: 6/1/2017



N-1-1 Thermal (FG# N2-T1 and N2-T3):

- Carlisle to Gardners 115 kV circuit is overloaded for N-1-1 contingency loss of the Hunterstown – Gardners and Middletown Jct. – Collins – Newberry –Round Tap 115 kV circuits.

Alternatives considered:

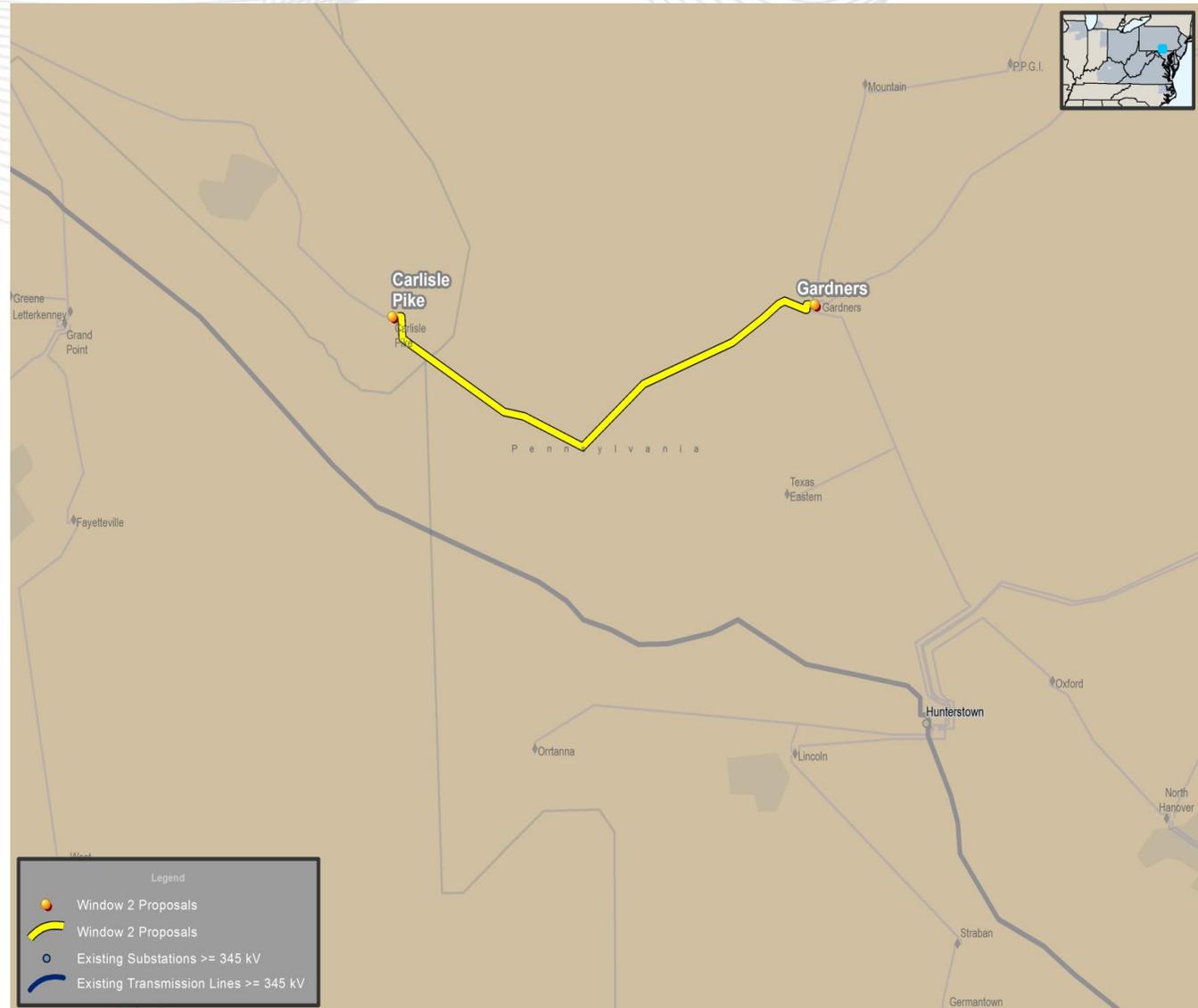
- 2016_2-3E (\$10 M)
- 2016_2-8D (\$0.1 M)
- 2016_2-9F (\$13.3 M)
- 2016_2-9G (\$18.7 M)

Recommendation:

- Upgrade bus conductor Gardners substation. Upgrade bus conductor and adjust CT ratios at Carlisle Pike. (b2765)

Estimated Project Cost: \$ 0.1 M

Required IS Date: 6/1/2021



N-1 First Energy Planning Criteria (FERC Form 715):

- The North Boyertown – West Boyertown 69 kV is overloaded for a single contingency outage of the North Boyertown – Cabot Tap 69 kV circuit.

Immediate Need:

- Due to the time – sensitive nature and current issue this problem presents, MetEd (Local TO) will be the Designated Entity

Alternatives Considered:

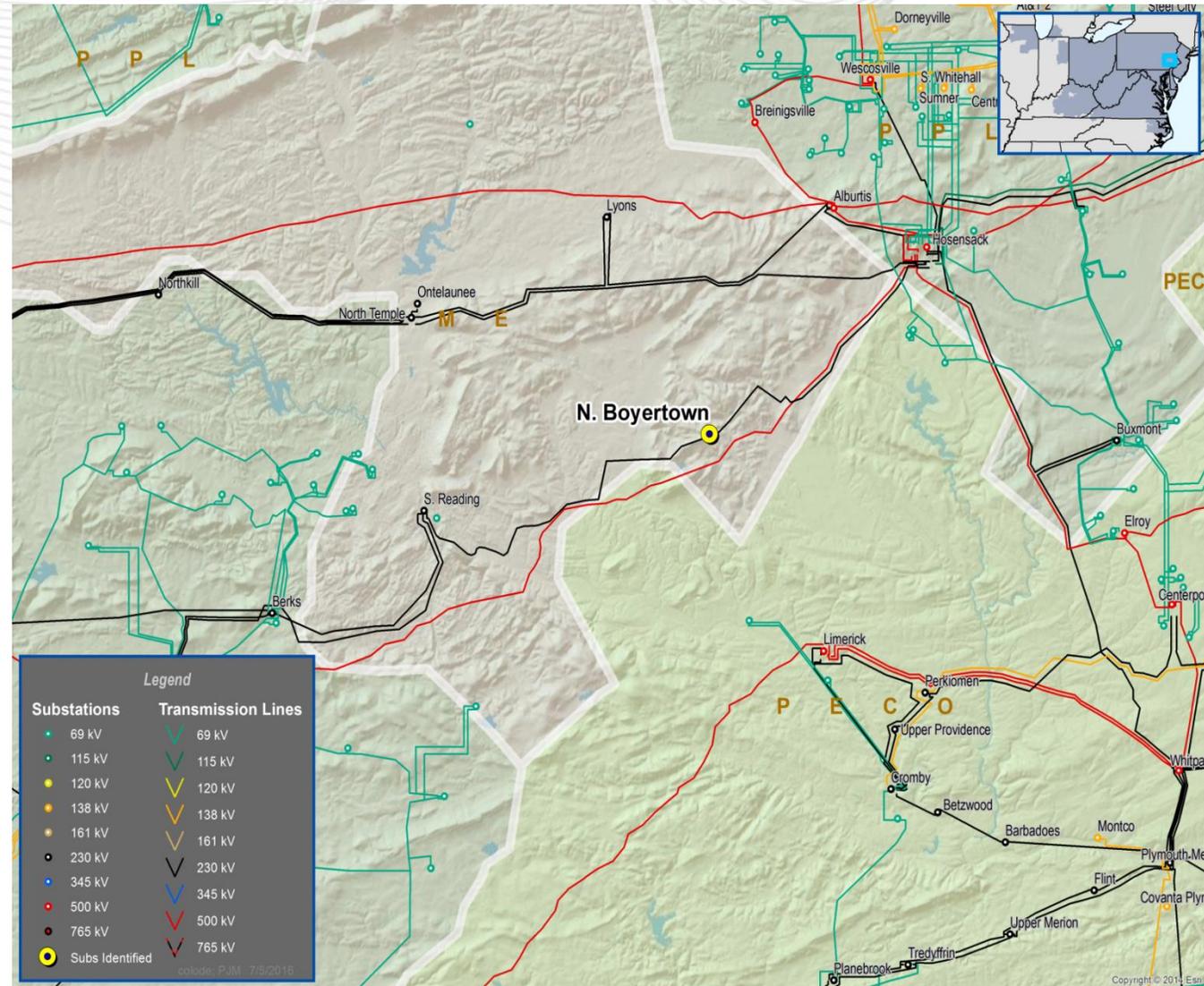
- Do to the immediate need of the project, no alternative solution was considered.

Proposed Solution:

- Replace relay at West Boyertown 69 kV station - on the West Boyertown to North Boyertown 69 kV circuit. (B2749)

Estimated Project Cost: \$ 0.05 M

Projected IS Date: 6/1/2017



Stability

- Martins Creek and Lower Mount Bethel Energy units go unstable for a 3-Phase fault at 80% of Martins Creek – Morris Park 230 kV line with zone 2 clearing

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

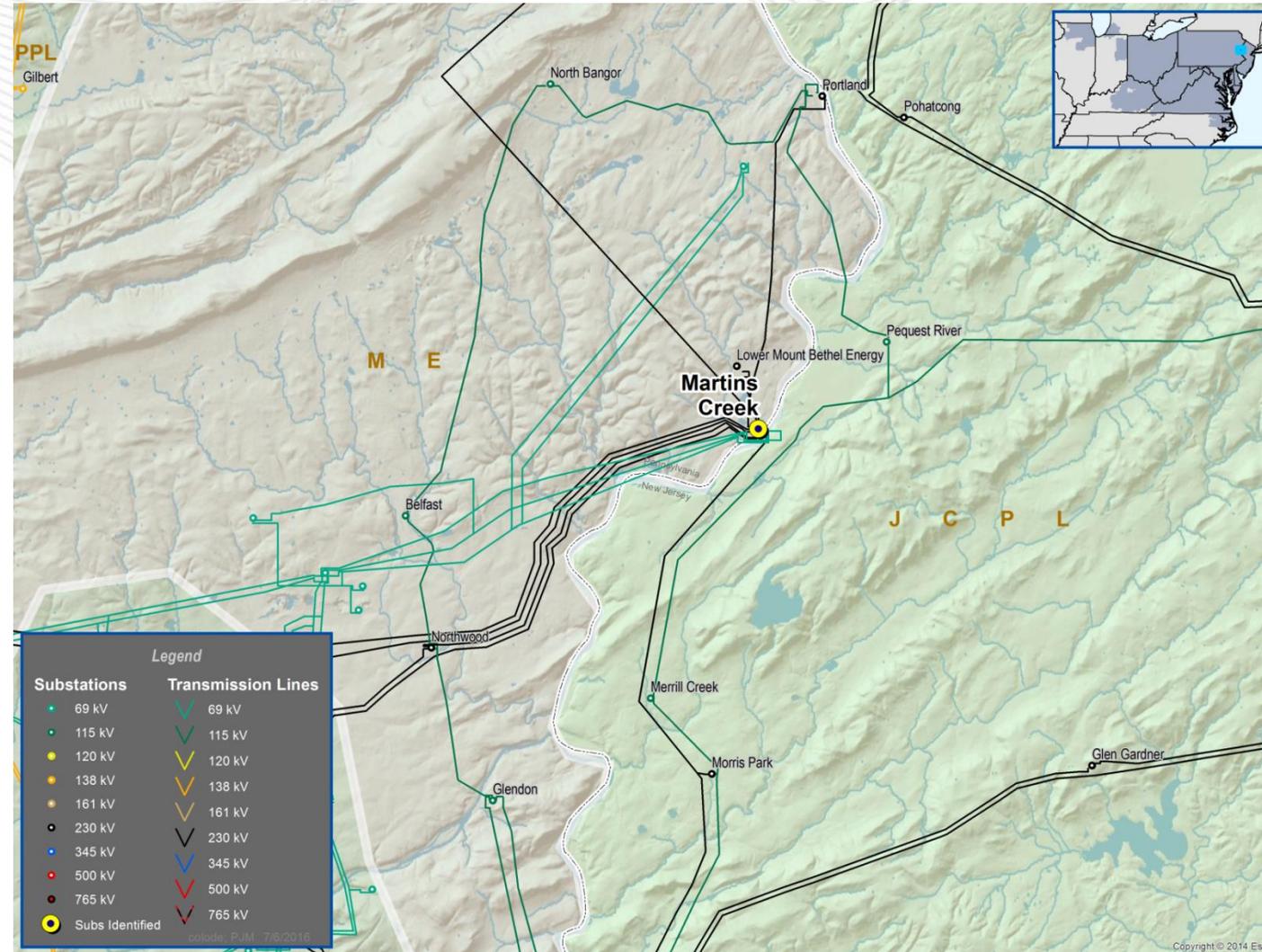
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Install 12 mi of optical pilot ground wiring (OPGW) between Gilbert and Springfield substations
 - 7 mi of construction by PPL on bulk power lines **(b2754.1)**
 - 5 mi of construction by JCPL on bulk power lines **(b2754.2)**
- Install 7 mi of all-dielectric self-supporting (ADSS) fiber optic cable between Morris Park and Northwood substations (JCPL) **(b2754.3)**
- Use ~ 40 route mi. of existing fibers on PPL system to establish direct fiber circuits **(b2754.4)**
- Upgrade relaying at Martins Creek (PPL) **(b2754.5)**; Morris Park (JCPL) **(b2754.6)**; and Gilbert (JCPL) **(b2754.7)**

Estimated Cost: \$ 1.001 M(PPL)
\$1.456 M (JCPL)

Projected IS Date: 12/01/2019



Short Circuit:

- The Martins Creek 230kV breakers are overdutied

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

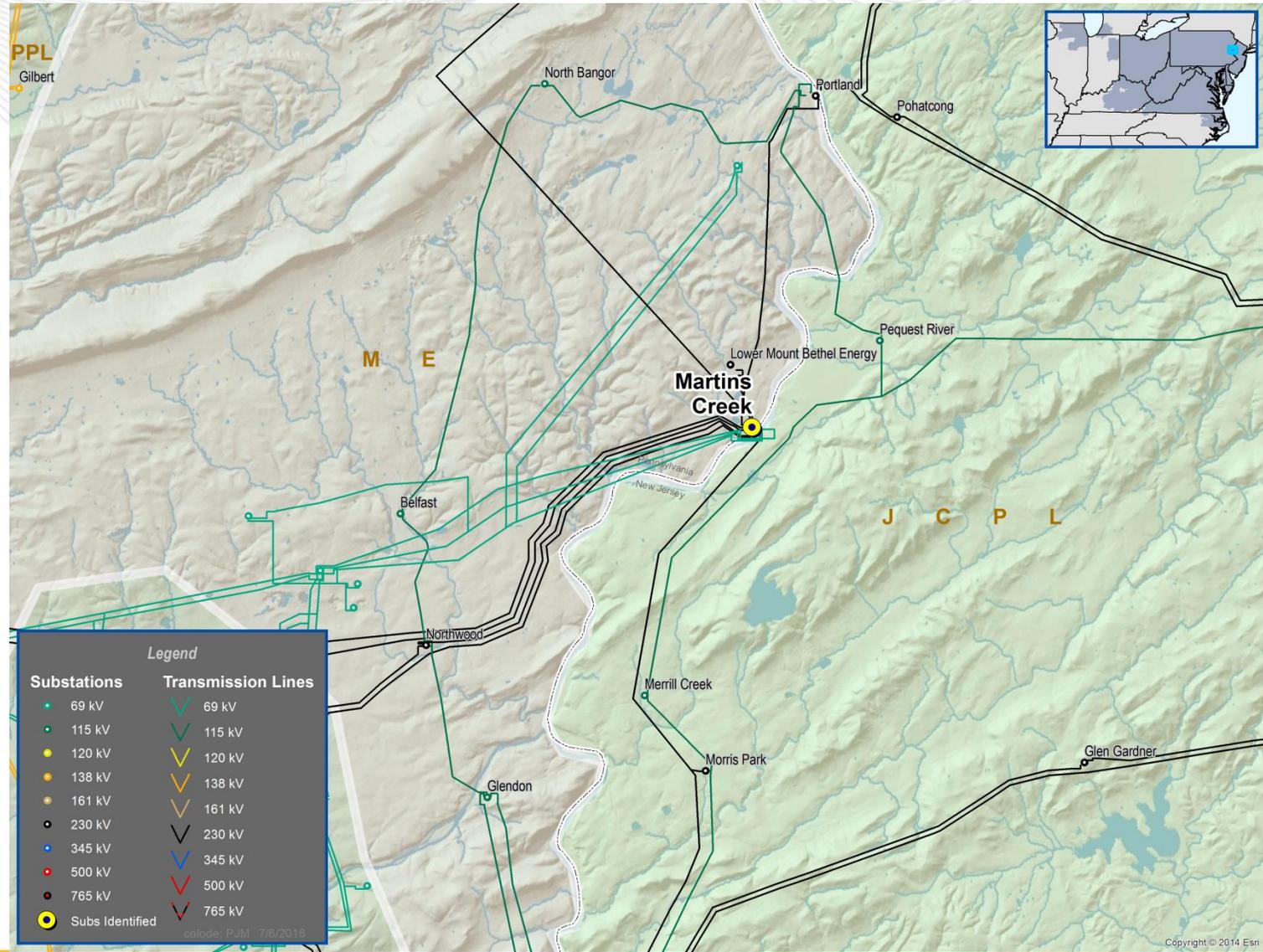
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Install 2% reactors at Martins Creek 230kV (B2756)

Estimated Cost: \$ 10 M

Required IS Date: 06/01/2018



Generation Deliverability (FG# 294, 295, 296):

- Conastone to Peach Bottom 500 kV circuit is overload pre-contingency and for the loss of the Peach Bottom – TMI 500 kV circuit.

