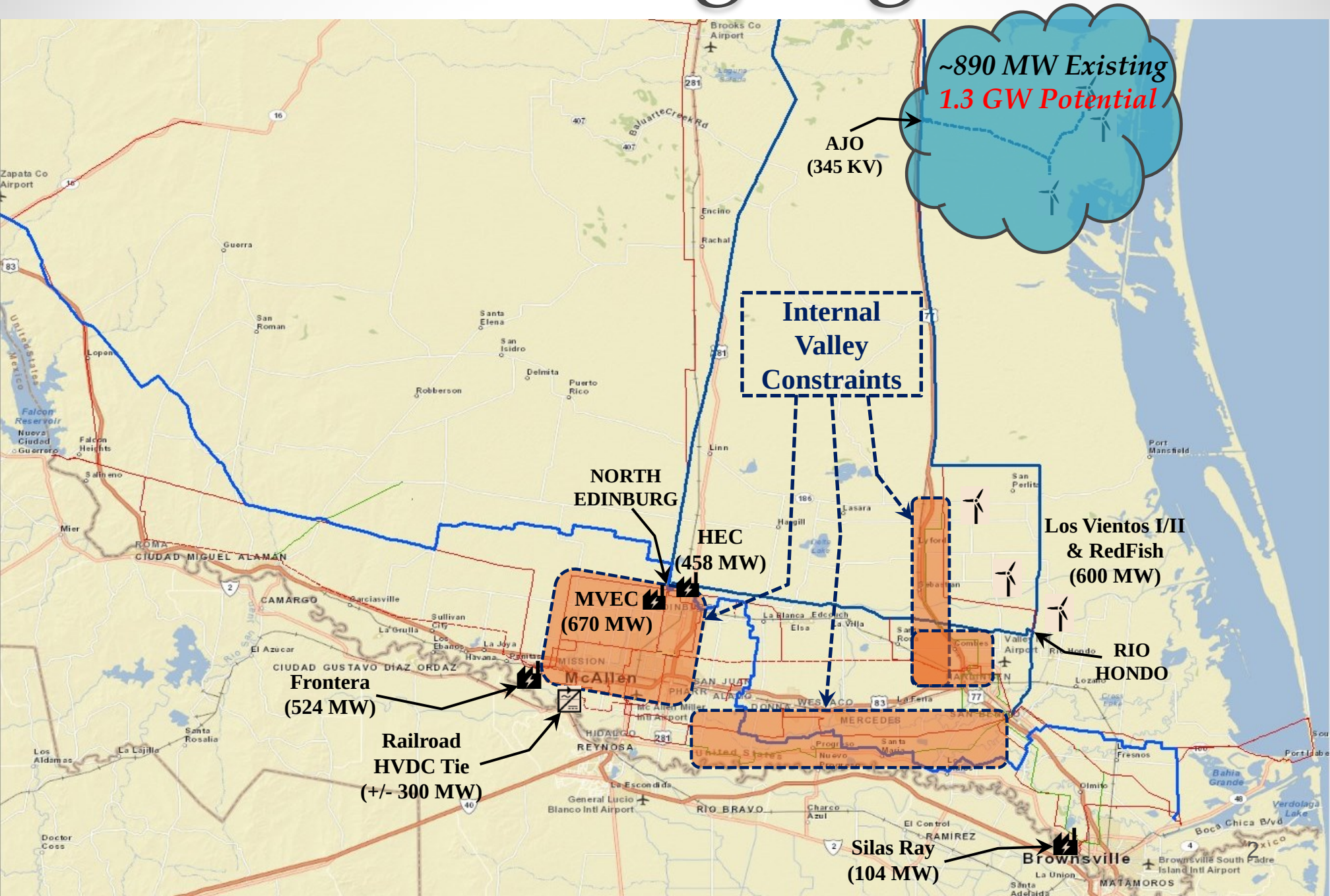
LRGV Area Transmission Improvements

ERCOT Regional Planning Group

May 19th, 2015

(Prepared by AEPSC)

LRGV Highlights



Study Drivers (1 of 2)

- Revised NERC TPL Standards
  - Assessments Begin in 2015
  - Enforcement Begins in January, 2021
  - TPL-001-4 Performance Requirement P3 Includes G-1, G-1
    - G-1: MVEC Combined Cycle Plant (678 MW) +
    - G-1: HEC Combined Cycle Plant (463 MW)
  - Non-Consequential Load Loss from P3 Event Must Not Exceed 75 MW
    - Eliminates Usage of LRGV Under Voltage Load Shed (UVLS) Plan
- Loss of Local Generation
  - Frontera is Exiting from the ERCOT Market to the Mexico Market
  - Loss of 524 MW of LRGV Generation by Mid-2016

Study Drivers (2 of 2)

- Stability Limitations for Coastal (Ajo) Area Wind
  - ~890 MW Wind (Available or in Final Stages of Construction)
  - Wind Export Limitations:
    - 580 MW (N-1 Conditions)
    - 305 MW (N-1-1 Conditions)
  - Additional Wind Under Study
  - Existing SSCI Exposure
- Recent LRGV Load Shed Events
  - February 2011 Load Shed Event (~300 MW)
  - October 2014 Load Shed Event (~150 MW)
    - G-1, G-1 Events
- Sustained High Rate of LRGV Load Growth

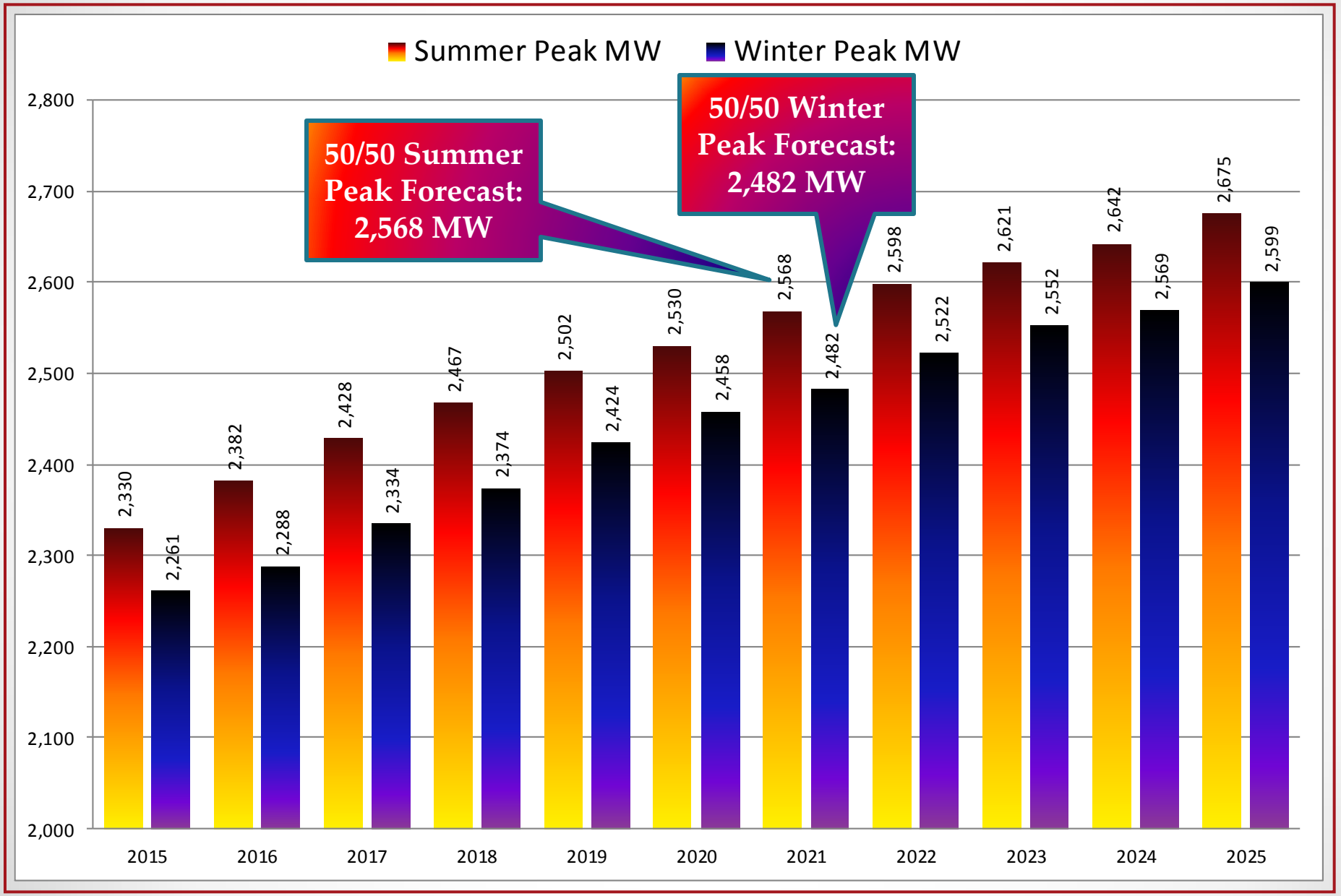
Study Prep and Objective

- Case Preparation Aligns with ERCOT's 2014 Assessments
  - Study Case: DWG 2018 Summer Peak Flat Start Case
  - Case Updates: Alignment with Latest SSWG Cases
    - Planned LRGV 345 kV System Improvements Included
  - Frontera Plant: Unavailable
  - LRGV Conventional Generation Dispatched at Full Output
  - Wind Dispatch: 10%
  - Railroad DC Tie: Neutral
  - Voltage Schedule and Reactive Devices Set for High Pre-Disturbance LRGV Voltage Profile
- Study Objective(s)
  - Identify LRGV Load Serving Capability for Existing System (Need Date Assessment)
  - Compare Transmission Investment Value of 'Layers' of Potential Solutions
    - MW/$M Basis
  - Evaluate Alternative Source Location Solutions
  - Ajo Area Wind Sensitivity:
    - Evaluate incremental cost and capability of LRGV transmission plan to mitigate stability limitations and SSCI concerns impacting Ajo Area Wind
  - Future Generation Sensitivities:
    - Identify Impact of Future Generation with IAs, but NOT Other PG Section 6.9 Criteria
    - Quantify Generation Export Limitations for Existing System Under Light Load Conditions
  - *"RECOMMEND A LONG-TERM TRANSMISSION EXPANSION PLAN THAT WILL SUPPORT LRGV LOAD LEVELS WELL BEYOND THE 10 YR PLANNING HORIZON"*

