Raquel J. Webster
Senior Counsel

January 5, 2016

BY HAND DELIVERY AND ELECTRONIC MAIL

Luly E. Massaro, Commission Clerk
Rhode Island Public Utilities Commission
89 Jefferson Boulevard
Warwick, RI 02888

RE: Docket 4592 - National Grid's Proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan
Response to PUC Data Requests – Set 1

Dear Ms. Massaro:

I have enclosed ten copies of National Grid's[1] responses to the PUC's first set of data requests in the above-referenced docket.

Thank you for your attention to this matter. If you have any questions, please contact me at 781-907-2121.

Very truly yours,

Raquel J. Webster

Enclosures

cc: Docket 4592 Service List
Leo Wold, Esq.
Steve Scialabba, Division
Greg Booth, Division

[1] The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

40 Sylvan Rd. Waltham, MA 02451
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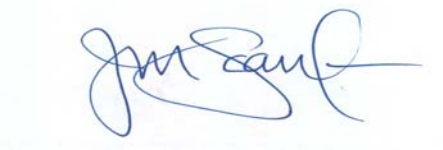
Certificate of Service

I hereby certify that a copy of the cover letter and any materials accompanying this certificate was electronically transmitted to the individuals listed below.

The paper copies of this filing were hand delivered to the Rhode Island Public Utilities Commission and to the Rhode Island Division of Public Utilities and Carriers.



_____ January 5, 2016

Joanne M. Scanlon Date

Docket No. 4592 National Grid's Electric Infrastructure, Safety and Reliability Plan FY 2017 - Service List as of 12/10/15

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File an original & nine copies w/: Luly E. Massaro, Commission Clerk Public Utilities Commission 89 Jefferson Blvd. Warwick, RI 02888	Luly.massaro@puc.ri.gov; Cynthia.WilsonFrias@puc.ri.gov; Alan.nault@puc.ri.gov; Todd.bianco@puc.ri.gov;	401-780-2107

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PUC 1-1

Request:

Please provide a copy of any data responses provided to the Division of Public Utilities and Carriers as part of its review of National Grid's FY 2017 Electric ISR Proposal prior to being filed with the Commission.

Response:

Attached are copies of the Company's data responses and attachments that were provided to the Division of Public Utilities and Carriers (Division) as part of the Division's review of the Company's proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan. The enclosed responses include:

- Attachment PUC 1-1-1: The Company's responses to the Division's First Set of Data Requests, dated October 26, 2015.

In Division data request R-I-1-1, the Division requested an electronic copy of the CYME system model for East Bay Area with existing and projected feeder loads which support the capital line construction and upgrade projects. Please note that Attachment PUC-1-1-1 does not include an attachment for the Company's response to Division Data request R-I-1-1 because the Company provided this attachment to the Division on a CD ROM, which the Division's consultant accessed using software known as CYME. The requested CYME model can only be accessed using CYME software and data files. (*See* www.cyme.com for further information). CYME is a costly software program that is used by many engineering firms.

- Attachment PUC 1-1-2: The Company's remaining responses to the Division's First Set of Data Requests, dated October 29, 2015.

- Attachment PUC 1-1-3: The Company's responses to the Division's Second Set of Data Requests, dated November 17, 2015.

- Attachment PUC 1-1-4: The Company's response to Division R-II-2, dated November 18, 2015.

- Attachment PUC 1-1-5: The Company's response to Division R-II-1, dated November 23, 2015.

Raquel J. Webster
Senior Counsel

October 26, 2015

BY HAND DELIVERY AND ELECTRONIC MAIL

Luly E. Massaro, Clerk
Rhode Island Division of Public Utilities and Carriers
89 Jefferson Boulevard
Warwick, RI 02888

RE: National Grid's Proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan
Responses to Division Data Requests – Set 1

Dear Ms. Massaro:

I have enclosed five (5) copies of National Grid's[1] responses to the Division's First Set of Data Requests issued in the above-referenced matter.

In this transmittal, the Company is providing responses to the following Division data requests: R-I-1-1, R-I-1-2, R-I-1-4, R-I-1-8, R-I-1-10, R-I-1-12, and R-I-1-13. The Company will be submitting the remaining responses in this set shortly.

Thank you for your attention to this transmittal. If you have any questions, please contact me at 781-907-2121.

Very truly yours,

Raquel J. Webster

Enclosures

cc: Steve Scialabba
Leo Wold, Esq.
Jim Lanni
Al Contente

[1] The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

40 Sylvan Road, Waltham, MA 02451
T: 781-907-2121 ■ raquel.webster@nationalgrid.com ■ www.nationalgrid.com

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R-I-1-1

Request:

Provide an electronic copy of the CYME system model for East Bay Area with existing and projected feeder loads which support the capital line construction and upgrade projects.

Response:

Please see Attachment R-I-1-1, which includes two copies of the East Bay Area CYME models with existing and projected (2020) feeder loads. National Grid has not advanced any capital line construction and upgrade projects in the East Bay Area in the FY 2017 ISR. Therefore, the East Bay Area CYME models would support future ISR capital line construction and upgrade projects. Furthermore, the East Bay Study utilizes a comprehensive review of which CYME analysis is a partial input. The capital line construction and upgrade projects to be included in future ISRs, supported by the East Bay Study analysis, are not solely based on the CYME analysis.

Prepared by or under the supervision of: Ryan Constable

R-I-1-2

Request:

Provide an electronic copy of the CYME system model for Providence Area, if complete, with existing and projected feeder loads which support the capital line construction and upgrade projects.

Response:

The Providence Short Term Study is in progress and the CYME models are under active use. National Grid prefers to provide the CYME models after the study is complete. The Company has not advanced any capital line construction and upgrade projects in the Providence Area in the FY 2017 ISR Plan that have not already been communicated as a part of the Providence Long Term Study (i.e., South Street Substation Projects). Note that CYME models used during the Providence Long Term Study were provided to the Division in September 2014.

Prepared by or under the supervision of: Ryan Constable

R-I-1-4

Request:

For the increase in tree related interruptions on bar Chart 2, explain how much is hazard tree related and how much is simply vegetation contact related.

Response:

Customer Interrupted Caused by Tree over Years								
Cause	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Tree - Broken Limb	58143	46901	61116	49656	57941	26660	38586	**339003**
Tree - Vines	502	375	663	2935	378	2167	356	**7376**
Tree Fell	38159	26355	35367	27474	41103	25619	30903	**224980**
Tree Growth	564	485	661	816	1037	610	432	**4605**

Customer Interrupted Caused by Tree over Years								
Cause	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Tree - Broken Limb	59.7%	63.3%	62.5%	61.4%	57.7%	48.4%	54.9%	**58.9%**
Tree - Vines	0.5%	0.5%	0.7%	3.6%	0.4%	3.9%	0.5%	**1.3%**
Tree Fell	39.2%	35.6%	36.2%	34.0%	40.9%	46.5%	44.0%	**39.1%**
Tree Growth	0.6%	0.7%	0.7%	1.0%	1.0%	1.1%	0.6%	**0.8%**

Hazard trees have accounted for 39% of tree related interruptions since 2008.

Prepared by or under the supervision of: Ryan Moe

R-I-1-8

Request:

Provide an electronic copy of the capital spending annual budget project for FY 2017 through FY 2020, excluding the South Street Substation. Also, provide Chart 6 excluding South Street Substation expenditures for comparison purposes.

Response:

An electronic copy of the capital spending annual budget project for FY 2017 through FY 2021 excluding the South Street Substation is provided in Attachment DIV R-I-1-8(A).

Chart 6 excluding South Street Substation expenditures has been provided in Attachment DIV R-I-1-8(B). Chart 7 has been included for comparison purposes. In addition, the figures in Chart 6 are built upon the figures in Chart 7.