Alternatives considered:

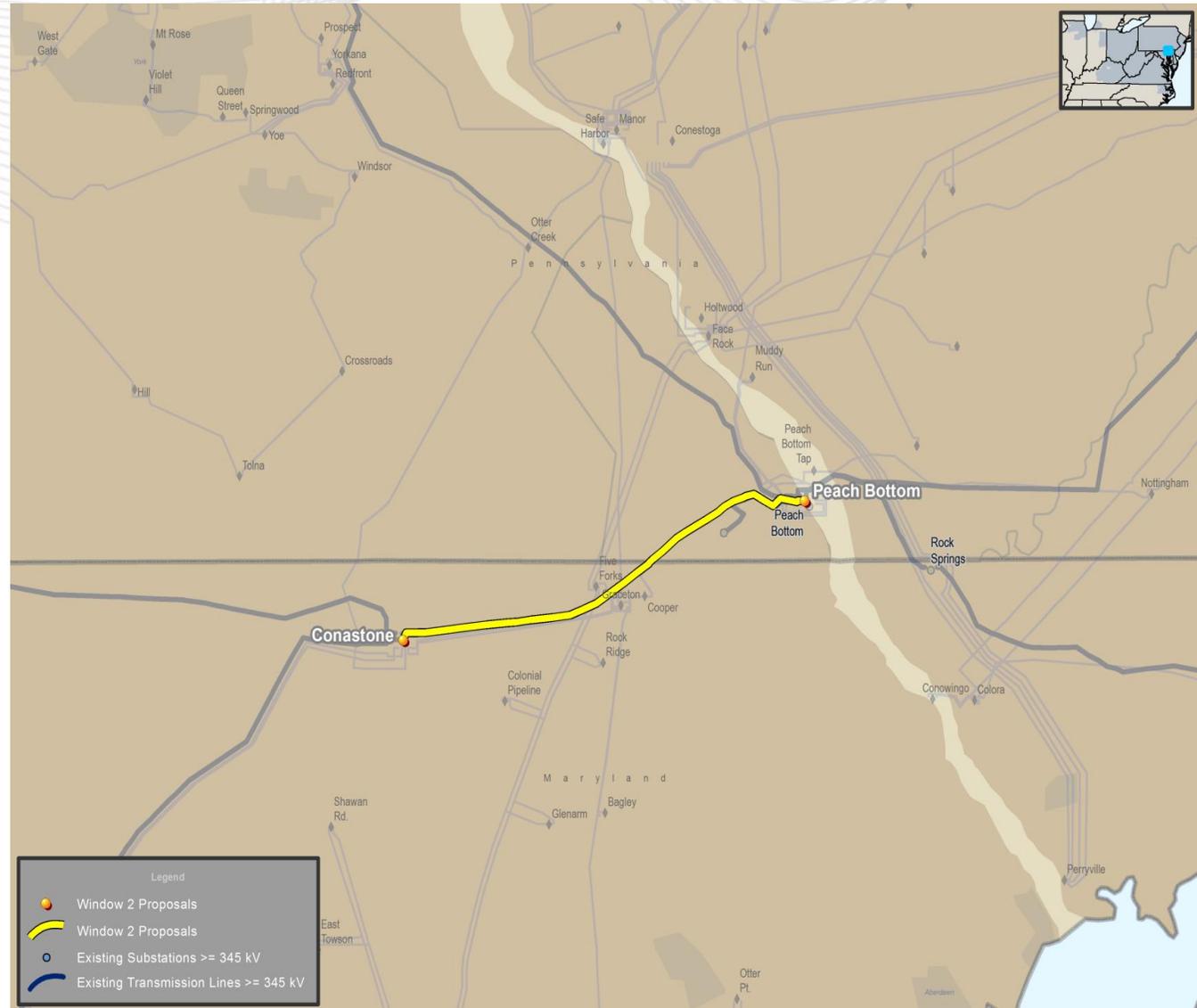
- 2016_2-4A (\$2.0 M)
- 2016_2-4B (\$7.0 M)
- 2016_2-9A (\$12.5 M)
- 2016_2-9B (\$19.2 M)
- 2016_2-9P (\$26.8 M)
- 2016_2-9Q (\$13.4 M)

Recommendation:

- Upgrade Substation Equipment at Conastone and Peach Bottom to increase facility rating to 2826 MVA normal and 3525 MVA emergency. (b2766.1 - b2766.2)

Estimated Project Cost: \$ 7.0 M

Required IS Date: 6/1/2021





PSEG Transmission Area

Short Circuit:

- The Bergen 138kV breakers “40P” and “90P” are overstressed.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

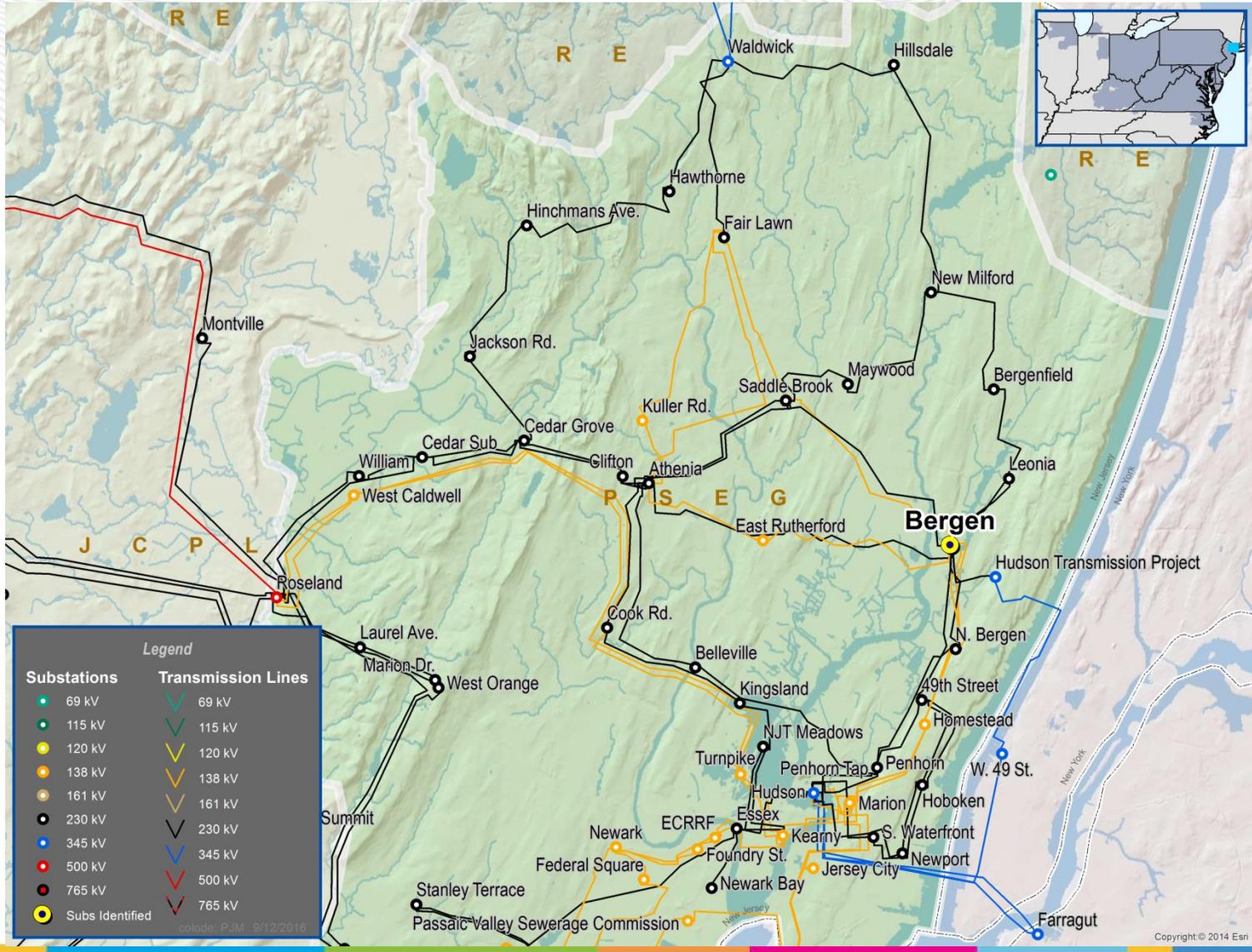
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace the Bergen 138kV breakers “40P” and “90P” with 80kA breakers (b2712 – B2713)
- PSEG Fossil is responsible for 100% of the cost allocation

Estimated Cost: \$3.27 M per breaker

Required IS Date: 06/01/2018



Short Circuit:

- The Mickleton 69kV breakers “PCB A,” “PCB B,” “PCB C,” and “PCB D,” are overstressed

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

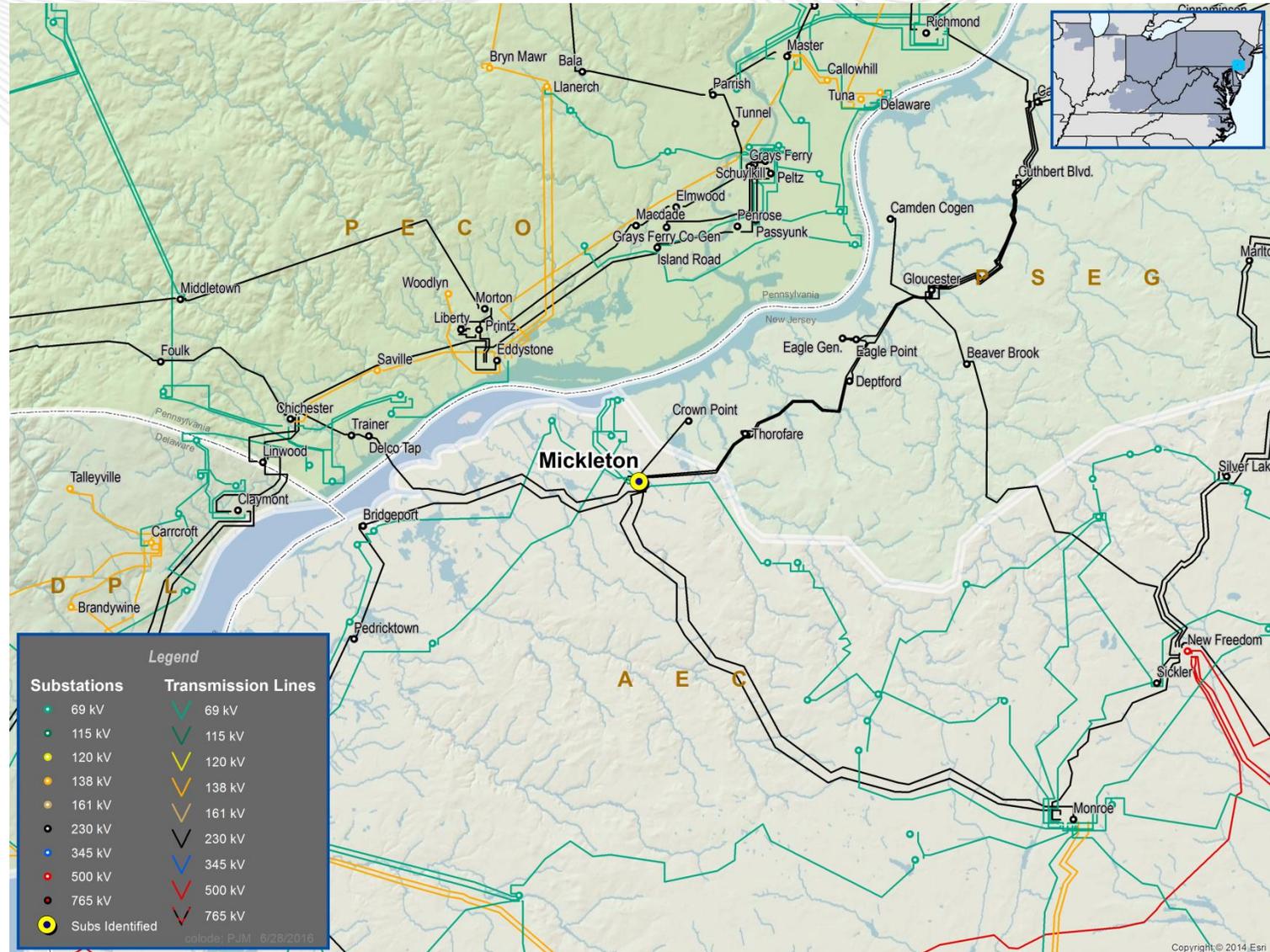
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace the Mickleton 69kV breakers “PCB A,” “PCB B,” “PCB C,” and “PCB D,” with 63kA breakers (b2723.1-b2723.4)

Estimated Project Cost: June 1, 2018

Required IS Date: \$357 K per breaker



Baseline and Common Mode Outage (FG# 109, 916):

- The Bredinville – Cabrey Tap 138 kV circuit is overloaded for 138 kV tower contingency loss of the McCalmont – Mt. Gathering – Cobot – Houseville – Fawn.

Alternatives considered:

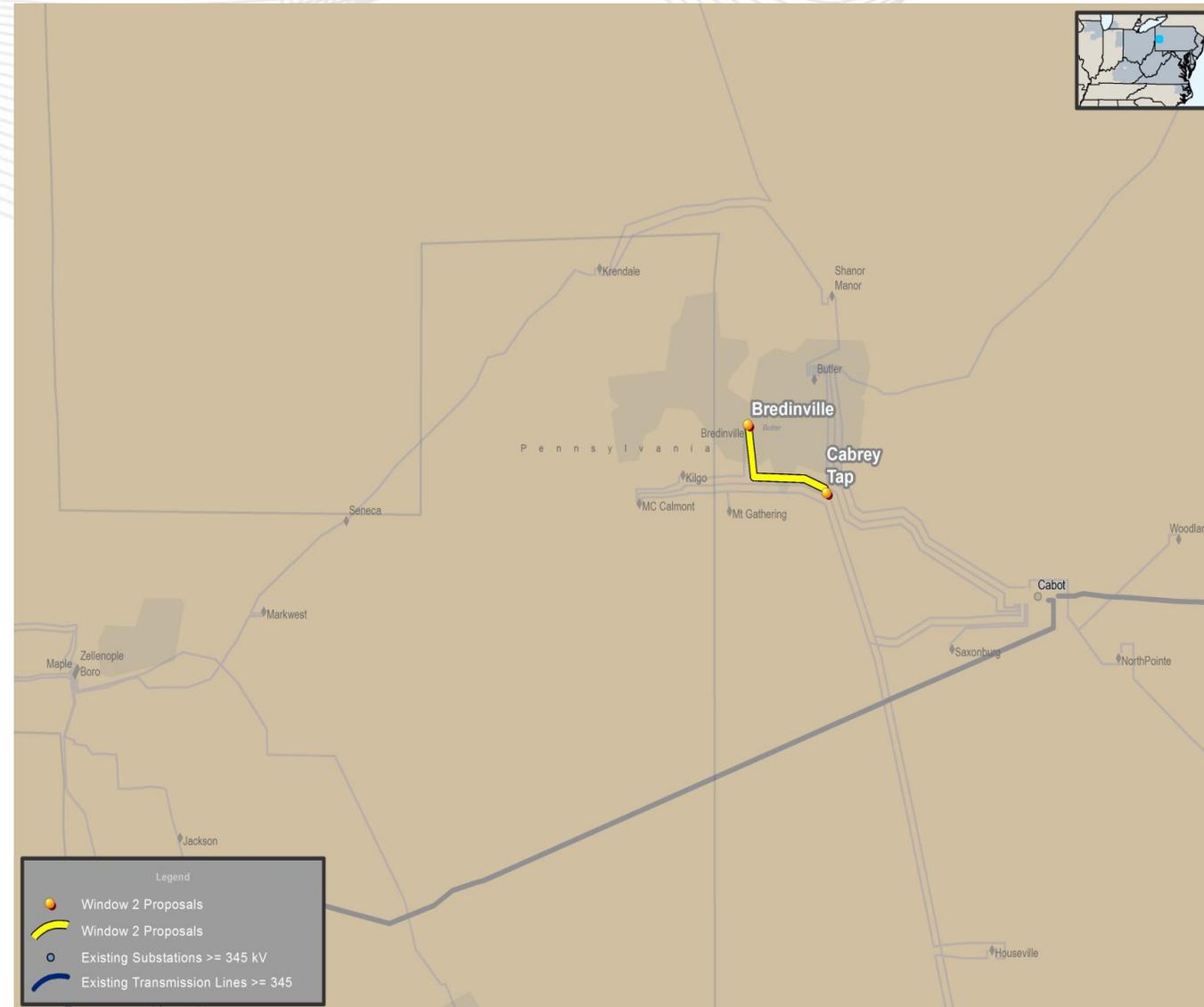
- 2016_2-3D (\$12 M)
- 2016_2-8K (\$0.97 M)
- 2016_2-9C (\$7.4M)
- 2016_2-9BS(\$12.1 M)

Recommendation:

- Replace the Breaker Risers and Wavetrapp at Bredinville Substation on the Cabrey Junction terminal. (b2763)

Estimated Project Cost: \$ 0.97 M

Required IS Date: 6/1/2021





APS Transmission Zone

N-1-1 Thermal (FG# N2-T2):

- Fairview to Flat Run 138 kV circuit is overloaded for N-1-1 contingency loss of the Belmont – Middlebourne – Jacksonburg 138 kV.