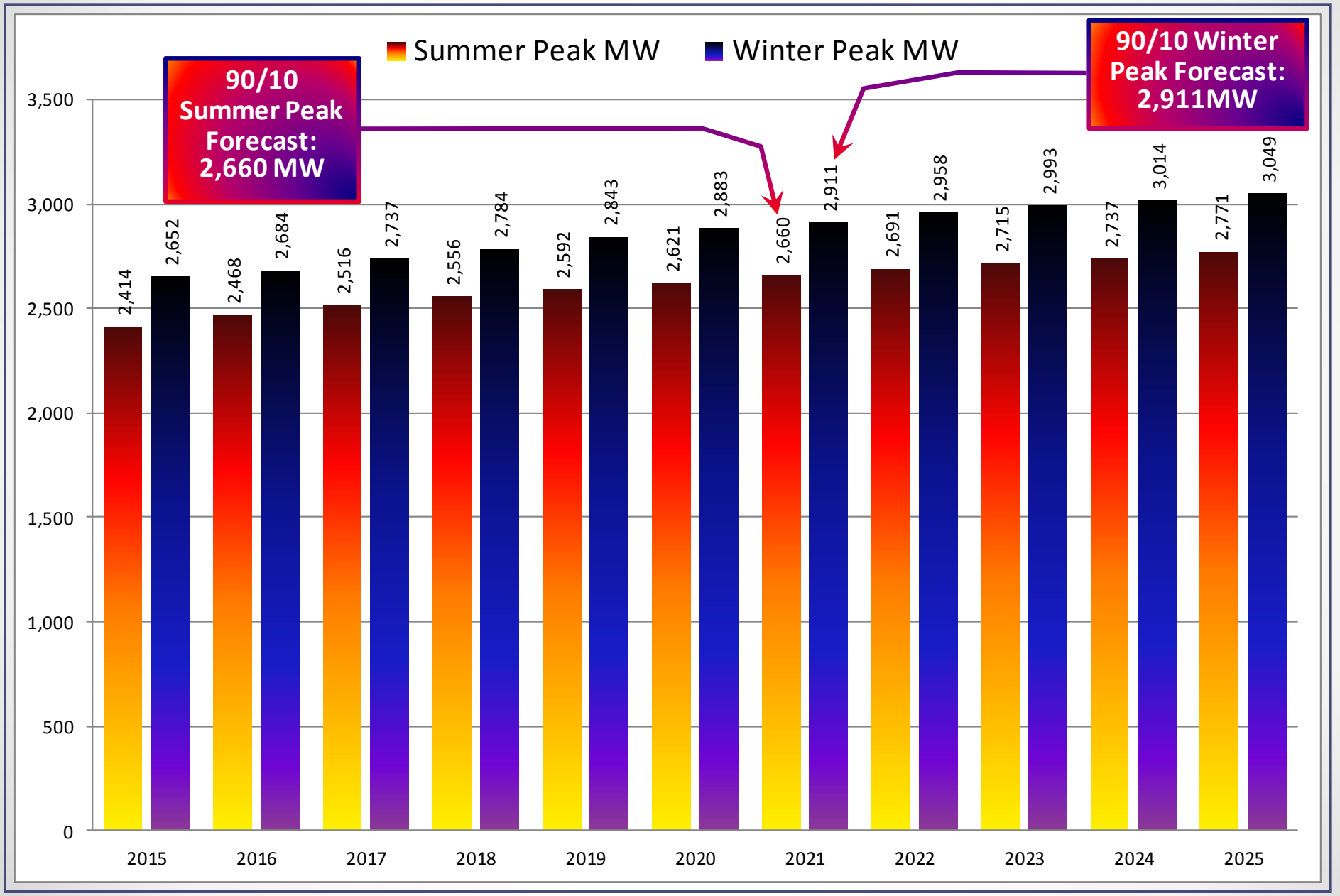
Study Methodology

- LRGV 'Study Area' Comprised of Zones along with Interface
  - LRGV Load Busses Defined by Zones 610, 615, 800, 829, 875, and 876
  - LRGV Interface Composed of 3 - 345 kV lines and 3 - 138 kV lines
- Analyze Impact of Incremental Increases in LRGV Load
  - Increase LRGV Load in 100 MW Increments, Reapplying Contingency Conditions
  - Scale LRGV Load Using Constant P/Q Ratio
  - Capture Contingency Conditions and Corresponding Max LRGV Load Resulting in Acceptable System Conditions (i.e. Identify the Limit)
  - Apply Analysis Methodology to Existing System and System with Alternative Solutions
- Quantify Results in Terms of 'LRGV Load Serving Capability'
  - Enables Extrapolation of System Limits to Point-in-Time via Load Forecast Overlay
- Use NERC TPL-001-4 Criteria During Study Analysis
  - Study Focuses on Long-Term LRGV Plan (Post 2021 Enforcement of TPL-001-4)
  - Operation of UVLS Scheme is Not Acceptable
  - Contingencies Tested Include: G-1+G-1, N-1-1, N-1+G-1, and G-1+N-1
- Assume G-1, G-1 to be Loss of Entire Combined Cycle Plants