Prepared by or under the supervision of: Glen L. DiConza

FY2017-2021 Annual Capital Spending Plan by Project
(as filed) **EXCLUDING SOUTH STREET**

ISR Spending Rationale	ISR Category	Project #	Project Description	Approved Capital	PRE-FY2016 Spend	FY16 Actuals (4-MTD)	FY16 Forecast (4MTD)	Total FY16 ISR Budget	Total FY17 Budget	Total FY18 Budget	Total FY19 Budget	Total FY20 Budget	Total FY21 Budget
				Values									
System Capacity & Performance	Aquidneck Island (includes former Jepson & Newport projec	C015158	Newport Substation (D-Sub)	1,000	724	115	473	300	1,028	2,288	4,149	-	-
		C024159	Newport 69kV Line 63 (D-Line)	200	148	3	3	50	230	647	100	-	-
		C028628	Newport SubTrans & Dist Conversion	3,900	423	124	1,085	1,400	884	2,020	5,220	3,425	-
		C054054	Jepson Substation (D-Line)	800	-	-	-	50	372	350	4,268	1,600	-
		C058310	Harrison Sub Improvements (D-Sub)	50	-	-	-	-	-	23	-	100	-
		C058401	Merton Sub Improvements (D-Sub)	50	-	-	-	-	-	23	-	100	-
		C058404	Kingston Sub Improvements (D-Sub)	600	-	-	-	-	-	114	-	175	-
		CD00649	Gate 2 Substation (D-Sub)	1,100	195	126	616	50	-	-	500	-	-
		CD00651	Bailey Brook Retirement (D-Sub)	50	0	-	-	-	-	-	-	-	-
		CD00652	Vernon Retirement (D-Sub)	50	0	-	-	-	-	109	-	-	-
		CD00656	Jepson Substation (D-Sub)	2,100	86	43	50	200	368	2,151	4,250	5,600	-
	Aquidneck Island (includes former Jepson & Newport projects) Total			9,900	1,577	411	2,227	2,050	2,882	7,725	18,487	11,000	-
	Chase Hill (Hopkinton) & Related	C024175	Chase Hill Sub (D_Line)	1,387	706	39	1,461	2,700	2,945	1,901	-	-	-
		C024176	Chase Hill Sub (D-Sub)	5,177	3,942	(222)	1,474	2,200	1,990	1,626	-	-	-
		C034102	Retire Ashaway 43 Substation	0	-	-	-	-	-	-	-	-	-
		C036233	Hope Valley (D_Sub)	0	-	-	-	-	-	-	-	-	-
		C036234	Hope Valley (D_Line)	0	-	-	-	-	-	-	-	-	-
	Chase Hill (Hopkinton) & Related Total			6,564	4,648	(183)	2,934	4,900	4,935	3,526	-	-	-
	Clarke St	C046831	CLARKE 65J12 Feeder Upgrade (D-Sub)	2,194	1,005	685	1,120	200	-	-	-	-	-
		C046832	CLARKE St Feeder Upgrades (D-Line)	445	111	230	313	50	-	-	-	-	-
	Clarke St Total			2,639	1,117	915	1,433	250	-	-	-	-	-
	East Bay Study	C046726	East Bay Study (D-Sub)		-	-	78	84	-	100	470	1,400	3,340
		C046727	East Bay Study (D-Line)		-	-	-	-	-	100	550	1,600	3,920
	East Bay Study Total				-	-	78	84	-	200	1,020	3,000	7,260
	EMS	C035726	EMS - Narragansett Elec	696	-	-	-	(500)	-	510	1,350	1,350	1,350
		C049679	Harrison #32 - EMS Expansion	520	23	3	34	147	105	142	-	-	-
		C049680	Rochambeau Ave - EMS Expansion	20	6	2	10	178	14	168	-	-	-
		C049681	Clarkson - EMS Expansion	263	107	17	174	92	303	-	-	-	-
		C049682	Warwick 52 - EMS Expansion	446	143	38	46	155	261	-	-	-	-
		C049699	Knightsville 66 - EMS Expansion	20	32	2	10	178	12	86	-	-	-
		C049700	Anthony 64-EMS Exp & Upgrades	20	0	-	-	145	-	-	-	-	-
		C049705	Apponaug- EMS Expansion	464	25	9	11	147	7	12	-	-	-
		C049799	Central Falls - EMS Expansion	378	24	3	3	147	-	216	-	-	-
		C049800	Coventry #54 - EMS Expansion	20	20	2	71	178	190	211	-	-	-
		C050698	Davisville #84 - EMS Expansion	473	23	1	20	155	209	6	-	-	-
		C050699	Hopkins Hill #63 - EMS Expansion	415	123	51	307	147	18	-	-	-	-
		CD00528	EMS Expansion - Natick 29 Substatio	435	155	88	205	14	176	-	-	-	-
		CD00529	EMS Expansion - Hospital Sub 146	475	432	21	28	5	-	-	-	-	-
		CD00530	EMS Expansion - Elmwood Outdoor 7	287	298	251	263	10	-	-	-	-	-
		CD00533	EMS Expansion - Lincoln Ave 72	925	895	150	158	5	-	-	-	-	-
		CD00526	EMS Add-Peacedale 59 RI	588	598	(1)	(1)	5	-	-	-	-	-
		CD00531	EMS Expansion - Division Street 61	585	624	(2)	(2)	2	-	-	-	-	-
	EMS Total			7,030	3,528	636	1,339	1,210	1,295	1,350	1,350	1,350	1,350
	Highland Drive	CD00972	New Highland Drive Substation - DSu	13,133	12,612	(1)	23	-	-	-	-	-	-
		CD00978	New Highland Drive Substation - DLi	3,590	2,250	1	24	1,200	-	1,329	-	-	-
	Highland Drive Total			16,723	14,862	1	48	1,200	-	1,329	-	-	-
	Johnston Sub	C033535	Johnston Sub 12.47 kV Expansion	4,714	4,163	367	373	-	-	-	-	-	-
	Johnston Sub Total			4,714	4,163	367	373	-	-	-	-	-	-
	Kent County	CD01101	Kent County 2nd Transformer (D-Sub)	855	538	55	159	1,100	1,750	-	-	-	-
		CD01102	Hunt River Substation Retirement	96	(3)	1	1	10	-	-	-	-	-
		CD01104	Kent County 2nd Transformer (D-Line	99	26	4	12	100	190	-	-	-	-
	Kent County Total			1,050	561	61	173	1,210	1,940	-	-	-	-
	Kilvert St - DLine	C036516	Kilvert St 87 - New Fdr (DLine)	3,831	2,345	28	1,112	-	-	-	-	-	-
	Kilvert St - DLine Total			3,831	2,345	28	1,112	-	-	-	-	-	-
	Kilvert St - DSub	C036522	Kilvert St 87 - Install TB#2	1,520	1,291	482	1,761	1,100	146	-	-	-	-
	Kilvert St - DSub Total			1,520	1,291	482	1,761	1,100	146	-	-	-	-
	New London Ave Substation #150	C028920	New London Ave (D-Sub)	2,543	1,108	475	731	2,900	2,585	2,000	953	-	-
		C028921	New London Ave (D-Line)	8,613	158	23	84	3,900	1,805	3,000	1,677	-	-
		C032002	New London Ave (DxT)	3,746	(1)	1	1	-	-	-	-	-	-
	New London Ave Substation #150 Total			14,902	1,265	499	816	6,800	4,390	5,000	2,630	-	-
	OH Line Tranformer Replacement Program	C005505	IE - OS Dist Transformer Upgrades	2,299	8,835	229	597	600	625	650	725	750	775
	OH Line Tranformer Replacement Program Total			2,299	8,835	229	597	600	625	650	725	750	775
	Other Asset Replacement	C053149	NW Vlt 89 Federal Courthouse, Prov.	250	201	1	1	-	-	-	-	-	-
	Other Asset Replacement Total			250	201	1	1	-	-	-	-	-	-
	Other Flood	C059882	Flood Contingency Plan NECO - D		-	-	-	-	350	-	1,000	1,200	750
	Other Flood Total				-	-	-	-	350	-	1,000	1,200	750
	Other Load Relief	C013967	PS&I Activity - Rhode Island	265	2,197	(231)	(89)	250	290	295	300	305	310
		C024179	Coventry MITS (Dist Sub)	2,970	2,070	7	15	-	-	-	-	-	-
		C036167	Manton 69F3 - Upgrade getaway, etc		-	-	-	-	-	103	-	-	-
		C036397	Clarkson - new 13F10 feeder (line)	630	563	88	356	-	-	-	-	-	-
		C036450	83F2 Load Relief - New Fdr (Dline)	495	502	60	60	-	-	-	-	-	-
		C051385	Central Falls Sub Relief	295	5	0	319	298	-	-	-	-	-
		C053268	Pawtucket No 1 Bus Sect 73 Relief	1,300	748	463	526	425	-	-	-	-	-
		CD00410	38K23 Line Upgrade	374	249	-	-	-	-	-	-	-	-
		CD00557	Harrison Feeder Upgrades	432	13	-	208	300	-	-	-	-	-
		CD01093	KENTS CORNER transformer contingenc	590	41	0	21	-	-	-	-	-	-
	Other Load Relief Total			7,351	6,389	387	1,415	1,273	290	398	300	305	310
	Other Reliability	C005461	FH - OS Feeder Hardening	2,214	18,464	42	42	-	-	-	-	-	-
		C005524	IE - OS Cutout Replacements	31	7,514	-	-	25	-	-	-	-	-