Alternatives considered:

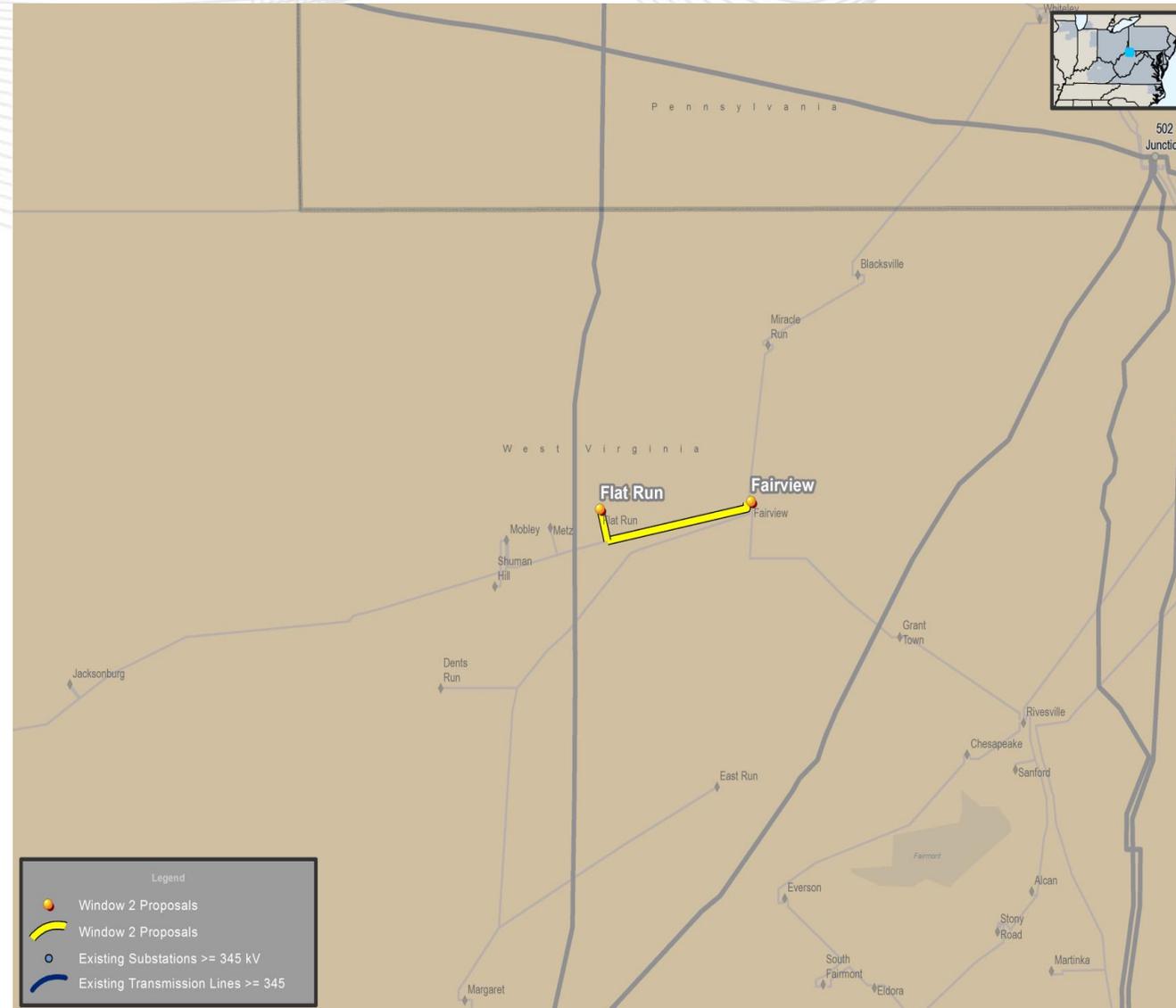
- 2016_2-8E (\$ 0.03 M)
- 2016_2-9O (\$ 9.3 M)

Recommendation:

- Upgrade breaker risers and disconnect leads;
Replace 500 CU breaker risers and 556 ACSR disconnect leads with 795 ACSR.. (b2764)

Estimated Project Cost: \$ 0.03 M

Required IS Date: 6/1/2021



Problem: Short Circuit

- The Hoytdale 138 kV '83-B-26' and '83-B-30' breakers (40kA) are overstressed

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

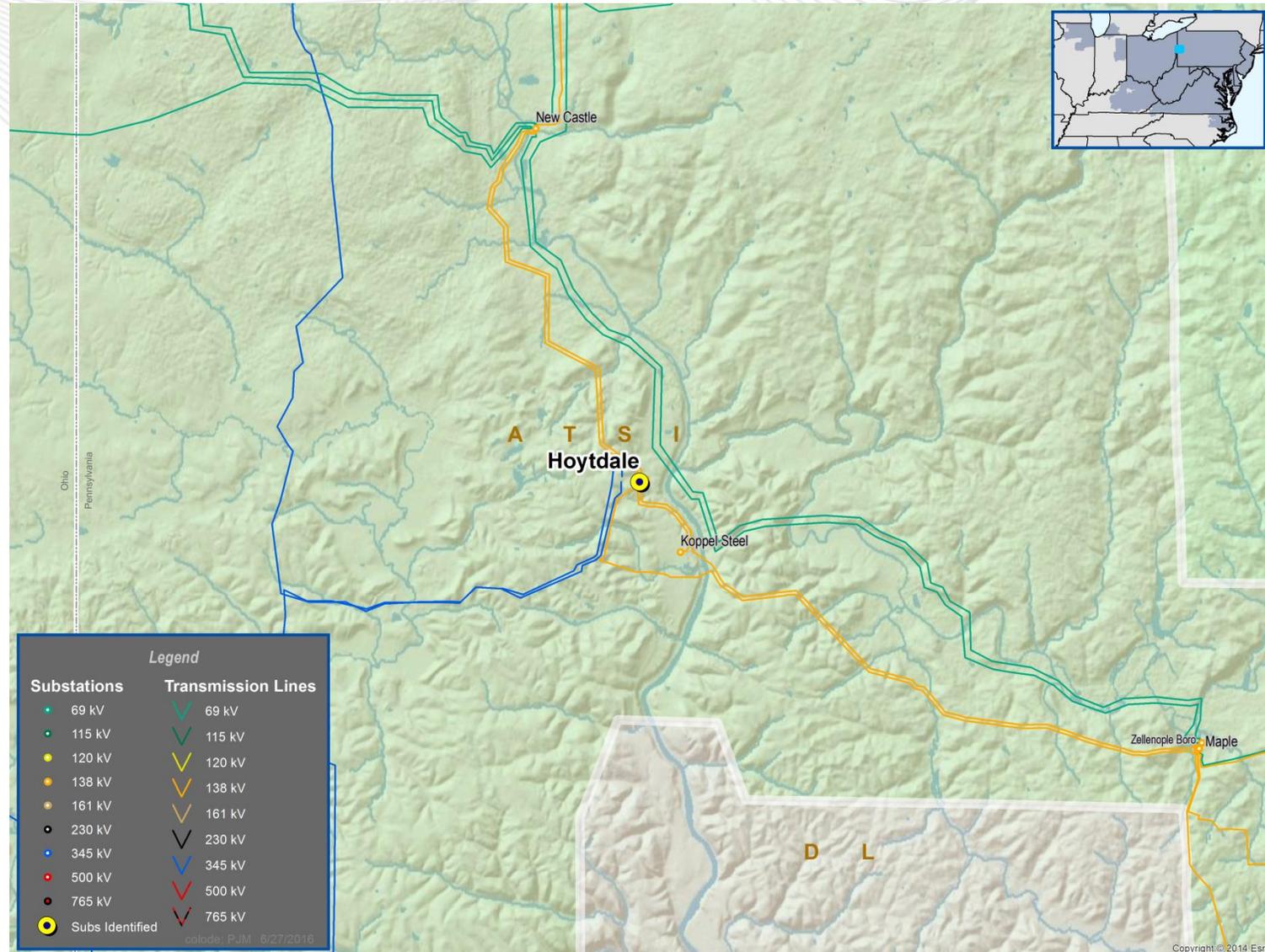
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace the Hoytdale 138 kV '83-B-26' and '83-B-30' breakers with 63 kA breakers (b2742)

Estimated Project Cost: \$410K

Required IS Date: 6/1/2017



Generation Deliverability (FG# 150):

- Saltville to Tazewell 138 kV circuit is overloaded for the loss of the Jackson Ferry – Broadford 765 kV and Broadford 138 kV bus tie .

Alternatives considered:

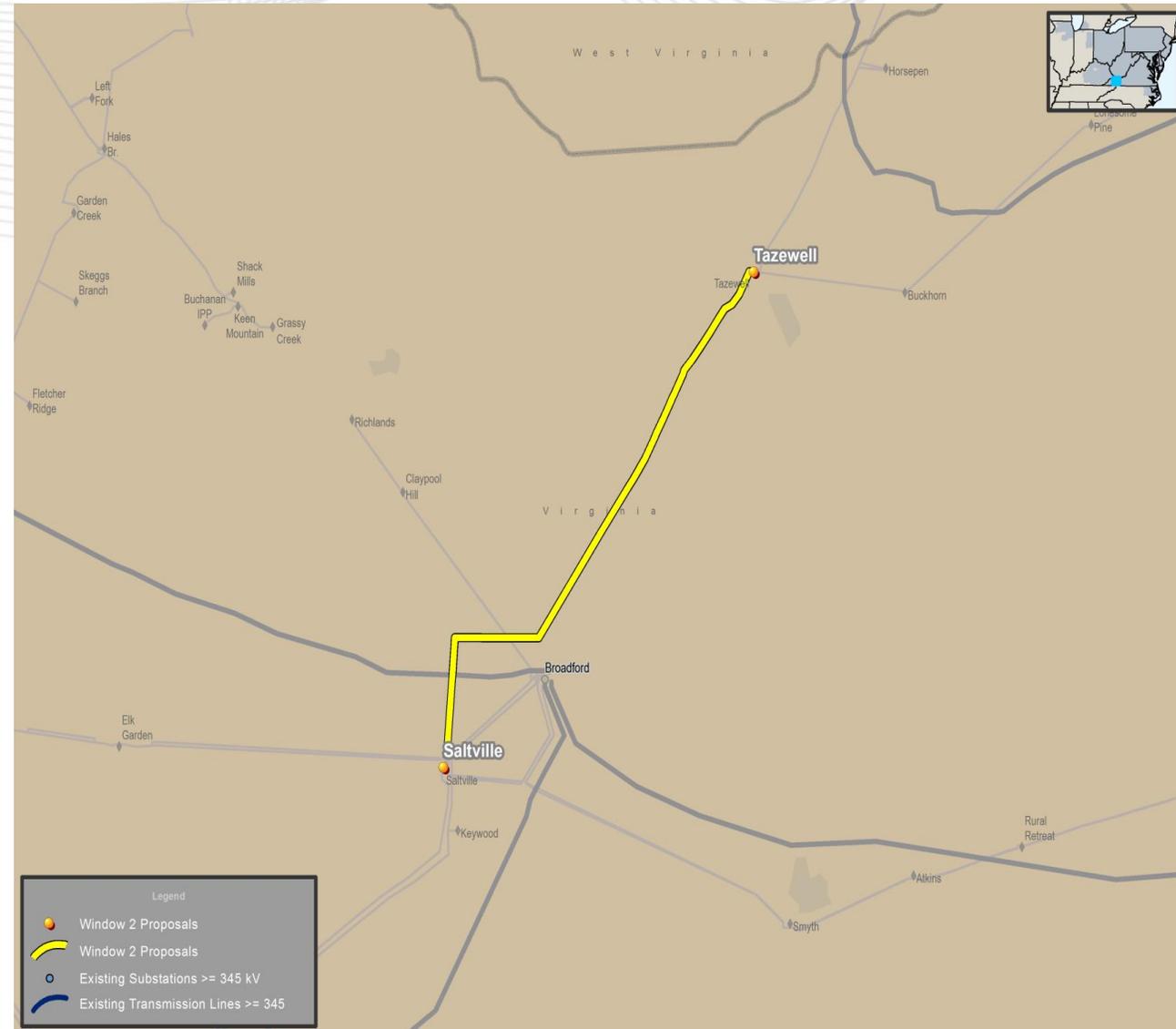
- 2016_2-7E (\$0.1 M)

Recommendation:

- Perform a Sag Study of the Saltville to Tazewell 138 kV line to increase the thermal rating of the line. (b2760)

Estimated Project Cost: \$ 0.1 M

Required IS Date: 6/1/2021



Common Mode Outage (FG# 874, 875, 901, 902):

- Hazard 161/138 kV transformer and Hazard to Wooten 138 kV circuit are overloaded for multiple 138 kV tower contingencies from Clinch River to Fremont/Lockhart to Dorton.

Alternatives considered:

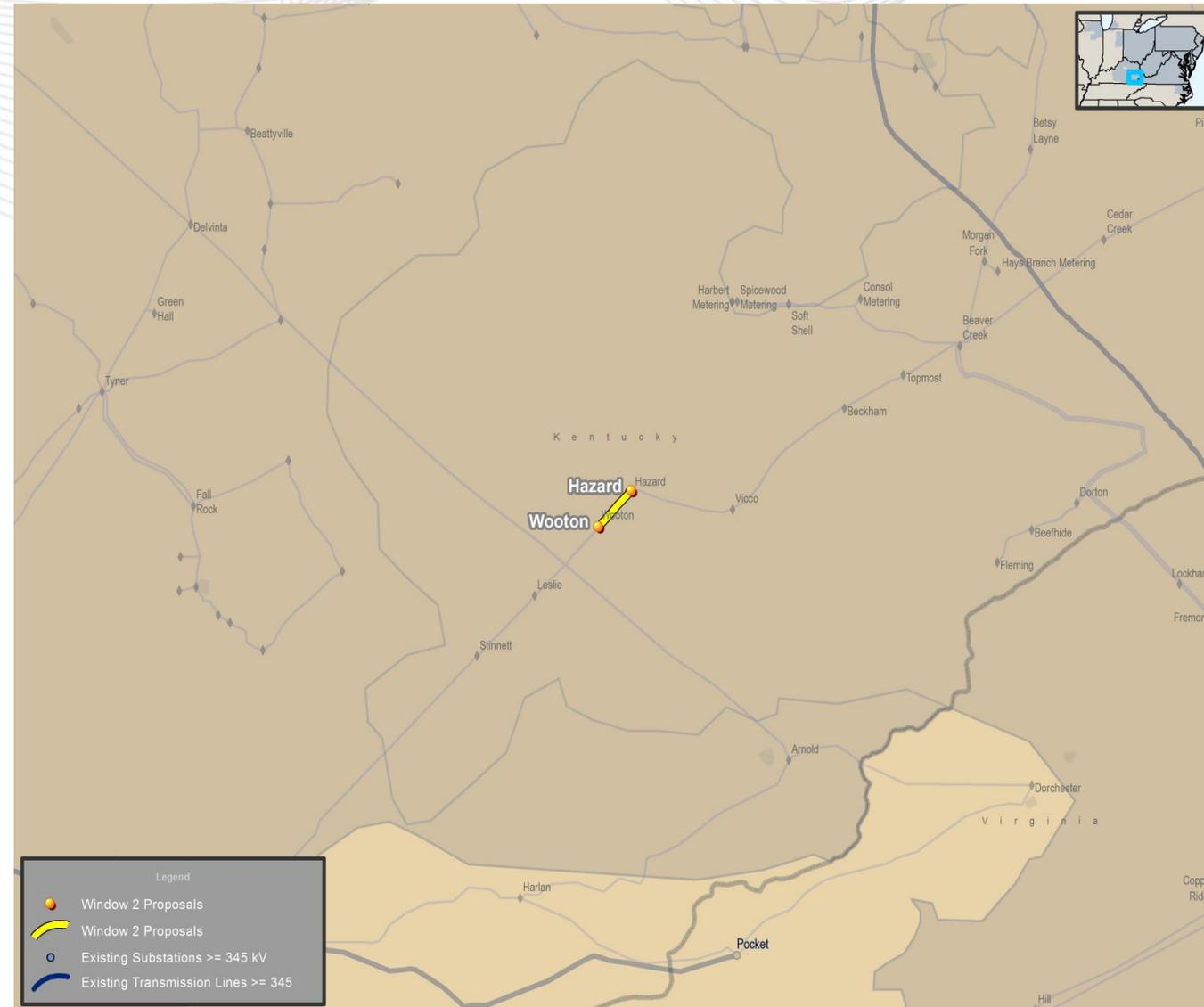
- 2016_2-7A (\$2.3 M)
- 2016_2-7B (\$10.45M)

Recommendation:

- Replace the Hazard 161/138 kV Transformer
- Perform a Sag Study of the Hazard – Wooten 161 kV line to increase the thermal rating of the line. (b2761.1 - b2761.2)

Estimated Project Cost: \$ 2.3 M

Required IS Date: 6/1/2021



Common Mode Outage (FG# 1152):

- Nagel to West Kingsport 138 kV circuit is overloaded line fault stuck breaker contingency loss of the Nagel – Sullivan Gardens and Nagel – Phipps Bend 500 kV circuits.

