NEW HAMPSHIRE – SYSTEM ENGINEERING
SYSTEM PLANNING & STRATEGY

Webster Substation Review

June 24, 2019

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Executive Summary

This study looks at the future of Webster Substation and possible replacement substations in the Franklin area. It is driven by obsolescence and equipment overload at Webster Substation. [redacted] the solution needs to maintain some transformation in the immediate area to support the extensive 34.5 kV system. The system currently fed by Webster Substation feeds over [redacted] Eversource customers and over [redacted] New Hampshire Electric Coop (NHEC) customers.

The largest limitation, with utilizing the existing Webster Substation property, is the placement of the NHEC Webster Substation. The NHEC substation is located in the middle of Eversource's property and makes it difficult to expand the existing Webster Substation. There is additional property available for Eversource to develop on the other side of NHEC's substation.

It is recommended that Eversource replace the [redacted] existing bulk substation transformers [redacted] transformers. The new bulk transformers will be located within the existing Webster Substation. In a separate enclosure, on the other side of NHEC Webster Substation, a 34.5 kV bus and switching station will be constructed. The separate 34.5 kV will be designated as Daniel Substation. The finished project will increase capacity, eliminate obsolesce issues, and fit within limited land constraints, while maintaining the existing transmission assets. The new substation site will also allow for future expansion by supplying additional breaker positions. This solution is the best project to address loading issues in an area where transformation is critical.

Respectfully submitted:

[redacted]

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I. Introduction

This review was initiated to address transformer overloads identified in the 10 Year Study. The existing system configuration, equipment limitations, system loading and area load growth rate are used to assess future system requirements. The objective of this study is to develop recommendations that address the long term loading requirements and equipment obsolescence in the Webster Substation area.

II. Study Background

The electric system is primarily 34.5 kV in the Webster Substation area, making it is necessary for this study to focus on a 34.5kV transformation solution. This report summarizes the best solution for the electrical system need at Webster Substation, developed in the 10 Year Study. Webster Substation has been identified in the past as an area with need for improvement. [redacted]

III. System Analysis

Area Problems & Limitations

1. **Natural Load Growth** – A 1.5 % natural load growth is expected for the area fed by Webster Substation. [redacted] The "TFRAT" is a rating, above the nameplate, that assumes no additional loss of life, which is calculated based on its respective load curve.
2. **New Large Customers** – Two large customers are expected to come online within the next five years, significantly increasing substation loading. [redacted]. is expected to add an additional [redacted] of load within the next year to the 3548 line, fed from Webster Substation. Also, the Northern Pass Converter Station is expected to add another 1 MW of station service load to the 3548 line by 2019.
3. **Geography** – The existing Webster Substation is located in a desirable location to transform power to the local distribution circuits. [redacted]

Substation Problems & Limitations

1. **Obsolescence** – The [redacted] transformers at Webster Substation are all in excess of 60 years old. There are also four oil circuit breakers that are older than 60 years. The age of all bulk transformers and circuit breakers are shown below in Table 3.1. Based on a useful life expectancy of 55 years, about 80% of the distribution equipment at Webster Substation is obsolete. Potential failure of a transformer due to age and loading is the biggest concern.
2. **Crowding** – [redacted], there is little room at Webster Substation for construction and improvement. Significant outages would be necessary to facilitate construction at the site. For more detail, please see Appendix C for a one-line diagram of Webster Substation.
3. **Outage Coordination** – [redacted] The 34.5 kV bus is a shared bus between all [redacted] bulk transformers, requiring a complete 34.5 kV station outage for certain work.

SUBSTATION	EQUIPMENT	POSITION	MANUFACTURER	YEAR	AGE
Webster	LTC Transformer [redacted]	TB37	Westinghouse	1951	64
	LTC Transformer [redacted]	TB54	Westinghouse	1954	61
	LTC Transformer [redacted]	TB96	Westinghouse	1955	60
	Oil Circuit Breaker	TB37	General Electric	1949	66
	Oil Circuit Breaker	TB54	General Electric	1954	61
	Oil Circuit Breaker	TB96	General Electric	1955	60
	Oil Circuit Breaker	3216	General Electric	1950	65
	SF6 Circuit Breaker	3548	Siemens	2004	11
	SF6 Circuit Breaker	BT40	Siemens	2003	12

Table 3.1 - Equipment ages at Webster Substation

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Transformer Loading

Base equipment loading was examined for all 34.5 kV equipment at Webster Substation. The 2015 Summer Forecast peak load was used to model the distribution system. The 2015 forecasted load was then brought forward to 2025 at a load growth rate of 1.50 % for the first five years and then 1.25% for the latter five. These values were recorded in Table 3.2 below, which shows the result of the projected 2015 and 2025 loading on the substation equipment, if the current configurations were to remain the same.

SUBSTATION	EQUIPMENT	2015 Forecast	2025 Forecast	NAMEPLATE RATING	TFRAT RATING
Webster	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 3.2 – Results of a loading analysis for 34.5 kV Webster Substation equipment (modeled at 2015 and 2025 load levels)

The results of the equipment loading analysis show [redacted]. Due to the impedance similarity between the [redacted] bulk transformers, the units tend to share the load equally, even though they have different MVA ratings. There have been no circuit reconfigurations or planned construction included with these loading values. No other equipment has considerable projected overloads by 2024.

Loadflow Analysis

A loadflow model was developed in accordance with the 10 Year Study. Included with the regular load growth, were two large spot loads that will be impacting Webster Substation: [redacted]. and the Northern Pass Converter Station.

Modeling the system base case for 2025, [redacted] There were no voltage or line limit violations found for the Webster area at any point during the study.

Eversource policy ED-3002 identifies that distribution system contingencies shall be studied at peak load times for loss of 34.5 kV line breakers and loss of distribution power transformers. The contingent loss of a 34.5 kV line breaker or transformer was analyzed. There were no contingency scenarios available that would violate system design criteria. For more detail, Appendix E provides a one line of the 34.5 kV system involving Webster Substation.

Webster Substation Transmission Line Map

[redacted]

Figure 3.3 – Aerial view of Webster Substation and associated transmission lines.

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Line Construction Restrictions

New Hampshire Electric Coop (NHEC) Webster Substation

The NHEC Webster Substation lies between the existing Webster Substation and the rest of the available property at the site. This substation restricts the ability to expand the existing Webster Substation or add new lines. This does not prevent construction from happening elsewhere on the property; it only increases the difficulty and requires additional steps to be taken when planning. The property is located between Route 11, Webster Lake Rd. and Carr St. in Franklin, NH. See Appendix D for additional property information.

Figure 3.4 – Location of the NHEC Webster Substation.

IV. Solution Options

Five solutions to address the Webster Substation transformer overload were developed. These options were reviewed for the best solution in terms of cost, construction, and future use. Project estimates are included in Appendix A. There are no other substation overloads in the area that a similar project could address. Figure 4.1 below helps emphasize the [redacted] and its assets in relation to the surrounding transmission lines and substations.

[redacted]

Figure 4.1 – Webster Substation position in relation to other 115 and 34.5 kV lines. Black lines are 115 kV while red are 34.5 kV.

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Option 1: Rebuild the Existing Webster Substation with [redacted] transformers

Remove the three existing bulk transformers from Webster Substation and replace them with [redacted] transformers. Perform 34.5 kV bus work in order to facilitate the new transformer installation.

Target
- Addresses all obsolescence and loading issues at Webster Substation.

Positives
- Requires minimal footprint.
- Immediately resolves all loading and obsolescence issues at Webster Substation.
- Has the least disturbance for abutters.
- Minimal line work would be required.

Negatives
- Does not allow for the existing equipment to remain in service during construction. A mobile transformer would be necessary to facilitate construction.
- Does not allow any room for future expansion.
- Creates difficulty when trying to add future breaker positions or bus ties.

Conclusion
- This is a feasible option that will solve the obsolescence and loading problems, but does not allow for any expansion at the site.

Option 2: Construct a New Substation on the Existing Property and Replace the Bulk Transformers with [redacted] Transformers (Daniel Substation)

A new substation will be constructed on the existing property, adjacent to the current Webster and NHEC Webster Substations. The existing Webster Substation will be utilized as a transmission yard with [redacted] transformers. A 34.5 kV bus and switching yard will be added at the new site, Daniel substation, and the old bulk substation transformers will be retired.

Target
- Addresses all obsolescence and loading issues at Webster Substation.

Positives
- Utilizes existing property.
- Immediately resolves all loading and obsolescence issues at Webster Substation.
- Minimal line work would be required.
- Allows for construction with existing equipment remaining in service.
- Allows for future expansion at the existing Webster Substation and the newly constructed substation.

Negatives
- Requires construction around the NHEC Webster Substation.
- Costs slightly more up-front than the one transformer option. (Option 3)

Conclusion
- This would be the ideal solution at a moderate cost due to the increased flexibility for both substations located on the property.

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Option 3: Construct a New Substation on the Existing Property with [redacted] Transformer Now and [redacted] Transformer Later (Daniel Substation)

A new substation will be constructed on the existing property, adjacent to the current Webster and NHEC Webster Substations. Initially, [redacted]

Target
- Addresses all obsolescence and loading issues at Webster Substation.

Positives
- Utilizes existing property.
- Immediately resolves all loading issues but not obsolescence issues at Webster Substation.
- Minimal line work would be required.
- Allows for construction with existing equipment remaining in service.
- Eventually allows for future expansion at the existing Webster Substation and allows for expansion at the new substation.

Negatives
- Does not resolve all obsolescence issues immediately.
- Requires construction around the NHEC Webster Substation.
- Costs significantly more to add [redacted] and construct 115 kV feeds.

Conclusion
- This is a feasible option but will require significantly more money to construct 115 kV lines and [redacted] in the future.

Option 4: Methods of Load Curtailment Including Battery Storage, Distributed Generation, or Conservation and Load Management

Utilize conservation and load management, battery storage, and/or distributed generation to reduce the loading on Webster Substation and postpone capital spending.

Target
- Addresses only loading issues at Webster Substation.

Positives
- Helps to postpone a capital investment and reduces the amount of spending needed in the short term.

Negatives
- Would not be a long term solution and would only delay spending.
- Does not resolve any obsolescence issues.
- Does not solve the overcrowded substation problem to allow for future construction.

Conclusion
- This is not a feasible option since it only temporarily addresses loading issues. Obsolescence issues are not addressed and loading issues would need to be fixed eventually.

Option 5: Construct a New 115 – 34.5 kV Substation at a New Location

Find an entirely new location to build a new 115 – 34.5 kV substation and create the infrastructure to feed the existing 34.5 kV system.

Target

- Addresses all obsolescence and loading issues at Webster Substation.

Positives

- Immediately resolves all loading and obsolescence issues at Webster Substation.
- Allows for construction with existing equipment remaining in service.
- Allows for future transmission expansion at the existing Webster Substation.

Negatives

- Does not utilize existing property.
- Extensive line work would be required.
- Requires acquisition of new property, in a convenient location, to feed the 34.5 kV system.
- Would not be as operationally efficient as the Webster Substation property location.

Conclusion

- This is a not a feasible option, since it requires the acquisition of new property, when there is already property owned in a prime location to feed the 34.5 kV system.

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V. Recommendations

New Hampshire's System Planning and Strategy has studied several options and has evaluated them based on feasibility, plausibility, reliability, cost, and system operational flexibility (See Section IV and Appendix B). The Webster Substation area solution incorporates design standards and justifications from the Distribution System Engineering Manual, as well as Eversource policy ED-3002. The resulting design will be reliable and allow for future growth as the economy recovers.

Based on the information contained in this report, it is recommended that Eversource select Option 2: Construct a New Substation on the Existing Property and Replace the Bulk Transformers with [redacted] Transformers (Daniel Substation) – $8,800,000. Included with Option 2 is the following:

1. Construct a new substation on the existing property, next to Webster Substation.
2. Install t[redacted] transformers in the existing Webster Substation.
3. Install a 34.5 kV bus and switching yard in a new substation (Daniel Substation) on the existing property with five 34.5 kV breakers.
4. Allow for a fourth position in which to add a future 34.5 kV breaker.
5. Retire the existing [redacted] bulk transformers at Webster Substation [redacted])
6. Provide two 34.5 kV feeds from the existing Webster Substation to the 34.5 kV bus at Daniel Substation.
7. Utilize the third empty breaker position at Webster Substation for a mobile substation connection.

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Appendix A: Distribution Estimates for Projects

Option 1: Rebuild the Existing Webster Substation with [redacted] transformers
$8,500,000
Estimate includes:

- Site development and new foundations.
- Installation of [redacted] transformers and two line breakers with a position to add a third.
- Protection and Control upgrades at the existing station.

Option 2: Construct a New Substation on the Existing Property and Replace the Bulk Transformers with [redacted] Transformers (Daniel Substation)
$8 800,000
Estimate Includes:

- Site development and new foundations.
- Installation of [redacted] transformers.
- 34.5 kV lines from the bulk transformers at Webster Substation to the 34.5 kV switching yard at Daniel Substation.
- Installation of five breakers at Daniel Substation (three feeder breakers) with a position to add a sixth.
- Retirement of the existing, three bulk substation transformers.

Option 3: Construct a New Substation on the Existing Property with [redacted] and [redacted] (Daniel Substation)
$13,400,000
Estimate includes:

- Site development and new foundations.
- Construction of an open-air 115 – 34.5 kV substation in two stages. [redacted]
- Transmission line work to feed across the property from Webster Substation to the new transformers at Daniel Substation.
- Retirement of transformer [redacted].

Option 4: Methods of Load Curtailment Including Battery Storage, Distributed Generation, or Conservation and Load Management
Not a feasible solution.

Option 5: Construct a New 115 – 34.5 kV Substation at a New Location
Not a feasible solution.