ISR Spending Rationale	ISR Category	Project #	Project Description	Approved Capital	PRE-FY2016 Spend	FY16 Actuals (4-MTD)	FY16 Forecast (4MTD)	Total FY16 ISR Budget	Total FY17 Budget	Total FY18 Budget	Total FY19 Budget	Total FY20 Budget	Total FY21 Budget
		C059663	Cutout Mnted Recloser Program_RI	20	9	19	19	-	-	-	-	-	-
		C065470	Recloser Communication Upgrade - RI		-	19	19	-	600	-	-	-	-
	Other Reliability Total			2,265	25,987	81	81	25	600	-	-	-	-
	Providence LT Study	C046415	PROVIDENCE LONG TERM STUDY: D-SUB		-	-	-	-	-	-	-	-	-
		C046421	PROVIDENCE LONG TERM STUDY: D-LINE		-	-	-	-	-	-	-	-	-
	Providence LT Study Total				-	-	-	-	-	-	-	-	-
	Quonset Sub	C053646	Quonset Sub Expansion (D-Sub)	600	407	88	1,700	400	784	2,244	-	-	-
		C053647	Quonset Sub Expansion (D-Line)	300	18	99	146	80	297	288	-	-	-
	Quonset Sub Total			900	426	186	1,845	480	1,081	2,532	-	-	-
	Storm Hardening	C046383	STORM HARDENING FOR RHODE ISLAND		-	-	-	-	-	-	-	-	-
		C046506	Tunk Hill Road, Scituate RI, Storm	1,850	1,310	77	77	-	-	-	-	-	-
		C054090	Reconductor Anthony Road, Foster RI	1,165	71	6	6	25	-	-	1,100	-	-
	Storm Hardening Total			3,015	1,381	83	83	25	-	-	1,100	-	-
	Volt/Var	C046352	Volt Var Dline RI Pilot Project	2,750	1,509	641	884	664	752	-	-	-	-
		C052708	Volt Var-Substation	207	166	17	41	-	-	-	-	-	-
		C053111	Volt Var - IT/IS	1,282	397	325	603	800	100	-	-	-	-
	Volt/Var Total			4,239	2,071	983	1,528	1,464	852	-	-	-	-
	Blanket Projects	COS0015	Ocean St-Dist-Reliability Blanket	805	834	305	770	660	798	816	834	853	872
		COS0016	Ocean St-Dist-Load Relief Blanket	457	539	85	256	381	380	389	398	407	416
		COS0025	OS-Dist-Substation LR/Rel Blnkt	120	-	-	34	100	100	105	110	115	120
	Blanket Projects Total			1,382	1,373	390	1,059	1,141	1,278	1,310	1,342	1,375	1,408
	Reserves	C046971	Reserve for Reliability Unidentifie		-	-	-	-	-	-	-	-	1,500
		C046972	Reserve for Reliability Unidentifie		-	-	-	-	-	-	-	-	1,500
		C046975	Reserve for Load Relief Unidentifie		-	-	-	(700)	-	-	-	-	1,000
		C046987	Reserve for Load Relief Unidentifie		-	-	-	(964)	-	-	-	-	3,000
	Reserves Total				-	-	-	(1,664)	-	-	-	-	7,000
System Capacity & Performance Total				90,574	82,021	5,556	18,903	22,148	20,663	24,021	27,954	18,980	18,853
Asset Condition	Eldred Substation Rebuild	CD00648	Eldred Sub Asset Replacement (D-Sub	3,688	3,167	36	88	-	-	-	-	-	-
		CD00659	Eldred Sub Asset Replacement (D-Lin	186	244	0	0	-	-	-	-	-	-
	Eldred Substation Rebuild Total			3,874	3,411	36	88	-	-	-	-	-	-
	New Southeast Sub	C053657	Southeast Substation (D-Sub)	2,050	-	-	-	25	13	250	1,900	4,100	2,750
		C053658	Southeast Substation (D-Line)	1,600	-	-	-	25	12	150	1,750	2,250	650
		C055683	Pawtucket No 1 (D-Sub)	500	-	-	-	5	-	-	10	10	10
	New Southeast Sub Total			4,150	-	-	-	55	25	400	3,660	6,360	3,410
	Langworthy Substation Rebuild (flood)	C036230	Langworthy Substation (D-Sub)	1,667	1,633	41	54	-	-	-	-	-	-
		C036232	Langworthy Substation (D-Line)	138	171	1	1	-	-	-	-	-	-
	Langworthy Substation Rebuild (flood) Total			1,805	1,804	42	55	-	-	-	-	-	-
	Memorial Blvd_Cable Relocation	C046398	Memorial Blvd Easton's Beach inst d	600	33	0	826	730	532	-	-	-	-
	Memorial Blvd_Cable Relocation Total			600	33	0	826	730	532	-	-	-	-
	Flood - Hope Substation	C046697	Hope Substation Flood Restoration	410	54	79	107	612	221	629	-	-	-
	Flood - Hope Substation Total			410	54	79	107	612	221	629	-	-	-
	Flood - Pontiac	CD01242	Pontiac Substation Flood Restoratio	2,846	1,984	480	928	952	-	-	-	-	-
		CD01243	Pontiac Substation Flood Restoratio	501	278	210	232	138	-	-	-	-	-
	Flood - Pontiac Total			3,347	2,262	690	1,160	1,090	-	-	-	-	-
	Flood - Warwick Mal Sub	CD01097	Warwick Mall Substation Flood Resto	850	228	48	48	24	-	580	-	-	-
	Flood - Warwick Mal Sub Total			850	228	48	48	24	-	580	-	-	-
	Flood - Westerly	C036527	Westerly Flood Restoration (D-Sub)	2,800	8	0	0	540	-	300	2,600	2,200	500
		C055215	Westerly Flood Restoration (D-Line)	700	-	-	-	110	-	50	500	500	550
	Flood - Westerly Total			3,500	8	0	0	650	-	350	3,100	2,700	1,050
	Asset Replacement - I&M (NE)	C014326	I&M - OS D-Line UG Work From Insp	151	765	-	-	105	110	115	120	125	150
		C026281	I&M - OS D-Line OH Work From Insp	9,107	16,006	2,233	6,599	6,600	2,400	2,500	2,600	7,000	7,250
	Asset Replacement - I&M (NE) Total			9,258	16,771	2,233	6,599	6,705	2,510	2,615	2,720	7,125	7,400
	Battery Replacement	C032019	Batts/Chargers NE South OS RI	258	1,160	77	200	200	245	200	200	200	-
		C033843	BatteryRplStrategyCo49DxT	1,019	680	-	-	-	167	-	-	-	-
	Battery Replacement Total			1,277	1,840	77	200	200	411	200	200	200	-
	Indoor Sub Replacement	C051205	Dyer St replace indoor subst D-SUB		-	-	-	100	13	-	110	1,798	2,090
		C051211	Dyer St replace indoor subst D-LINE		-	-	-	79	12	-	110	275	350
	Indoor Sub Replacement Total				-	-	-	179	25	-	220	2,073	2,440
	Metalclad Replacement	C032583	OS ARP Metal Clad MC		-	-	-	(370)	-	-	-	(1,000)	1,000
		C049910	Southeast Sub MC Retirement (DLine)	708	110	23	1,283	254	242	-	-	-	-
		C050006	Hyde Ave MC Retirement (D-Line)	710	95	164	1,504	468	213	-	-	-	-
		C050017	Daggett Ave MC Retirement (D-Line)	830	89	27	727	500	860	-	-	-	-
		C050758	Lee St MC Retirement (D-Line)	490	91	18	30	20	-	50	2,250	-	-
		C050760	Cottage St MC Retirement (D-Line)	490	114	12	28	25	-	50	2,750	-	-
		C050778	Front St Sub MC Retirement (D-Line)	240	161	0	170	236	128	-	-	-	-
		C051118	Lee St MC Retirement (D-Sub)	10	9	1	1	10	-	-	-	-	-
		C051126	Cottage St MC Retirement (D-Sub)	10	10	1	1	10	-	-	-	-	-
		C051200	Hyde Ave MC Retirement		-	-	-	142	-	-	-	-	-
		C051273	Front St Metalclad-Sub Retirement	100	-	-	-	10	-	-	-	-	-
		C051274	Daggett Ave MC Retirement (D-Sub)	150	-	-	-	190	-	-	-	-	-
		C056391	Centre St MC Retirement (D-Sub)		-	-	-	10	-	-	10	-	-
		C056392	Crossman Retirement (D-Sub)		-	-	-	-	-	10	-	-	-
		C056411	Centre St MC Retirement (D-Line)		-	-	-	10	-	-	150	950	-
		C056507	Crossman Retirement (D-Line)		-	-	-	-	-	-	125	600	-
		C056570	Hospital Sub MC Replacement (D-Sub)		-	-	-	25	-	-	150	1,300	800
		C056571	Kingston 131 - Metalclad Replacemen		-	-	-	-	-	-	240	1,000	200
	Metalclad Replacement Total			3,738	681	246	3,744	1,540	1,442	110	5,675	2,850	2,000
	Network Arc Flash	CD01257	Distribution Secondary Network Arc	600	1,282	87	87	600	598	514	250	261	-
	Network Arc Flash Total			600	1,282	87	87	600	598	514	250	261	-
	Other Asset Replacement	C006644	IE - OS Targeted Pole Replace	30	8,977	4	4	25	-	-	-	-	-
		C020297	Sac AB Repl Prog Phase 7 NEC DxT	1,127	846	1	1	-	-	-	-	-	-
		C025815	OS ARP Insul, SensDev, Surge Arrest	260	1,226	26	188	250	250	250	250	250	-
		C032258	ACNW VII47 Structural Repairs Prov	970	158	6	519	514	-	-	-	-	-
		C036093	Elmwood#7Replace 23KV Groun Bank	540	451	2	8	-	-	-	-	-	-
		C041726	Replace HMIs - NEC	20	6	-	-	174	71	19	-	-	-
		C049726	UG Fdrs 1141-1143 Hurr Barrier Prov	210	63	182	188	-	-	-	-	-	-
		C051198	Abandoned Equipment Removal	275	28	1	1	25	10	-	-	-	-
		C052686	Prov RI Survey/Repl UG sec. cables	525	350	47	47	85	-	-	-	-	-
		C054365	63 Line Improvements	85	10	-	19	-	-	-	-	-	-
		C062633	HMI RI Replacements	180	-	35	140	-	189	-	-	-	-
		CD00601	Retire Pawtuxet Substation (D-Sub)	106	52	9	9	-	-	-	-	-	-
	Other Asset Replacement Total			4,328	12,167	314	1,124	1,073	520	269	250	250	-