Alternatives considered:

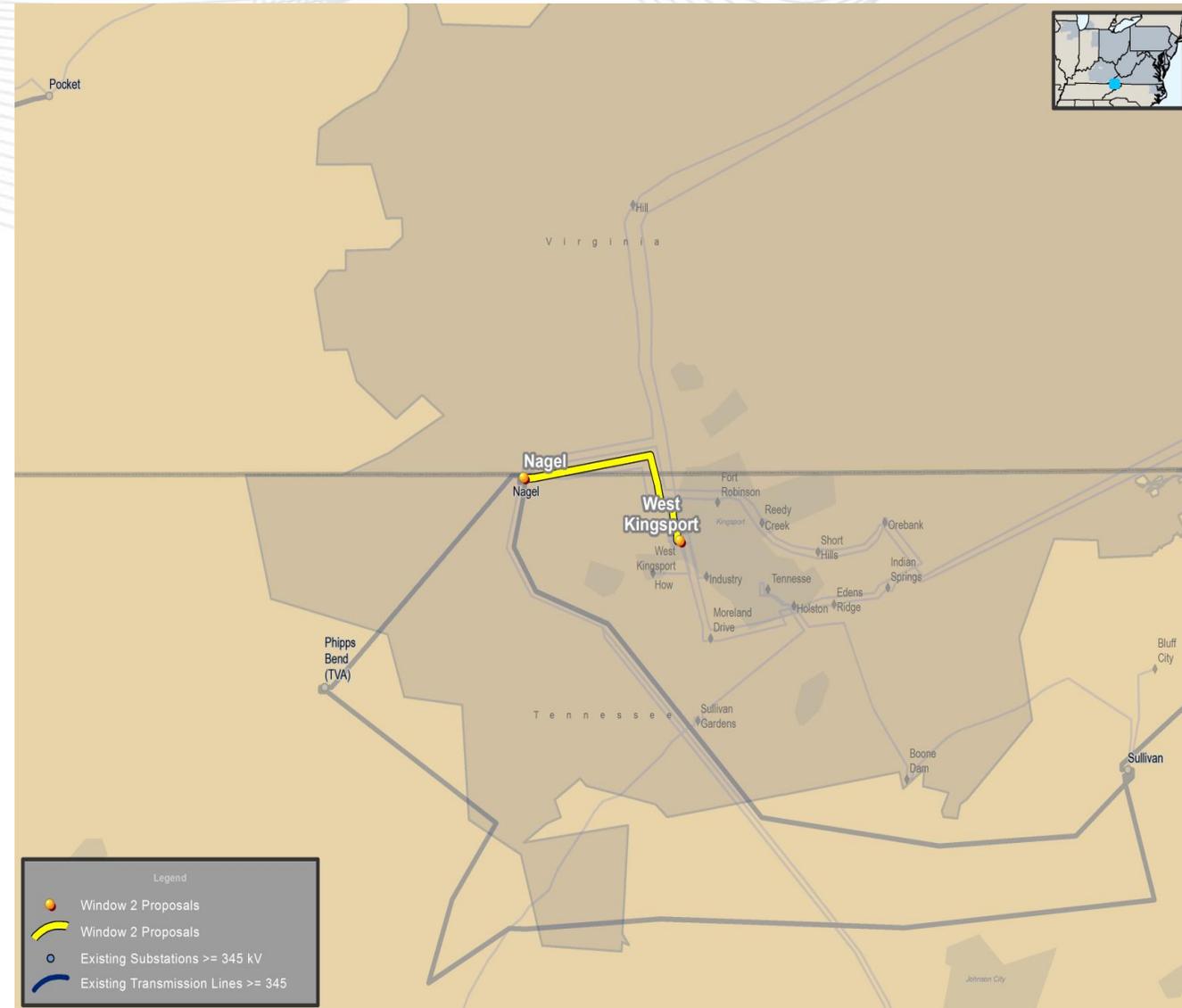
- 2016_2-7D (\$0.1 M)
- 2016_2-9V (\$12.1 M)

Recommendation:

- Perform a Sag Study of the Nagel to West Kingsport 138 kV line. During the study, perform any necessary work to improve the thermal rating of the line.(b2762)

Estimated Project Cost: \$ 0.1 M

Required IS Date: 6/1/2021



Short Circuit:

- The South Canton 138 kV 'K', 'J', 'J1', and 'J2' breakers (63kA) are overstressed

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

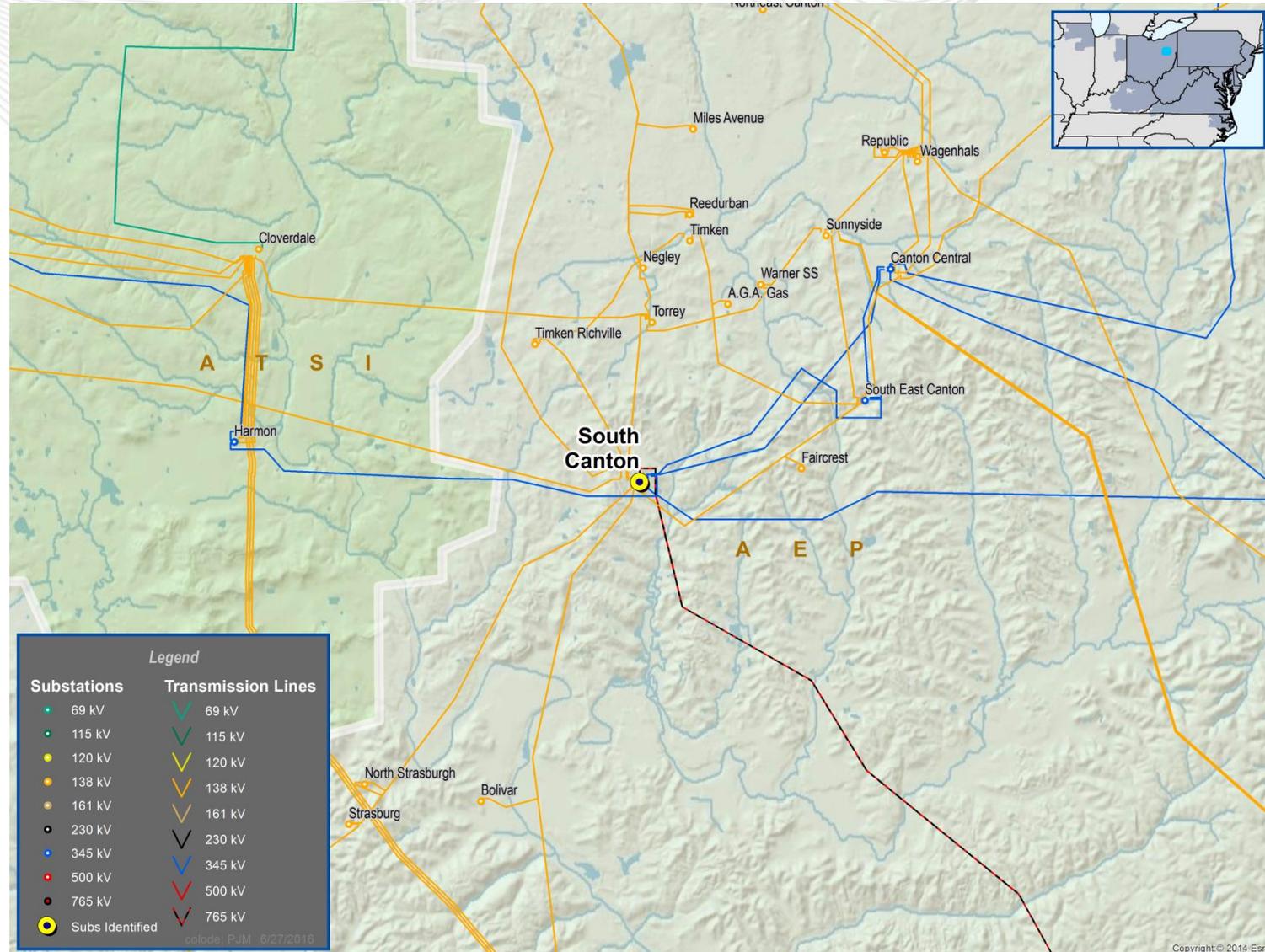
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace the South Canton 138 kV breakers 'K', 'J', 'J1', and 'J2' with 80 kA breakers (b2727)

Estimated Project Cost: \$1.2M

Required IS Date: 6/1/2018



AEP Criteria Violation

- The Betsy Layne 138/69/46KV transformer is overloaded and voltage deviation violations occur at Pikeville and South Pikeville 69kV stations for the loss of the Cedar Creek 138/69kV transformer; Betsy Layne station is currently located in a flood plain and has severe access issues
- Retire Betsy Layne station and replace it with the greenfield Stanville station about a half mile north of the existing Betsy Layne station. (B2750.1)
- Relocate the capacitor bank to the 69 kV bus at Stanville and increasing the size (the current 9.6 MVAR capacitor at Betsy Layne is located on the 46 kV bus) to 14.4 MVAR. (B2750.2)

Immediate Need

- Due to the timing of the need for the reinforcement an RTEP proposal window is infeasible

Alternatives Considered

- Upgrade the size of the 138/69/46 kV transformer at Betsy Layne. Install a 14.4 MVAR 69 kV capacitor bank.

The current Betsy Layne station is confined from expansion. Access issues to the station (single lane railroad bridge) would make it physically improbable that a larger bank could be delivered to the existing station site. The station site is prone to flooding. Ability to deliver a mobile transformer to the site is doubtful (access issues) under outage scenarios.

- Install a redundant 138/69 kV bank at Cedar Creek station.

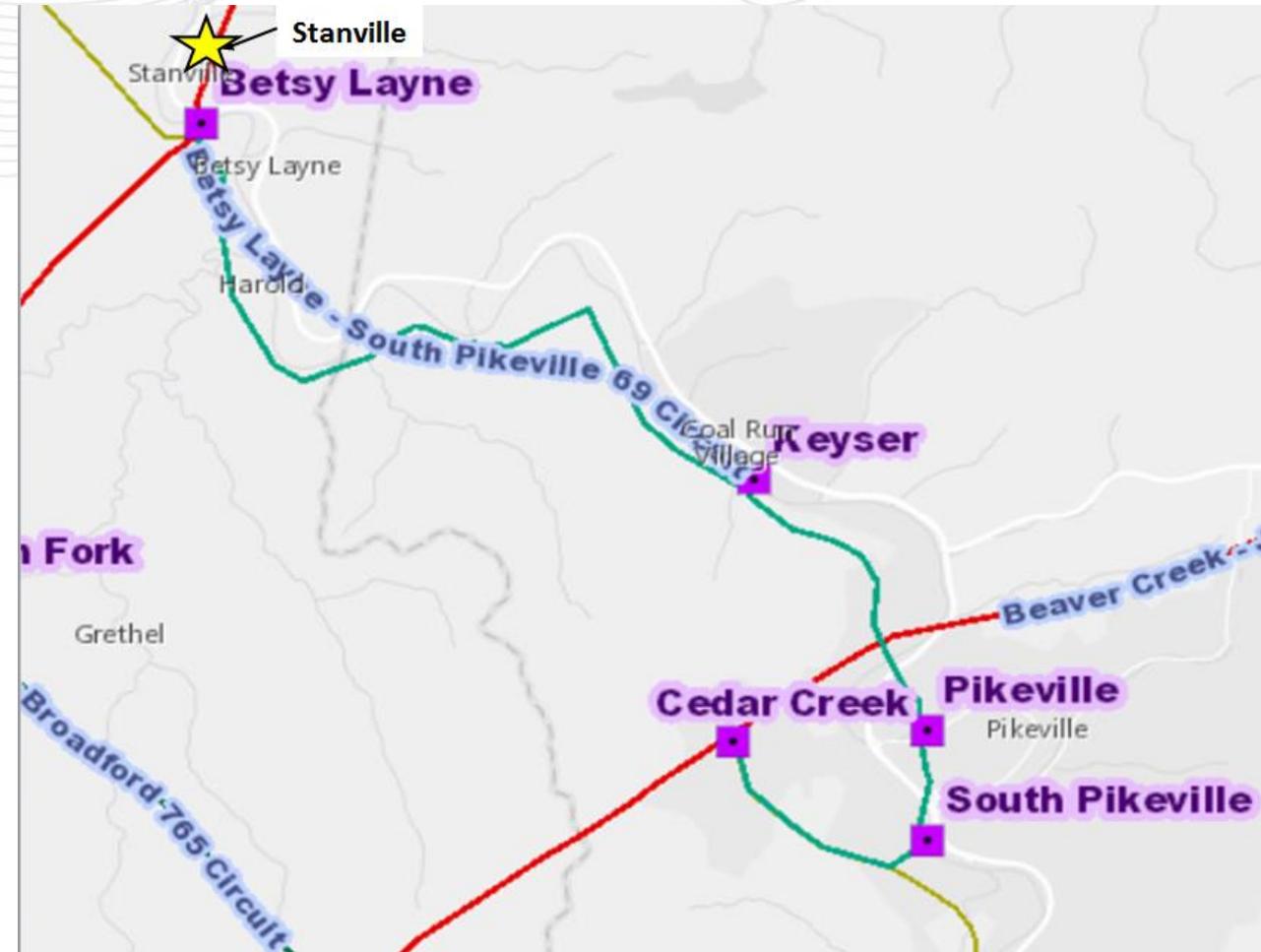
This solution would solve the violations for loss of the existing Cedar Creek transformer, but would not resolve the issues for a loss of the Cedar Creek – South Pikeville 69 kV line.

Construction Designation

- Due to the immediate need, the local Transmission Owner will be the Designated Entity

Estimated Project Cost: \$14.0M

Required IS Date: 12/1/2016





NERC Reliability Violation

- Moundsville Power IPP queues (Y3-068 and Z2-048) combined have a signed ISA with IPP responsibility of \$24,561,400 including largely 69kV upgrades to eliminate violations with otherwise minimal system benefits. Backfeed date is March 1, 2018 and Commercial Operation Date is January 1, 2019.
- After the ISA's were signed, AEP identified that a George Washington bus conductor overloaded when the bus tie is open
- There are tight physical constraints, the nearby environmental issues and the age of the existing structure. To simply upgrade the existing bus work would require a very extensive (months at least) total outage of the 138kV bus at George Washington. This would be even less likely to happen after the IPP connects. It still would be left with a configuration that is not very flexible, expandable, or reliable

New Plan:

Cancel:

- N4200: Install two (2) new 138 kV circuit breakers to connect the proposed generation. SCADA, 138 kV revenue metering, and associated equipment will also need to be installed.
- N4205: Replace the George Washington 138/69 kV TR #2
- N4201: Line protections and controls at the existing George Washington 138 kV station will need to be upgraded.
- N4202: Replace the George Washington 138/69 kV TR #2
- N4203: Replace "D", "F", and "G" CBs at Geo Washington Substation
- N4204: Replace "D", "F", and "G" CBs at Geo Washington Substation
- N4206: Rebuild the entire 5.83 mile section of DILLES - SHADYSID 69 kV line
- N4207: Rebuild the entire 5.02 mile section of Glendale- Brues 69 kV

George Washington Station – Replace existing 138kV yard with GIS 138kV breaker and a half yard in existing station footprint. Install 138kV revenue metering for new IPP connection. (N5076.1/B2753.1) --AEP

Dilles Bottom Station – Replace Dilles Bottom 69/4kV Distribution station as breaker and a half 138kV yard design including AEP Distribution facilities but initial configuration will constitute a 3 breaker ring bus. (N5076.2/B2753.2) --AEP

Holloway Station – Connect two 138kV 6-wired ckts from “Point A” (currently de-energized and owned by First Energy) in ckt positions previously designated Burger #1 & Burger #2. Install interconnection settlement metering on both circuits exiting Holloway station. (N5076.3/B2753.3) --AEP



AEP/ATSI Transmission Zone

Holloway-"Point A" FE "Burger-Cloverdale No.2" 138kV Line – 6 wire "Burger-Cloverdale No. 2" 138kV Line for double capacity and connect at Holloway and "Point A" (N5076.4/B2753.4)--FE

Holloway-"Point A" FE "Burger-Longview" 138kV Line – 6 wire "Burger-Longview" 138kV Line for double capacity and connect at Holloway and "Point A" (N5076.5/B2753.5)--FE

Dilles Bottom-"Point A"138kV Line - Build dbl ckt 138kV line from Dilles Bottom to "Point A". Tie each new AEP ckt in with a 6 wired line at Point A. This will create a Dilles Bottom-Holloway 138kV ckt and a George Washington-Holloway circuit. (N5076.6/B2753.6) --AEP

Dilles Bottom-Bellaire and Moundsville-Dilles Bottom 69kV Lines - Retire line sections south of First Energy 138kV line corridor, near "Point A". Tie George Washington-Moundsville 69kV ckt to George Washington-West Bellaire 69kV ckt (N5076.7/B2753.7) --AEP

Washington-Dilles Bottom 69kV Line – Rebuild existing line as dbl ckt 138kV from George Washington to Dilles Bottom. One circuit will cut into Dilles Bottom initially and the other will go past with future plans to cut in. (N5076.8/B2753.8) --AEP

Immediate Need

- Due to the timing of the need for the reinforcement an RTEP proposal window is infeasible

Fixed Project Cost: \$24.5614M (N5076.1-8)

Estimated Project Cost: \$25M (B2753.1-8)

- B2753.1: \$0M
- B2753.2: \$9M
- B2753.3: \$2M
- B2753.4: \$0.25M
- B2753.5: \$0.25M
- B2753.6: \$5M
- B2753.7: \$4.96M
- B2753.8: \$3.56M

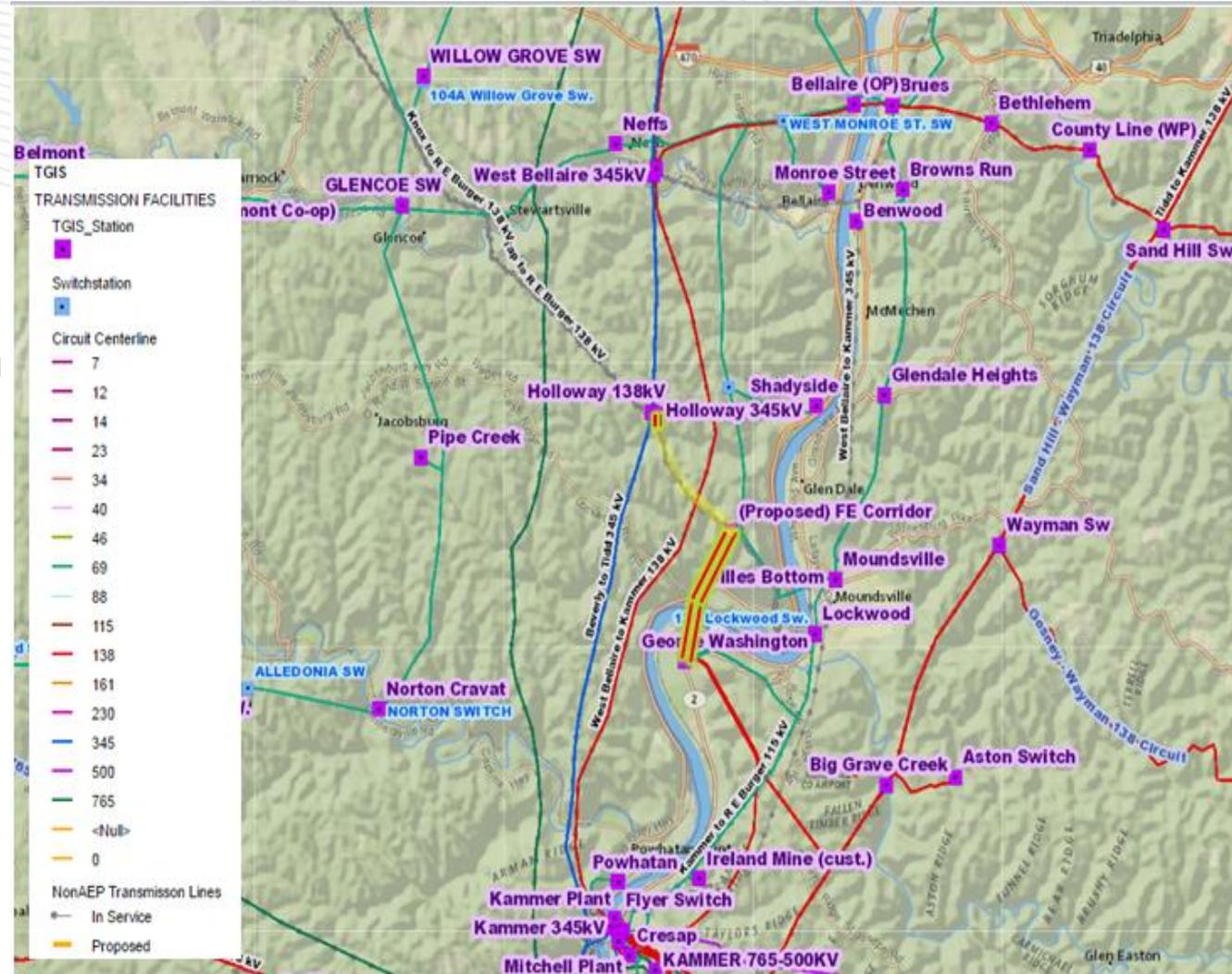
Alternatives Considered

- Upgrade / Rebuild George Washington bus work in place to alleviate overload. This would require outage of all 138kV facilities at George Washington for several months due to the existing interlaced bus configuration and the older facilities involved. Most likely the entire yard would need to be wrecked out and replaced and would make meeting the IPP milestones impossible. This is not acceptable.
- Expand the George Washington 138 kV yard to replace the existing yard. Any expansion would still need to tie in with existing bus work unless full replacement is done. The station is bounded by houses, mountains, and highway. No space is available and timing is not conducive to expanding and replacing the yard via conventional means. Given all constraints, this alternative is not feasible.
- Relocate the essentials of the George Washington 138kV yard to a new greenfield site. Surrounding the station are significant mountains, houses, and a highway. Across the highway is an EPA superfund site which would make any such endeavor prohibitively expensive and time consuming. Mountain top siting would also involve significant civil costs and timing issues making milestone dates for the IPP impractical and impossible. The Ohio River is also very nearby further reducing available sites for consideration. This is not acceptable.