Appendix B: Decision Matrix for Proposed Work

	Weight	**RATING** 4-5 Superior, 2-3 = Adequate, 0-1 = Inferior		
		Option 1: Existing Site w/ 2 Transformers	**Option 2:** New Site @ Webster w/ 2 Transformers	**Option 3:** New Site @ Webster w/ 1 Transformer Later
Addresses ED-3002 Design Criteria	8	3	3	3
Addresses Area Load Growth (Long Term, 10 Years)	8	3	5	5
Improves Reliability: SAIDI	8	4	4	3
Net Present Value (2015)	7	4	4	3
Environmental Impact	5	3	3	3
Contingency Solution	5	2	3	3
Power Quality Improvement (SARFI-70)	4	3	3	3
Operating Cost	3	2	3	3
System Loss Savings	3	3	3	3
Total		160	184	169

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Appendix C: Substation One Lines

[redacted]

Appendix D: Property Information

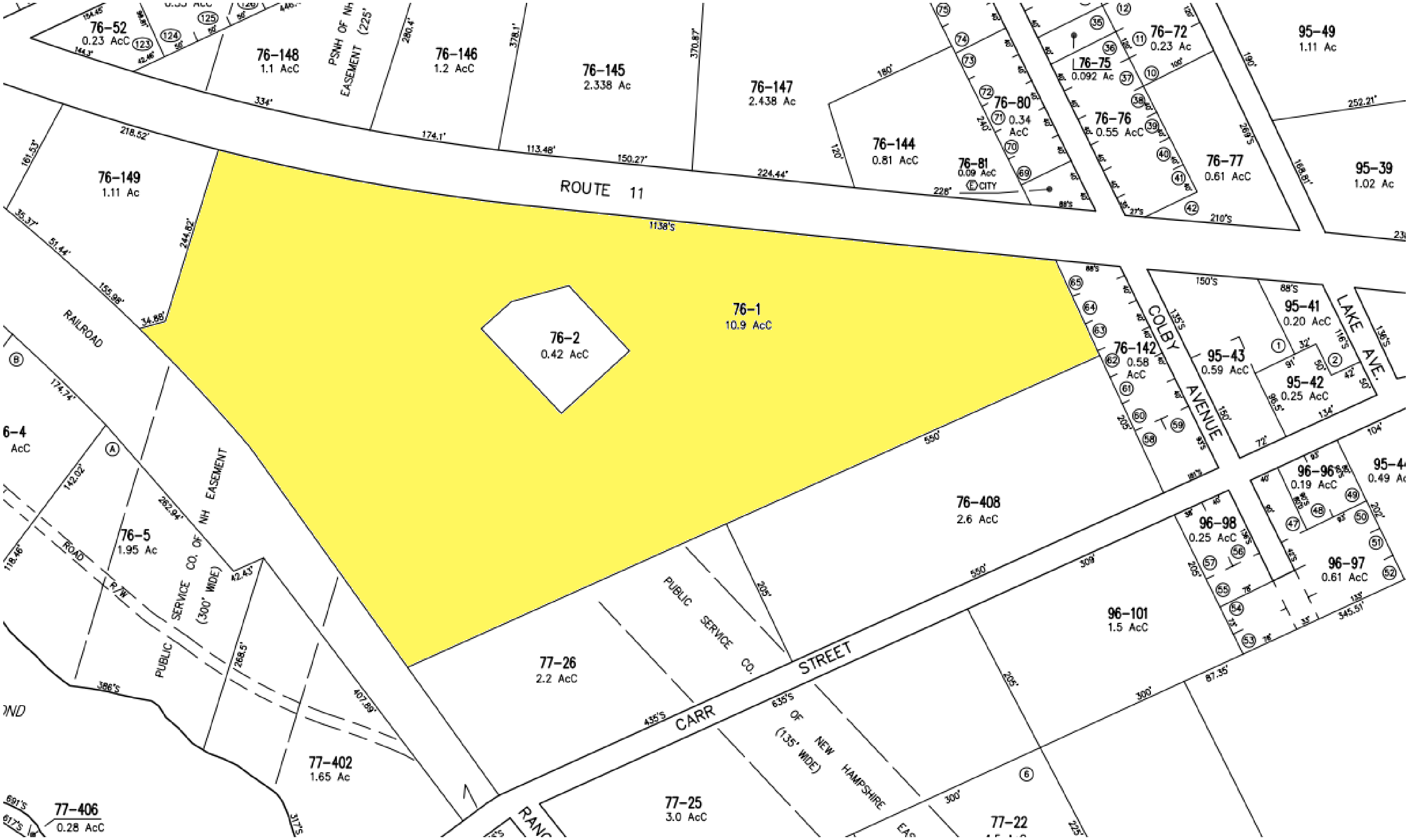

Figure D.1 – 10.9 Acres of land at Webster Substation, not including the NHEC land positioned in the center.

Appendix E: Webster Area One Line

[redacted]

Public Service of New Hampshire

The Northeast Utilities System

SYSTEM PLANNING & STRATEGY

Keene Area

Distribution System Study

May 2, 2012

Approved: James C. Eilenberger

Confidential

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Executive Summary

One of the recommendations of the 2011 Ten Year Load Flow Study was to perform a comprehensive study of the Keene area distribution system. This study analyzes the 12.47 kV distribution system in the greater Keene area.

The distribution system in this area is served entirely at 12.47 kV and fed by Keene and Swanzey Substations, serving approximately 20,000 PSNH customers. This area is presently experiencing a 3.1% load growth which is expected to continue for the foreseeable future.

Keene Substation is currently crowded with [redacted] Of a more urgent nature is the fact that the available fault current at the Keene Substation exceeds the interrupting rating of two of the transformer breakers and much of the switchgear. Moreover, the equipment at Keene Substation is old and obsolete.

It is recommended that two new 115 kV to 12.47 kV substations be built to replace the existing equipment currently concentrated at the Keene Substation on Emerald St: one on Emerald St, adjacent to the existing substation; and one in the North section of Keene. This approach will place the sources closer to the load, reduce fault current, and provide separated electrical sources to the area. As the load continues to increase in this area, an additional transformer will be required at the new Keene Substation.

Respectfully submitted:

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I. Introduction

This study addresses the recommendation that was made in the 2011 Ten Year Load Flow Study to complete a comprehensive study of the Keene Area distribution system. The existing system configuration, equipment limitations, system loading and area load growth rate are used to assess future system requirements. The objective of this study is to develop recommendations that address the long term loading requirements and equipment issues.

Since the electric system feeding the greater Keene area is entirely islanded and separated from PSNH's 34.5kV distribution system, this study focuses on serving this area with a 12.47 kV distribution system.

II. System Background

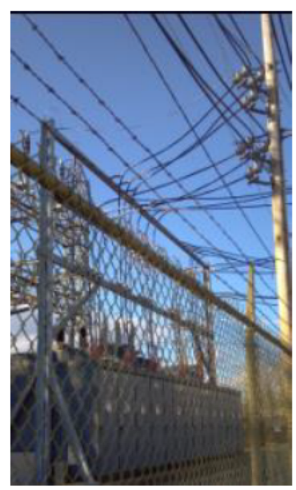
This report summarizes the work of the Keene Area Planning Study Team as it considered the dynamics of the electrical system serving the greater Keene area. Several alternatives were considered by the group. Ultimately, System Planning & Strategy recommends moving forward with the construction of a new North Keene Substation and the rebuilding of the existing Keene Substation to modern standards. These proposed projects will effectively address existing loading, equipment rating deficiencies, obsolescence, power quality, and reliability issues.

III System Analysis

A. Area Problems & Limitations

1. **Single Source** – [redacted] This condition could subject multiple circuits to outages from a single event.
2. **Power Quality** – Customers who are sensitive to power quality are affected by disturbances on other Keene Substation circuits due to the interconnected nature of the substation.

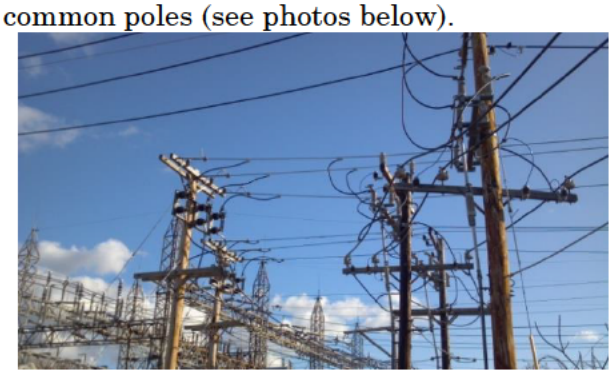
B. Substation Problems & Limitations

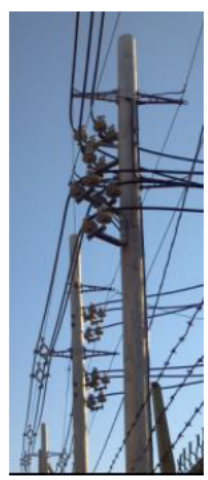


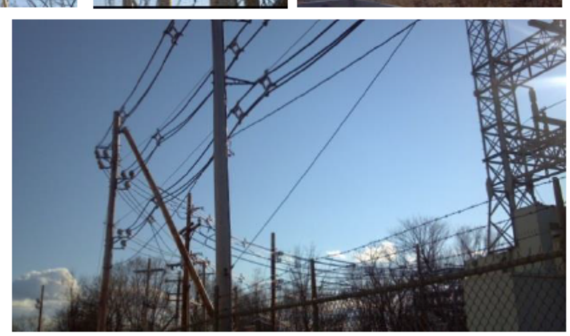
1. **Transformer Breaker Ratings** – Because of the existing transformer impedances and their parallel configuration, the available fault current exceeds the transformer breaker interrupting ratings for TB12 and TB18. (per manufacturer interrupting ratings of 10,000 amps.)
2. **Switchgear Ratings** – System Engineering has identified several breaker ratings which have been exceeded by available fault current. (See Appendix B – PCM report dated 6/24/2009, Vermont 115 kV Southern Loop Expansion – Short Circuit Duty Review)

3. **Obsolescence** – Part of PSNH's strategic plan is to replace obsolete equipment. Four of the five transformers at Keene Substation are between 45 and 60 years old. Based on a useful life expectancy of 55 years for distribution substation equipment, 90% of the distribution equipment at Keene Substation is considered obsolete. Note: Transformer TB3 and its associated equipment, installed in 2000, is excluded from this category.

4. **Limited Capacity** – There is limited line and transformer capacity to serve the area effectively. By 2014, in order to switch out of some contingent transformer outages, up to five load block transfers will need to be made in order to restore all customers. This violates the requirements of Procedure ED-3002.
5. **Congested Physical Site** – The nine (9) 12.47 kV circuits leaving Keene Substation, along with their associated tie switches, encircle the substation, with double- and triple-circuited spacer cable on common poles (see photos below).

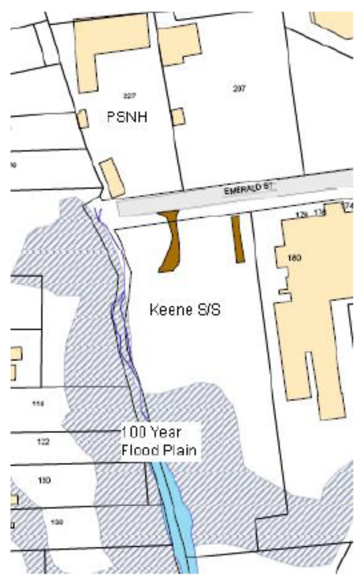






6. **Maintenance Planning** – Maintenance is difficult to schedule on the existing in-service power transformers at Keene Substation, due to loading. Exacerbating the situation is the fact that PSNH does not own a 115 kV to 12.47 kV mobile substation.
7. **Load Growth** – The Loadflow analysis indicates that additional transformation is required prior to the summer of 2014 to resolve all contingent outages without the use of a mobile transformer. With a mobile transformer available, additional transformation is then required prior to the summer of 2020 to address base case overloading conditions.

[redacted]



9. **Proximity to Flood Plain** – Maps furnished by the City of Keene indicate that the southernmost section of Keene Substation falls within the 100-year flood plain (see diagram at right). During the historic flooding event in Keene in the fall of 2005, there was sufficient threat of the substation being submerged that we proposed parking the CL&P 115 - 12 kV mobile substation on Court Street and backfeeding the majority of the city (see LGL document North Keene SS Discussion.doc). During the flooding event in the spring of 2006 – when

the Ashuelot River did overflow its banks – the high water level encroached within three feet of the footings of the fence on the substation's west side. (Sources: Keene DPW; US Army Corps of Engineers)

10. **Environmental Concerns** – Solution options which entail rebuilding the Distribution portion of the station on the 0.97 acre property across the street from the existing station will trigger an environmental evaluation for the use as a substation site. The summary of the Former Keene MGP Final Construction Report (Weston & Sampson Engineers, Inc., September 2005) states: "activity and use restrictions will include direct contact barriers and restrict future excavation and residential use of the site without further risk assessment."

C. **Loadflow Analysis** – A 12.47 kV Loadflow model was developed with all 12.47 kV circuits modeled out to their respective three phase tie points. Circuit and transformer loads were captured for 2011 and escalated out in time at an annual growth rate of 3.1%. Base case loadflows and various contingencies were run. It was determined that additional transformation is required by 2014 to prevent a contingent violation. Specifically, in 2014, it will require five load block transfers for the loss of either TB7 or TB12 at Keene Substation to reduce the loading on its respective parallel-connected transformer to within TFRAT without additional transformation. The first base case violation occurs in 2017 in which the first portion of the W110 circuit, from Keene Substation to the 110DX5 switch, is projected to exceed its 477 ACSR normal conductor rating. (See Appendix D – 12.47 kV Loadflow Synopsis)

IV Solution Options

All of the viable options listed below (Options 2 through 5) involve removal of existing obsolete transformers and switchgear at the Keene Substation, except for TB-3 and its associated circuit reclosers, W2A and W9A, which will stay in service at the South end of the substation yard. In addition, this study assumes that PSNH will complete the procurement of a 115 kV – 12.47 kV mobile substation by 2014, as back-up for a transformer failure. Otherwise, the installation of [redacted] will be required in order to limit the number of load block transfers to three, per ED-3002. This alternative to have a [redacted] transformer installed by 2014 is an unrealistic timeframe.