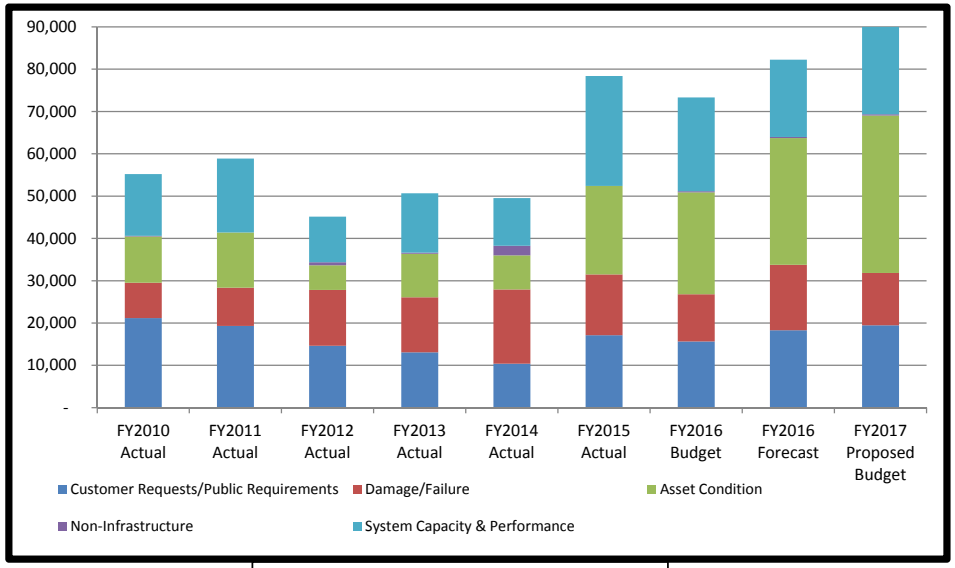
ISR Spending Rationale	ISR Category	Project #	Project Description	Approved Capital	PRE-FY2016 Spend	FY16 Actuals (4-MTD)	FY16 Forecast (4MTD)	Total FY16 ISR Budget	Total FY17 Budget	Total FY18 Budget	Total FY19 Budget	Total FY20 Budget	Total FY21 Budget
	Other Reliability	C051199	Mobile Battery Trailer	88	81	1	1	-	-	-	-	-	-
	Other Reliability Total			88	81	1	1	-	-	-	-	-	-
	RAPR	C048969	RI RAPR ARP	188	118	-	-	180	182	190	195	200	-
	RAPR Total			188	118	-	-	180	182	190	195	200	-
	Relay Replacements	C035586	Relay Replacement Strategy Co 49DxT	1,250	2,394	811	980	600	669	74	-	-	-
		C049354	NEC Relay Replacement Co.49- SG157	320	68	10	20	340	77	15	-	-	-
	Relay Replacements Total			1,570	2,463	821	999	940	746	88	-	-	-
	Substation Breakers & Reclosers	C032278	OS ARP Breakers & Reclosers	1,040	6,136	353	1,173	1,000	1,175	1,100	1,100	1,200	-
	Substation Breakers & Reclosers Total			1,040	6,136	353	1,173	1,000	1,175	1,100	1,100	1,200	-
	Substation Transformers	C025803	OS ARP Transformers	10	-	-	-	-	-	-	-	-	-
		C026058	OS ARP Spare Substation Transforme.	1,100	-	-	-	-	538	-	600	-	-
		C051824	Lafayette Sub Transformer Replaceme	514	356	34	459	475	99	700	-	-	-
		C055421	Warwick 52 - Replace TRFs		-	-	-	-	-	-	400	450	500
		C055844	W Cranston Transformer #2 Replaceme		-	-	-	320	319	1,716	-	-	-
	Substation Transformers Total			1,624	356	34	459	795	956	2,417	1,000	450	500
	T-Body	C046400	Capital Ctr Fdrs - Elim T-body join	950	723	117	117	43	-	-	-	-	-
		C051202	13F1 Elim T-Body Joints Prov	400	14	12	12	-	-	-	-	-	-
	T-Body Total			1,350	737	129	129	43	-	-	-	-	-
	UG Cable	C046397	Fdr 1109A - Install Cable Dorrance	470	373	11	11	298	-	-	-	-	-
		C046405	Fdr 1113 Inst Cable Fountain St Pro	320	277	5	5	-	-	-	-	-	-
		C055343	RI UG Cable Placeholder FY19-24		-	-	-	(1,700)	-	-	2,610	2,800	4,400
		C055357	RI UG Cable Repl Program - Fdr 1111	950	-	435	677	750	-	-	-	-	-
		C055359	RI UG Cable Repl Program - Fdr 79F1	773	3	(3)	57	250	979	-	-	-	-
		C055360	RI UG Cable Repl Program - Fdr 2J8		-	-	-	-	390	-	-	-	-
		C055361	RI UG Cable Repl Program - Fdr 1107		-	-	-	-	-	-	-	-	-
		C055362	RI UG Cable Repl Program - Fdr 1105		-	-	-	-	-	-	-	-	-
		C055363	RI UG Cable Repl Program - Fdr 1127		-	-	-	-	-	-	-	-	-
		C055364	RI UG Cable Repl Program - Fdr 13F1		-	-	-	-	-	-	-	-	-
		C055365	RI UG Cable Repl Program - Fdr 1113		-	-	-	-	-	-	90	-	-
		C055367	RI UG Cable Repl Program Fdr 54K21	800	-	5	61	500	741	-	-	-	-
		C055369	RI UG Cable Repl Program Fdr 54K23	800	-	-	-	-	380	-	-	-	-
		C055370	RI UG Cable Repl Program Fdr 1144		-	-	-	-	-	-	-	-	-
		C055371	RI UG Cable Repl Program Fdr 1142		-	-	-	-	-	-	280	-	-
		C055392	RI UG Cable Repl Program - Secondar	500	-	208	250	900	10	2,500	2,520	2,300	2,850
		C059579	Fdr 3324 Install Cable Transf Leads	190	-	-	42	-	-	-	-	-	-
	UG Cable Total			4,803	653	660	1,104	998	2,500	2,500	5,500	5,100	7,250
	URD	C047375	IRURD Mystery Farms Estates	620	33	2	7	-	938	34	-	-	-
		C047377	IRURD Wethersfield Commons	600	153	68	1,496	-	437	-	-	-	-
		C047378	IRURD Willowbrook	80	1	2	16	-	62	-	-	-	-
		C047379	IRURD Wood Estates Ph II	350	70	18	35	-	196	-	-	-	-
		C047389	IRURD Stone Ridge Acres	215	133	2	78	-	43	-	-	-	-
		C047394	IRURD Tanglewood	650	25	-	-	-	-	-	-	-	-
		C047396	IRURD Silver Maple Drive	300	261	-	-	-	-	-	-	-	-
		C047397	IRURD CEDARHURST	575	377	-	-	-	-	-	-	-	-
		C047398	IRURD Wionkheige	700	70	12	12	600	493	-	493	-	-
		C047422	IRURD Maplewood	400	114	66	1,250	1,700	-	-	-	-	-
		C047828	IRURD Westwood Estates	310	99	42	45	-	-	-	-	-	-
		C047829	IRURD High Hawk	600	3	-	-	-	22	22	240	-	-
		C049237	IRURD Phase 2 Wethersfield Comm.	400	-	-	-	-	213	-	-	-	-
		C049291	IRURD Wood Estates Phase 2	700	10	1	1	-	24	24	119	-	-
		C049356	IRURD Silver Maple Phase 2	400	2	-	-	-	17	340	-	-	-
		C049462	IRURD Stone Ridge Acres Phase 2	900	3	0	0	-	85	-	128	-	-
		C050070	IRURD Placeholder RI		-	-	-	200	(567)	1,978	794	2,500	3,500
		C050299	IRURD Eastward Look	900	-	-	-	-	43	43	128	-	-
		C052964	IRURD Rollingwood	800	51	-	24	-	209	-	-	-	-
		C056947	IRURD Juniper Hills WWarwick	150	0	0	0	-	21	-	-	-	-
		C057921	IRURD-Robin Hills Estates	150	-	-	-	-	80	-	150	-	-
		C058042	IRURD-Brookridge Estates.	184	-	-	-	-	80	-	150	-	-
		C058045	IRURD-Tockwotton Farm_TF Road.	36	-	-	-	-	16	-	-	-	-
		C058285	IRURD Case Farm Estates URD	890	-	-	-	-	60	30	150	-	-
		C058287	IRURD Ferncliffe Farms URD	220	-	-	-	-	30	30	150	-	-
		CD00686	IRURD Carriage Drive	950	753	(5)	(1)	-	-	-	-	-	-
		CD00827	IRURD South Rd Est So. Kingstown	550	454	(4)	(4)	-	-	-	-	-	-
		CD00937	IRURD Village Green Rehab	1,500	1,084	9	9	-	-	-	-	-	-
	URD Total			14,130	3,696	212	2,968	2,500	2,500	2,500	2,500	2,500	3,500
	Woonsocket Sub	C015200	Woonscket Sub - 3 Dist. fdrs	1,750	1,281	-	-	-	-	-	-	-	-
	Woonsocket Sub Total			1,750	1,281	-	-	-	-	-	-	-	-
	Blanket Projects	COS0017	Ocean St-Dist-Asset Replace Blanket	2,604	1,856	1,021	2,219	1,929	2,605	2,664	2,724	2,785	2,848
		COS0026	OS-Dist-Substation Asset Repl Blnk	300	158	-	47	250	200	210	220	230	240
	Blanket Projects Total			2,904	2,015	1,021	2,266	2,179	2,805	2,874	2,944	3,015	3,088
	Reserves	C046982	Reserve for Asset Replacement Unide		-	-	-	(2,500)	-	-	-	-	4,000
		C046984	Reserve for Asset Replacement Unide		-	-	-	(100)	-	-	-	-	3,972
	Reserves Total				-	-	-	(2,600)	-	-	-	-	7,972
Asset Condition Total				67,185	58,076	7,084	23,136	19,493	17,148	17,336	29,314	34,284	38,610
Non-Infrastructure	Corp/Admin/General	C05360E	CAP OH 5360 RIE1000		(63)	399	(0)	-	-	-	-	-	-
	Corp/Admin/General Total				(63)	399	(0)	-	-	-	-	-	-
	General Equipment	C058982	Doble DCU's NEC0	216	210	0	0	-	-	-	-	-	-
		COS0006	Ocean St-Dist-Genl Equip Blanket	100	323	12	84	100	100	110	115	120	125
	General Equipment Total			316	532	12	84	100	100	110	115	120	125
	Telecommunications	C040644	Telecom Small Capital Work - RI	175	358	86	206	175	175	175	175	175	175
	Telecommunications Total			175	358	86	206	175	175	175	175	175	175
Non-Infrastructure Total				491	827	498	291	275	275	285	290	295	300
Customer Requests/Public Requirements	3rd Party Attachments	COS0022	Ocean St-Dist-3rd Party Attch Blnkt	180	267	205	411	154	155	158	162	166	170
	3rd Party Attachments Total			180	267	205	411	154	155	158	162	166	170
	Block Island	C046386	BITS Wakefield Sub Upgrades (D-Sub)	600	83	19	595	595	519	-	-	-	-
	Block Island Total			600	83	19	595	595	519	-	-	-	-
	Land and Land Rights - Dist	COS0009	Ocean St-Dist-Land/Rights Blanket	167	165	66	188	167	187	193	199	205	212
	Land and Land Rights - Dist Total			167	165	66	188	167	187	193	199	205	212
	Meters - Dist	CN04904	Narragansett Meter Purchases	1,180	(24)	1,327	2,147	1,180	1,500	1,550	1,600	1,650	1,700
		COS0004	Ocean St-Dist-Meter Blanket	863	635	222	608	595	670	692	714	737	761
		CRSE109	Meter Work-RI		2	118	118	-	-	-	-	-	-
	Meters - Dist Total			2,043	612	1,667	2,874	1,775	2,170	2,242	2,314	2,387	2,461