LRGV *50/50* Load Forecast



LRGV *90/10* Load Forecast

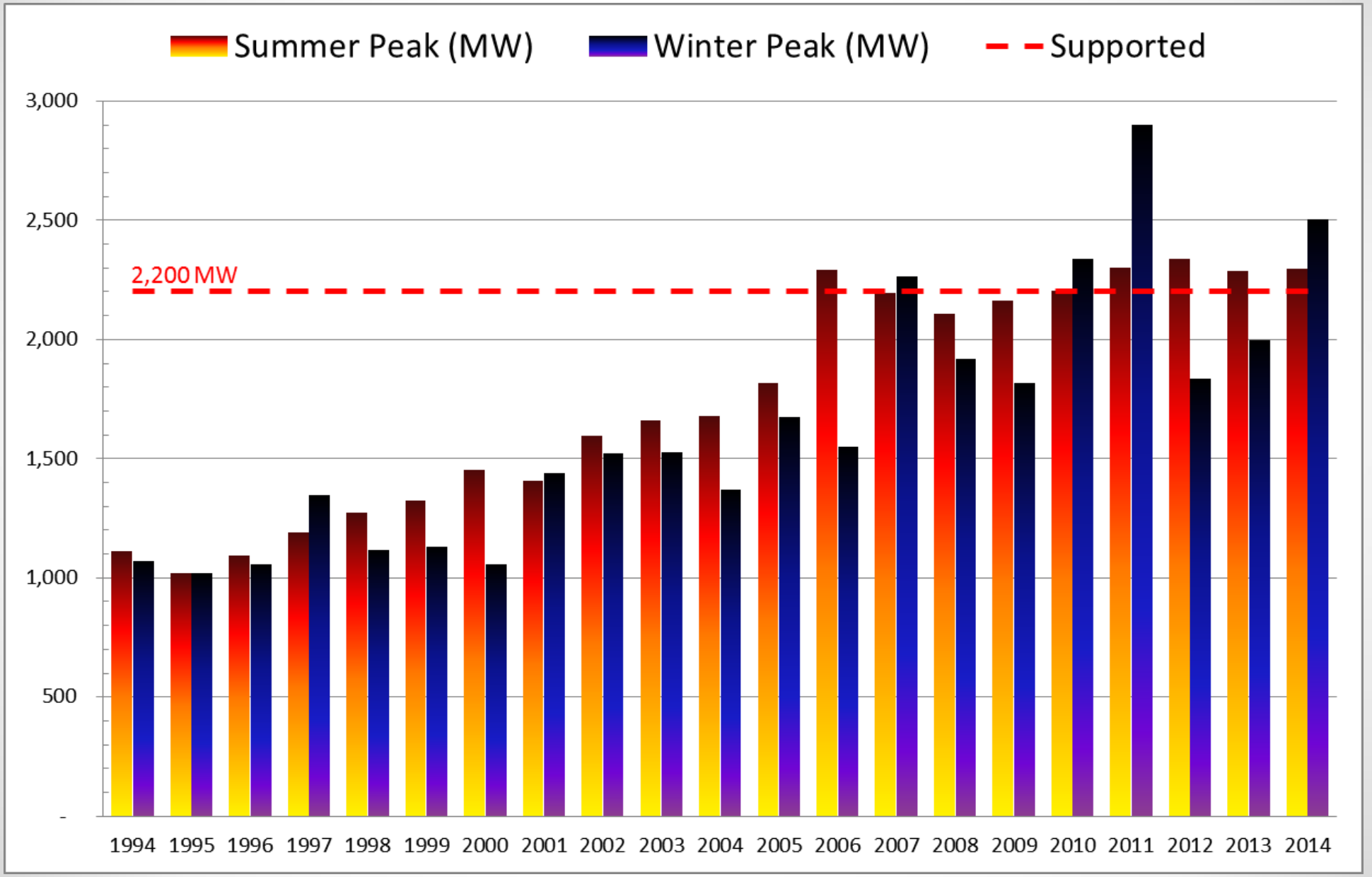


Existing System Results

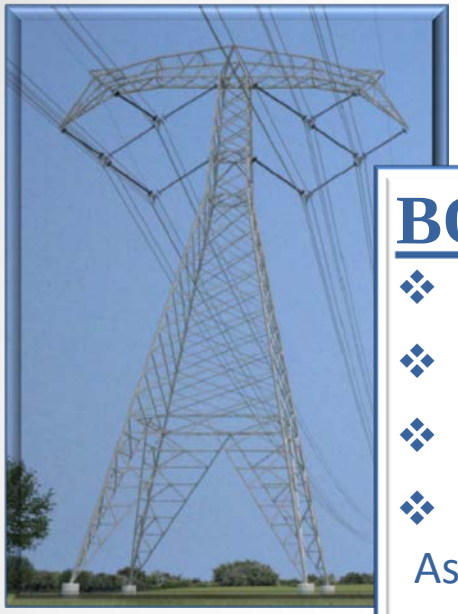
- Existing Transmission System Can Support **~2,200 MW** of LRGV Load
  - Most Limiting Contingency:
    - G-1+G-1 Loss of MVEC and HEC Plants
  - System Limitation:
    - Post Contingency Voltages in LRGV Fall Below 0.90 Per Unit UVLS Threshold
  - AEP's LRGV 50/50 Peak Load Forecast for Year 2021:
    - Summer Peak: 2,598 MW / Winter: 2,482 MW
  - AEP's LRGV 90/10 Peak Load Forecast for Year 2021:
    - Winter Peak: 2,911 / Summer: 2,660 MW

- **Additional Facilities Required By Jan. 2021**
  - Existing LRGV UVLS Scheme May Shed Up To 30% LRGV Load and….
  - *Is a Clear Violation of 75 MW Non-Consequential Load Loss Limit Imposed by NERC TPL-001-4 Requirement "P3" for G-1+G-1 Conditions*
  - Improvements are Required to Maintain NERC Compliance

LRGV Historical Load



AEP's Breakthrough Overhead Line Design (BOLD^{SM})

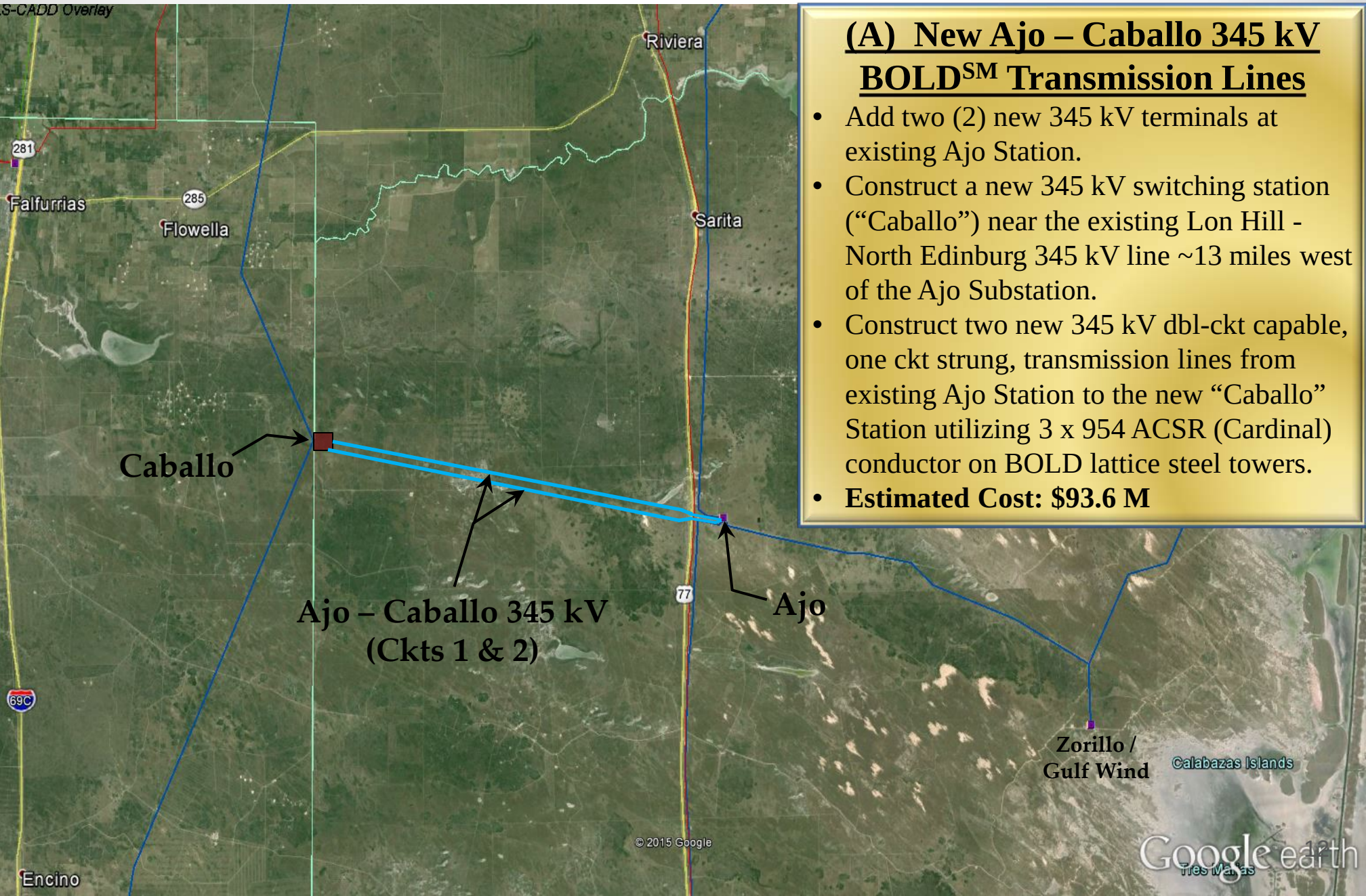


BOLD Line Advantages:

- Lower Impedance
- Eliminates Need for Series Compensation
- No Added SSR/SSCI Risk to Area Generation
- Mitigates Operational and P&C Complexities Associated with Series Compensated Lines
- Increased Capacity
- Comparable Cost to Traditional Series Compensated 345 kV Transmission