Construction Designation

- Due to the immediate need, the local Transmission Owner will be the Designated Entity

Required IS Date: 1/1/2019





Rochelle Municipal (RMU) Transmission Zone

Generator Deliverability Violation:

- The H440 – H440 Tap 138KV Line is overloaded for the loss of the H440 tap – Steward 138kV line
- Reason: Line ratings update on the overloaded facility

Immediate Need:

- Due to the timing of the need for the reinforcement an RTEP proposal window is infeasible

Alternatives Considered:

- Due to the immediate need of the project no alternatives were considered

Construction Designation:

- Due to the immediate need, the local Transmission Owner will be the Designated Entity

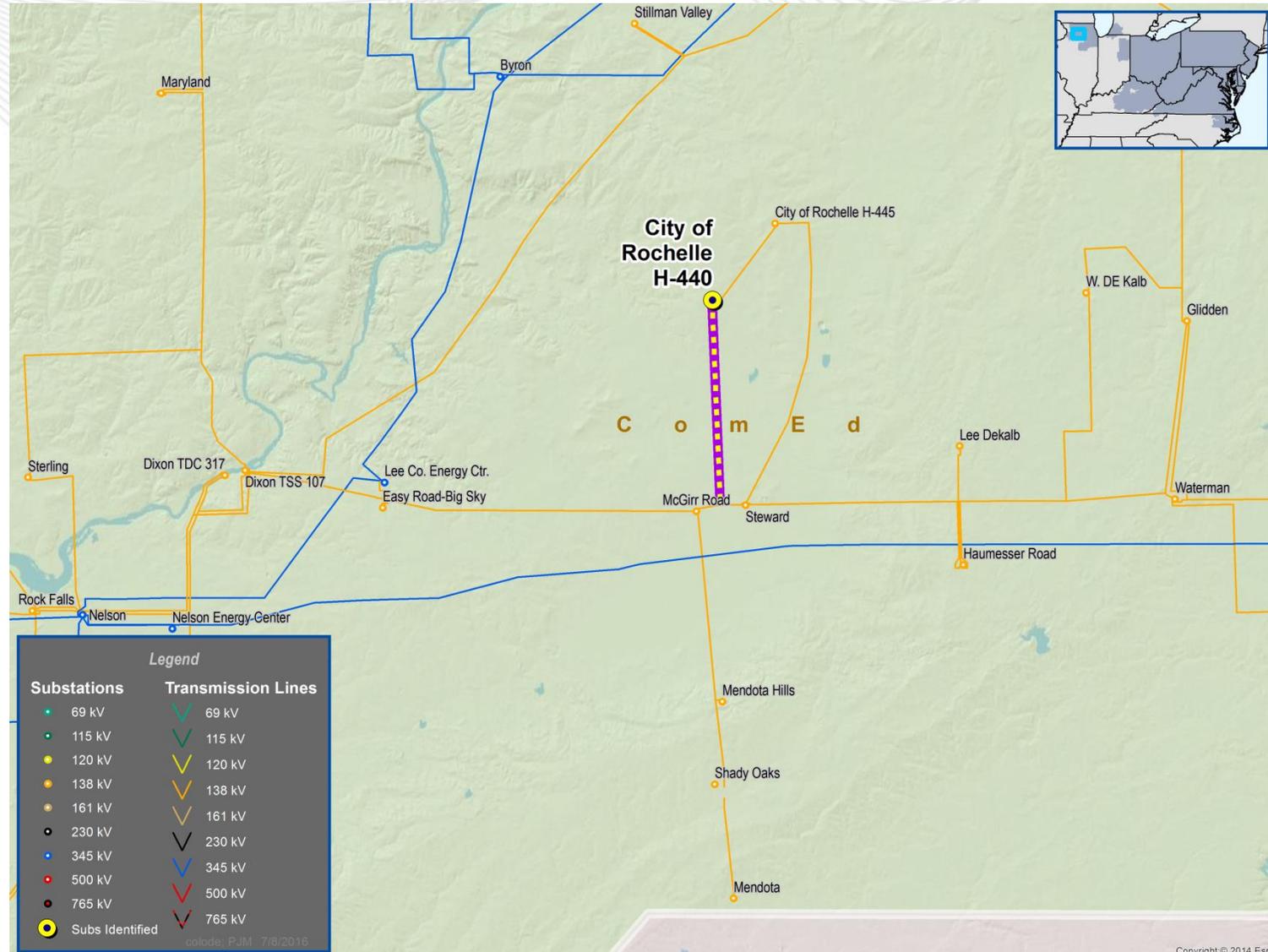
Proposed Solution:

- Rebuild/Resag the H440 – H440 Tap 138KV Line 16914-2 (Hays Road to SW 1403) (B2751)

Estimated Project Cost: \$3.5M

Required IS Date: 6/1/2016

Projected IS Date: 6/28/2017



Dominion End of Life Criteria Violation:

- Original SVC at its End of Life
 - Harsh Environment / High Salt Contamination has led to component corrosion
 - Cap/filters have reached end of life
 - Non-redundant design
 - Unique components with no spares

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

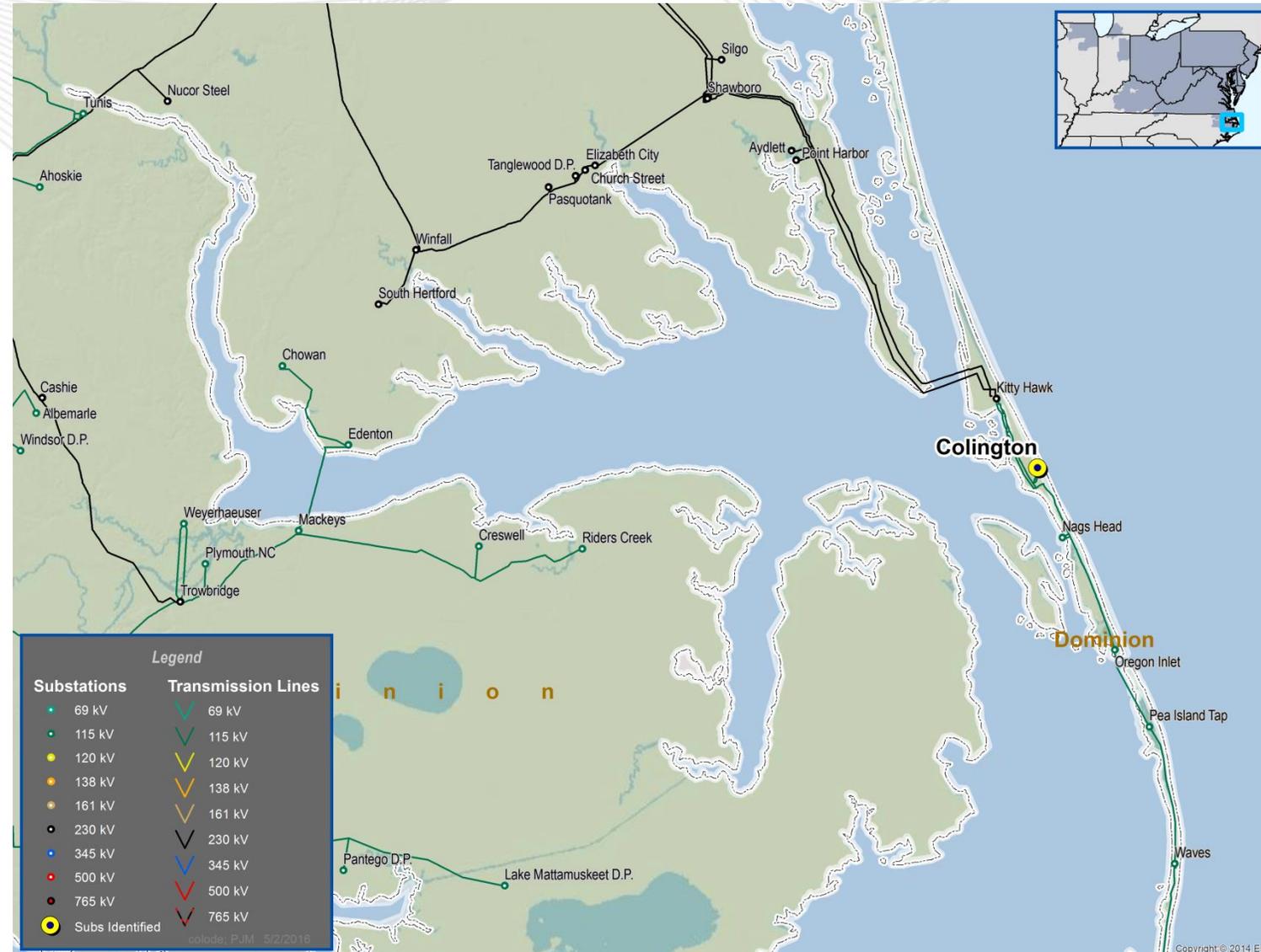
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Install a +/-125 MVar Statcom at Colington 230kV (B2757)

Estimated Project Cost: \$30 M

Projected IS Date: 06/01/2017



Dominion End of Life Criteria Violation:

- The Dooks - Valley 500 kV Line has reached its End of Life
- Third party evaluation:
 - Confirmed the Dooks - Valley 500 kV has reached its End of Life
- PJM Reliability Assessments without the line result in Criteria violations:
 - Numerous thermal and voltage violations for various contingencies around and at Bath County, Lexington, Clifton, Lowmoor, and Dooks.

Alternatives Considered:

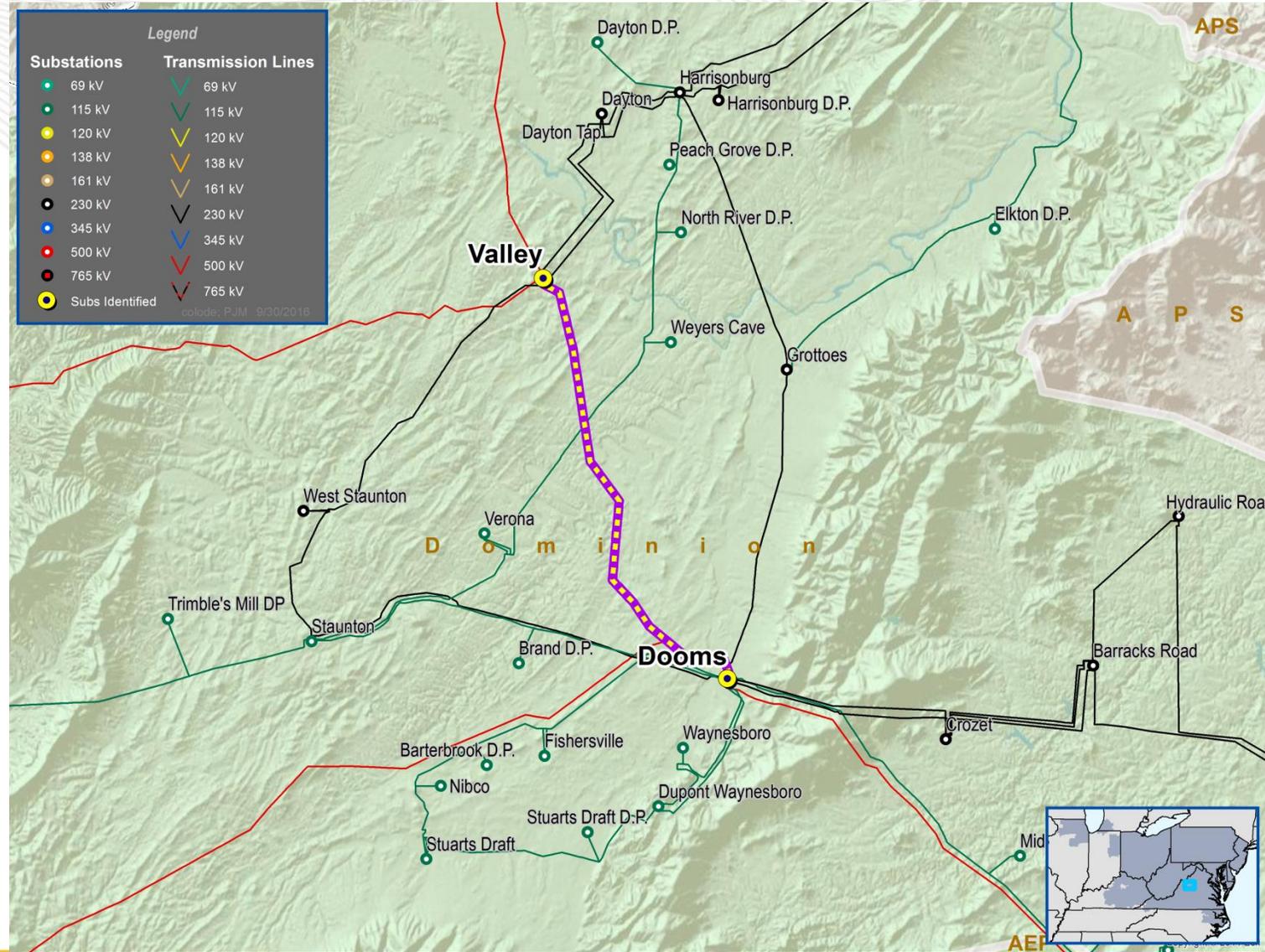
- Alternatives that would require new lines to be built were not considered.