ISR Spending Rationale	ISR Category	Project #	Project Description	Approved Capital	PRE-FY2016 Spend	FY16 Actuals (4-MTD)	FY16 Forecast (4MTD)	Total FY16 ISR Budget	Total FY17 Budget	Total FY18 Budget	Total FY19 Budget	Total FY20 Budget	Total FY21 Budget
	New Business - Commercial	C046977	Reserve for New Business Commercial		-	-	374	400	1,500	1,525	1,550	1,600	1,650
		C048798	1000 Danielle Dr, Burrillville, R	190	146	0	0	-	-	-	-	-	-
		C049981	Nsnville 127W41 New Customer Load	728	112	66	1,605	553	-	-	-	-	-
		C051203	LNG Plant Svc Terminal Rd Prv DLine		-	-	560	30	441	-	-	-	-
		C051204	LNG Plant Svc Terminal Rd Prv DSub		-	-	88	30	256	3,082	144	-	-
		C053266	NW Vlt 122 Kinsley Bldg, Prov.	355	17	172	325	-	-	-	-	-	-
		C054929	Fox Pl, Provodence, RI	198	2	3	73	-	-	-	-	-	-
		C055228	Hobbs Brook 2nd Fdr Svc Johnston RI	5	41	38	38	-	-	-	-	-	-
		C055268	AMGEN 35 kV-Second Feeder Service	1,325	33	(3)	(3)	-	-	-	-	-	-
		C055465	OKONITE COMPANY, Cumberland RI	130	82	35	35	-	-	-	-	-	-
		C056567	RI School of Design, Providence RI	15	(43)	60	60	-	-	-	-	-	-
		C058179	General Dynamics, N Kingstown RI	15	13	110	168	-	-	-	-	-	-
		C061446	NARRAGANSETT INDIAN, Charlestown RI	15	4	43	43	-	-	-	-	-	-
		C061667	RI Veterans Home, Bristol RI	110	3	(61)	(61)	-	-	-	-	-	-
		C061805	RI State House, Providence RI	173	0	12	12	-	-	-	-	-	-
		C061885	JOHNSON & WALES UNIVERSTY	143	(34)	1	1	-	-	-	-	-	-
		C061986	Moses Brown School, Providence RI	252	-	(0)	(0)	-	-	-	-	-	-
		COS0011	Ocean St-Dist-New Bus-Comm Blanket	3,851	3,057	1,186	3,668	3,200	3,380	3,490	3,603	3,720	3,841
	New Business - Commercial Total			7,505	3,436	1,662	6,988	4,213	5,577	8,097	5,297	5,320	5,491
	New Business - Residential	C046978	Reserve for New Business Residentia		-	-	115	100	105	110	115	120	-
		C054005	SHARPE BUILDING ASSC-Foundry Bld 4	215	66	189	189	-	-	-	-	-	-
		COS0010	Ocean St-Dist-New Bus-Resid Blanket	4,522	3,655	1,496	3,926	3,400	3,623	3,741	3,863	3,989	4,119
	New Business - Residential Total			4,737	3,721	1,685	4,230	3,500	3,728	3,851	3,978	4,109	4,119
	Outdoor Lighting - Capital	COS0012	Ocean St-Dist-St Light Blanket	1,066	476	49	408	711	541	553	565	578	591
	Outdoor Lighting - Capital Total			1,066	476	49	408	711	541	553	565	578	591
	Public Requirements	C012118	DOTR-Slatersville Stone Arch Br273	111	2	0	0	-	-	-	-	-	-
		C012179	DOTR-Repl Great Island Bridge No499	169	11	6	52	102	102	-	-	-	-
		C015403	DOTR-Atwood Av/Plainfield PikeInter	140	126	0	0	-	-	-	-	-	-
		C020711	DOTR-Repl Capron Rd Bridge No. 792	20	10	2	2	-	170	-	-	-	-
		C027123	Watch Hill OH to UG, Westerly RI	386	185	2	2	-	-	-	-	-	-
		C032285	DOTR-Prov Dean St, Cahir St Improv	110	18	(4)	(4)	-	-	-	-	-	-
		C035087	DOTR-Apponaug Circulator Imprv Warw	1,879	767	243	482	616	154	-	-	-	-
		C045656	DOTR-Blackstone River Bikeway Seg8A	50	0	-	170	170	-	-	-	-	-
		C045657	DOTR-Repl Bridges No.475 & 476 E.P.	50	18	-	85	-	-	-	-	-	-
		C045684	Second Beach RI OH-UG conversion	15	5	0	90	89	-	-	-	-	-
		C046970	Reserve for Public Requirements Uni		-	-	-	(1,816)	250	1,000	1,000	1,000	1,000
		C047039	DOTR-East Main Rd, Portsmouth	50	9	0	0	170	170	-	-	-	-
		C047075	DOTR-Blackstone River Bikeway Seg8C	50	6	-	170	170	-	-	-	-	-
		C048599	DOTR-Putnam Pike/Money Hill Rd	147	12	0	68	-	68	-	-	-	-
		C048717	DOTR-EMain/WMain Int Recon	40	21	2	172	85	-	-	-	-	-
		C050419	DOTR-Woonsocket-Hamlet AvBridge#500	160	22	92	92	-	-	-	-	-	-
		C050422	Admrl St 9J1 Line Relocation	199	-	-	9	85	170	-	-	-	-
		C050687	DOTR-Hi Haz Int/Ramps C2 Newport Co	40	3	-	-	170	85	-	-	-	-
		C050921	DOTR-Hi Haz IntersectionsBristol Co	40	10	0	0	170	85	-	-	-	-
		C051783	DOTR-E.Providence Bridges 471&472	100	-	-	-	170	85	-	-	-	-
		C051892	DOTR-N.Prov-1R Woonasquatucket Av	40	1	5	5	-	-	-	-	-	-
		C052069	DOTR-Providence-Allens Av Arterial	40	0	0	0	85	85	-	-	-	-
		C052268	DOTR-Central St Bridge No.449	50	3	-	9	-	9	-	-	-	-
		C054045	DOTR-HarrisAV#510TobeySTR#509	40	1	(5)	(5)	-	-	-	-	-	-
		C054787	DOTR-Richmond: Kingston Rd Br # 403	150	2	0	0	-	77	-	-	-	-
		C054828	DOTR-Arterial Impr to Warwick Av	100	4	-	77	77	-	-	-	-	-
		C054830	DOTR-Carolina Bridges 54,55&56	100	2	-	-	-	77	-	-	-	-
		C056850	RIAC TF Green Runway Expansion	1,728	(173)	85	(1,021)	-	1,024	-	-	-	-
		C057779	DOTR-Coventry:FlatRiverRd@VictoryHw	140	7	5	5	-	-	-	-	-	-
		C058539	General Dynamics- System reconfig	15	5	2	2	-	-	-	-	-	-
		C059639	DOTR-Prov:Viaduct Br NB-Smith St Br	40	1	0	0	-	-	-	-	-	-
		C061525	Westminster St Bridge 505 - Relocns	240	163	57	61	-	-	-	-	-	-
		C062012	DOTR-WGreenwich-Victory Hwy Br#589	220	-	2	2	-	-	-	-	-	-
		C062014	DOTR-Barrington&Warren Bike Path Br	220	-	1	1	-	-	-	-	-	-
		CD00076	DOTR-Atwells Avenue Bridge No. 975,	40	83	1	17	64	-	-	-	-	-
		CD00135	I-195 Contract 14 - Providence	5,021	4,401	36	44	-	-	-	-	-	-
		CD00160	DOTR-Prov Downtown Circulation Impr	50	23	3	3	-	-	-	-	-	-
		CD00189	DOTR-Central Bridge No. 182 Replace	250	80	41	41	-	-	-	-	-	-
		CD00229	DOTR-Statewide Hi Haz Int/Ramps W.S	41	16	2	2	-	-	-	-	-	-
		CD00246	DOTR-Bartons Corner Bridge No. 518	146	4	(7)	(7)	-	-	-	-	-	-
		CD00373	Watch Hill UG Phase 2	15	34	41	49	173	-	-	-	-	-
		CD00409	DOTR-Improvements to Division St, E	202	102	0	0	-	-	-	-	-	-
		CD00567	DOTR-East Main Rd, Turnpike Av-Hedl	41	5	-	-	80	80	-	-	-	-
		CD00646	DOTR-Douglas Pike/Branch Pike Traff	30	1	-	-	80	80	-	-	-	-
		CD00766	I-195 Contract 15 - Providence	1,429	1,385	36	43	-	-	-	-	-	-
		CD00790	DOTR-Providence-Harbour Junction Br	40	7	0	0	-	-	-	-	-	-
		CD01066	DOTR-Union Village Railroad Bridge	216	3	-	-	34	34	-	-	-	-
		CD01080	NBC Seekonk CSO interceptor	800	(67)	14	14	-	-	-	-	-	-
		CD01205	DOTR-Hussey Memorial Bridge No. 011	84	4	0	62	-	-	-	-	-	-
		COS0013	Ocean St-Dist-Public Require Blankt	1,159	1,089	296	913	828	1,009	1,042	1,076	1,111	1,147
	Public Requirements Total			16,443	8,413	956	1,705	1,602	3,814	2,042	2,076	2,111	2,147
	Transformers & Related Equipment	CN04920	Narragansett Transformer Purchases	2,880	2,488	224	2,000	2,880	2,750	2,890	3,030	3,180	3,340
	Transformers & Related Equipment Total			2,880	2,488	224	2,000	2,880	2,750	2,890	3,030	3,180	3,340
	Distributed Generation	C045555	DG Svc to rTerra (RI-243)	191	-	(0)	(0)	-	-	-	-	-	-
		C047495	DG SVC OCI Solar RI-233	985	216	1	1	-	-	-	-	-	-
		C051496	Toray Plastics (12.5MW GT)	425	526	102	102	-	-	-	-	-	-
		C051909	PS&I Dist Gen RI	55	(25)	(69)	(69)	50	10	10	10	10	10
		C058281	DG Svc to rTerra Johnston, RI	178	(67)	97	110	-	-	-	-	-	-
		C061669	DG Svc to Foster Solar Foster, RI	195	-	17	27	-	-	-	-	-	-
		C061826	DG Svc to Foster Solar Foster, RI	336	-	11	11	-	-	-	-	-	-
		C063146	DG Svc to Brandywick N Smithfield,	103	-	(89)	(89)	-	-	-	-	-	-
	Distributed Generation Total			2,468	650	70	93	50	10	10	10	10	10
	Regulatory Requirement	C054788	ValleySub 102 NERC CIP v3.25	250	14	12	12	-	-	-	-	-	-
	Regulatory Requirement Total			250	14	12	12	-	-	-	-	-	-
Customer Requests/Public Requirements Total				38,338	20,324	6,615	19,503	15,647	19,451	20,036	17,631	18,066	18,541