**AEP Awarded Two Patents by U.S. Patent and Trademark Office (Third Patent Pending)*

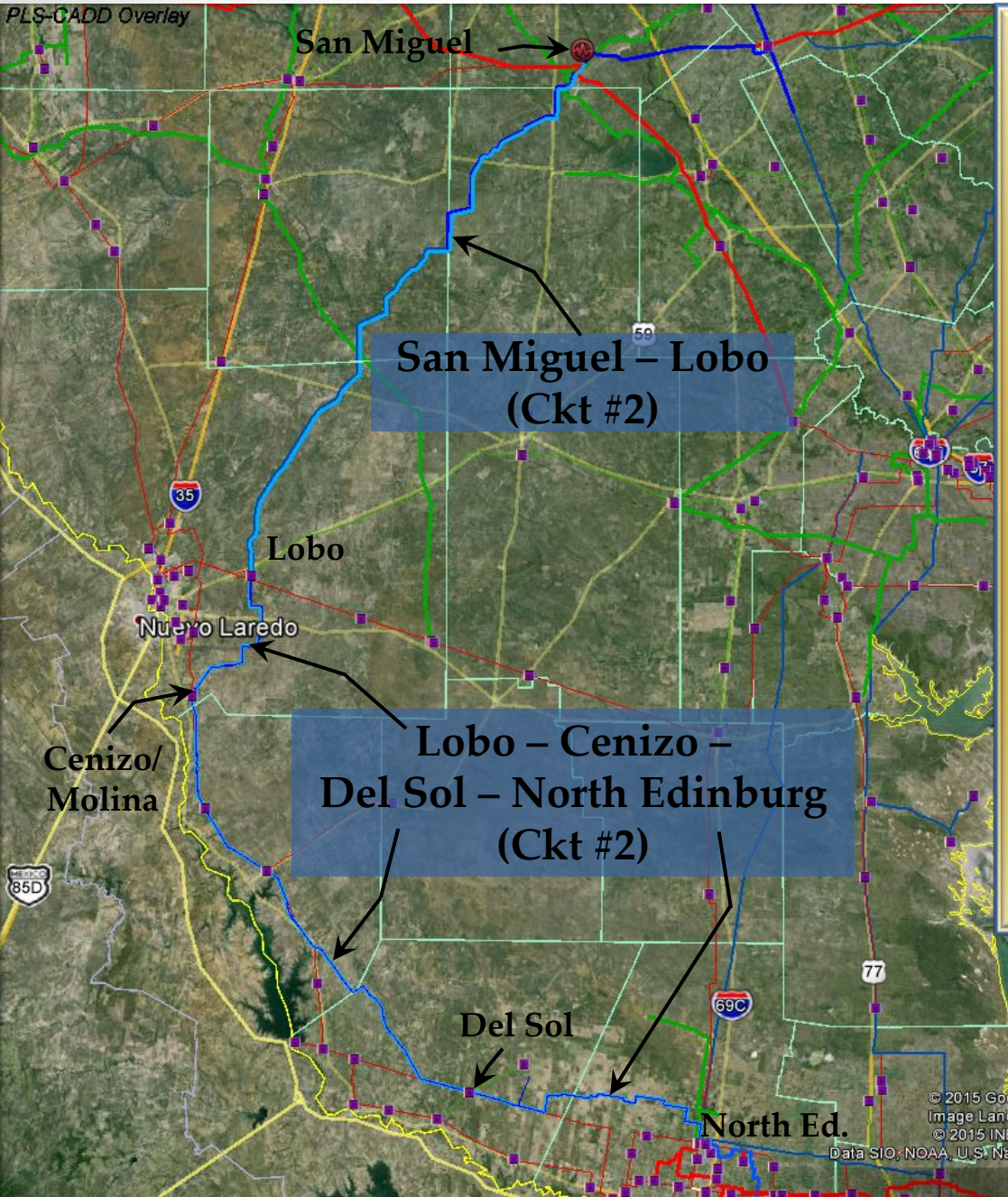
Solution Options Evaluated (A)



(A) New Ajo – Caballo 345 kV BOLD^{SM} Transmission Lines

- Add two (2) new 345 kV terminals at existing Ajo Station.
- Construct a new 345 kV switching station ("Caballo") near the existing Lon Hill - North Edinburg 345 kV line ~13 miles west of the Ajo Substation.
- Construct two new 345 kV dbl-ckt capable, one ckt strung, transmission lines from existing Ajo Station to the new "Caballo" Station utilizing 3 x 954 ACSR (Cardinal) conductor on BOLD lattice steel towers.
- **Estimated Cost: $93.6 M**

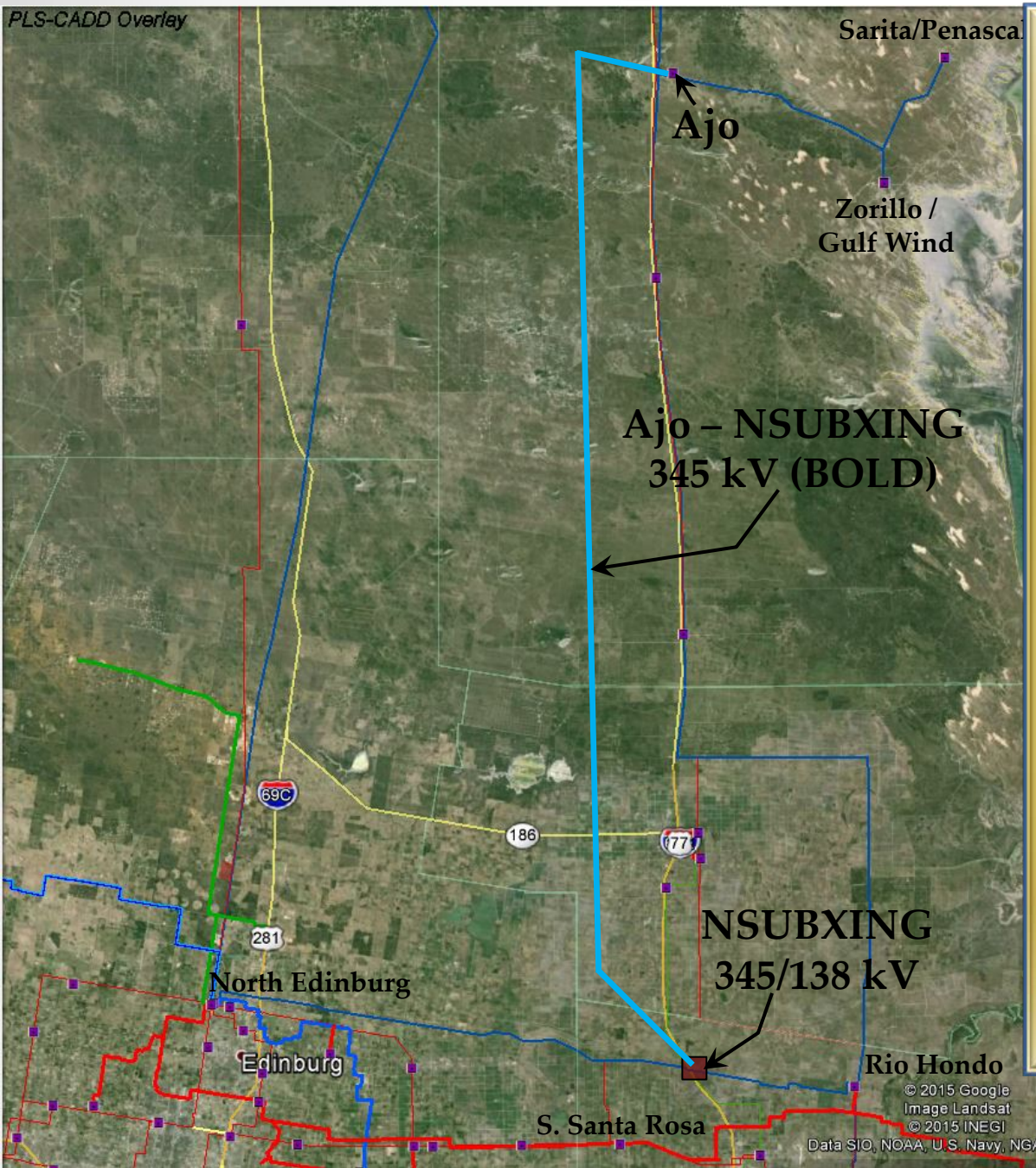
Solution Options Evaluated (B)



(B) San Miguel – Lobo – North Ed. 345 kV 2nd Ckt with Series Comp.

- New 345 kV terminals at San Miguel, Lobo (2), Cenizo (2), Del Sol (2) and North Edinburg.
- Install 24 ohm series capacitor at Cenizo with bypass switching.
- Install 24 ohm series capacitor at Del Sol with bypass switching.
- String 2nd Ckt on existing dbl-ckt capable structures from San Miguel to Lobo, and Cenizo to Del Sol to North Edinburg (~235 miles) utilizing 2 x 954 ACSR (Cardinal) conductor.
- Convert Lobo to Molina 138 kV line to 345 kV operation.
- Install two (2) 675 MVA, 345/138 kV autos tying the Cenizo 345 kV and Molina 138 kV stations.
- **Estimated Cost: $293.8 M**