Option 1 – <u>34.5 kV Expansion</u> (Expand at 34.5kV to alleviate substation transformer overloads) –

Approximately 20,000 customers in the greater Keene area are presently served by the existing 115 kV – 12.47 kV distribution system. The closest 115 kV – 34.5 kV sources are Chestnut Hill Substation, Hinsdale (17 miles), Monadnock Substation, Troy (10 miles), and Jackman Substation, Hillsborough (27 miles). The possible circuit ties at the outer extremities of the Keene area are all presently single phase and would therefore not provide suitable ability to offload any significant amount of load. In addition, the deficient substation interrupting ratings issues would still exist at Keene Substation and need to be addressed. Furthermore, for reliability reasons, PSNH has been moving in the direction of expanding its 12.47 kV system where it makes sense rather than serving the area at 34.5 kV, for reliability reasons.

Option 2 – <u>Replacement of Existing Equipment at Keene Substation (Emerald Street) Only</u> –

The Keene (Emerald St.) Substation projects would include:

- Replace TB7, TB12, TB18, and TB23 along with associated switchgear with new equipment at a proposed substation on Emerald St, retaining existing TB3 in service at the original Emerald Street site. This option would be complicated by the requirement to remove existing distribution transformation in order to install the 115kV feed to the new substation lot.
    - **2014 work:**
        - Procure a 115 kV to 12.47 kV mobile substation
    - **2015 work:**
        - Build new 115 kV to 12.47 kV substation with [redacted] transformers adjacent to the existing Keene Substation.
        - Provide eight (8) breaker positions to feed existing circuitry now fed from the original substation site

Option 3 – <u>Replace Existing Keene Substation and Construct New Distribution Substation (North Keene)</u> –

The Keene (Emerald St.) Substation projects would include:

- Replace [redacted] along with associated switchgear with new equipment at a proposed substation on Emerald St, retaining existing [redacted] in service at the original Emerald Street site.
    - **2014 work:**
        - Procure a 115 kV to 12.47 kV mobile substation
    - **2015 work:**
        - Build new 115 kV to 12.47 kV substation with [redacted] transformer
        - Provide 8 breaker positions to feed existing circuitry now fed from the original substation site

The North Keene Substation projects would include:

- Construct new substation to feed some of the 12.47 kV load from the North end of Keene.
    - **2013 work:**
        - Purchase property to site the new North Keene Substation
    - **2015 work:**
        - Build new 115 kV to 12.47 kV substation with [redacted] transformer
        - Provide for four feeds to the existing W13, W14, and W1 circuits

Option 4 – <u>Replace Existing Keene Substation and Construct New Distribution Substation (South Keene)</u> –

The Keene (Emerald St.) Substation projects would include:

- Replace TB7, TB12, TB18, and TB23 along with associated switchgear with new equipment at a proposed substation on Emerald St, retaining existing TB3 in service at the original Emerald Street site.
    - **2014 work:**
        - Procure a 115 kV to 12.47 kV mobile substation
    - **2015 work:**
        - Build new 115 kV to 12.47 kV substation with [redacted] transformer
        - Provide 8 breaker positions to feed existing circuitry now fed from the original substation site

The South Keene Substation projects would include:

- Construct new substation to feed 12.47 kV load from the South end of Keene.
    - **2013 work:**
        - Purchase property to site the new South Keene Substation
    - **2015 work:**
        - Build new 115 kV to 12.47 kV substation with [redacted] transformer
        - Provide for three feeds to the existing W15, W185 and W2 circuits
        - Provide for one feed to a future W6 circuit

Option 5 – <u>Construct Two New Distribution Substations (South Keene and North Keene)</u> –

The South Keene Substation projects would include:

- Replace TB7, TB12, TB18, and TB23 along with associated switchgear with new equipment at a proposed substation located in the vicinity of the 115 kV crossing of highway Route 101 in Keene, retaining existing TB3 in service at the existing Keene Substation.

- **2013 work:**
  - Purchase property to site the new South Keene Substation
- **2014 work:**
  - Procure a 115 kV to 12.47 kV mobile substation
- **2015 work:**
  - Build new 115 kV to 12.47 kV substation with [redacted] transformer
  - Provide 8 breaker positions to feed existing circuitry now fed from the original substation site
  - Construct new 12kV line (1800') to connect the new South Keene Substation to the W2 circuit on Winchester St. (Additional line construction will not be needed for the W15 or W185 circuits because both circuits already share the right-of-way crossing with the two 115 kV lines A152 and T198; see picture above.)

The North Keene Substation projects would include:

- Construct new substation to feed 12.47 kV load from the North end of Keene.
  - **2013 work:**
    - Purchase property to site the new North Keene Substation
  - **2015 work:**
    - Build new 115 kV to 12.47 kV substation with [redacted] transformer
  - **2015 work:**
    - Provide for four feeds to the existing W13, W14, and W1 circuits

Option 6 – <u>Install Distributed Generation</u> –

The installation of distributed generation could defer the base case need for additional transformation in the Keene area; however, it cannot address the equipment obsolescence and inadequate breaker interrupting ratings that presently exist. Significant work would be required at the Keene substation to make this a viable option. This option is not an effective solution.

V Recommendation

Based on the information contained in this report it is recommended that PSNH:

1. Procure 115 kV to 12.47 kV mobile substation. ISD 2014
2. Construct new North Keene Substation with [redacted] transformer and associated switchgear. ISD = 2015
3. Replace existing obsolete equipment at Keene Substation with [redacted] transformer and associated switchgear. ISD = 2015 (Note: If environmental issues are uncovered during an environmental risk assessment on the property adjacent to the existing Keene Substation, then a new South Keene substation would be a viable alternative.)

Implementation of the above recommendation will address the following outstanding issues:

- Limited line and transformer capacity to serve the area reliably.
- Maintenance is difficult to schedule on the existing in-service power transformers at Keene Substation, [redacted] Exacerbating the situation is the fact that PSNH does not own a 115 kV to 12.47 kV mobile substation.
- Current [redacted].
- Current one-substation design could potentially cause widespread power quality issues due to localized events.

If the above outstanding issues are not addressed, there is increasing concern that a major outage and continued decline in service quality will result.

PSNH's System Planning and Strategy has studied several options and evaluated them based on reliability, net present value, and system operational flexibility. (See Appendix J – Project Benefit Comparison.) The Keene solution incorporates design standards and justifications from Northeast Utilities Distribution System Engineering Manual, as well as PSNH policy ED-3002. The resulting design will be reliable and allow for future expansion as the economy continues to recover.

Appendix A — Substation Transformer Characteristics

Keene Substation

There are five power transformers in service at Keene Substation at the end of Emerald St in Keene. Details of this equipment are listed below.

Transformer TB 18

- Transformer size is [redacted], voltage class 115 kV to 12.47 kV with Δ / 'Y connected windings.
- Transformer was manufactured in 1953 and installed in 1978.
- Maximum TFRAT rating is [redacted].
- Loading on the transformer was [redacted] (July of 2011).
- Three circuits serve a total of [redacted] PSNH customers (shared with TB12).
- The connected secondary switchgear was manufactured in 1949 and installed in 1949.
- The available fault current is at 103% of its interrupting rating of 10,000 amps.

Transformer TB 23

- Transformer size is [redacted], voltage class 115 kV to 12.47 kV with Δ / 'Y connected windings.
- Transformer was manufactured in 1954 and installed in 1968.
- Maximum TFRAT rating is [redacted]
- Loading on the transformer was [redacted] (July of 2011).
- Four circuits serve a total of [redacted] PSNH customers (shared with TB7).
- The connected secondary switchgear was manufactured in 1954 and installed in 1954.
- The available fault current is at 47% of its interrupting rating of 22,000 amps.

Transformer TB 7

- Transformer size is [redacted], voltage class 115 kV to 12.47 kV with Δ / 'Y connected windings.
- Transformer was manufactured in 1964 and installed in 1969.
- Maximum TFRAT rating is [redacted].
- Loading on the transformer was [redacted] (July of 2011).
- Four circuits serve a total of [redacted] PSNH customers (shared with TB23).
- The connected secondary switchgear was manufactured in 1954 and installed in 1954.
- The available fault current is at 47% of its interrupting rating of 22,000 amps.

Transformer TB 12

- Transformer size is [redacted], voltage class 115 kV to 12.47 kV with Δ / Y connected windings.
- Transformer was manufactured in 1969 and installed in 1969.
- Maximum TFRAT rating is [redacted].
- Loading on the transformer was [redacted] MVA (July of 2011).
- Three circuits serve a total of [redacted] PSNH customers (shared with TB18).
- The connected secondary switchgear was manufactured in 1949 and installed in 1949.
- The available fault current is at 103% of its interrupting rating of 10,000 amps.

Transformer TB 3

- Transformer size is [redacted], voltage class 115 kV to 12.47 kV with Δ / Y connected windings.
- Transformer was manufactured in 2000 and installed in 2007.
- Maximum TFRAT rating is [redacted].
- Loading on the transformer was [redacted] (July of 2011).
- Two circuits serve a total of [redacted] PSNH customers.
- The connected secondary switchgear was manufactured in 2000 and installed in 2000.
- The available fault current is at 56% of its interrupting rating of 12,000 amps.

<u>Swanzey Substation</u>

Transformer TB 2S

- Transformer size is [redacted], voltage class 115 kV to 13.09 kV with Δ / Y connected windings.
- Transformer was manufactured in 2009 and installed in 2009.
- Maximum TFRAT rating is [redacted]
- Loading on the transformer was [redacted] (July of 2011) based on actual thermal ammeter maximum readings.
- Two circuits serve a total of [redacted] PSNH customers.
- The connected secondary switchgear was manufactured in 2009 and installed in 2009.
- The available fault current is at 31% of its interrupting rating of 24,000 amps.

Transformer TB 8S

- Transformer size is [redacted], voltage class 115-13.2 kV with Δ / Y connected windings.
- Transformer was manufactured in 1991 and installed in 2011 (not in service).
- Maximum TFRAT rating is [redacted].
- This transformer would be placed in-service if TB2S failed.

Appendix B — Substation Switchgear Characteristics

Vermont 115KV Southern Loop Expansion - Short Circuit Duty Review (DRAFT) 6/24/09 PCM

P&CE (D) has been asked to review the impact on PSNH distribution equipment of proposed changes to the 115 KV in Vermont. The changes in Vermont are specifically defined in "ISO-NE I.3.9 Studies of the Southern Loop".

On May 6, 2008, Vermont Electric Power Company issued a report on the effects caused by the increase in fault currents which will result from the changes in Vermont. The conclusion of that report was that "there are no fault current issues on the 115KV and above voltage system in the area of the project." Potential problems were, however, identified on a 4.16KV bus at Vermont Yankee.

The review of the PSNH distribution equipment in the area of the project was done by using the same short circuit case as that used in the VELCO study and as summarized on May 6, 2008. The case name for ASPEN One-Liner purposes is "2008 NEPOOL Short Circuit Model (Feb) rev 01_ALL NRP-Fitzwilliam_Nominal.OLR on 3/10/08". The only changes made were as follows:

The Swanzey 115KV-12.47KV transformer model was changed to [redacted] per construction currently underway, and the new breaker ratings were applied.

The Jackman GSU was modeled with its estimated new impedance.

The electrical location of the Fitzwilliam 345-115KV tie was corrected per information from [redacted].

Chestnut Hill 34.5 KV, Swanzey (new) 12.47KV, Keene 12.47KV, Monadnock 34.5 KV, and Jackman 34.5 KV were all given a preliminary review of their interrupting ratings. Of those locations, only Keene breakers were within 20% of their nominal ratings, so those breakers were given further analysis.

Keene 12.47KV Breaker Ratings Detailed

Matthew Cosgro contacted GE, who guided him to references which allowed him to detail the capability of the Keene breakers based on their nameplate information, and the application voltage (since the breakers are not nominally rated at 12.47KV). His results are shown on a spreadsheet located at K:\Deptdata\Energy Delivery\Distribution Asset Management\Equipment\Western Central\Keene SS Switchgear Nameplate and Ratings Infomation.xls. This base data was then used to develop interrupting capabilities based on in-service automatic reclose derating using standard P&CE (D) methodology previously developed for 34.5KV oil circuit breakers, and recently confirmed for these air circuit breakers. Specifically, IEEE C37.7-1952 was used for all breakers except for W1, since all but W1 were manufactured in either 1949 or 1954. W1 was manufactured in 1964, in fact has a much higher inherent capability, and was derated for reclosing using C37.010-1999. The results of this derating, along with available fault currents with and without the Vermont expansion, are shown in the spreadsheet on page 3.

By comparing this derated breaker information with today's base case, it was confirmed that the breakers are not currently operating above their theoretical interrupting capability. "Theoretical" is an operative term, however, since some of them are confirmed to be 60 years old as of this year. As shown on the attached spreadsheet, several of the breakers are currently within 5% of their theoretical interrupting ratings, the closest being within 2.56%. This data is shown in the spreadsheet as "3 Phase and L-G Fault Today".

The modestly revised VELCO case (with the changes identified above) was then run using the same fault options as PSNH currently applies to its base case. On the attached spreadsheet this column is identified as " 3 Phase + L-G Fault Future A". This still didn't push any breakers above their capability, and neither did the use of the same case using exactly the same fault options as is used for the New England wide NEPOOL case (see "3 Phase + L-G Fault Future B"), although the closest was within 1.38% of its capability.

It should be noted, however, that these results are for base case conditions, with bus tie breaker 1200 open. There are many alternate feeds to the Keene feeders which could change the results. For example, Keene State College is adding generation to feeder W9A, which poses no interrupting rating issues. For the loss or any outage of TB3, this generation could be tied to Bus #1 through W2A, adding approximately 160A of fault current to the bus total, or enough to put several breakers very close to or slightly over 100% of their capability.

Conclusion

The average increase in fault current on the Keene 12.47KV breakers due to the Vermont system expansion is 1.68%. That said, no breakers on base case are above their calculated interrupting capability today, and none are predicted to be after the Vermont 115KV system enhancements.

Further P&CE (D) Comments on Keene Breaker Ratings

The results of the Keene 12.47 KV breaker review unearthed some facts about Keene which should be documented.