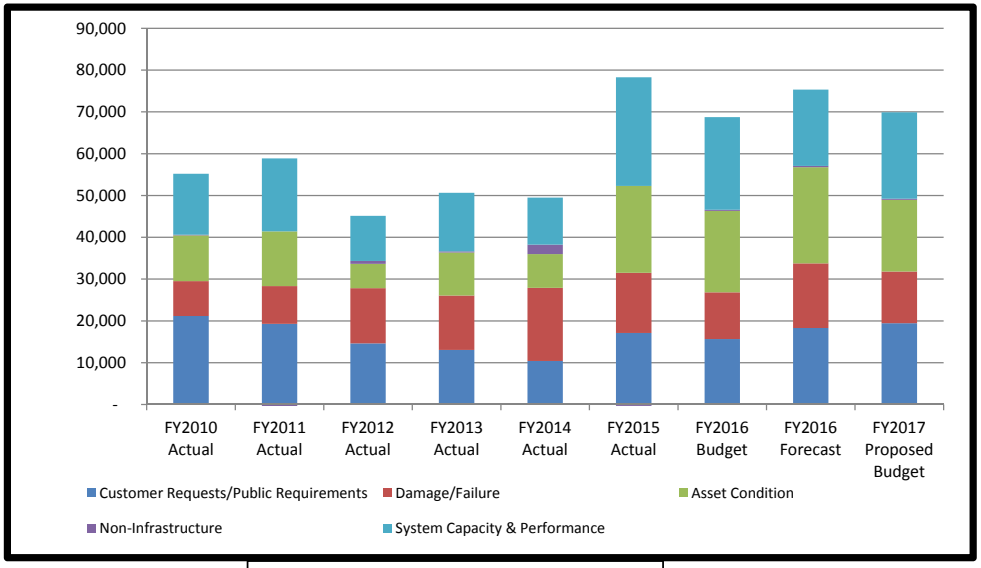
ISR Spending Rationale	ISR Category	Project #	Project Description	Approved Capital	PRE-FY2016 Spend	FY16 Actuals (4-MTD)	FY16 Forecast (4MTD)	Total FY16 ISR Budget	Total FY17 Budget	Total FY18 Budget	Total FY19 Budget	Total FY20 Budget	Total FY21 Budget
Damage/Failure	Damage/Failure	C054323	Franklin Square Breaker Replacement	350	334	8	22	17	-	-	-	-	-
		C054909	Warwick Mall Trf 2 Failure	610	359	1	1	-	-	-	-	-	-
		C056023	Franklin Sq Boiler Repalcement	119	154	2	2	-	-	-	-	-	-
		C063246	Franklin Sq Fire Escape Replacement	250	-	182	182	-	-	-	-	-	-
		COS0002	Ocean St-Dist-Subs Blanket	884	960	178	667	660	724	740	757	774	791
		COS0014	Ocean St-Dist-Damage&Failure Blankt	11,305	9,211	4,159	12,850	8,500	9,043	9,246	9,454	9,667	9,885
	Damage/Failure Total			13,518	11,018	4,530	13,725	9,177	9,767	9,986	10,211	10,441	10,676
	Major Storms - Dist	C022433	OSD Storm Cap Confirm Program Proj	1,160	9,307	249	2,324	1,000	1,500	1,550	1,600	1,650	1,700
	Major Storms - Dist Total			1,160	9,307	249	2,324	1,000	1,500	1,550	1,600	1,650	1,700
	Reserves	C046986	Reserve for Damage/Failure Unidenti		-	-	539	500	100	105	110	115	120
		C051608	Reserve for Damage/Failure Substati		-	-	-	500	1,000	1,050	1,100	1,150	1,200
	Reserves Total				-	-	539	1,000	1,100	1,155	1,210	1,265	1,320
Damage/Failure Total				14,678	20,325	4,779	16,589	11,177	12,367	12,691	13,021	13,356	13,696
Grand Total				211,266	181,573	24,531	78,421	68,740	69,904	74,368	88,210	84,981	90,000