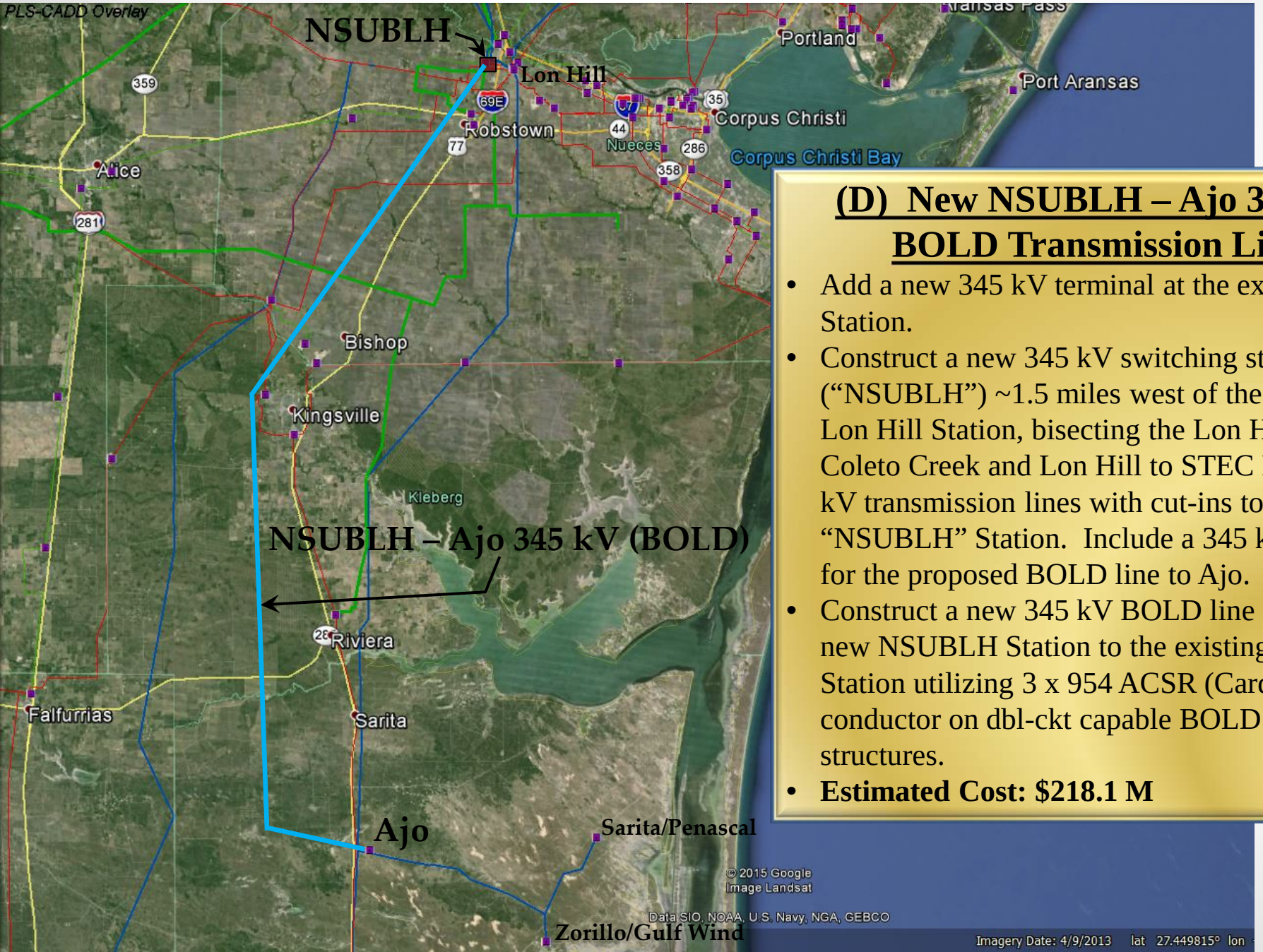
Solution Options Evaluated (C)



(C) New Ajo – NSUBXING 345 kV BOLD Transmission Line

- Add a new 345 kV terminal at the existing Ajo Station.
- Construct a new 345/138 kV station ("NSUBXING") west of the Rio Hondo Station at a point near the crossing of the east-west dbl-ckt North Edinburg to Rio Hondo 345 kV and Rio Hondo to South Santa Rosa 138 kV lines and the north-south Raymondville to Harlingen 69kV transmission lines. Cut-in the existing North Edinburg to Rio Hondo 345 kV and Rio Hondo to South Santa Rosa 138 kV lines. Terminate the proposed 345 kV BOLD line from Ajo. Install two (2) 675MVA, 345/138 kV autos.
- Construct a new 345 kV BOLD transmission line from Ajo to NSUBXING utilizing 3 x 954 ACSR (Cardinal) conductor on dbl-ckt capable BOLD lattice steel structures.
- **Estimated Cost: $234.8 M**

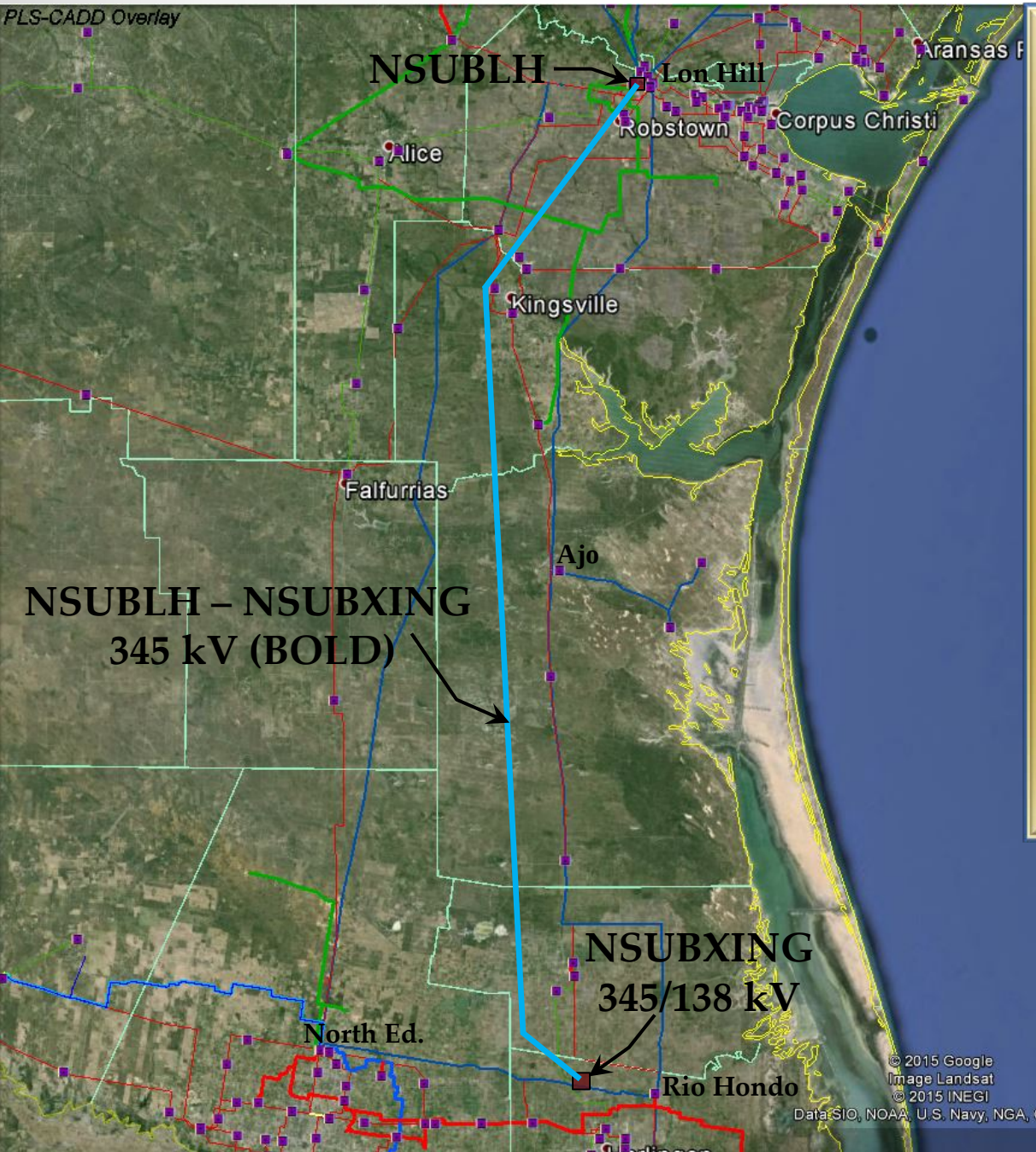
Solution Options Evaluated (D)



(D) New NSUBLH – Ajo 345 kV BOLD Transmission Line

- Add a new 345 kV terminal at the existing Ajo Station.
- Construct a new 345 kV switching station ("NSUBLH") ~1.5 miles west of the existing Lon Hill Station, bisecting the Lon Hill to Coleto Creek and Lon Hill to STEC Pawnee 345 kV transmission lines with cut-ins to the new "NSUBLH" Station. Include a 345 kV terminal for the proposed BOLD line to Ajo.
- Construct a new 345 kV BOLD line from the new NSUBLH Station to the existing Ajo Station utilizing 3 x 954 ACSR (Cardinal) conductor on dbl-ckt capable BOLD lattice steel structures.
- **Estimated Cost: $218.1 M**