As stated above, there are presently four breakers within 5% of their calculated interrupting capabilities, and a total of 10 within 10%, and there will shortly be a total of eleven breakers within 10% of their capabilities. One breaker is 45 years old, and the rest are between 55 and 60 years old.

The subject of the Keene breaker interrupting capabilities has been raised many times over the last 30 years. There has been, and still is a limit on the use of the bus tie breaker due to the feeder breaker interrupting ratings. Any three transformers in service with the bus tie breaker closed puts the feeder breakers well above their interrupting capability. At one point in the past, GE was approached about "plug and play" breaker modules with higher interrupting capabilities to replace the existing breakers. The subject review raises the question again.

One small step could be taken to increase the margin between the calculated interrupting capability and the available fault current. There are many reclosing combinations in use at Keene today. The IEEE Standard reclose cycle is CO-15 seconds-CO. More than one reclose, and/or any time shorter than 15 seconds reduces the breaker's interrupting capability. The following reclose combinations shows the impact on the breaker's nominal interrupting capability. The overall time was assumed to be less than twenty seconds (though preferably 15 seconds) per recent practice.

RECLOSE OPEN TIMES	DERATING FACTOR
1- 5 sec	.9667X
1- 7 sec	.9733X
1-10 sec	.9830X
1-15 sec	1.000X
2 - 5, 5 sec	.9111X
2 - 5, 10 sec	.9265X
2 - 7, 8 sec	.9268X
2 - 7, 13 sec	.9426X
2 - 5, 15 sec	.9425X

This chart shows that more than 5% in breaker interrupting capability can be gained by avoiding multiple short open times. It is suggested that either 1 reclose at 7 - 10 seconds (preferred) or 2 recloses totaling 20 seconds be considered on all Keene feeder breakers until the time when the breakers are changed out.

PCM
6/24/09

KEENE 12.47 KV FAULT DUTY CAPABILITIES WITH VT 115 KV SOUTHERN LOOP EXPANSION 6/24/09

A	B	C	D	E	F	G	H	J	K
YEAR MANUF	BREAKER (RECLOSE OPEN TIMES - SEC)	BRKR RTNG AT NOM'L V WITH RECLOSING	BRKR RTNG AT 1.05 PU V WITH RECLOSING	3 PHASE + L-GROUND TODAY	PCT COL "E"/ COL "D"	3 PHASE + L-GROUND FUTURE *A* (NOTE 4)	PCT COL "G"/ COL "D"	3 PHASE + L-GROUND FUTURE *B* (NOTE 5)	PCT COL "J"/ COL "D"
		AMPS	AMPS	AMPS		AMPS		AMPS	
1949	W15 (5)	11,632	11,078	9,577	86.45%	9,709	87.64%	9,783	88.31%
		11,632	11,078	10,035	90.58%	10,086	91.05%	10,163	91.74%
1949	W110 (5, 10)	11,151	10,620	9,577	90.18%	9,709	91.42%	9,783	92.12%
		11,151	10,620	10,120	95.29%	10,167	95.73%	10,251	96.53%
≤1949	W2 (5, 4)	10,921	10,401	9,577	92.08%	9,709	93.35%	9,783	94.06%
		10,921	10,401	10,120	97.30%	10,167	97.75%	10,251	98.56%
1952	W175 (15)	12,029	11,456	9,577	83.60%	9,709	84.75%	9,783	85.40%
		12,029	11,456	10,120	88.34%	10,167	88.75%	10,251	89.48%
1949	BUS #1 to 1200	12,029	11,456	9,577	83.60%	9,709	84.75%	9,783	85.40%
		12,029	11,456	10,120	88.34%	10,167	88.75%	10,251	89.48%
1954	W185 (10, 10)	11,052	10,525	9,635	91.54%	9,759	92.72%	9,831	93.41%
		11,052	10,525	10,089	95.86%	10,135	96.29%	10,211	97.02%
1954	W14 (6, 16)	11,304	10,766	9,635	89.49%	9,759	90.65%	9,831	91.32%
	(NOTE 7)	11,304	10,766	10,089	93.71%	10,135	94.14%	10,211	94.84%
1954	W13 (5, 10)	10,872	10,354	9,635	93.06%	9,759	94.25%	9,831	94.95%
		10,872	10,354	10,089	97.44%	10135	97.88%	10,211	98.62%
1964	W1 (5, 5)	21,140	20,228	9,398	46.46%	9,523	47.08%	9,596	47.44%
		24,311	23,262	9,839	42.30%	9,886	42.50%	9,962	42.83%
1949	BUS #2 to 1200	12,029	11,456	9,635	84.10%	9,759	85.19%	9,831	85.82%
		12,029	11,456	10,089	88.07%	10,135	88.47%	10,211	89.13%

NOTES:

1) Breaker data and nominal interrupting capabilities supplied by (D) Substation Engineering's Matthew Cosgro.
2) Breaker interrupting ratings "W/RECL'G" (with reclosing) were derated for reclosing based on C37.7-1952, except W1 (C37.010-1999).
3) 3P & L-G faults "TODAY" are based on the PSNH base case Psnh092.
4) 3P & L-G faults "Future A" are from the OneLiner case from VELCO via Jim DiLuca but PSNH Base Case fault options were used. See (6)
5) 3P & L-G faults "Future B" are from the OneLiner case from VELCO via Jim DiLuca; 2008 NEPOOL Case fault options were used. See (6)
6) Non VELCO revisions to the VELCO case: Fitwilliam 115 KV tie corrected, the Swanzey dist xfmr and Jackman Hydro GSU were updated.
7) W14 reclosing with 6, 16 seconds open times assume the existing 0 sec (inst) is removed as planned.

Appendix C Circuit and Substation Loading Characteristics

K:\Deptdata\Energy Delivery\System Plan&Strategy\Comprehensive Studies\Keene Area Study\Report\Study Circuit Loadings xlsx

K:\Deptdata\Energy Delivery\Distribution Asset Management\System Loading Data\Western Central\Loadings - Keene Monadnock\SS Loading – Keene xls

[redacted]

Cust.		2011	2012	2013	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]												[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]											[redacted]	[redacted]
[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		

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Attachment L
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Appendix D — 12.47 kV Loadflow Synopsis

Development of PSS/E Model

In order to perform the load flow studies on the Keene 12.47 kV distribution, it was necessary to build the circuit model in PSS/E from scratch as, up until this point in time, the only thing modeled in PSS/E were three bus loads at Keene Substation (representing the total combined load fed from Keene Substation 12.47 kV Buses 1, 2 & 3) and one bus load at Swanzey Substation (representing the entire load fed by Swanzey Substation). It was decided that all mainline sectionalizing devices (those that could be used to transfer load from one circuit to another) would be modeled for each individual 12.47 kV circuit to accommodate the analysis required for contingency operations. The mainline section of a circuit in between sectionalizing devices would be represented as one PSS/E branch, and all collective load in between sectionalizing devices would be assigned to the downstream bus in PSS/E. All radial parts of each 12.47 kV circuit would simply be modeled in PSS/E as one collective bus load, reducing the complexity of the model which is only needed to analyze mainline issues.

All conductor data utilized to calculate branch impedances in PSS/E were gathered from the most recent Keene AWC prints (with input from Field Engineering where discrepancies arose), and all load data utilized for the PSS/E bus loads were taken from the most recent substation load database, provided by Field Engineering, as well as from load data in Field Engineering's Aspen Distriview circuit models (depicting how load is allocated throughout each individual circuit).

It was then decided to employ an annual load growth rate specific to the Keene 12.47 kV distribution in order to reflect a more localized load growth pattern for the load flow analysis. Similar to the summer peak load forecasting performed tor the 12 load flow areas in PSS/E for System Planning & Strategy's Ten-Year Study, the load forecast calculation methodology used in Procedure ED-3029 was utilized to calculate an annual growth rate specific to the Keene 12.47 kV distribution using the total combined annual peak loads of the six 115 kV to 12.47 kV transformers feeding the Keene 12.47 kV distribution. It should be noted, however, that only seven years of historical load data was used in this forecasting calculation, as opposed to ten year's worth of load data as prescribed in ED-3029, as that was all that was available. Nonetheless, upon executing the ED-3029 forecast calculation with the available load data, an annual load growth rate of 3.1% was calculated for the Keene 12.47 kV distribution, which is used to scale all future year loads in the Keene load flow analysis.

Load Flow Analysis

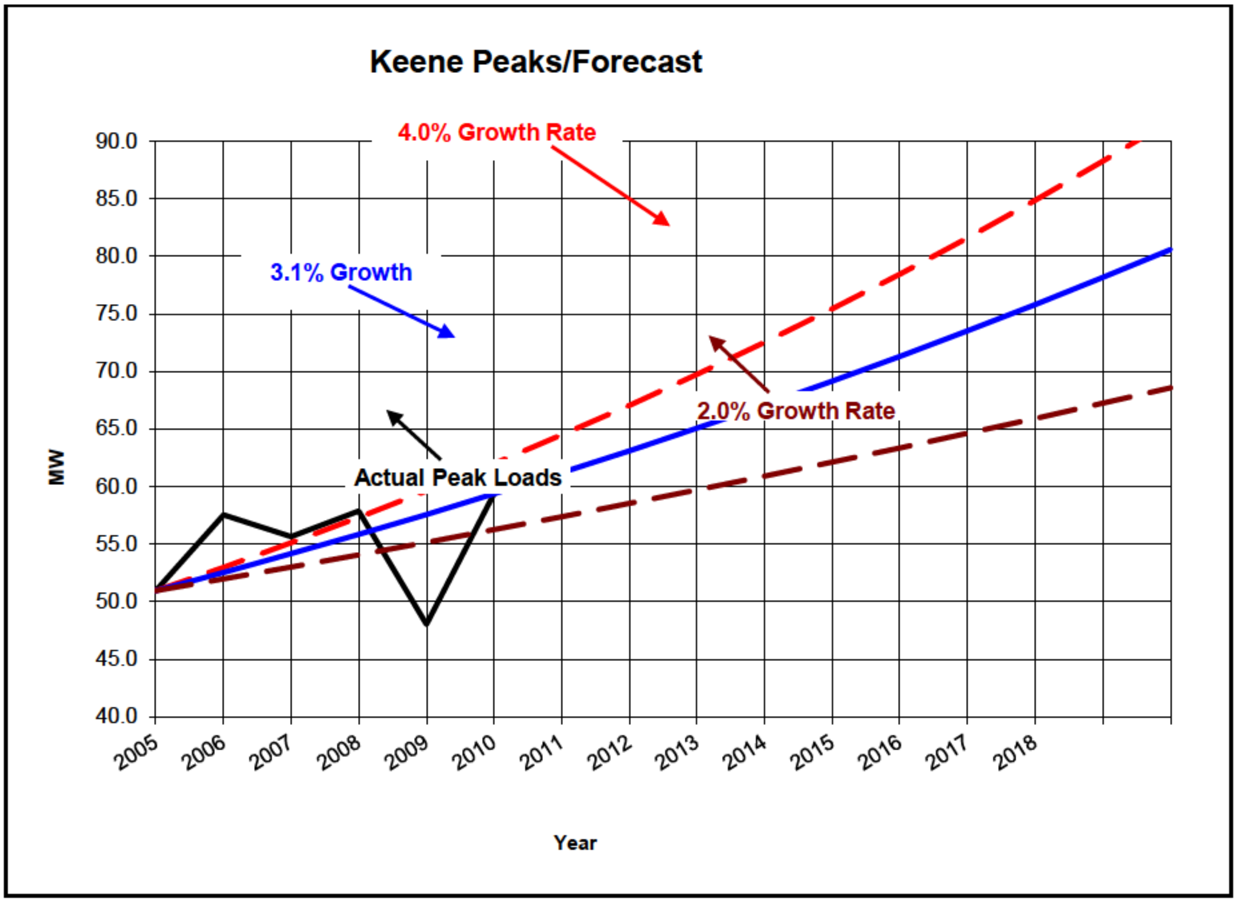
With a proper load flow model developed for the Keene 12.47 kV distribution, the load flow analysis could now be performed, beginning with an initial base case model for 2011. From a purely base case perspective (only looking at base case loading and voltage) and only scaling up the loads from year to year without making any other changes to the model, there are no load flow violations until the year 2017. At this point in time, it is projected that the first 6,300' of the W110 circuit from Keene Substation to the 110DX5 switch (477 ACSR) exceeds its normal rating. Without making any changes to the model and continuing to scale the loads, the next violation occurs in 2020 when TB3 at Keene Substation is projected to [redacted]. Also, in that same year, it is projected that the first 1,050' of the W2 circuit from Keene Substation (336 ACSR) exceeds its normal rating.

However, when also taking contingency analysis into account, the first load flow violation is actually expected to occur in 2014 upon contingent loss of either TB7 or TB12 at Keene Substation. Both scenarios simulate the loss of a [redacted] Both contingency scenarios also require five load block transfers in order to reduce the loading on TB23 or TB18 to within their respective TFRAT ratings. In order to limit the number of load block transfers to three in either of these contingency scenarios, load would need to be isolated. However, the accepted load isolation criteria utilized for 34.5 kV contingencies, as illustrated in procedure ED-3002, can't be employed for contingencies on the Keene 12.47 kV distribution because PSNH currently doesn't have a dedicated 115 kV to 12.47 kV mobile transformer. Therefore, no load isolation is acceptable for contingencies involving the Keene 12.47 kV distribution, which means 2014 is the first year where an area solution needs to be determined for the existing distribution.

Going one step further as an added measure, it was decided to see if the W6 circuit installation in the 115 kV right-of-way between Keene Substation and Swanzey Substation (currently in the capital budget to be in-service for 2015) would solve the aforementioned contingency violations seen in 2014, assuming the W6 line would be in-service for 2014. With the W6 line added to the PSS/E model, the same contingency analysis was performed. Having the additional W6 line available does enable the number of load block transfers to be reduced from five to three to relieve the overloading of TB23 for loss of TB7, resolving the previous violation. However, for loss of TB12, it still requires five load block transfers to relieve the overloading of TB18. The reason for this is that the W6 line, as proposed, would be normally fed by the parallel-connected TB12 and TB18 transformers and would be utilized to feed the Keene State College load that's currently served by the W9 circuit. This approximate 4 MW load swap to the W6 line would increase the base case loading on the TB12/TB18 transformers. Therefore, for a contingent loss of the larger TB12, this additional W6 load actually contributes to the overloading of TB18, thus increasing the amount of load needing to be transferred to reduce the loading on TB18 to within TFRAT. Subsequently, the number of load block transfers needed to accomplish this in 2014 remains at five.