Proposed Solution:

- Rebuild Line #549 Dooks – Valley 500kV (B2758)

Estimated Project Cost: \$58.16 M

Projected IS Date: 6/1/2021



NERC Category P1 N-1 Thermal and Voltage Analysis:

- New block loads being added at Ridge Road substation (38 MW in 2017 & 38 MW in 2018) produce the following N-1 violations for summer 2018
- Chase City – Ridge Rd 115kV line and Kerr – Ridge Rd 115kV are overloaded for various single contingencies
- Ridge Road 115kV and Boydton Plank 115kV have low voltage for various contingencies.
- This is an immediate need project based on NERC TPL-001-004 criteria.
- When this criteria violation was identified, the need date was already in the immediate need timeframe

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

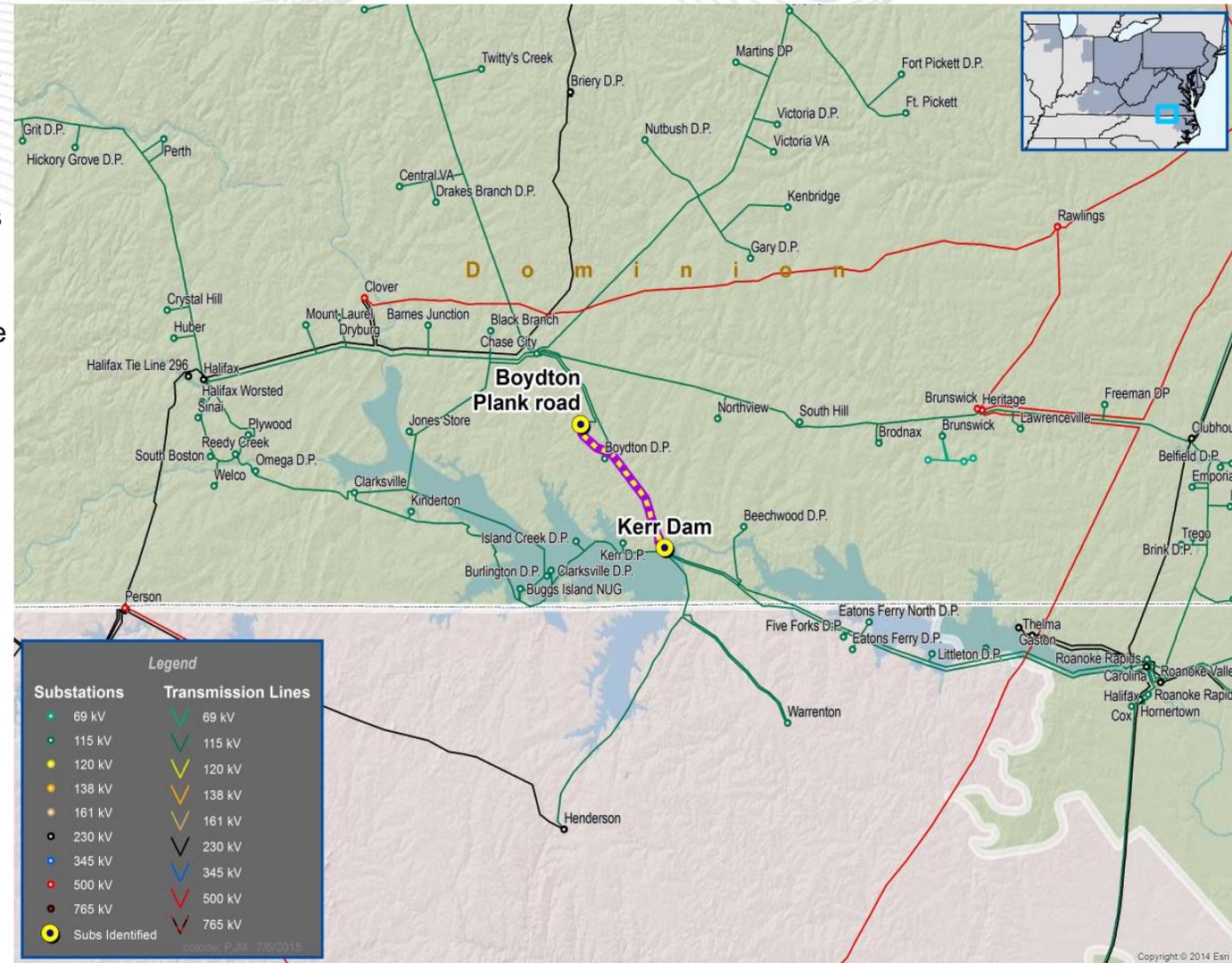
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Rebuild Line #137 Ridge Rd - Kerr Dam 115kV, 8.0 miles, for 346 MVA summer emergency rating **(B2746.1)**
- Rebuild Line #1009 Ridge Rd - Chase City, 9.5 miles, for 346 MVA summer emergency rating **(B2746.2)**
- Install a 25 MVAR 115kV capacitor bank at Ridge Rd **(B2746.3)**

Estimated Cost: \$39 M

Projected IS Date: 5/1/2018



Operational Performance:

- Isolation of FirstEnergy's 115kV transmission line to REC's Pratts Substation is needed at Dominion's Gordonsville Substation and presently would be accomplished by the dispatch of local forces to manually open an air-break switch at Gordonsville.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

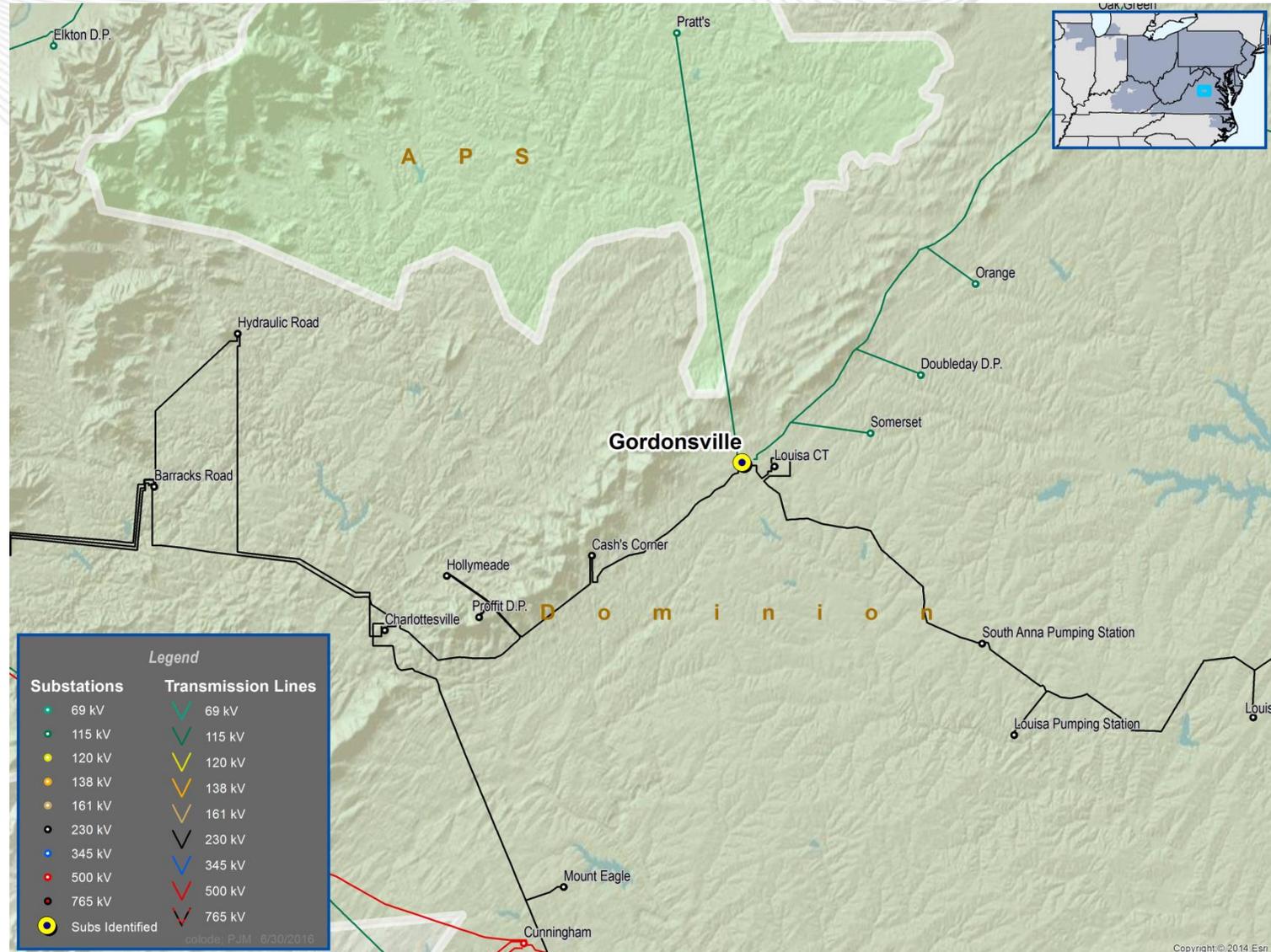
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Install a Motor Operated Switch and SCADA control between Dominion's Gordonsville 115kV bus and FirstEnergy's 115kV line. (B2747)

Projected IS Date: 06/01/2018

Estimated Cost: \$350K



Short Circuit:

- The Idylwood 230kV breakers “25112” and “209712” are overstressed.

Significant Driver:

- Install a breaker and a half scheme for five existing lines at Idylwood 230 kV

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

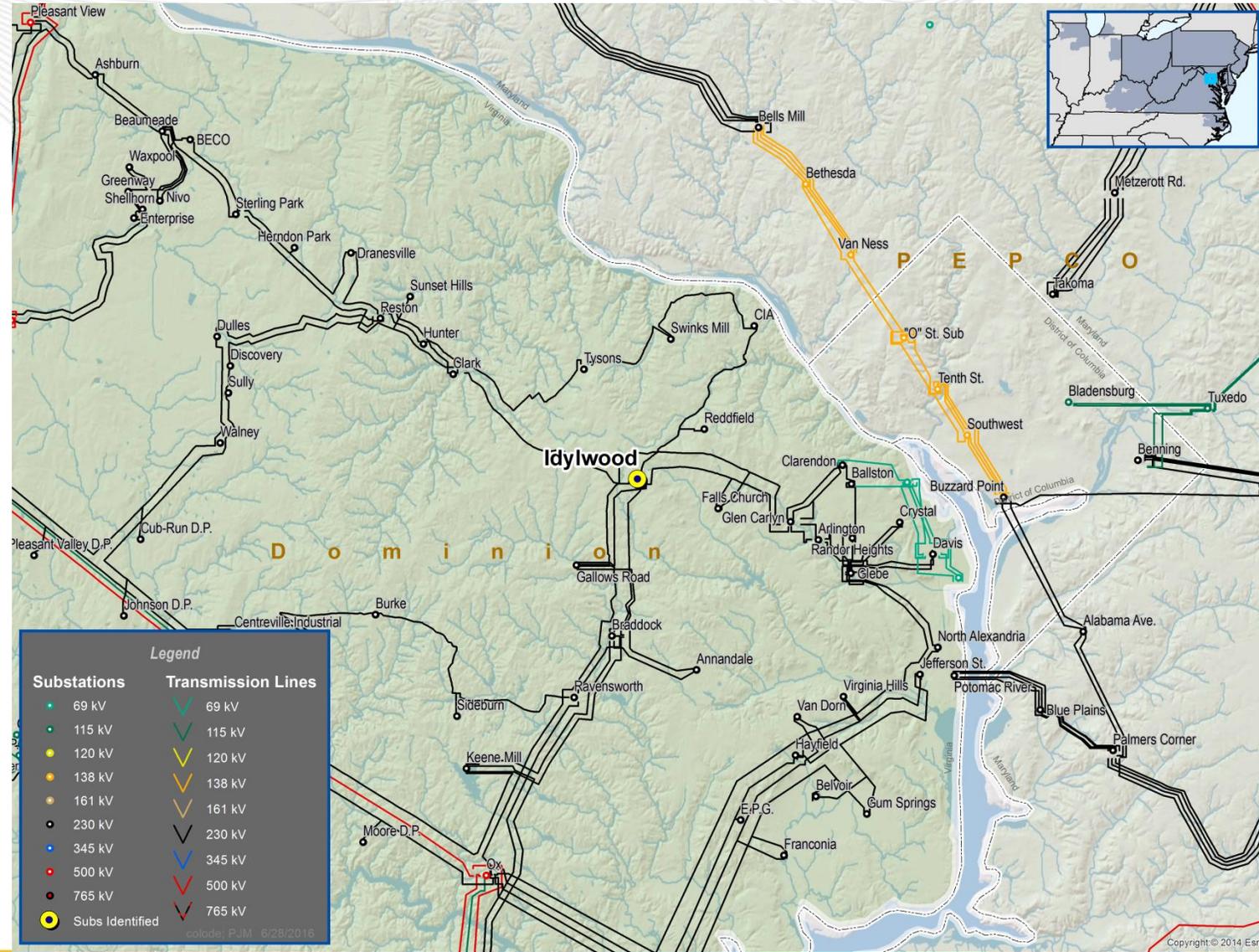
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace Idylwood 230kV breakers “25112” and “209712” with 50kA breakers (b1696.1-b1696.2)

Estimated Cost: \$350 K

Required IS Date: 06/01/2017



Cost Update For B1690:

Scope:

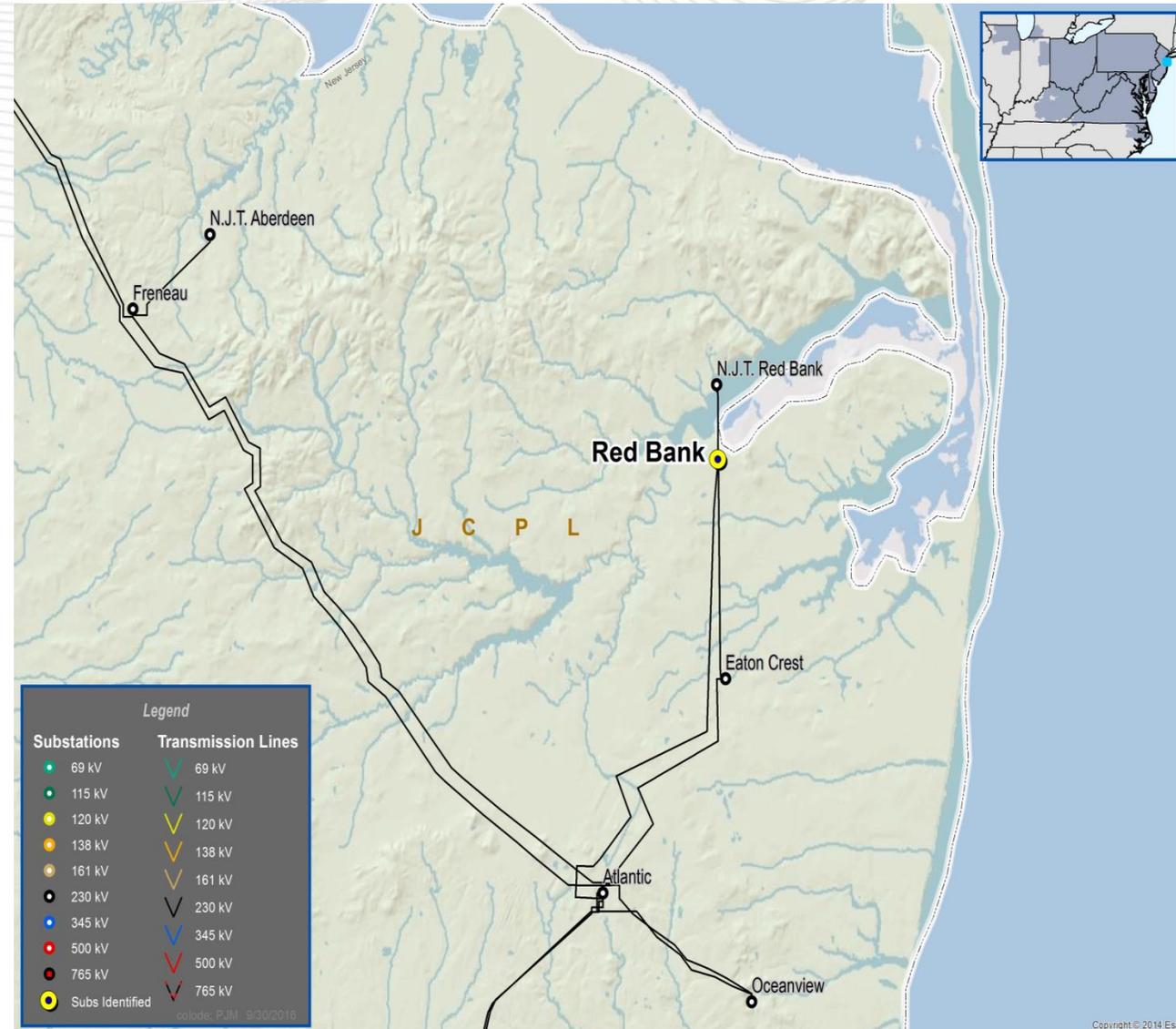
- Build a new third 230 kV line into the Red Bank 230 kV substation from NJT Aberdeen 230 kV

Old Cost Estimate: \$ 22 M

New Cost Estimate: \$ 111 M

Reason for Cost Increase

- See next slide



- The original \$22M cost estimate was a planning level estimate for a conceptual 8 mile 230kV transmission line with an undefined route.
 - Assumptions for the transmission line included 700' spans (60 structures), typical concrete foundations, and minimal access road issues and did not include fully loaded costs.
- The current estimated project cost of \$111M includes the following:
 - The estimates have been more fully refined as FE has obtained better quotes as some preliminary engineering has been completed and costs include fully loaded costs.
- The preferred transmission line route, pending NJ BPU approval, is now 10.1 miles in length and routed along the NJ Transit railway.
 - Based on this routing, greater than 100 structures, using shorter spans, were assumed due to the curvature of the railway corridor and transmission design requirement to help maintain conductor (minimum) clearances within the 100-foot railway corridor.
 - Helical or micropile foundations are now required due to the proximity of the railway tracks. A solution developed jointly with NJ Transit to avoid major ground disturbances near the railway tracks.
 - More extensive access roads are needed along the railway corridor. Currently, the NJ Transit corridor in this area has very limited accessible areas to accommodate large construction vehicular traffic.
- Project management and construction management costs were increased based on recent NJ transmission projects which involve significant support to manage municipal, property owner, commercial, and environmental impacts.
 - In addition, project costs now include associated substation work at Taylor Lane substation and 2.1 miles of 34.5kV transmission line rearrangement work required within the NJ Transit corridor.
- Added ROW costs for acquisition of required vegetation clearing from private property owners adjoining the railway corridor.