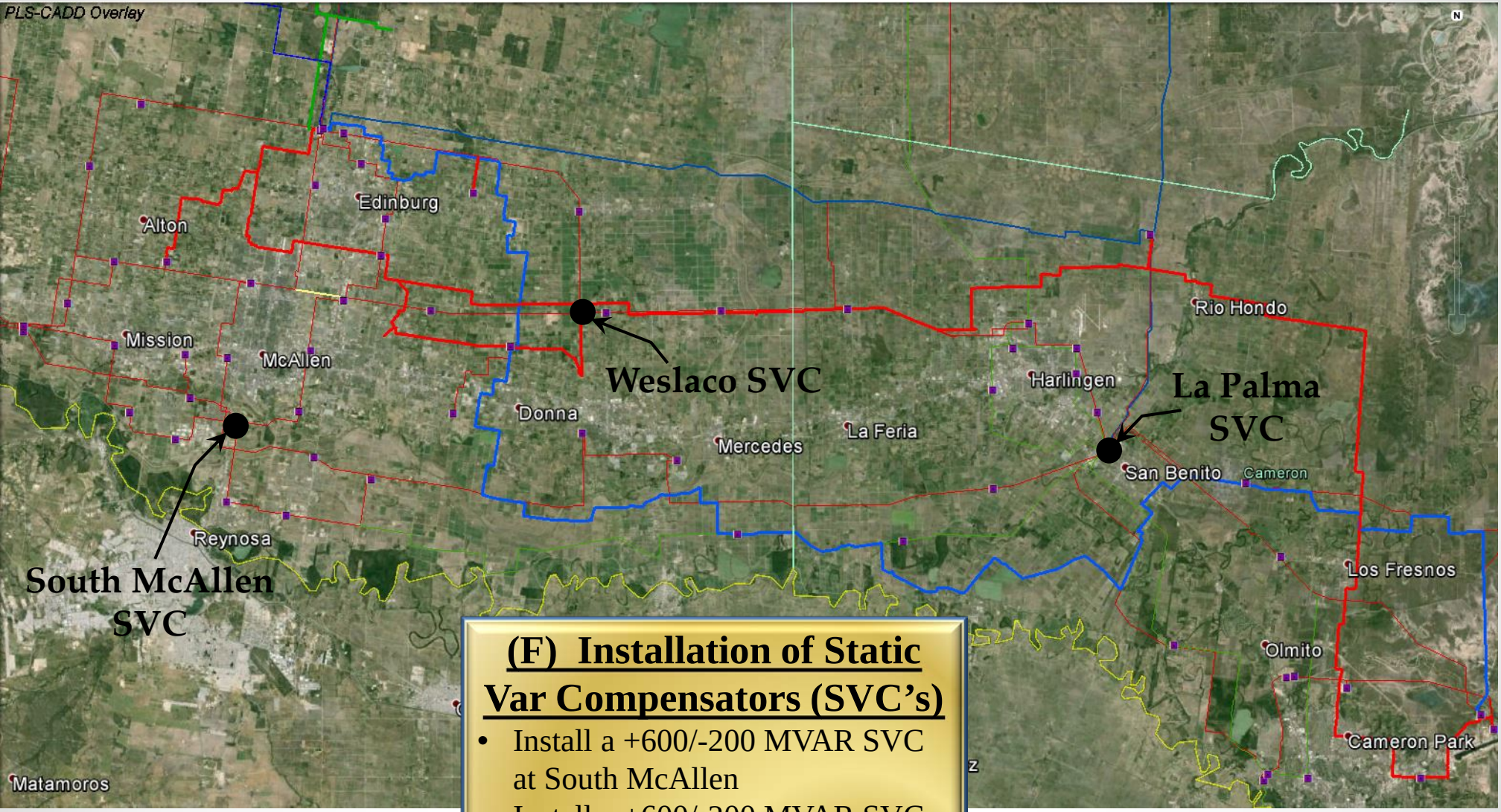
Solution Options Evaluated (E)



(E) New NSUBLH – NSUBXING 345 kV BOLD Transmission Line

- Construct a new 345 kV switching station ("NSUBLH") as introduced with Option "D". Include a 345 kV terminal for the proposed BOLD line to NSUBXING, instead of Ajo.
- Construct a new 345/138 kV station ("NSUBXING") as introduced with Option "C". Include a 345 kV terminal for the proposed BOLD line to NSUBLH, instead of Ajo.
- Construct a new 345 kV BOLD transmission line from NSUBLH to NSUBXING utilizing 3 x 954 ACSR (Cardinal) conductor on dbl-ckt capable BOLD lattice steel structures.
- **Estimated Cost: $373.2 M**

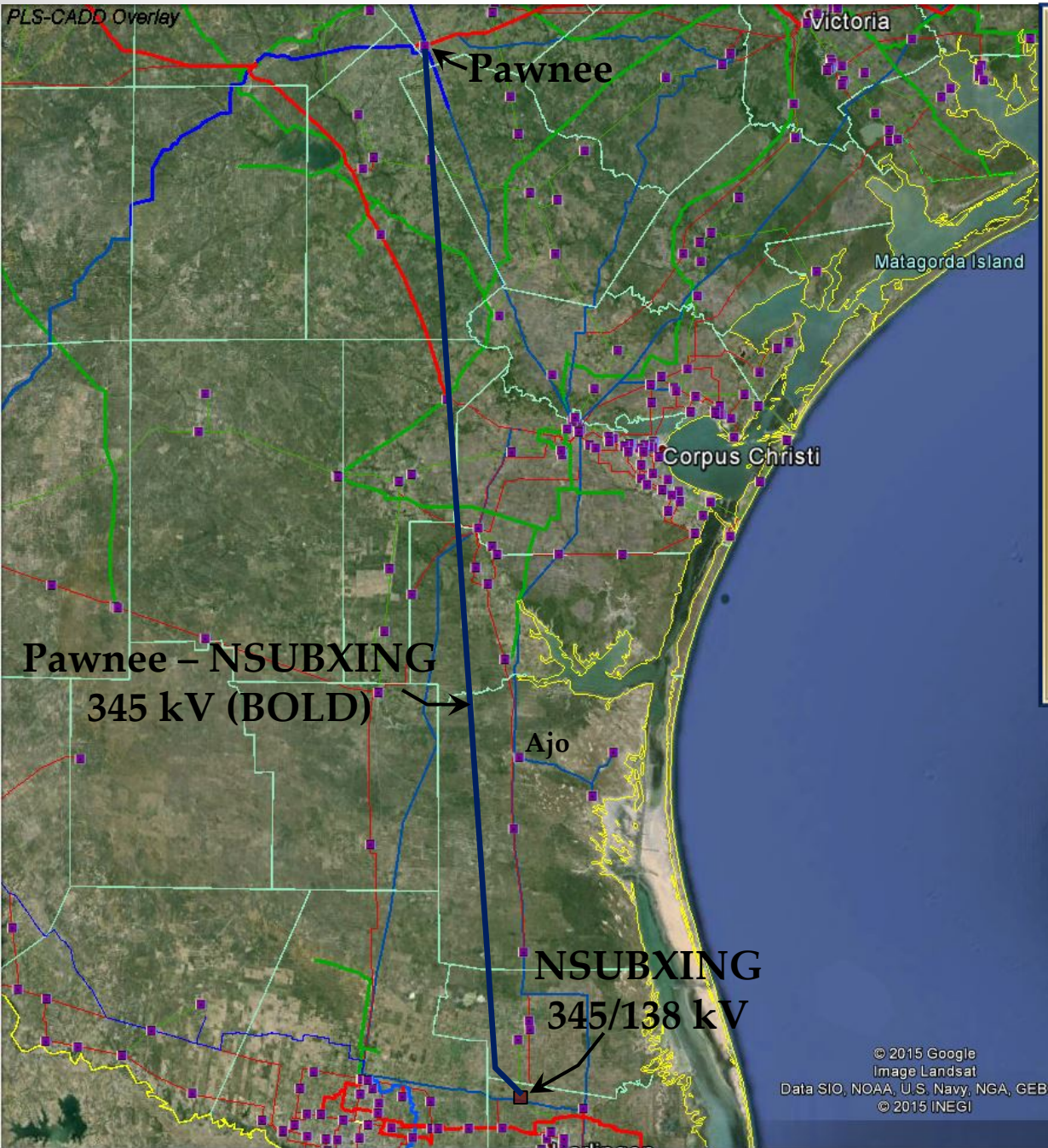
Solution Options Evaluated (F)



(F) Installation of Static Var Compensators (SVC's)

- Install a +600/-200 MVAR SVC at South McAllen
- Install a +600/-200 MVAR SVC at La Palma
- Install a +400/-100 MVAR SVC at Weslaco
- **Estimated Cost: $175.4 M**

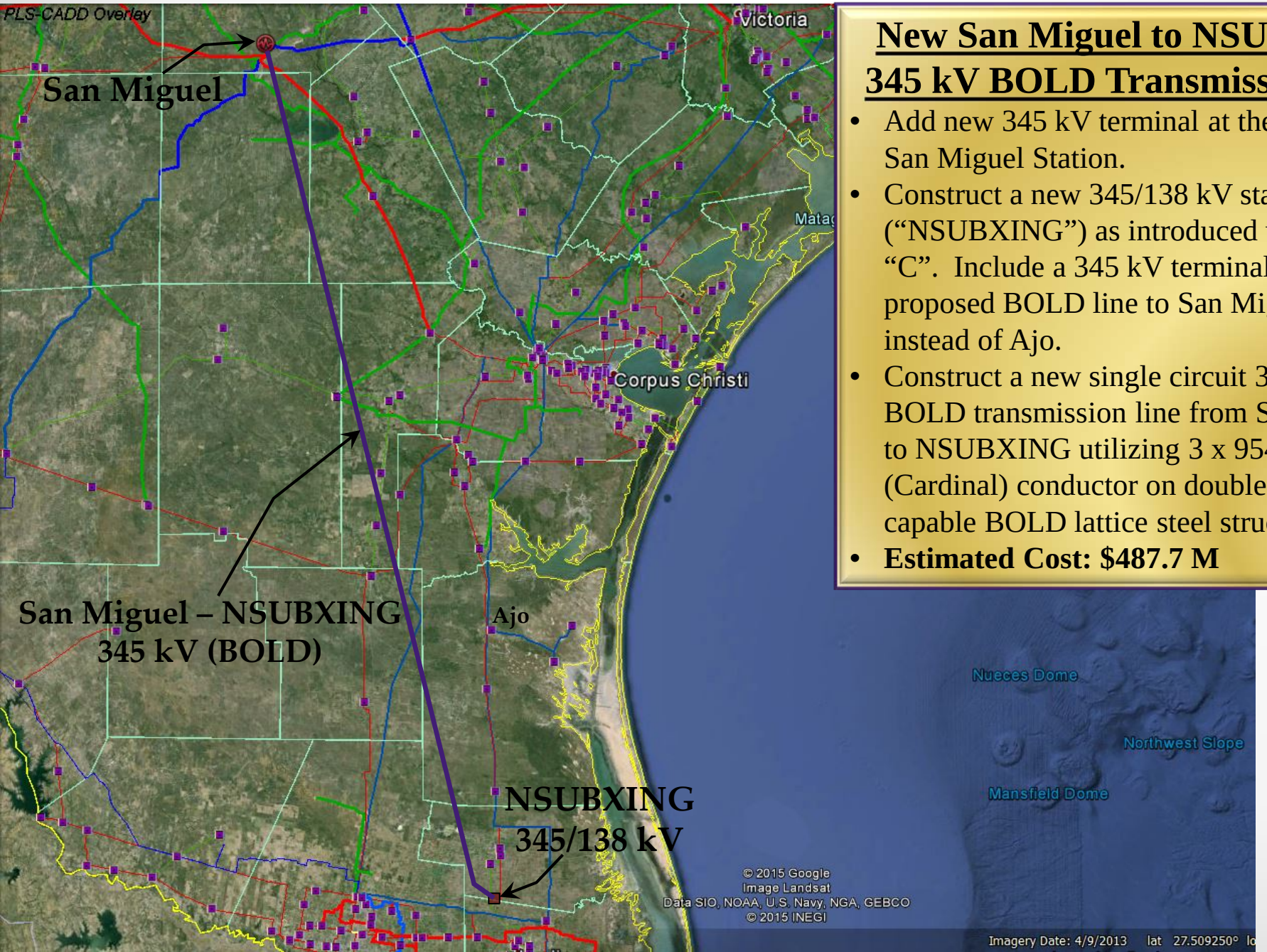
Alternate Source Option (G)