It has therefore been determined that some type of solution needs to be implemented by 2014 in order to prevent violating any design criteria. Since requiring a solution by 2014 doesn't provide adequate time for a long-term permanent construction solution, and since the violation needing to be resolved is a contingency violation rather than a base case loading violation, it is recommended that PSNH acquires a dedicated 115 kV to 12.47 kV mobile transformer. This will not only restore load for certain Keene 12.47 kV contingencies and buy us time until the first base case loading violation is expected in 2017, but having a 115 kV to 12.47 kV mobile transformer readily available will also benefit the Derry area which also has 115 kV to 12.47 kV transformation.

Keene Area Peak Load Forecast:



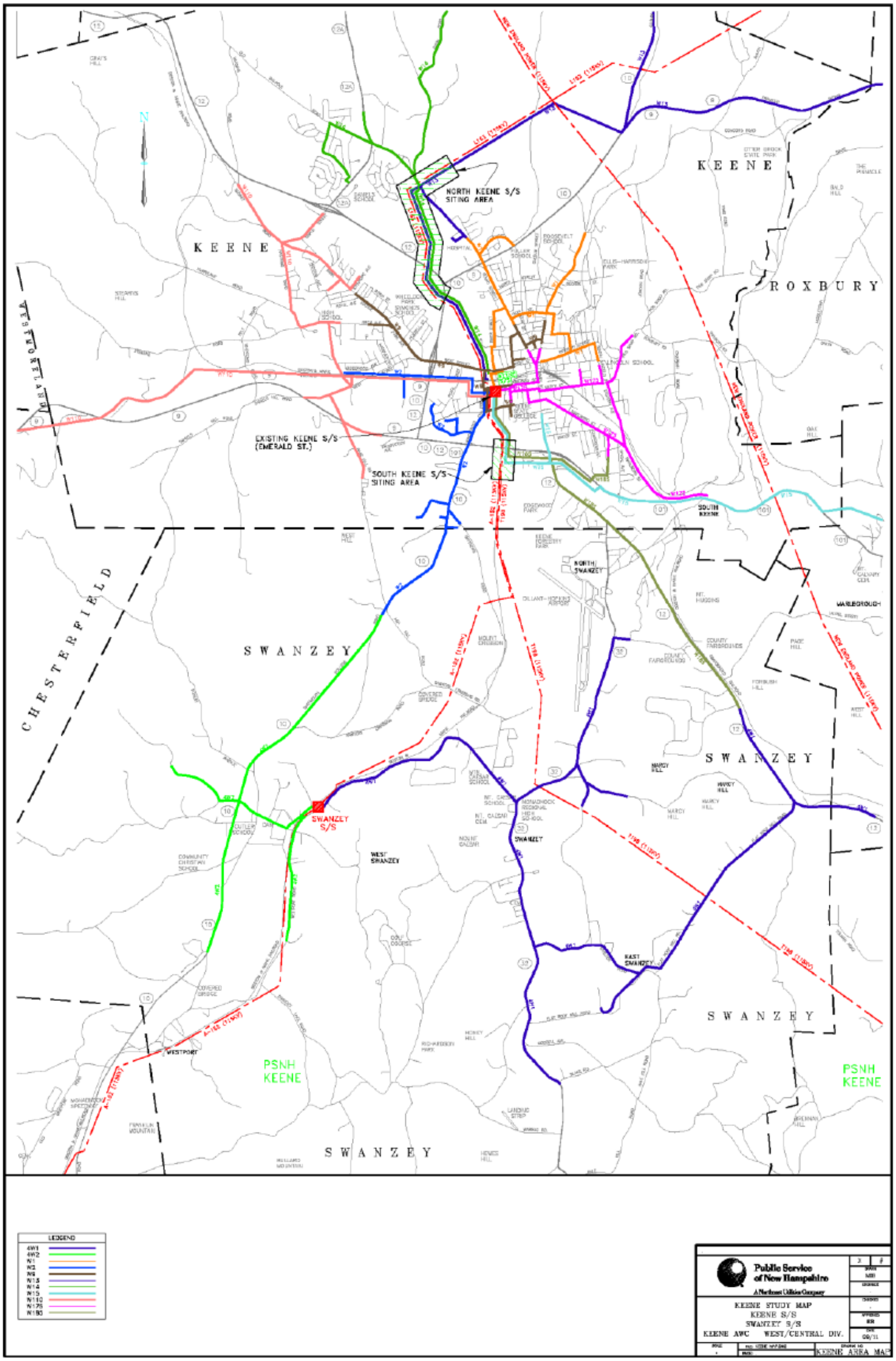
Appendix E — Keene Substation One-Line Diagram

[redacted]

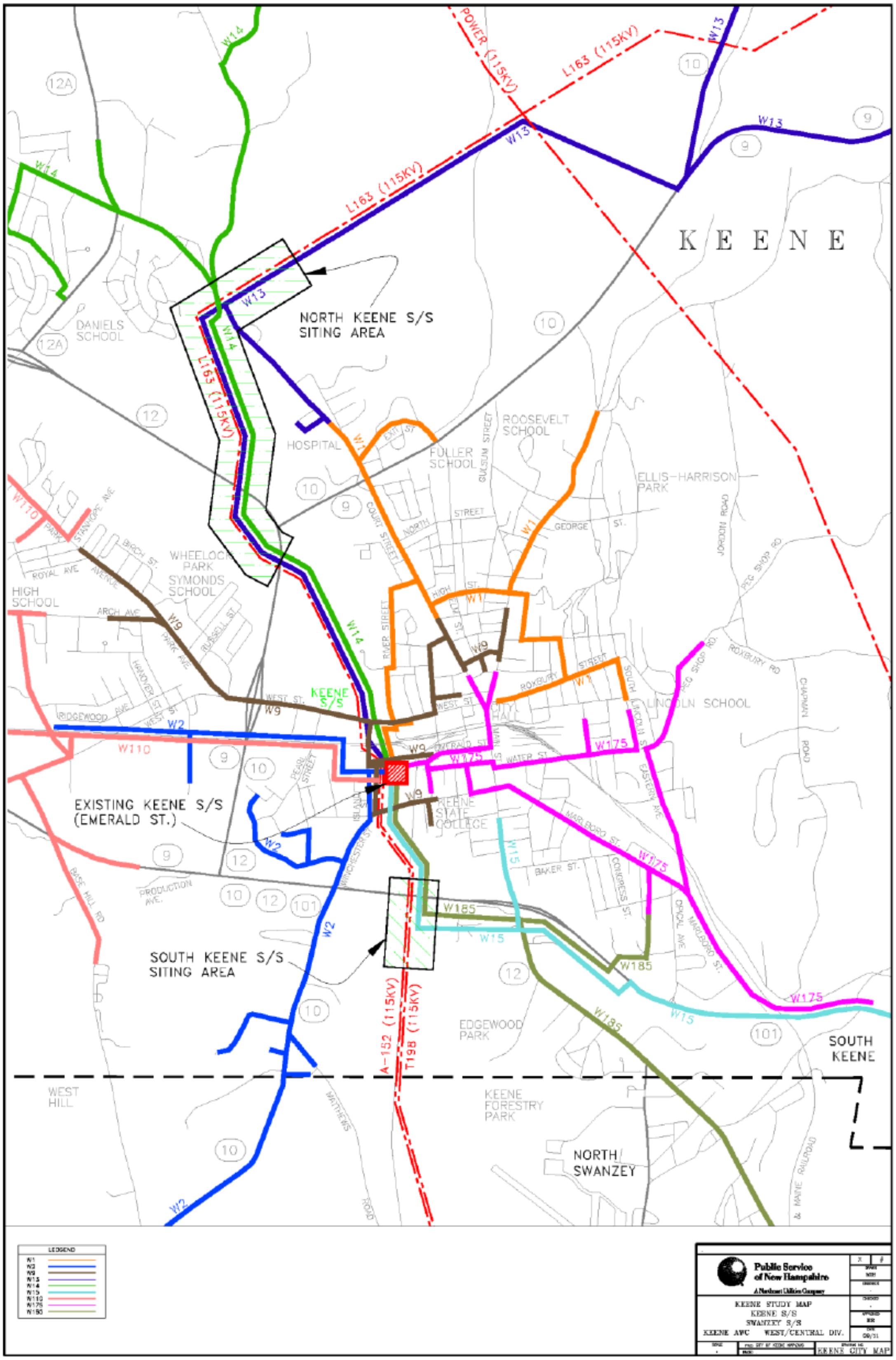
Appendix F Swanzey Substation One-Line Diagram

[redacted]

Appendix G Keene Area 12.47 kV Circuit Diagram



Appendix H City of Keene Circuit Diagram



Appendix I — Cost and Net Present Value Summary

K:\Deptdata\Energy Delivery\System Plan&Strategy\Comprehensive Studies\Keene Area Study\Report\Options Costs T and D.xlsx

Costs are in $Millions

2012 Dollars **Options**	New North eene /S	Rebu Emer St.	Rebuild Emerald St. w/ two units	New South Keene Site
Distribution S/S	5.94	7.03	7.97	5.94
Distribution Line	1.20	0.50	0.50	0.70
Transmission S/S	12.42	6.00	6.00	12.42
Total	19.56	13.53	14.47	19.06

	Present Value	
Emerald Only	option 2	26.2
No. Keene	option 3	33.7
So. Keene	option 4	33.2
No. & So. Keene	option 5	39.2

The above present values were developed from the information provided below:

Distribution Substation: [redacted] 2/28/2012)

Please find the high level cost estimates for the Distribution portions of potential Keene area projects. The cost is in 2012 dollars. The estimates are based on ED3064 "Capital Budget Estmating" - DISTRIBUTION SUBSTATION ENGINEERING UNIT COST.

New North Keene S/S: $4.0M - $9.5M
The order of magnitude is conceptual where the scope is similar to a previously completed project and has not been sufficiently defined to make a direct comparison. The expected accuracy ranges from -30% to + 60% and the contingency from 25% to 50% .
Assumptions:
The Distribution cost for one (1) 115 to 12.47 kVtransformer, one capacitor bank and four feeder positions (W1, W13, W14)

Rebuild Emerald Street with two transformers: $6.25M - $12.75M
The order of magnitude is conceptual where the scope is similar to a previously completed project and has not been sufficiently defined to make a direct comparison. The expected accuracy ranges from -30% to + 60% and the contingency from 25% to 50% .
Assumptions:

The 0.97 A property across the street from existing station is large enough accommodate the 115kV terminals
The 0.97 A property does not require extreme environmental mitigation
[redacted] transformer units
Eight (8) 12.47 kV feeder positions (W15, W110, 75W1&2, W185, W1, W13, W14, spare) , two transformer breaker; provisions for two capacitor banks.
TB3 and bus 3 will remain in the station to feed W9 and W2.
The cost to remove and provide a temporary set-up for TB12 or TB 18 is not included.

Rebuild Emerald Street with one transformer: $5.00M - $11.25M
The order of magnitude is conceptual where the scope is similar to a previously completed project and has not been sufficiently defined to make a direct comparison. The expected accuracy ranges from -30% to + 60% and the contingency from 25% to 50% .
Assumptions:
The 0.97 A property across the street from existing station is large enough accommodate the 115kV terminals
The 0.97 A property does not require extreme environmental mitigation
[redacted] units
Eight (8) 12.47 kV feeder positions (includes 2-4 future or spare feeders) , one transformer breaker; provisions for one capacitor bank.
TB3 and bus 3 will remain in the station to feed W9 and W2.
The cost to remove and provide a temporary set-up for TB12 or TB 18 is not included.

New South Keene S/S: $4.0M - $9.5M:
The order of magnitude is conceptual where the scope is similar to a previously completed project and has not been sufficiently defined to make a direct comparison. The expected accuracy ranges from -30% to + 60% and the contingency from 25% to 50% .
Assumptions:
The Distribution cost for one (1) 115 to 12.47 kV transformer, one capacitor bank and four feeder positions (W15, W185, W2)

Transmission Substation: [redacted] 2/27/2012)

The following can be used for budgetary planning. These are high level estimates, once the full scope is defined, new estimates with better detail should be developed.
The costs are in 2015 dollars.

New substation on the north end of Keene
The design would be our standard distribution substation, 2-115 kV breakers with a motor operated switch between the transformers.

The estimate for the transmission only portion of the yard is: **$6.21M - $25.26M**
Order of Magnitude (-50%+200%) estimate:
As the specific location has not been determined, an additional $1.5 mil has been added for land/row costs.

Expansion at Keene
This includes the following assumptions:
Removal of existing 12.47 kV transformers except TB3
Distribution can fit it new facilities on the existing .9 acres currently owned by PSNH
Connections will be underground cable using the former location and facilities of TB 18 and TB12 (approx 500 ft for each transformer)
No 115 kV breakers will be added, assume distribution will be using fully rated circuit switchers at new substation

Underground cables will be included in existing bus protection, distribution will provide sufficient CT's on new transformers for this
Assumes Emerald street can be ended at existing gas facilities and new parcel can be made contiguous with existing land.
Assumes distribution will allow removal of either TB18 or TB12 prior to completion of new substation.

The estimate for the transmission only portion is: **$3M - $12M**

New substation on the south end of Keene:

Same as North Keene estimate:
The estimate for the transmission only portion of the yard is: **$6.21M - $25.26M**
Order of Magnitude (-50%+200%) estimate:
As the specific location has not been determined, an additional $1.5 mil has been added for land/row costs.