Short Circuit:

- The Ringgold 138 kV breakers '138 BUS TIE' and 'RCM0' are overstressed

Significant Driver: Market Efficiency Project 9A - West (b2743)

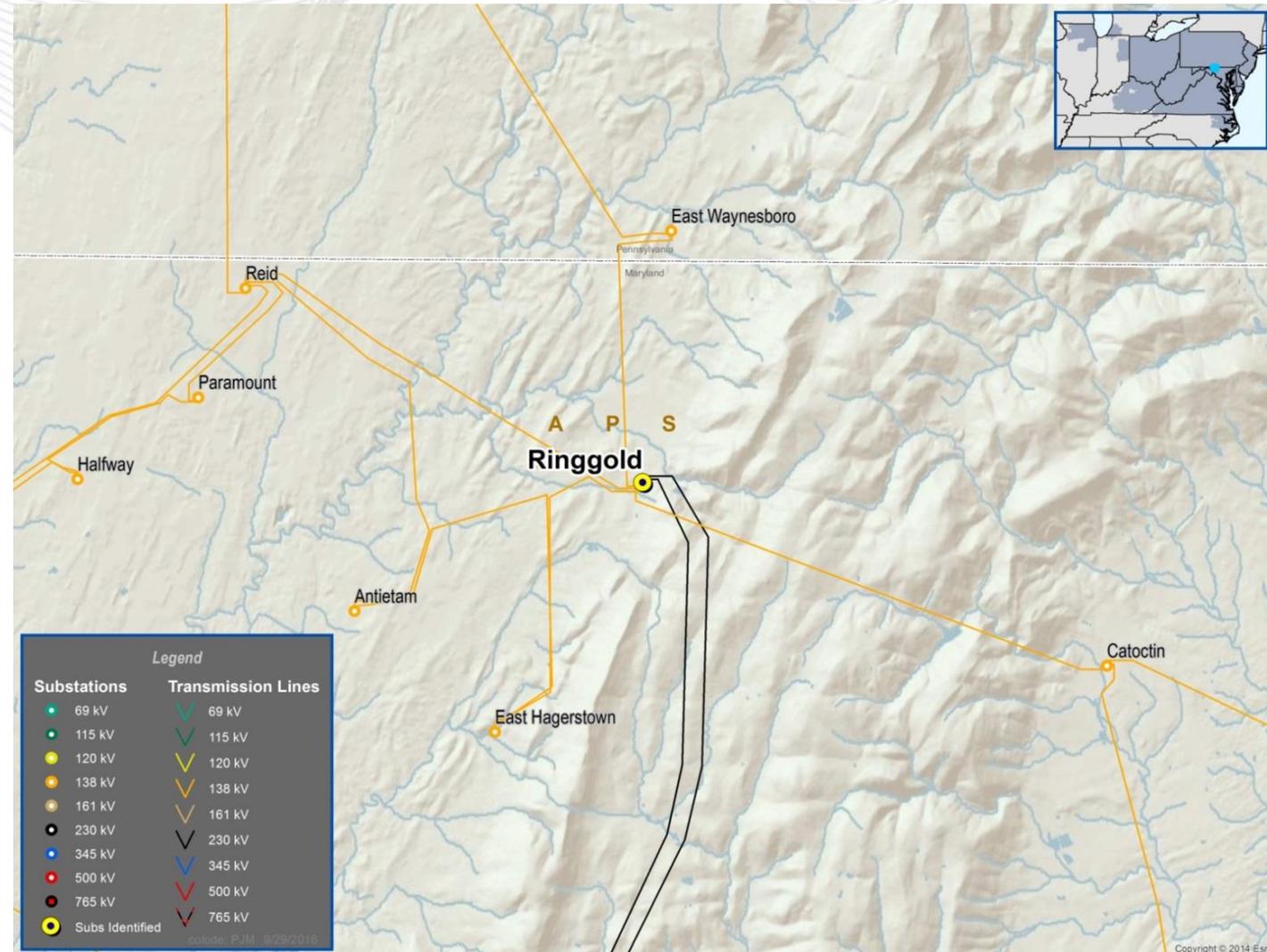
- Tap the Conemaugh - Hunterstown 500 kV line and tie in new Rice 500 kV station
- Build new 230 kV double circuit line between Rice and Ringgold 230 kV

Proposed Solution:

- Replace the Ringgold 138 kV breakers '138 BUS TIE' and 'RCM0' with 40 kA breakers (b2743.8)

Estimated Project Cost: \$710 K

Required IS Date: 06/01/2020



Modification to existing approved baseline project (B2609.4):

Old Scope:

- Establish new 138 kV tap substation on Powell Mountain - Goff Run, construct 15 miles of new 138 kV line from Thorofare Creek to the new 138 kV tap substation, establish Chloe 138 kV substation

New Scope:

- Establish the new Chloe 138 kV substation tapping the Powell Mountain - Goff Run 138 kV line, construct 25 miles of new 138 kV line from Thorofare Creek to the new Chloe 138 kV substation

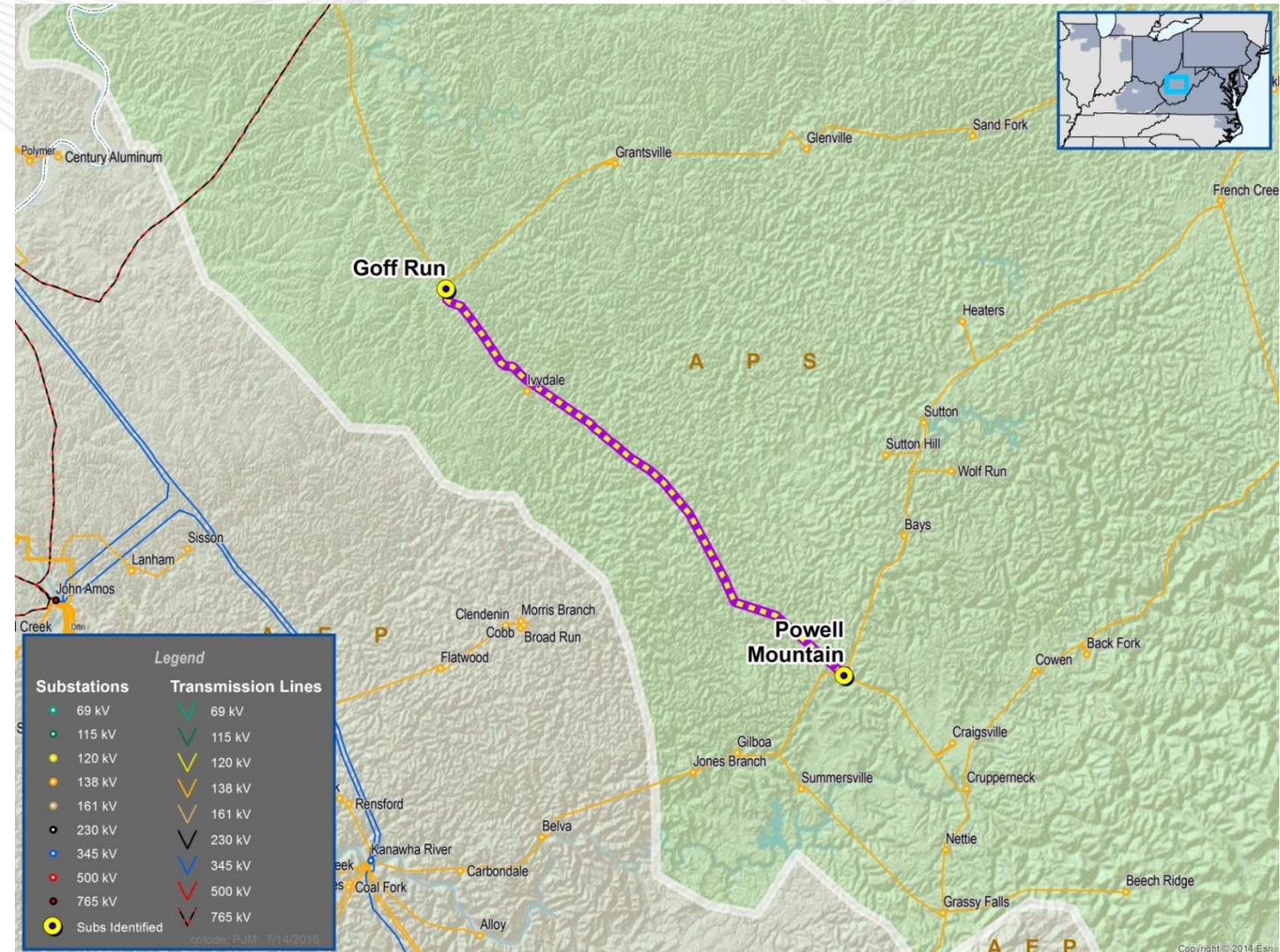
Reason:

- It is subject to the approved CPCN and Joint Stipulation that modified that project component by adding 10 miles of new line to support the future enhancement of the reliability of the APCO distribution system, as ordered by the Public Service Commission of West Virginia.
- (new line will be routed to accommodate the future Walton 138 kV substation (separate project to support future distribution substation) as ordered by the Public Service Commission of West Virginia).

Old Estimated Project Cost: \$59.5M

New Estimated Project Cost: \$72.0M

Required IS Date: 6/1/2019



B1696 Cost Increase and Scope Addition:

N-1 and N-1-1 Thermal Violations:

- For various contingencies, the Idylwood 230kV bus is overloaded

Proposed Solution:

- Install a Breaker and Half Scheme at Idylwood

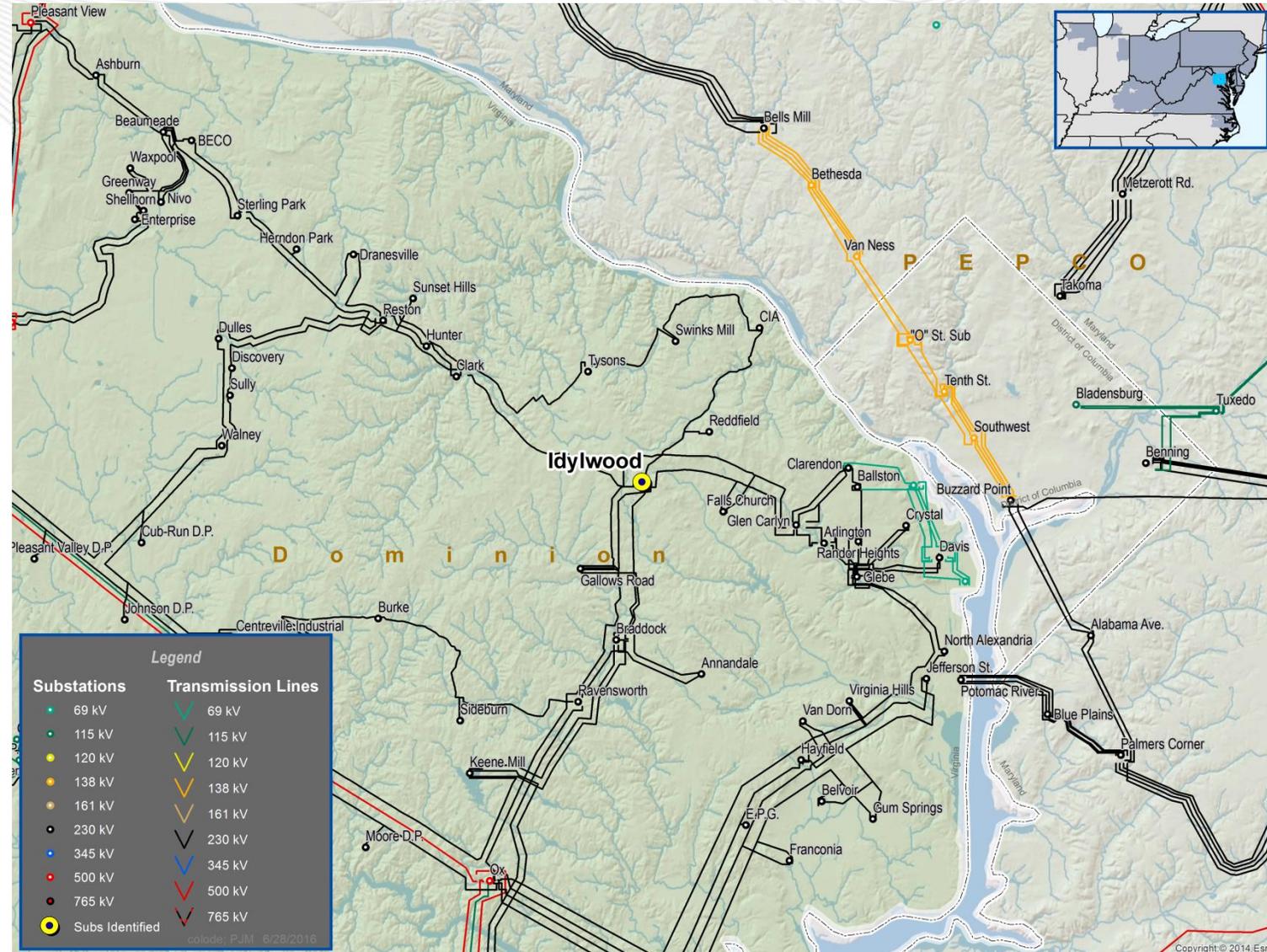
Reason for cost increase:

- Detailed cost estimate included additional cost due to GIS breakers, security wall, transmission structures, labor, and permitting.

Previous Cost Estimate: \$55 M

Revised Cost Estimate: \$80 M

Projected IS Date: 02/01/2020



**Existing B1792 Cost Increase and Scope Modification:
N-1 and N-1-1 Thermal Violations:**

- For several contingencies, the Halifax- Chase City 115kV line is overloaded

Proposed Solution:

- Rebuild line #33 Halifax to Chase City 26 miles and install a 230kV four breaker ring bus at Halifax to eliminate the motor operator schemes.

Reason for Revision:

- The original plan was to expand Halifax substation. Halifax substation cannot be expanded because it is located in a flood plain.

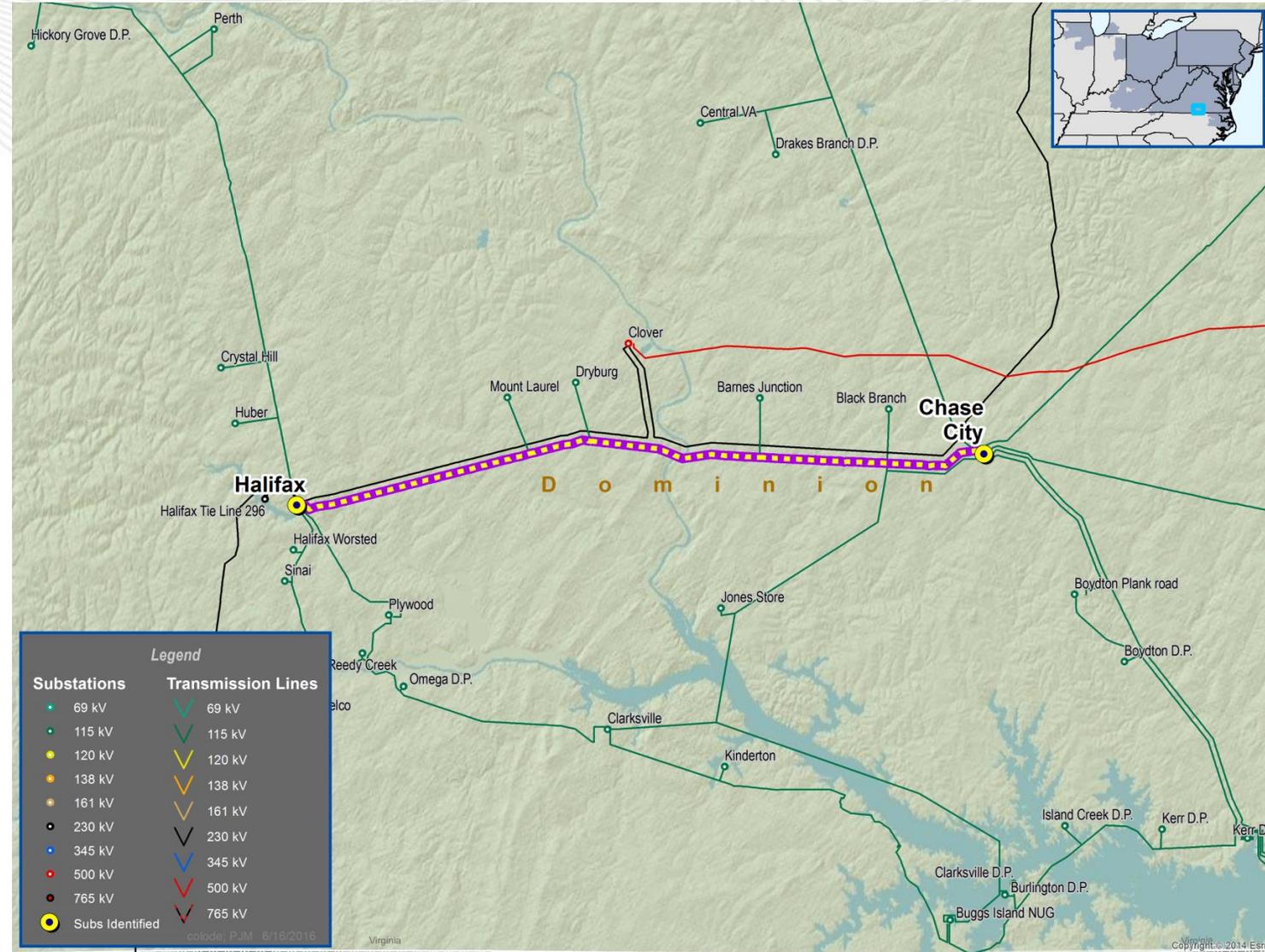
Proposed Revised Solution:

- Rebuild Line #33 Chase City – Halifax 230kV to a minimum summer emergency rating of 300 MVA.
- Relocate Halifax switching station out of the flood plain
- Build a new switching station, to be called Sedge Hill, with 230kV four breaker ring and a 115kV breaker and a half scheme with seven breakers.