New Pawnee to NSUBXING 345 kV BOLD Transmission Line

- Add a new 345 kV terminal at the existing Pawnee Station.
- Construct a new 345/138 kV station ("NSUBXING") as introduced with Option "C". Include a 345 kV terminal for the proposed BOLD line to Pawnee, instead of Ajo.
- Construct a new single circuit 345 kV BOLD transmission line from Pawnee to NSUBXING utilizing 3 x 954 ACSR (Cardinal) conductor on double-circuit capable BOLD lattice steel structures.
- **Estimated Cost: $486.6 M**

Alternate Source Option (H)



New San Miguel to NSUBXING 345 kV BOLD Transmission Line

- Add new 345 kV terminal at the existing San Miguel Station.
- Construct a new 345/138 kV station ("NSUBXING") as introduced with Option "C". Include a 345 kV terminal for the proposed BOLD line to San Miguel, instead of Ajo.
- Construct a new single circuit 345 kV BOLD transmission line from San Miguel to NSUBXING utilizing 3 x 954 ACSR (Cardinal) conductor on double-circuit capable BOLD lattice steel structures.
- **Estimated Cost: $487.7 M**

Initial Observations

- No Single Option Presented Above Yielded any Significant Increase in LRGV Load Serving Value
- Two Existing System Limitations Impacting LRGV
  - Broad LRGV Steady-State Low Voltage (2200 MW)
    - Add SVCs
  - Next System Limitation: Angular Stability for LRGV Import Conditions (2300 MW)
    - Add New Transmission Paths
- Combinations of Options Presented Above Yielded Greatest Increases in LRGV Load Serving Value:
  - LRGV Reactive Support: Bolsters LRGV Voltage Profile
  - New 345 kV BOLD Line: Improves Angular Stability

Option Performance

Comparison of Top Performing Improvement Options

Option	Incremental Load Served (MW)	Limiting Contingency	Limiting System Condition	Estimated Cost ($M)	Load Serving Value (MW/$M)
E+F	1300	HEC+MVEC	Voltage	$556.2_{(LC1)}$	2.3
C+D+E+F	1500	HEC+MVEC	Voltage	$695.0_{(LC7)}$	2.2
A+D+E+F	1500	HEC+MVEC	Voltage	$693.0_{(LC6)}$	2.2
C+D+F	1300	HEC+MVEC	Voltage	$621.5_{(LC2)}$	2.1
D+E+F	1300	HEC+MVEC	Voltage	$632.5_{(LC3)}$	2.1
A+E+F	1300	HEC+MVEC	Voltage	$649.8_{(LC4)}$	2.0
A+C+D+F	1300	HEC+MVEC	Voltage	$663.1_{(LC5)}$	2.0

***Ranked According to Incremental LRGV Load Serving Value (MW/$M)**

Option Assignment Reference Table

Option A: New Ajo – Caballo 345 kV (Two dbl-ckt BOLD lines)
Option B: San Miguel – Lobo – North Edinburg (2nd circuit)
Option C: New Ajo – NSUBXING 345 kV BOLD
Option D: New NSUBLH – Ajo 345 kV BOLD
Option E: New NSUBLH – NSUBXING 345 kV BOLD
Option F: SVC's at South McAllen, Weslaco and LaPalma
Option G: New Pawnee – NSUBXING 345 kV BOLD
Option H: New San Miguel – NSUBXING 345 kV BOLD

Contingency Reference Table

MVEC = Magic Valley Combined Cycle Plant
HEC = Hidalgo Combined Cycle Plant
LH-NE = Lon Hill – North Edinburg 345 kV Line
RH-AJ = Rio Hondo – Ajo 345 kV Line

Observations

- Top Performing Option (*Per Investment Dollar)
  - E+F = Direct Corpus to Valley 345 kV BOLD Line with LRGV SVCs
  - ✓ Increases LRGV Load Serving Capability: ~2,200 MW Increases To 3,500 MW
  - ✓ Supports Valley Well Beyond AEP's 10-Year Valley Forecast: 50/50 or 90/10
  - ✓ Lowest Cost Option Amongst Best Performers ($556.2M)
  - ❖ Adds No New Export Paths from Ajo

Alternate Source Location

Comparison of BOLD Transmission Line "Source" Locations					
Option	**Incremental Load Served (MW)**	**Limiting Contingency**	**Limiting System Condition**	**Estimated Cost ($M)**	**Load Serving Value (MW/$M)**
E+F (NSUBLH)	1300	HEC+MVEC	Voltage	$556.2	2.3
F+G (Pawnee)	1300	HEC+MVEC	Voltage	$668.0	1.9
F+H (San Miguel)	1300	HEC+MVEC	Voltage	$667.9	1.9

- Incremental LRGV load serving capability is basically neutral across BOLD line source locations.
- E+F (NSUBLH Source) has significantly lower line miles resulting in significantly lower cost.

Option Assignment Reference Table

Option A: New Ajo – Caballo 345 kV (Two dbl-ckt BOLD lines)
Option B: San Miguel – Lobo – North Edinburg (2nd circuit)
Option C: New Ajo – NSUBXING 345 kV BOLD
Option D: New NSUBLH – Ajo 345 kV BOLD
Option E: New NSUBLH – NSUBXING 345 kV BOLD
Option F: SVC's at South McAllen, Weslaco and LaPalma
Option G: New Pawnee – NSUBXING 345 kV BOLD
Option H: New San Miguel – NSUBXING 345 kV BOLD

Ajo Wind Export (Analysis)

- **Basecase: 2016 DWG HWLL**
  - Planned (ERCOT Endorsed) LRGV 345 kV Improvements In-Service
  - Total Ajo Area Wind: 888 MW
  - LRGV Upgrade Options Presented Above Not Included in Baseline Analysis
- **Existing Ajo Area Wind Export Stability Limitations**
  - N-1-1 Export Limit: 305 MW (34%)
  - N-1-1 Limiting Outage: Ajo – Rio Hondo & Lon Hill – Nelson Sharpe 345 kV
  - System Condition: Unstable Post-Contingency Voltage Oscillations
- **Wind Export Study Objective**
  - Identify Best Overall Solution for Improving
    - LRGV Load Serving Capability
    - Ajo Wind Export Capability
  - Not Aimed at Resolving Voltage Oscillation Issue
    - Separate Ongoing Studies for this Specific Issue
    - 200 MVAR Synchronous Condenser Added to Model at Sarita
    - Masks the Voltage Oscillation Issue to Identify Next Limiting Condition

Ajo Wind Export (Results)

Wind Export Capability (Existing System and Option Performance)

Option	N-1 Limit (MW)	Limiting Contingency	Limiting Condition	N-1-1 Limit (MW)	Limiting Contingency	Limiting Condition
Existing System	580	Ajo-NS	Voltage Oscillations	305	Ajo-RH NS-LH	Voltage Oscillations
C+D	1,788	Ajo-NS	Voltage Oscillations	988	Ajo-NSUBLH Ajo-NS	Voltage Oscillations
200 MVAR SC @ Sarita ("SC")	1,288	Ajo-NS	Control Instability	614	Ajo-RH NS-LH	Control Instability
A+SC	2,088+	N/A	N/A	1,788	CB-LH Ajo-NS	Control Instability
C+D+SC	2,088+	N/A	N/A	1,488	Ajo-NSUBLH Ajo-NS	Control Instability
A+E+SC	2,088+	N/A	N/A	1,788	CB-LH Ajo-NS	Control Instability
A+C+D+SC	2,088+	N/A	N/A	2,088+	N/A	N/A