Appendix J — Project Benefit Comparison

K:\Deptdata\Energy Delivery\System Plan&Strategy\Comprehensive Studies\Keene Area Study\Report\MATRIX FORM Keene Area Study xls

Keene Area Study - Matrix for Option Comparison

Project: Construct New 115-12.47 kV Substations in Keene Area with [redacted] in 2015. Remove obsolete equipment in Existing Keene Substation.	**Weighting**	**Rating** 4-5 = Superior, 2-3 = Adequate, 0-1 = Inferior					
		Option 1 Expand at 34.5kV to alleviate S/S transformer overloads	**Option 2** Reconstruct 115-12.47 kV Keene S/S with [redacted] replacing obsolete equipment at existing Keene S/S.	**Option 3** Construct a 115-12.47 kV North Keene S/S with [redacted]. Replace obsolete equipment at existing Keene S/S with [redacted]	**Option 4** Construct a 115-12.47 kV South Keene S/S with [redacted]. Replace obsolete equipment at existing Keene S/S with [redacted]	**Option 5** Construct a 115-12.47 kV North Keene S/S with [redacted]. Construct a 115-12.47 kV South Keene S/S with [redacted] Remove obsolete equipment at existing Keene S/S.	**Option 6** Install Distributed Generation (20MW Combustion Turbine)
Cost			$26.2M	$33.7M	$33.2M	$39.2M	~$45M
Addresses Area Load Growth (Long Term)	8	1	3	5	5	5	1
Improves Reliability: SAIDI	8	1	2	3	3	4	1
Net Present Value (2012) (Appendix A)	7	2	5	4	4	3	2
Feasibility of In-Service Date (ISD)	6	2	2	4	3	3	4
Environmental Impact	5	3	1	2	2	3	1
Contingency Solution	5	1	2	3	3	4	3
Power Quality Improvement (SARFI -70)	4	2	3	3	3	3	2
Operating Cost	3	2	3	3	3	3	2
System Loss Savings (Appendix B)	3	1	1 adds 36.8 kw	4% 3 205.3 kw	2% 2 94.9 kw	6% 4 345.9 kw	4
Total		**79**	**126**	**171**	**162**	**179**	**100**

REDACTED

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000116

Technical Authorization Form

TAF # NH-160001-TDS Rev. 0

Date Prepared: November 18, 2016	Project Title: Emerald Street SS Rebuild
Company/ies: Eversource, NH	Project ID Number: A14W01 (D) & T1347A (T)
Organization: NH Operations	Class(es) of Plant: Distribution & Transmission
Project Initiator: [redacted] PE	Project Category: Substation
Project Owner/Manager: Thelma Brown	Project Type: *Specific*
Project Sponsor: James Eilenberger	Project Purpose: part of regulatory tracked program? No
Estimated in service date: December 1, 2018	If Transmission Project: *Non-PTF*
Authorization Type: *Conceptual Engineering*	Authorization Amount: $1,000,000 for Engineering

Project Need Statement *(Description of Issue)*

In 2012 an area study was performed to determine how to best address the area loading and retirement of equipment at the Emerald Street SS. The study recommended two substation projects to replace the existing equipment currently concentrated at the Emerald Street SS in Keene: 1) a new 115-12.47kV substation in the north section of Keene; and 2) a new/rebuilt 115-12.47kV substation on Emerald Street, at the site of the existing substation. This approach places sources closer to the load, addresses aging and overduty equipment, and provides two separate electrical sources to the area.

In November 2016 the North Keene SS was put in-service. This TAF is for the second phase of the 2012 solution, a project which will replace and/or rebuild the existing Emerald Street SS in Keene.

Project Objectives

1. Retire aging infrastructure.

Much of the equipment at Emerald Street substation is more than 50 years old. There are five 115-12.47kV transformers feeding the 15kV switchgear which was installed around 1949.

The testing and maintenance on the transformers has identified that the 47 year old TB-12 is in the worst shape of the transformers with degraded oil and it is recommended that the transformer be reconditioned or replaced. Three of the transformers are more than 50 years old.

Besides the age and condition of the 67 year old switchgear, there is a concern about the fault duty of the equipment. Operating in the normal , the bus 1 and bus 2 switchgear breakers are at 85.40% to 98.62% of their interrupting rating. Because of the fault duty the bus tie breaker must remain open in the switchgear which limits loading on one bus for the failure of a single transformer.

2. Flood Mitigation

The Ashuelot River is near Emerald Street SS and has been identified as a flood threat. When there has been flooding in the Keene area the river level has come up to the south west corner of the substation but not actually flooded the yard. The 500 year flood plain does penetrate the south west corner of the substation. The plan to rebuild the substation will include grading and retaining walls to prevent potential flooding.

3. 115kV Bus Differential Protection

This project will include adding a 2nd 115kV bus differential protection to Emerald Street SS. Emerald Street Substation is classified as a NERC Bulk Electric System (BES) element and is subject to the maintenance and testing requirements outlined in NERC Standard PRC-005-2. This testing includes the trip testing of the 115kV bus differential protection scheme. The existing system lacks redundancy to permit the triup testing without de-energizing the distribution load served by this substation. . The new construction includes adding the equipment and protection to eliminate this exposure to customers. This 2nd 115kV bus differential scheme installation was defined and approved in 2013 in accordance with the

NERC Standard PRC-005-2 relay test requiremens for BES elements. The project was deferred to allow coordination with the proposed transformer changes.

Project Scope

1) Remove four (4) 115-12.47kV transformers (TB3 will remain)
2) Remove existing 15kV switchgear and associated equipment
3) Install [redacted] transformers
4) Install six (6) 115kV CCVTs
5) Install new switchgear with integral control room and associated systems
6) Install underground control cable raceway systems from the existing control house to new switchgear/control house
7) Install new fence and grounding
8) Regrade yard and install a retaining wall to address 500 year flood levels
9) Install yard lighting
10) Install CIP security measures including cameras
11) Protection and control system upgrades including 2nd 115kV bus differential scheme.
12) Install new batteries and monitoring system.

Background / Justification

In 2012 an area study was performed to determine how to best address the loading and retirement of equipment at the Emerald Street SS. The study recommended that two new 115 kV to 12.47 kV substations be built to replace the existing equipment currently concentrated at the Emerald Street SS in Keene: one in the North section of Keene; and one on Emerald Street, adjacent to the existing substation. This approach places sources closer to the load, reduces fault current, and provides two separately located electrical sources to the area.

In November 2016 the North Keene SS was put in-service. This TAF is for the second phase of the study, a project which will replace and/or rebuild the existing Emerald Street SS in Keene. In addition to providing for future peak load in the area, the transformation at Emerald Street SS will be sized to back up North Keene SS which currently has only one transformer but two express lines between the substations.

The switchgear was installed in 1949 and is 67 years old. The transformers were installed at different times and four of the five will be retired by this project:

Transformer	Size(MVA)	Age (yrs)
TB18	[redacted]	61
TB23		59
TB7		52
TB12		47
TB3		16 (to remain)

Three of the transformers are over 50 but TB12 condition is of the most concern. The oil fluid quality in the main tank of TB12 is wet, has poor dielectric strength, is dark in color and oxidized, and has low interfacial tension.

Emerald Street (Keene) Substation currently has five 115 kV to 12.47 kV transformers feeding three switchgear busses that cannot be tied together. There are operational issues with the switchgear which limit the flexibility to use bus ties. Closing a bus tie breaker to put three or more transformers on the combined bus puts seven of eight feeder breakers well above their interrupting ability. This is a potential safety risk and limits the loadability and reliability of the substation. Additionally, there are many advantages to upgrading the relay protection as part of the project. In most cases, the existing relaying is as old as the switchgear being replaced, is inflexible as to settings, and gives no remote (or local) access to fault information for event investigation.

This project will include adding a 2nd 115kV bus differential protection to Emerald Street SS. This 2nd 115kV bus differential scheme installation was defined and approved in 2013 in accordance with the NERC Standard PRC-005-2 relay test requiremens for BES elements. The project was deferred to allow coordination with the proposed transformer changes.

Business Process and / or Technical Improvements:

This project addresses aging infrastructure, equipment fault duty, and flood mitigation. It is also a part of the overall area plan and strategy to provide a reliable backup to North Keene SS and provide for future growth.

Cost Estimate and Assumptions

The total price of this project is estimated to cost:

Distribution:	9,500,000
Transmission:	500,000
Total:	$10,000,000

($7,500,000 - $12,500,000) (-25% +25%)

Alternatives Considered with Cost Estimates

Note that this PAF addresses step two in the Alternative recommended in the 2012 Keene Area Study.

Alternative 1: Do nothing.
Emerald Street SS equipment is aging. By doing nothing there is more exposure to customer outages for failure of equipment. The failure of an existing transformer without the proposed 115kV differential system protection results in an outage for all customers fed from Emerald Street SS. Estimated cost for Alternative 1: $0.

Alternative 2: Install a second 115-12.47kV transformer at North Keene SS.
This solution will provide capacity and transformer redundancy at North Keene SS. However, as shown on Attachment A – All circuits were originally fed out of Emerald Street as a hub. North Keene bisects two of the circuits and provides a ROW backup feed to Emerald Street. While this could work load-wise it puts a majority of the circuits on two lines fed from Keene to Emerald Street which is much more exposure to line outages. This may require a switching station at Emerald Street, Keene, potentially switchgear. If this alternative was preferred, additional ROW lines and breakers from North Keene SS are recommended. Estimated cost for Alternative 2: $5,000,000

Alternative 3: Construct a new 115-12.47kV South Keene SS.
North Keene SS was constructed to feed the circuits to the north of Emerald Street SS. A second substation could be constructed south of Keene to address the load. Originally this solution was not preferred partially because of the difficulty of finding a location that is not within the 100 year flood plain. Estimated cost for Alternative 3: $15,000,000

Alternative 4: Construct the Emerald Street SS with one 115-12.47 transformer instead of two.
This alternative will save approximately $1,000,000. It does remove a level of reliability from the solution. This also limits future growth. Between the North Keene SS and Emerald Street SS projects, the effective capacity in the Keene area will be reduced by 5MVA if a second transformer is not installed with this project. Estimated cost for Alternative 4: $9,000,000.

Project Schedule

Milestone/Phase Name	Estimated Completion Date
TAF Approval	12/15/16

Milestone/Phase Name	Estimated Completion Date
Scoping Document Development	12/31/16
Engineering & Design	9/1/17
PAF Approval	9/1/17
Construction	12/1/18
Substation tested, In-Service and Complete	12/1/18

Regulatory Approvals

ISO-NE Level 1 approval for the distribution transformer replacements will be required.

Permitting required by the City of Keene, the State of New Hampshire or US Regulatory Departments

Permitting for excavations on the site of a former MPG site.

Risks and Risk Mitigation Plans

The difficulty of constructing, in effect, around an active station. This will be mitigated by getting a thorough engineering design including identification of phasing for construction and a complete constructability reviews.

Outages cancelled due to unplanned events on the system resulting in schedule delay and potential labor cost to remobilize.

- Mitigation Plan - Establish and manage outages using proven coordination teams; 1) Construction Management 2) Coordination Meetings 3) Outage Planning and Risk Mitigation Meeting 4) Utilization of the circuit ties to North Keene Substation and 5) Deploying a mobile substation (MX66 – CL&P mobile) as required.

Internal and external resource availability for engineering.

- Effort is being exerted to balance engineering and review work between internal resources and external resources.

- Lack of sufficient, qualified, local construction labor results in the need to import labor which potentially increases costs or lengthen the schedule which will result in project delays.
    - Develop overall strategy for construction allocation.

References

Keene Area Study Report

Scope Document

One-Line Diagrams, Attachments, and Images

[redacted]

REDACTED

EVERSOURCE ENERGY

NEW HAMPSHIRE

WESTERN

EMERALD ST. 115/12.47KV

EMERALD STREET, KEENE, NH

357-3545

LJG			12/5/16	SKT-EMERALD

[redacted]

REDACTED

EVERSOURCE ENERGY NEW HAMPSHIRE	WESTERN
EMERALD ST. 115/12.47KV EMERALD STREET, KEENE, NH 357-3545	
LJG	11/15/16	SKT-EMERALD

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Attachment M
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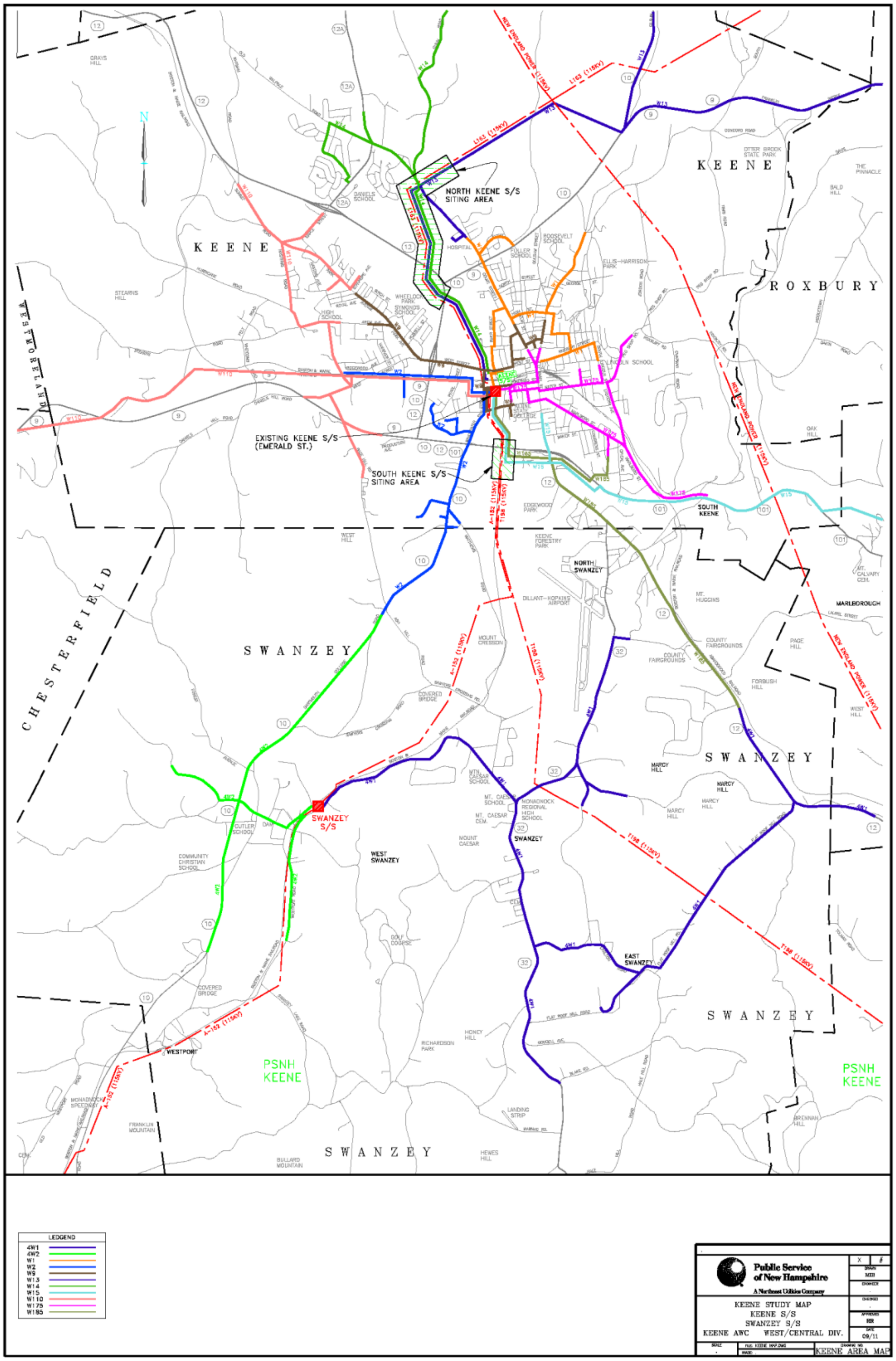
ATTACHMENT A - KEENE AREA CIRCUITS