ATTACHMENT 2 - DIV 1-8

COMPARISON CAPTIAL SPENDING/BUDGET CHARTS
INCLUDING/EXCLUDING SOUTH STREET PROJECTS



INCLUDING SOUTH STREET



EXCLUDING SOUTH STREET

FY2017 Electric ISR Plan
ATTACHMENT 2 - DIV 1-8

CAPITAL SPENDING BY CATEGORY ($000) - TOTAL PER "**CHART 7**" IN **FY2017 Electric Infrastructure, Safety, and Reliability Plan**

SPENDING RATIONALE	FY2010 Actual	FY2011 Actual	FY2012 Actual	FY2013 Actual	FY2014 Actual	FY2015 Actual	FY2016 Budget	FY2016 Forecast	FY2017 Proposed Budget
Customer Requests/Public Requirements	21,172	19,312	14,631	13,075	10,410	17,138	15,647	18,299	19,451
Damage/Failure	8,345	9,031	13,194	12,993	17,515	14,374	11,177	15,481	12,367
Asset Condition	10,941	13,065	5,831	10,320	8,071	20,905	24,053	29,928	37,244
Non-Infrastructure	151	(847)	706	267	2,269	(346)	275	285	275
System Capacity & Performance	14,596	17,454	10,795	13,995	11,249	25,972	22,148	18,264	20,663
TOTAL CAPITAL INVESTMENT PLAN IN SYSTEMS	**55,205**	**58,015**	**45,157**	**50,650**	**49,514**	**78,043**	**73,300**	**82,257**	**90,000**

CAPITAL SPENDING BY CATEGORY ($000) - **EXCLUDING SOUTH ST.**

SPENDING RATIONALE	FY2010 Actual	FY2011 Actual	FY2012 Actual	FY2013 Actual	FY2014 Actual	FY2015 Actual	FY2016 Budget	FY2016 Forecast	FY2017 Proposed Budget
Customer Requests/Public Requirements	21,172	19,312	14,631	13,075	10,410	17,138	15,647	18,299	19,451
Damage/Failure	8,345	9,031	13,194	12,993	17,515	14,374	11,177	15,481	12,367
Asset Condition	10,941	13,065	5,831	10,320	8,071	20,788	19,493	23,011	17,148
Non-Infrastructure	151	(847)	706	267	2,269	(346)	275	285	275
System Capacity & Performance	14,596	17,454	10,795	13,995	11,249	25,972	22,148	18,264	20,663
TOTAL CAPITAL INVESTMENT PLAN IN SYSTEMS	**55,205**	**58,015**	**45,157**	**50,650**	**49,514**	**77,926**	**68,740**	**75,340**	**69,904**

DIFFERENCE

SPENDING RATIONALE	FY2010 Actual	FY2011 Actual	FY2012 Actual	FY2013 Actual	FY2014 Actual	FY2015 Actual	FY2016 Budget	FY2016 Forecast	FY2017 Proposed Budget
Customer Requests/Public Requirements	-	-	-	-	-	-	-	-	-
Damage/Failure	-	-	-	-	-	-	-	-	-
Asset Condition	-	-	-	-	-	117	4,560	6,917	20,096
Non-Infrastructure	-	-	-	-	-	-	-	-	-
System Capacity & Performance	-	-	-	-	-	-	-	-	-
TOTAL CAPITAL INVESTMENT PLAN IN SYSTEMS	**-**	**-**	**-**	**-**	**-**	**117**	**4,560**	**6,917**	**20,096**

R-I-1-10

Request:

Explain how much of the load constraints are caused by growth versus shifting demands of Customers as stated on page 22. Also, provide the detail of how much is load on substations versus load on feeders. Does the CYME model actually support and clearly indicate the needs as stated?

Response:

When the Company mentions that it "has minimal discretion to address load constraints caused by the existing and growing and/or shifting demands of customers." (page 22), it is referring to the "Load Relief" portion of the "System Capacity and Performance" budget spending rationale in general terms. There is no specific analysis on shifting demand. Although a yearly forecast is developed, it is impossible to analyze historical data to determine exactly how much load growth actually occurred versus how much load may have shifted.

Prepared by or under the supervision of: Ryan Constable

R-I-1-12

Request:

For the EHTM program, how many hazard tree locations and hazard trees have been addressed each year by the Company's Hazard tree program from inception?

Response:

Please see the table below for details regarding how many hazard tree locations and hazard trees have been addressed each year by the Company's Hazard tree program since the program's inception:

Fiscal Year	Circuits	Removals
2008	7	1,307
2009	9	920
2010	13	1,030
2011	1	84
2012	6	1,040
2013	14	942
2014	7	701
2015	9	1,103

Prepared by or under the supervision of: Ryan Moe

R-I-1-13

Request:

For vegetation management, in what areas within the Core Activities budget has the Company seen growth over the past 4 years? Also, has the Company considered formalizing and tracking activities within the Core Activities?

Response:

The Company does track different activities within the Core Activities. The areas where the Company has seen the largest growth over the last four years are customer requests and make safe calls. Also, due to the increase in vine-related outages, for the past two years, the Company has requested additional money for the Core Activities budget.

Prepared by or under the supervision of: Ryan Moe

nationalgrid

Raquel J. Webster
Senior Counsel

October 29, 2015

BY HAND DELIVERY AND ELECTRONIC MAIL

Luly E. Massaro, Clerk
Rhode Island Division of Public Utilities and Carriers
89 Jefferson Boulevard
Warwick, RI 02888

RE: National Grid's Proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan
Responses to Division Data Requests – Set 1

Dear Ms. Massaro:

I have enclosed five (5) copies of National Grid's[1] responses to the Division's First Set of Data Requests issued in the above-referenced matter.

In this transmittal, the Company is providing responses to the following Division data requests: R-I-1-3, R-I-1-5, R-I-1-6, R-I-1-7, R-I-1-9, and R-I-1-11. This transmittal completes the Company's responses to the Division's First Set of Data Requests in this matter.

Thank you for your attention to this transmittal. If you have any questions, please contact me at 781-907-2121.

Very truly yours,

Raquel J. Webster

Enclosures

cc: Steve Scialabba
Leo Wold, Esq.
Jim Lanni
Al Contente

[1] The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

40 Sylvan Road, Waltham, MA 02451
T: 781-907-2121 ■ raquel.webster@nationalgrid.com ■ www.nationalgrid.com

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R-I-1-3

Request:

Provide a detailed explanation of the transmission interruptions reflected on bar Chart 2.

Response:

The chart below includes details regarding the transmission interruptions reflected on bar Chart 2. Specifically, the chart below provides the number of transmission interruption events and customers impacted by those events for 2008 through 2014.