***Ranked According to MW Increase Under N-1-1 Conditions**

Option Assignment Reference Table

"SC": 200 MVAR Synchronous Condenser at Sarita
Option A: New Ajo – Caballo 345 kV (Two dbl-ckt BOLD lines)
Option C: New Ajo – NSUBXING 345 kV BOLD
Option D: New NSUBLH – Ajo 345 kV BOLD
Option E: New NSUBLH – NSUBXING 345 kV BOLD

Contingency Reference Table

Ajo-RH: Ajo – Rio Hondo 345 kV (Ajo to South)
Ajo-NS: Ajo – Nelson Sharpe 345 kV (Ajo to North)
NS-LH: Nelson Sharpe – Lon Hill 345 kV
CB-LH: Caballo – Lon Hill 345 kV (Northern portion of existing Lon Hill – North Edinburg line once bisected)

Wind Export (Observations)

- E+F Option (without A): Top Performer for LRGV Load
  - Adds No Value to Ajo Area Wind Exports
  - Provides No Additional Paths Out of Ajo (Wind Farms Radial to Series Cap Under N-1)
- Voltage Oscillation Issue Effectively Masked by Synchronous Condenser
  - Next Stability Limitation, "Control Instability", Reached at 614 MW Under N-1-1
- Options A and C+D: Add Ajo Export Paths, Increase Export Capability, Reduce SSR Risk
- Option C+D+F:
  - Mid-Range Performer for Wind Exports per Transmission Investment Dollar; Better than Option A+E+F
  - Lowest Incremental Cost Option Addressing Ajo Area Wind Exports
  - Sufficient to Support Existing Wind (888 MW) + ~600 MW Future Wind

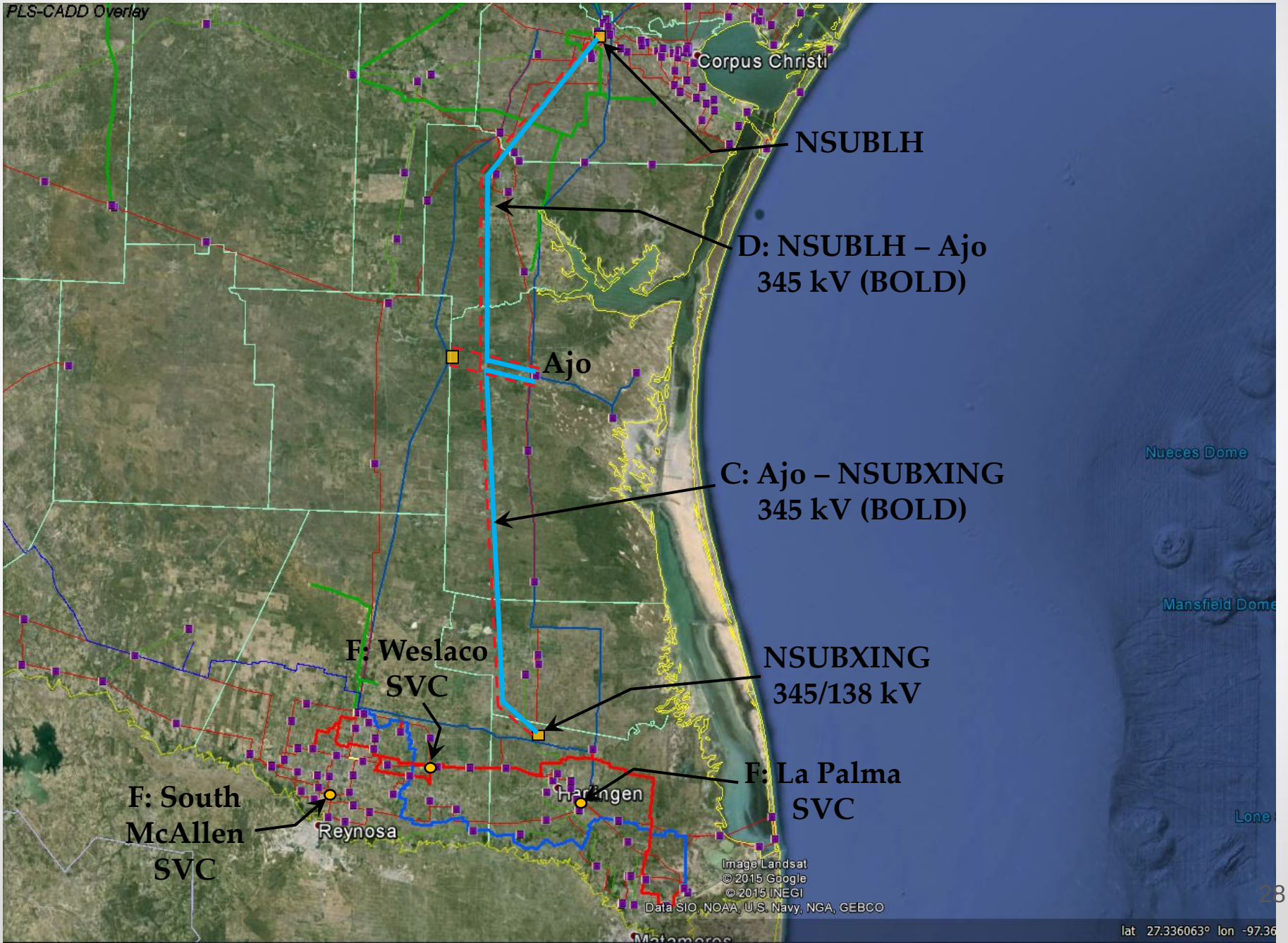
Comparison of Ajo Area Wind Export Improvement Options			
Option (all with "SC")	**Cost over Option E+F ($M)**	**Increase in Capability (MW)**	**Wind Export Value (MW/$M)**
A+C+D+F	$107_{(LC3)}$	1,474	13.8
C+D+F	$65_{(LC1)}$	874	13.4
A+E+F	$94_{(LC2)}$	1,174	12.5

***Ranked According to Incremental Increase in Wind Exports Per Cost Above Option E+F (MW/$M)**

AEP Recommendation

- AEPSC Recommends ERCOT Endorsement of Option C+D+F
  - ✓ LRGV Load Serving Capability: 3,500 MW
  - ✓ Ajo Area Wind Export Capability: >2,088 MW (N-1) / 1,488 MW (N-1-1)
  - ✓ One of Top Performing Options in Both Analyses
  - ✓ Lowest Cost Option Addressing Both Constraints
  - ✓ Optimal Solution Addressing LRGV Load Serving Capability and Ajo Area Wind Exports
- Estimated Cost: $621.5M

Recommended Solution



Generation Sensitivity (Valley Load Support)

- Same Basecase as Original LRGV Load Serving Capability Analysis
- Same LRGV Load Evaluation Methodology Employed
- Generation Added to Original Basecase Analysis
  - Recently Executed Interconnection Agreements
    - Coronado Ventures La Paloma EC: 785 MW Combined Cycle Facility
    - STEC Red Gate: 225 MW Peaking Facility
    - Duke Los Vientos III, IV, V: 200 MW per phase (600 MW Total) Wind
- LRGV Load Serving Impact: 2,200 MW Increased to 2,800 MW
  - G-1+G-1 (MVEC & HEC) Still Poses Worst Case Contingency
  - System Limitation is Post Contingency Low Voltages in LRGV
- What if we add LRGV SVCs on Top of Local Generation???
  - LRGV Load Serving Capability is Increased from 2,800 MW to 3,300 MW
  - Need Only West Valley (South McAllen) and Mid-Valley (Weslaco) SVCs
  - Above 3,300 MW: Angular Instability is Limiting Condition for N-1-1 Loss of AJ – RH & LH - NE

Generation Sensitivity (Valley Exports – Light Load)

- Purpose: Identify Operational Limits That May Exist Under Light Load
  - What is the Export Limitation and Ability of Conventional LRGV Generation to Run at Full Output?
- Case Preparation:
  - Same Case Topology as Original LRGV Load Serving Capability Analysis *(*No Improvements)*
  - Added Valley Generation with Recent IAs
  - LRGV Load: Scaled Down to ~1100 MW *(~40% of Peak Load Forecast in 2021)*
  - LRGV Conventional Generation: Dispatched at Full Output
  - LRGV Wind: Start at 10%; Incrementally Increase WFs to Export Limit
- Results:
  - Basecase LRGV System Topology Supports Exports of ~1,900 MW
  - 1,900 MW Measured as Summation of Flows Across LRGV Transmission Interface Facilities
  - Stability Limitation: "Unacceptable Power Swing Damping of LRGV Generation Facilities"
  - Limiting Contingency: N-1-1 Loss of…
    - Lon Hill to North Edinburg 345 kV Line
    - Mutually Coupled Del Sol to Cenizo 345 kV and Zapata to Lopeno 138 kV Lines
  - North Edinburg – Rachal – Falfurrias 138 kV Line is Loaded to 109% Under These Conditions