Operations Project Authorization Form

TAF # NH-160001-TDS

Date Prepared: March 10, 2017	Project Title: Emerald Street SS Rebuild
Company/ies: Eversource NH	Project ID Number: A14W01 (D) & T1347A (T)
Organization: NH Operations	Class(es) of Plant: Distribution & Transmission
Project Initiator: [redacted] PE	Project Category: Substation
Project Manager: Thelma Brown	Project Type: *Specific*
Project Sponsor: James Eilenberger	Project Purpose: part of regulatory tracked program? N
Estimated in service date: December 31, 2018	If Transmission Project: Non-PTF
Eng. /Constr. Resources Budgeted? Yes	Capital Investment Part of Original Operating Plan? Yes
	O&M Expenses Part of the Original Operating Plan? NA

Project Authorization

Project authorization must be in accordance with the approval levels included in the Delegation of Authority Policy (DOA).

If Subsidiary Board approval is required, document the review by Enterprise Risk Management (ERM) and Financial Planning and Analysis (FP&A)

ERM: ____

FP&A: ____

Executive Summary

This project is currently approved for $1,000,000 for engineering (see attached TAF). The approval for the transformers and switchgear in addition to the engineering previously approved adds up to the request for a total of $5,300,000 for this project.

This PAF is a request for approval to place long lead-time materials on order for the Emerald Street SS rebuild project. This request includes material funding of $4,300,000 for:

> [redacted] transformers. Transformers are estimated at $900,000 each for a total of [redacted] The lead time for transformers is approximately 52 weeks. The transformer needs to be delivered to the project in Q2 2018.
>
> 12.47kV Metalclad switchgear including fifteen (15) breakers and a control house enclosure. This switchgear is estimated at $2,500,000. The lead time for switchgear is approximately 52 weeks. The switchgear needs to be delivered to the project in Q2 2018.

This project is for the rebuild of the existing substation. Much of the equipment at Emerald Street substation is more than 50 years old. There are five 115-12.47kV transformers feeding the 15kV switchgear which was installed around 1949. There are issues with equipment condition, fault duty, and flooding at the site that will be addressed with this project.

The risk in procuring the transformers if the project does not go forward is limited. This transformer is the standard voltage used in the western part of the Eversource NH system. If this project is not approved the transformers will become system spares and be available for replacement of a failed unit. There are currently 7 of these units in-service including the 5 at Emerald Street SS. In the event it is decided to cancel the order within 20 weeks of placing it, the risk is a partial cost of the transformers. Below is a typical cancellation schedule for a recent transformer purchase.

Cancellation Schedule

The Purchaser may cancel order only upon written notice and upon payment to the Seller of reasonable and proper cancellation charges. These charges will be based on the following schedule unless separate written agreement is made with Seller:

Time frame is from PO date or letter of Intent date.

0	to	10 weeks	20% of the transformer Selling price
>10	to	20 weeks	80% of the transformer Selling price
>20	to	30 weeks	100% of the transformer Selling price

The risk in procuring the switchgear if the project does not go forward is substantial. There may be cancellation policies that can be negotiated but it is recognized that the approval to procure the switchgear should indicate a preference for the project to go forward, although it could be delayed due to funding in 2018 which would push the in-service date out. A $250,000 deposit payment on the switchgear is due in 2017.

Project Costs Summary

Note: Dollar values are in thousands

Distribution Project A14W01

	Prior Authorized	2017	2018	2020+	Totals
Capital Additions - Direct	$ 860	$ 250	$ 4,050	$ -	$ 5,160
Less Customer Contribution	-	-	-	-	-
Removals net of Salvage ____%	-	-	-	-	-
Total - Direct Spending	$ 860	$ 250	$ 4,050	$ -	$ 5,160
Capital Additions - Indirect	130	-	-	-	130
Subtotal Request	$ 990	$ 250	$ 4,050	$ -	$ 5,290
AFUDC	10	-	-	-	10
Total Capital Request	$ 1,000	$ 250	$ 4,050	$ -	$ 5,300
O&M	-	-	-	-	-
Total Request	$ 1,000	$ 250	$ 4,050	$ -	$ 5,300

Transmission Project T1347A

	Prior Authorized	2017	2018	2020+	Totals
Capital Additions - Direct	$ 45	$ -	$ -	$ -	$ 45
Less Customer Contribution	-	-	-	-	-
Removals net of Salvage ____%	-	-	-	-	-
Total - Direct Spending	$ 45	$ -	$ -	$ -	$ 45
Capital Additions - Indirect	5	-	-	-	5
Subtotal Request	$ 50	$ -	$ -	$ -	$ 50
AFUDC	-	-	-	-	-
Total Capital Request	$ 50	$ -	$ -	$ -	$ 50
O&M	-	-	-	-	-
Total Request	$ 50	$ -	$ -	$ -	$ 50

Financial Evaluation

Provide the following financial information (attach additional detail if summarized items are significant or additional information is needed). Note: Dollar values are in thousands
Distribution Project A14W01

Direct Capital Costs	Year 1	Year 2	Year 3+	Total
Straight Time Labor	60			60
Overtime Labor				
Outside Services	800			800
Materials	250	4,050		4,300
Other, including contingency amounts (describe)				
Total	1,110	4,050		5,160

Indirect Capital Costs	Year 1	Year 2	Year 3+	Total
Indirects/Overheads (including benefits)	130			130
Capitalized interest or AFUDC, if any	10			10
Total	140			140

Total Capital Costs	1,250	4,050		5,300
Less Total Customer Contribution				
Total Capital Project Costs	1,250	4,050		5,300
Total O&M Project Costs				

Transmission Project T1347A

Direct Capital Costs	Year 1	Year 2	Year 3+	Total
Straight Time Labor	5			5
Overtime Labor				
Outside Services	40			40
Materials				
Other, including contingency amounts (describe)				
Total	45			45

Indirect Capital Costs	Year 1	Year 2	Year 3+	Total
Indirects/Overheads (including benefits)	4			4
Capitalized interest or AFUDC, if any	1			1
Total	5			5

Total Capital Costs	50			50
Less Total Customer Contribution				
Total Capital Project Costs	50			50
Total O&M Project Costs				

Note: Explain unique payment provisions, if applicable

Future Financial Impacts:

Provide below the estimated future costs that will result from the project:
Note: Dollar values are in thousands:

Future Costs	Year 2017	Year 2018	Year20__	Year 20__+	Total Future Project Costs
Capital	$ 1,000	$ 9,000	$ -	$ -	$ 10,000
O&M	-	-	-	-	-
Other	-	-	-	-	-
TOTAL	**$ 1,000**	**$ 9,000**	**$ -**	**$ -**	**$ 10,000**

Total distribution cost of the project is estimated to be $10,000,000. This is proposed for 2018 construction.

What functional area(s) will these future costs be funded in?___NH Operations___
A representative from the respective functional area is required to be included as a project approver.

If this is other than a Reliability Project, please complete the section below;

Provide below the estimated financial benefits that will result from the project:

Note: Dollar values are in thousands:

Future Benefits	Year 20__	Year 20__	Year20__	Year 20__+	Total Future Project Benefits
Capital	$ -	$ -	$ -	$ -	$ -
O&M	-	-	-	-	-
Other	-	-	-	-	-
TOTAL	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**

Describe the estimated future Capital, O&M and/or Other benefits noted above:

This project is to replace aging equipment and address operational concerns with the existing substation.

What functional area(s) will these benefits be reflected in?_____NH Operations_____________

A representative from the respective functional area is required to be included as a project approver.

Asset Retirement Obligation (ARO) and/ or Environmental Cleanup Costs (Environmental Liabilities):

An ARO is a current legal obligation to remove or retire property, plant or equipment at some point in the future. Please refer to APS8 or contact Plant Accounting for further detail.

Is there an ARO associated with this project? If yes, please provide details: No

Are there other environmental cleanup costs associated with this project? If yes, please provide details.

This project is located at a former MPG site and handling of the subsurface materials during construction will need to be monitored. Formal cleanup of the site is complete but this needs to be considered for construction.

Technical Authorization Form

TAF # NH-160001-TDS Rev. 0

Date Prepared: November 18, 2016	Project Title: Emerald Street SS Rebuild
Company/ies: Eversource, NH	Project ID Number: A14W01 (D) & T1347A (T)
Organization: NH Operations	Class(es) of Plant: Distribution & Transmission
Project Initiator: [redacted] PE	Project Category: Substation
Project Owner/Manager: Thelma Brown	Project Type: *Specific*
Project Sponsor: James Eilenberger	Project Purpose: part of regulatory tracked program? No
Estimated in service date: December 31, 2018	If Transmission Project: *Non-PTF*
Authorization Type: *Conceptual Engineering*	Authorization Amount: $1,000,000 for Engineering

Project Need Statement *(Description of Issue)*

In 2012 an area study was performed to determine how to best address the area loading and retirement of equipment at the Emerald Street SS. The study recommended two substation projects to replace the existing equipment currently concentrated at the Emerald Street SS in Keene: 1) a new 115-12.47kV substation in the north section of Keene; and 2) a new/rebuilt 115-12.47kV substation on Emerald Street, at the site of the existing substation. This approach places sources closer to the load, addresses aging and overduty equipment, and provides two separate electrical sources to the area.

In November 2016 the North Keene SS was put in-service. This TAF is for the second phase of the 2012 solution, a project which will replace and/or rebuild the existing Emerald Street SS in Keene.

Project Objectives

1. Retire aging infrastructure.

Much of the equipment at Emerald Street substation is more than 50 years old. There are five 115-12.47kV transformers feeding the 15kV switchgear which was installed around 1949.

The testing and maintenance on the transformers has identified that the 47 year old TB-12 is in the worst shape of the transformers with degraded oil and it is recommended that the transformer be reconditioned or replaced. Three of the transformers are more than 50 years old.

Besides the age and condition of the 67 year old switchgear, there is a concern about the fault duty of the equipment. Operating in the normal , the bus 1 and bus 2 switchgear breakers are at 85.40% to 98.62% of their interrupting rating. Because of the fault duty the bus tie breaker must remain open in the switchgear which limits loading on one bus for the failure of a single transformer.

2. Flood Mitigation

The Ashuelot River is near Emerald Street SS and has been identified as a flood threat. When there has been flooding in the Keene area the river level has come up to the south west corner of the substation but not actually flooded the yard. The 500 year flood plain does penetrate the south west corner of the substation. The plan to rebuild the substation will include grading and retaining walls to prevent potential flooding.

3. 115kV Bus Differential Protection

This project will include adding a 2nd 115kV bus differential protection to Emerald Street SS. Emerald Street Substation is classified as a NERC Bulk Electric System (BES) element and is subject to the maintenance and testing requirements outlined in NERC Standard PRC-005-2. This testing includes the trip testing of the 115kV bus differential protection scheme. The existing system lacks redundancy to permit the triup testing without de-energizing the distribution load served by this substation. . The new construction includes adding the equipment and protection to eliminate this exposure to customers. This 2nd 115kV bus differential scheme installation was defined and approved in 2013 in accordance with the NERC Standard PRC-005-2 relay test requiremens for BES elements. The project was deferred to allow coordination with the proposed transformer changes.

Project Scope

1) Remove four (4) 115-12.47kV transformers (TB3 will remain)
2) Remove existing 15kV switchgear and associated equipment
3) Install [redacted]
4) Install six (6) 115kV CCVTs
5) Install new switchgear with integral control room and associated systems
6) Install underground control cable raceway systems from the existing control house to new switchgear/control house
7) Install new fence and grounding
8) Regrade yard and install a retaining wall to address 500 year flood levels
9) Install yard lighting
10) Install CIP security measures including cameras
11) Protection and control system upgrades including 2nd 115kV bus differential scheme.
12) Install new batteries and monitoring system.

Background / Justification

In 2012 an area study was performed to determine how to best address the loading and retirement of equipment at the Emerald Street SS. The study recommended that two new 115 kV to 12.47 kV substations be built to replace the existing equipment currently concentrated at the Emerald Street SS in Keene: one in the North section of Keene; and one on Emerald Street, adjacent to the existing substation. This approach places sources closer to the load, reduces fault current, and provides two separately located electrical sources to the area.

In November 2016 the North Keene SS was put in-service. This TAF is for the second phase of the study, a project which will replace and/or rebuild the existing Emerald Street SS in Keene. In addition to providing for future peak load in the area, the transformation at Emerald Street SS will be sized to back up North Keene SS which currently has only one transformer but two express lines between the substations.