Previous Estimated Cost: \$26.0 M

Revised Estimated Cost: \$50.2 M

Projected IS Date: 12/15/2016





Dominion Transmission Zone

Existing B2186 Cost Increase and Scope Modification:

N-1-1 Thermal Violation:

- For the loss of Line # 54 Carolina – Earleys and the Earleys 230-115kV transformer, the #108 line Boykins – Tunis 115kV is overloaded

Proposed Solution:

- Install a 2nd 230-115kV transformer at Earleys connected to the existing 115kV and 230kV ring busses. Add a 115kV breaker and 230kV breaker to the ring busses. (B2186)

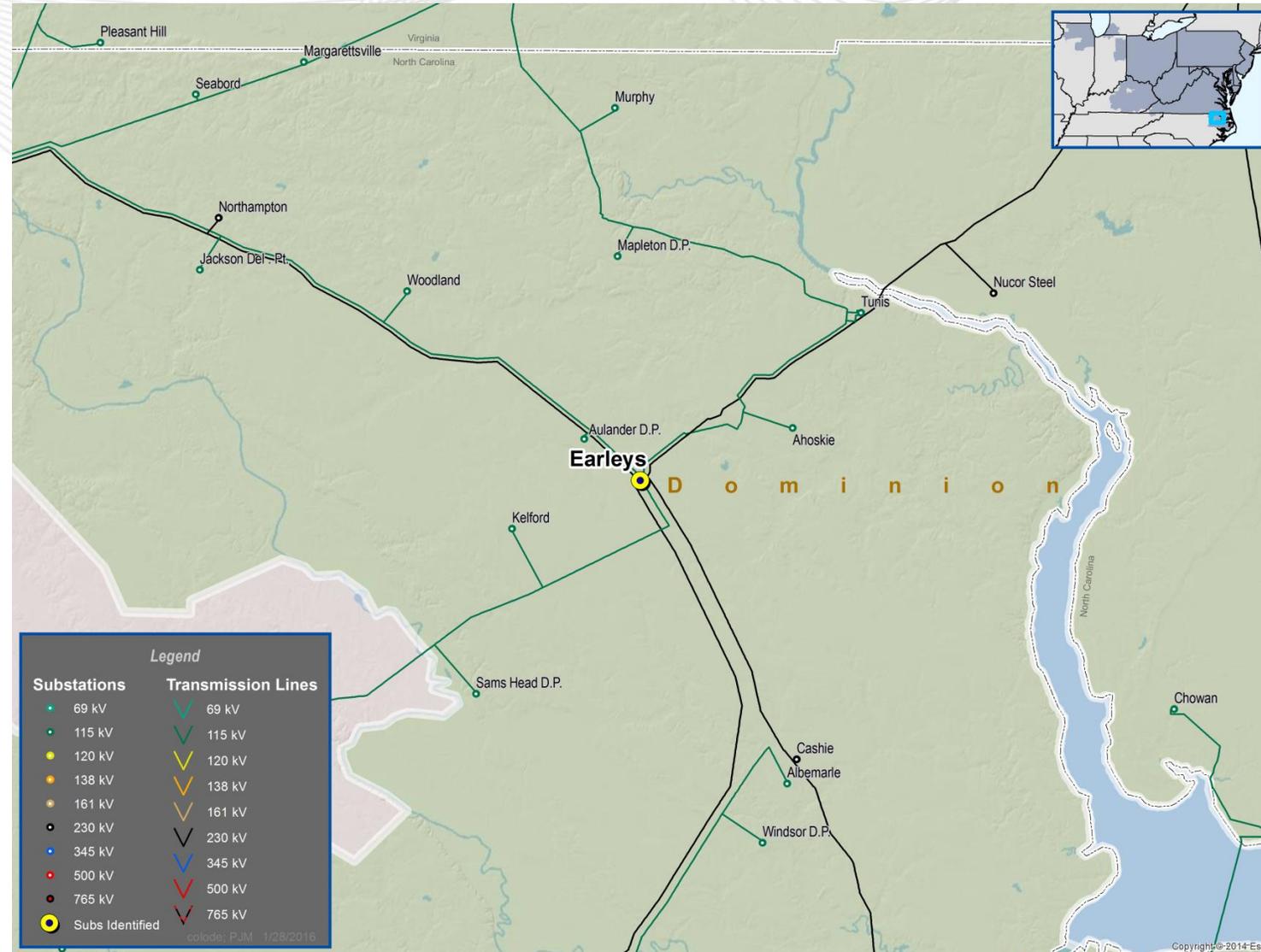
Reason for cost increase:

- Dominion design guidelines require that wood pole structures inside the station be replaced when there is a project at a substation.
- Therefore, four wood pole structures need to be replaced at Earleys.
- Two spans of conductor will be replaced on line #2012 Earleys- Roanoke Valley 230kV at Earley's substation that will increase the summer STE rating from 595 to 608 MVA.
- Due to additional DC load requirements from this project and previous projects and no room for expansion in the existing control house, a new battery enclosure is required.

Previous Estimated Cost: \$ 11.5 M

Revised Estimated Cost: \$ 13 M

Projected IS Date: 06/01/2017



Existing B2628 Cost and Scope Modification:

Dominion End of Life Criteria Violation:

- The Everetts – Voice of America 115kV line #82 was constructed on wood H-frame structures in 1953. This line has ACSR conductor and 3/8 inch steel static.
- System Impact Assessment - Failure of Line #82 would permanently drop 49 MW of load

Existing Project Scope:

- Rebuild 115kV Line #82 Everetts – Voice of America (20.8 miles) to current standards with a summer emergency rating of 261 MVA at 115kV (B2628)

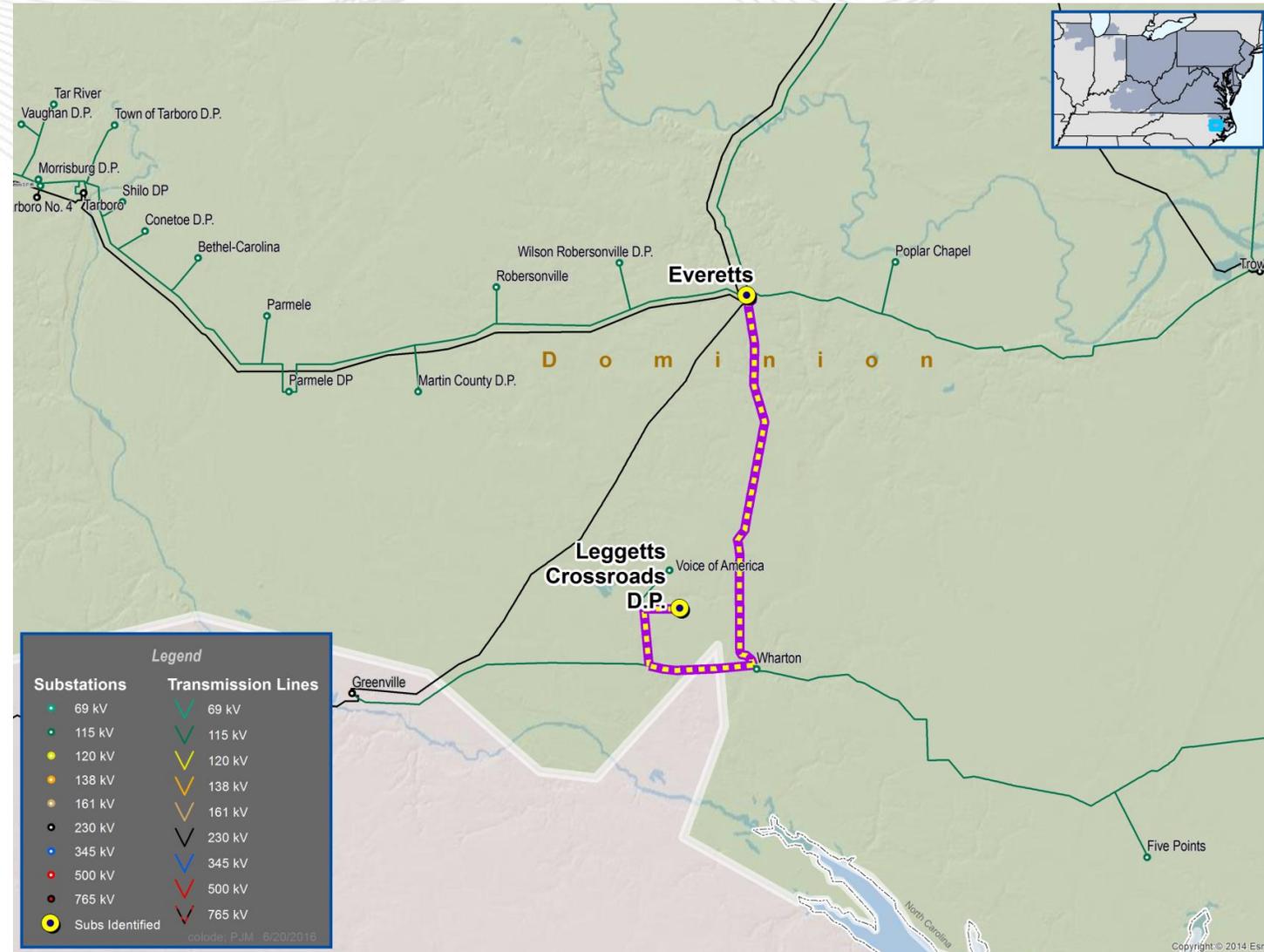
Scope Modification:

- Rebuild Everetts – Leggetts 115kV Line #82 Crossroads DP (19.1 miles) to current standards with a summer emergency rating of 353 MVA at 115kV (B2628)
- The cost increase is due to refined detailed cost estimates updates and the increase in line capacity.
- The last 1.75 mile section of Leggetts Crossroad DP to Voice of America (VOA) was removed from this project due to minimal load at VOA and the potential to remove this line section in the future for the load to be served from the distribution system.

Previous Estimated Cost: \$24.0 M

Revised Estimated Cost : \$32.1 M

Projected IS Date: 12/30/2019



Existing B2458 Cost Increase and Scope Modification:

N-1 Thermal Violation:

- Carolina – Woodland 115kV line is overloaded due to the loss Roanoke Valley NUG - Earleys 230 kV line

Existing Project Scope:

- Replace wood H- frame structure and 2.5 miles of static wire on Carolina - Woodland 115 kV
- Replace wood H- frame structures 4.5 miles of conductor between Carolina 115 kV and Jackson DP 115 kV with a minimum 174 MVA summer STE rating.

Construction Update:

- Broken strands at multiple locations along Carolina – Woodland 115kV circuit discovered during construction that need to be replaced. **(B2458.6)**

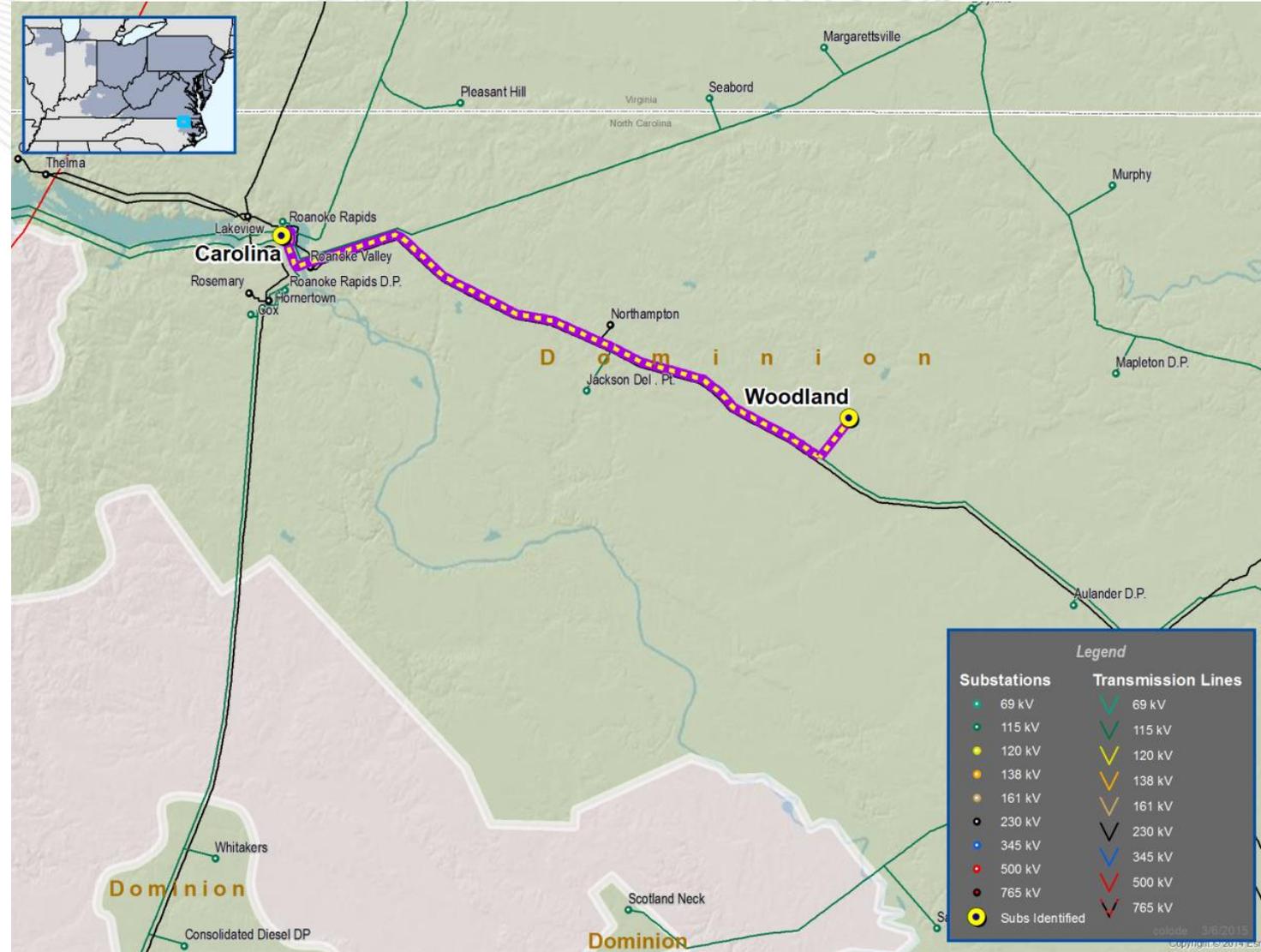
Addition to Project Scope:

- Reconductor 22.4 miles of Carolina–Jackson 115kV for min. 174 MVA summer STE rating using existing structures

Previous Estimated Cost: \$6.9 M

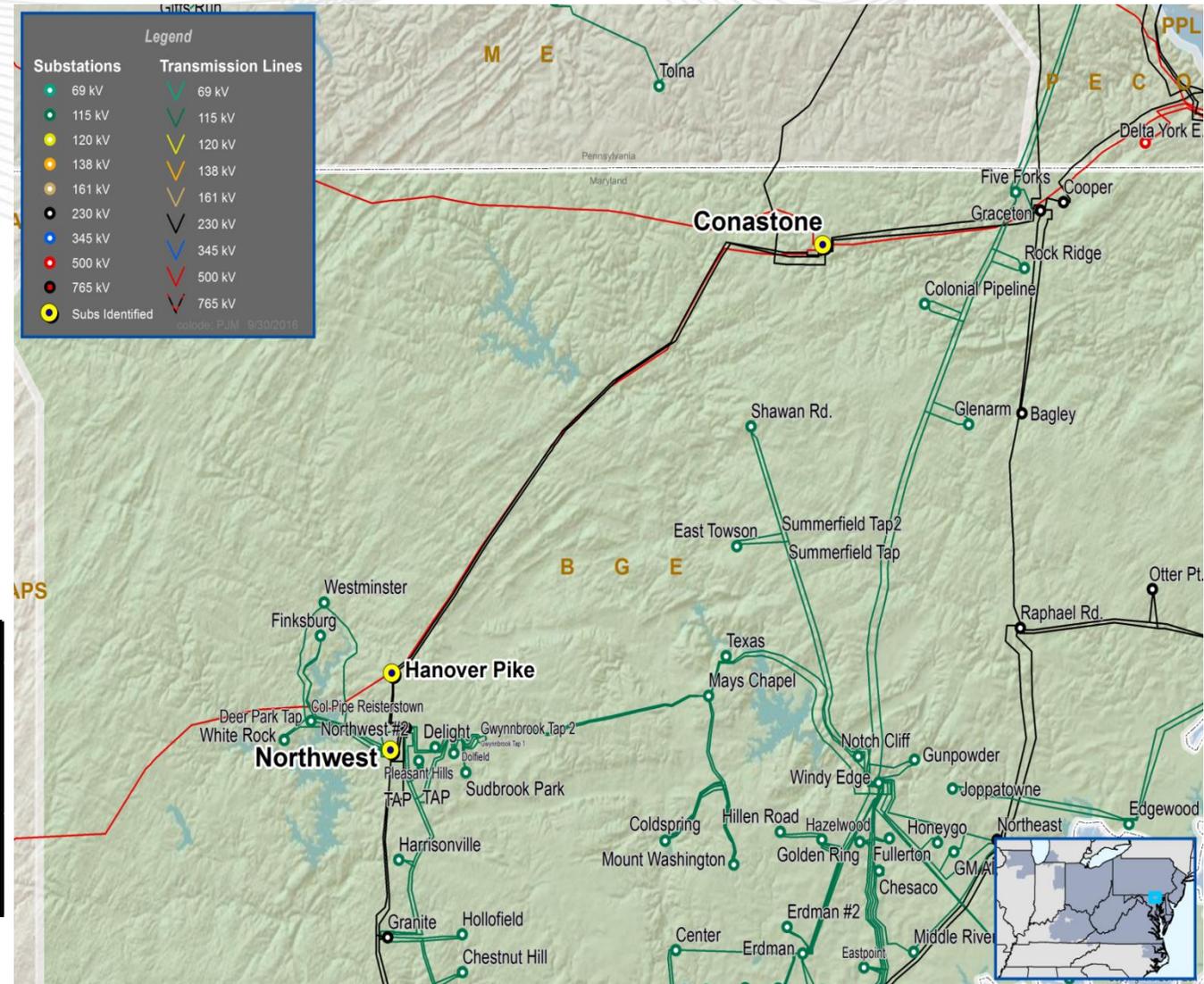
Revised Estimated Cost : \$13.9 M

Projected IS Date: 12/31/2018



- **Update:**
 - The planned Hanover Pike facility was not included in the 2016 RTEP as a sensitivity to determine the continued need for this facility.
- **Result:**
 - The latest analysis shows, there are no RTEP violations or drivers that would require the Hanover Pike upgrade.
- **Recommendation:**
 - Cancel the Hanover Pike and related upgrades. The upgrades are no longer required.

Upgrade Id	Description	Transmission Owner
b1254.1	Rebuild the Hanover Pike - North West 230 kV circuits to separate pole-lines with bundled conductor	BGE
b1254	Build a new 500/230 kV substation (Hanover Pike)	BGE





December 2016 Recommendations to the PJM Board

- All recommended baseline solutions in today's presentation will be presented to the PJM Board in December and recommended for inclusion in the RTEP.

RTEP Next Steps

- 2016 RTEP Window #3
- 2016/17 Long Term Window
- Cases and models build update
- Assumptions review in December 2016
- 2017 Scenario analysis

Questions?

Email: RTEP@pjm.com

- Revision History
 - V1 – 10/31/2016 – Original Version Posted to PJM.com
 - V2 – 11/1/2016 – Added Window 3 Slides
 - V3– 11/2/2016 – Added PSEG supplemental project
 - V4 – 11/3/0216 – Updated the expected IS date on slide #31, Updated the description of the AI data analysis on Slide #5
 - V5 – 11/7/2016 – Updated Required and Expected IS Dates on Slide 31, Updated Histograms on Slide 5, added Baseline Upgrade ID #s to all new projects
 - V6 – 11/8/2016 – Updated description of work on Slide 44 and 51
 - V7 – 03/13/2017 – Updated Required IS Date for B2609.4 on Slide 67