The switchgear was installed in 1949 and is 67 years old. The transformers were installed at different times and four of the five will be retired by this project:

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TB23		59
TB7		52
TB12		47
TB3		16 (to remain)

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Emerald Street (Keene) Substation currently has five 115 kV to 12.47 kV transformers feeding three switchgear busses that cannot be tied together. There are operational issues with the switchgear which limit the flexibility to use bus ties. Closing a bus tie breaker to put three or more transformers on the combined bus puts seven of eight feeder breakers well above their interrupting ability. This is a potential safety risk and limits the loadability and reliability of the substation. Additionally, there are many advantages to upgrading the relay protection as part of the project. In most cases, the existing relaying is as old as the switchgear being replaced, is inflexible as to settings, and gives no remote (or local) access to fault information for event investigation.

This project will include adding a 2^{nd} 115kV bus differential protection to Emerald Street SS. This 2^{nd} 115kV bus differential scheme installation was defined and approved in 2013 in accordance with the NERC Standard PRC-005-2 relay test requiremens for BES elements. The project was deferred to allow coordination with the proposed transformer changes.

Business Process and / or Technical Improvements:

This project addresses aging infrastructure, equipment fault duty, and flood mitigation. It is also a part of the overall area plan and strategy to provide a reliable backup to North Keene SS and provide for future growth.

Cost Estimate and Assumptions

The total price of this project is estimated to cost:

Distribution:	9,500,000
Transmission:	500,000
Total:	$10,000,000

($7,500,000 - $12,500,000) (-25% +25%)

Alternatives Considered with Cost Estimates

Note that this PAF addresses step two in the Alternative recommended in the 2012 Keene Area Study.

Alternative 1: Do nothing.
Emerald Street SS equipment is aging. By doing nothing there is more exposure to customer outages for failure of equipment. The failure of an existing transformer without the proposed 115kV differential system protection results in an outage for all customers fed from Emerald Street SS. Estimated cost for Alternative 1: $0.

Alternative 2: Install a second 115-12.47kV transformer at North Keene SS.
This solution will provide capacity and transformer redundancy at North Keene SS. However, as shown on Attachment A – All circuits were originally fed out of Emerald Street as a hub. North Keene bisects two of the circuits and provides a ROW backup feed to Emerald Street. While this could work load-wise it puts a majority of the circuits on two lines fed from Keene to Emerald Street which is much more exposure to line outages. This may require a switching station at Emerald Street, Keene, potentially switchgear. If this alternative was preferred, additional ROW lines and breakers from North Keene SS are recommended. Estimated cost for Alternative 2: $5,000,000

Alternative 3: Construct a new 115-12.47kV South Keene SS.
North Keene SS was constructed to feed the circuits to the north of Emerald Street SS. A second substation could be constructed south of Keene to address the load. Originally this solution was not preferred partially because of the difficulty of finding a location that is not within the 100 year flood plain. Estimated cost for Alternative 3: $15,000,000

Alternative 4: Construct the Emerald Street SS with one 115-12.47 transformer instead of two. This alternative will save approximately $1,000,000. It does remove a level of reliability from the solution. This also limits future growth. Between the North Keene SS and Emerald Street SS projects, the effective capacity in the Keene area will be reduced by 5MVA if a second transformer is not installed with this project. Estimated cost for Alternative 4: $9,000,000.

Project Schedule

Milestone/Phase Name	Estimated Completion Date
TAF Approval	12/15/16
Scoping Document Development	12/31/16
Engineering & Design	9/1/17
PAF Approval	9/1/17
Construction	12/1/18
Substation tested, In-Service and Complete	12/1/18

Regulatory Approvals

ISO-NE Level 1 approval for the distribution transformer replacements will be required.

Permitting required by the City of Keene, the State of New Hampshire or US Regulatory Departments

Permitting for excavations on the site of a former MPG site.

Risks and Risk Mitigation Plans

The difficulty of constructing, in effect, around an active station. This will be mitigated by getting a thorough engineering design including identification of phasing for construction and a complete constructability reviews.

Outages cancelled due to unplanned events on the system resulting in schedule delay and potential labor cost to remobilize.

- Mitigation Plan - Establish and manage outages using proven coordination teams; 1) Construction Management 2) Coordination Meetings 3) Outage Planning and Risk Mitigation Meeting 4) Utilization of the circuit ties to North Keene Substation and 5) Deploying a mobile substation (MX66 – CL&P mobile) as required.

Internal and external resource availability for engineering.

- Effort is being exerted to balance engineering and review work between internal resources and external resources.

- Lack of sufficient, qualified, local construction labor results in the need to import labor which potentially increases costs or lengthen the schedule which will result in project delays.
    - Develop overall strategy for construction allocation.

References

REDACTED

Keene Area Study Report

Scope Document

One-Line Diagrams, Attachments, and Images

[redacted]

One-line - Removals

REDACTED

EVERSOURCE

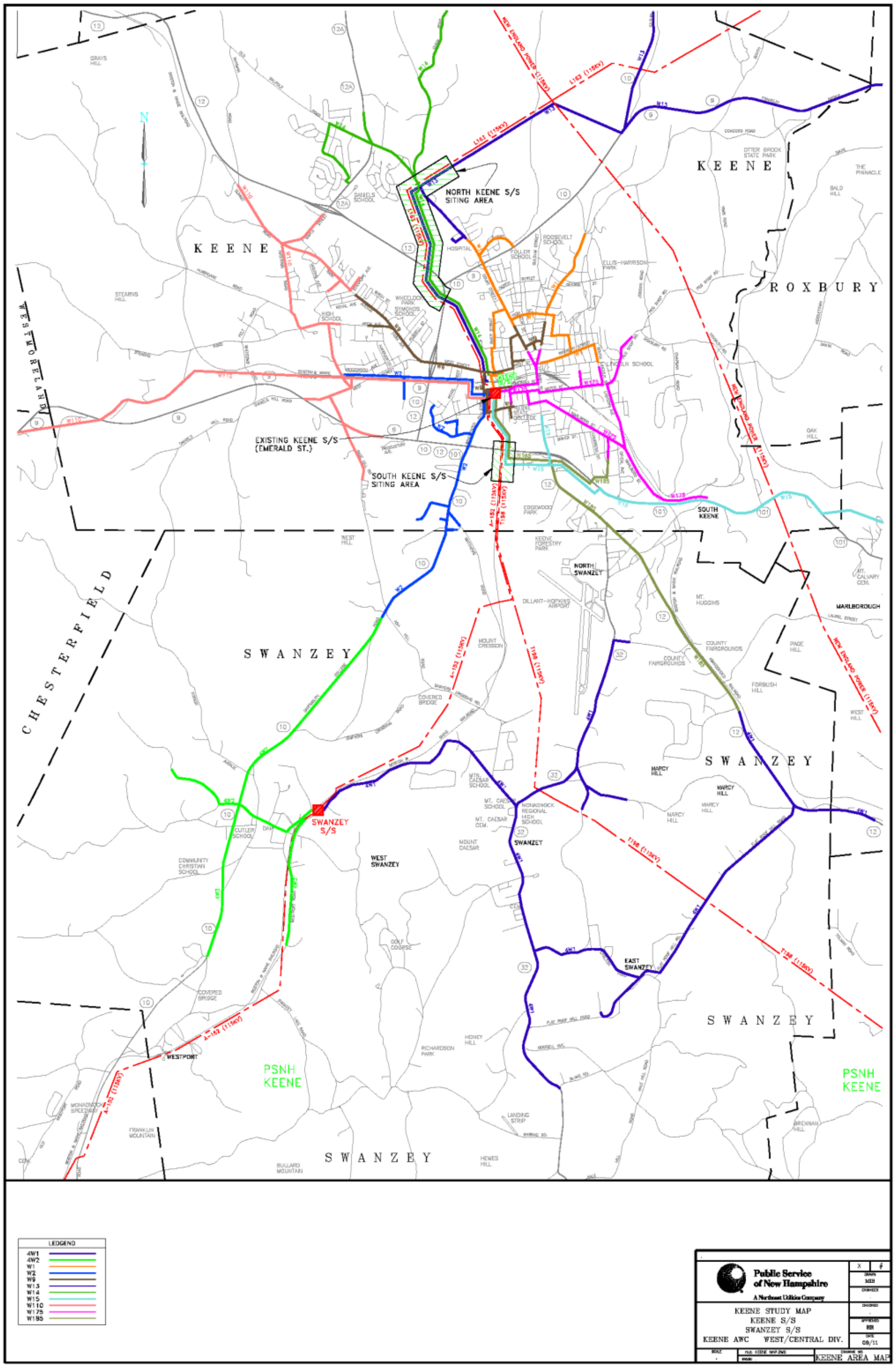
APS 1 - Project Authorization Policy

Appendix 2
Operations Project Authorization Form

[redacted]

One-line - Additions

ATTACHMENT A - KEENE AREA CIRCUITS



Operations Project Authorization Form

Date Prepared: 3/21/18	Project Title: Emerald Street S/S Distribution Line Work
Company/ies: Eversource NH	Project ID Number: A18W17
Organization: NH Operations	Class(es) of Plant: Distribution Line
Project Initiator: [redacted]	Project Category: Reliability - Other
Project Manager: [redacted]	Project Type: *Specific*
Project Sponsor: James Eilenberger	Project Purpose: Interconnection of Substation to Distribution System
Estimated in service date: 10/1/19	If Transmission Project: NA
Eng. /Constr. Resources Budgeted? Yes	Capital Investment Part of Original Operating Plan? Yes
Authorization Type: Full Funding	O&M Expenses Part of the Original Operating Plan? Yes
Total Request: $800,000	

Financial Requirements:

Project Authorization

ERM: ______________________________

FP&A: ______________________________

Executive Summary

The Emerald Street Substation in Keene is a 115/12.47 kV distribution substation. An approved major rebuild/replacement project (A14W01) is currently in design with construction slated to begin later in 2018. This distribution line work project is designed to integrate eight new risers needed to transition power from the substation breakers to the distribution circuits. The project will also require some line relocations to align new risers with existing circuitry in addition to the removal of parts of the W14 circuit and other associated equipment.

This work is to be performed in conjunction with the Emerald Street Substation rebuild project A14W01.

Project Costs Summary

Note: Dollar values are in thousands

	Prior Authorized	2018	20	20 +	Totals
Capital Additions - Direct	$ -	$ 209	$ 437	$ -	$ 646
Less Customer Contribution	-	-	-	-	-
Removals net of Salvage %	-	-	27	-	27
Total - Direct Spending	$ -	$ 209	$ 464	$ -	$ 673
Capital Additions - Indirect	-	35	75	-	110
Subtotal Request	$ -	$ 244	$ 539	$ -	$ 783
AFUDC	-	1	1	-	2
Total Capital Request	$ -	$ 245	$ 540	$ -	$ 785
O&M	-	5	10	-	15
Total Request	$ -	$ 250	$ 550	$ -	$ 800

Financial Evaluation

Provide the following financial information (attach additional detail if summarized items are significant or additional information is needed). Note: Dollar values are in thousands

Direct Capital Costs	Year 1	Year 2	Year 3+	Total
Straight Time Labor	9	20		30
Overtime Labor	0	0		0
Outside Services	91	197		288
Materials	109	246		355
Other, including contingency amounts (describe)				
Total	209	464		673

Indirect Capital Costs	Year 1	Year 2	Year 3+	Total
Indirects/Overheads (including benefits)	35	75		110
Capitalized interest or AFUDC, if any	1	1		2
Total				

Total Capital Costs	245	540		785
Less Total Customer Contribution	0	0		0
Total Capital Project Costs	245	540		785

Total O&M Project Costs	5	10		15

Future Financial Impacts:

No future financial impacts are anticipated with this project.

Asset Retirement Obligation (ARO) and/ or Environmental Cleanup Costs (Environmental Liabilities):

An ARO is a current legal obligation to remove or retire property, plant or equipment at some point in the future. Please refer to APS8 or contact Plant Accounting for further detail.

Is there an ARO associated with this project? No

Are there other environmental cleanup costs associated with this project? No

Operations Technical Authorization Form

Technical Justification:

Project Need Statement

There are currently nine circuits that originate from Emerald Street Substation. The new station design creates eight circuits that need to feed the exiting distribution lines. This work is to bring conductors from the load side of the new breakers to distribution circuits located outside the fence and is fundamental to the substation project.

Project Objectives

The goal in designing the new riser locations is to minimize line relocations while integrating the construction cut overs. Most new risers come up directly under existing circuitry, reducing construction costs.

Project Scope

The scope of this project is to bring conductors from the new circuit breakers out to the roadside distribution circuits. Eight new risers are to be installed for the new circuitry. Nine existing risers are to be removed. A portion of the W14 circuit is to be removed and the W9 circuit will be adjusted to put it in line with the new riser location. There will also be some other minor line adjustments.

Background / Justification

The interconnection of the new circuitry to the distribution lines was anticipated from the beginning of the substation rebuild project. The layout of the substation get away cables and location of the new risers could not be confirmed until significant substation design was completed. A decision was made early in the process to keep the distribution line work project separate from the substation construction process due to planning, accounting, and construction reasons.

Business Process and / or Technical Improvements:

Cost Estimate and Assumptions

Ten separate Storms jobs and estimates were created for the distribution line work outside the substation for each aspect of this project. These jobs have been fully written utilizing the assumptions within our project writing system. Estimates were developed for the underground conduits and cable work from the circuit breakers to the risers by the substation design team and provide to field engineering for inclusion in the PAF.

Alternatives Considered with Cost Estimates

The best riser locations were chosen to reduce line construction and substation design costs. No feasible alternatives were identified.

Project Schedule

Describe the project schedule and milestones. Include estimated start and end dates.

Milestone/Phase Name	Estimated Completion Date
Completion of project	10/1/2019

Regulatory Approvals

All regulatory requirements associated with this project were covered through the larger Emerald Street Substation approval process.

Risks and Risk Mitigation Plans

This project will need to work in conjunction with the Emerald Street Substation construction project. Timing will be driven by the progress of the larger project.

One-Line Diagrams, Attachments,

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