Year	CI Events	Estimated CI
2008	3	9,500
2009	1	25
2010	3	18,000
2011	1	2,973
2012	1	19,000
2013	2	5,900
2014	3	18,000

As shown on the chart above, the number of transmission interruption events is small, and the number of customers impacted differs due to a number of factors, including the length of the transmission line. Please see Attachment DIV-R-I-1-3 for additional details for each event.

Prepared by or under the supervision of: Daniel C. Wiecek

Attachment DIV-R-I-1-3
In Re: Rhode Island Division's Review of
FY 2017 Proposed Electric ISR Plan
Responses to Division's Data Requests - Set 1
Issued October 8, 2015

Event ID	Date	year	month	District	Feeder(s)	CAUSE_GROUP	Cause	Failed Component Group	Failed Component	Wind	Weather	Time Off	Time On	Duration	CI	CMI	SAIFI	SAIDI	Event Description
7891483	7/12/2014	2014	07	Coastal	56-88F1, 56-88F5, 56-88F3	Transmission	Control Trouble	No failure or Unknown	No failure or Unknown	Calm to light wind (0-12 mph)	Fair	07/12/2014 4:06:30 PM	07/12/2014 4:53:01 PM	46.52	7317	########	0.015113054	0.69520046	Found H-frame structure 162 about to fail on L-190 line. Rolled Davisville and Old Baptist Rd Subs to G-185 line. Via SCADA opened 88-22 airbreak at Tower Hill Sub, and the terminal breakers at Kent County Sub. When the 190-5 airbreak was opened at Davisville Tap switchtower, the L-190 line locked out. Opening the 190-5 should have been dead-line switching. Further investigation found the 88-22 airbreak closed and inoperable, but sending open status via SCADA. Manually opened 85-90 airbreak at Tower Hill Sub and closed L-190 line back in from the West Kingston terminal to restore supply to Tower Hill Sub. PowerOn Order Id: 2127354-1 PowerOn Order Id: 2127355-1 PowerOn Order Id: 2127353-1\r\n
7889290	7/9/2014	2014	07	Capital	53-37J5	Transmission	Insulation failure - cable	Cable	Cable - Other	Calm to light wind (0-12 mph)	Fair	07/09/2014 9:42:52 PM	###################	35.13	791	27685.00	0.001633788	0.05718257	R-144 line locked out at Franklin Square Station. Admiral St Sub #3 TR (23kv) and #1 TR (11kv) cleared properly. 11kV feeders transferred to 2 TR. At Rochambeau Sub, the 4kV feeders transferred before the 11kV supply was restored. The 37J5 breaker - bus transfer did not work properly for this bay, and the 56 tie breaker did not close. Sent switchman to Rochambeau Sub to close the tie breaker. PowerOn Order Id: 2126156-1
7894586	7/16/2014	2014	07	Coastal	56-36W41, 56-36W42, 56-36W43, 56-36W44, 56-33F1, 56-33F2	Transmission	Lightning	No failure or Unknown	No failure or Unknown	Thunderstorms	Rain - heavy	07/16/2014 7:10:19 AM	07/16/2014 7:17:55 AM	7.60	####	61076.00	0.021018236	0.12615073	M13 (115kV) tripped and reclosed from Somerset Station, L14 line locked out from Bellrock Sub to Dexter Sub. Loss of supply to Dexter Sub 13kV yard and Bates St Sub 153 bus. Tiverton Sub feeders 33F1 and 33F3 were remotely transferred to M13 line after auto transfer did not initiate. Via SCADA switching, transferred Dexter Sub 13kV to the M13 line. Lightning. See other IDS event for the Bates St feeders (Southeast District). PowerOn Order Id: 2129153-1
7734899	1/27/2013	2013	01	Coastal	56-46F1	Transmission	Device Failed	Overhead Device Other	Overhead Device Other	Wind - Mild (13-31 mph)	Extreme hot or cold (below 10 or above 90 degrees)	###################	###################	1.37	1390	1390.00	0.002863452	0.00286345	On 1/27/13, G-185S line locked out from Kent County Sub to West Kingston Sub. 46F1 feeder at Old Baptist Rd Sub did not auto-transfer and the tie breaker was closed via SCADA. Broken bracket on a structure on G-185S.
7766354	11/1/2013	2013	11	Capital	53-127W41, 53-127W43, 53-127W40	Transmission	Other Company Activities	No failure or Unknown	No failure or Unknown	Wind - Strong (32-54 mph)	Rain - light / moderate	###################	###################	47.00	4568	########	0.009410252	0.33436061	B23 line (115kV) lockout at West Farnum Sub. Loss of supply to Nasonville. Cause is phase making contact in the wind. Backfed Nasonville feeders on field ties. Closed loadbreak on 26W1 at P209 pascoag R/W picking up 127W42 (has no customers). Closed loadbreak P213 Pascoag R/W, picking up 127W43 (and Pascoag Muni). Closed loadbreak P230 Douglas pike, on 127W41 and closed P536 Great Rd loadbreak on 26W5 picking up 127W40 and 127W41. Stormy. PowerOn Order Id: 2053872-1 PowerOn Order Id: 2053874-1
7684122	6/7/2012	2012	06	Capital	53-18F1, 53-18F2, 53-18F3, 53-18F4, 53-18F5, 53-18F6, 53-18F7, 53-18F8, 53-18F9	Transmission	Lightning	No failure or Unknown	No failure or Unknown	Thunderstorms	Rain - heavy	06/07/2012 5:00:18 PM	06/07/2012 5:24:32 PM	24.00	####	########	0.039546291	0.87735867	S171 TRANSMISSION LINE LOCKED OUT RESULTING IN LOSS OF SUPPLY TO THE JOHNSTON SUBSTATION - SUSPECT LIGHTNING STRIKE. THE T172 LINE WAS OUT FOR PLANNED WORK AND THE S171 LINE WAS IN NON-RECLOSING FOR WORKER PROTECTION. 23 KV LINES OUT OF JOHNSTON SUB WERE NOT AFFECTED BY THIS TRANSMISSION OUTAGE, THE LINES STAYED ENERGIZED VIA THE 2228 LINE VIA HOPE SUB. TRANSMISSION ENERGIZED S171 LINE AFTER VERIFYING CREWS WERE OK AND LOAD WAS RESTORED ON JOHNSTON SUB VIA REMOTE SWITCHING. NOTE: A PORTION OF 6J6 FEEDER IS CONVERTED TO 13KV AND THE CUSTOMERS WERE ADDED TO 18F9 FEEDER. PowerOn Order Id: 1824765-1 & 1824764-1 & 1824763-1 & 1824762-1 & 1824761-1 & 1824760-1 & 1824759-1 & 1824758-1\r\n
7581388	5/31/2011	2011	05	Coastal	56-3309, 56-63F2, 56-63F4	Transmission	Insulation failure - other	Insulator	Insulator - disc	Calm to light wind (0-12 mph)	Fair	05/31/2011 1:53:34 PM	05/31/2011 2:33:05 PM	39.00	2973	########	0.006162169	0.22800439	While working on the G185 (115kV) line near Kent County Sub (de-energized), insulator broke causing phase to drop onto the 3309 and 3311 (34kV) lines. The #1 345 and 115kV busses at Kent County tripped and reclosed, the 1T115 circuit switcher locked out (feeding the 34kV #1 bus), the 7T115 circuit switcher locked out feeding the 3311 line, and the 3309 line locked out. Division St Sub transferred OK to 3312 line. Hopkins Hill Sub partially transferred load from 3311 to 3310 line.....the 1-2 and 3-4 tie breakers did not close, leaving no supply to the 63F2 and 63F4. The tie breakers were closed when personnel arrived at the sub, restoring all customers. Note: All six feeders were de-energized about a half hour later when the 1T34 circuit switcher opened at Hopkins Hill (the latter seems to be a separate issue). PowerOn Order Id: 1566439-1 PowerOn Order Id: 1566431-1 **followup - the 1TR was tested and found to be faulted - needs to be replaced*** see also IDS event 7581290.\r\n
7479300	3/2/2010	2010	03	Coastal	56-88F1, 56-88F5, 56-88F3	Transmission	Device Failed	Lightning arrester	Lightning arrester	Calm to light wind (0-12 mph)	Fair	###################	###################	19.32	7068	########	0.014777244	0.28076763	L-190 transmission line locked out from Kent County Sub to West Kingston Sub. All stations transferred, loss of supply to Tower Hill Rub (radial tap). Isolated Tower Hill via 115kV switching and re-energized feeders. Cause failed lightning arrester.
7489383	5/26/2010	2010	05	Coastal	56-36W43, 56-33F1, 56-36W42, 56-36W41, 56-36W44	Transmission	Device Failed	Circuit breaker	Circuit breaker	Calm to light wind (0-12 mph)	Extreme hot or cold (below 10 or above 90 degrees)	05/26/2010 6:32:12 PM	05/26/2010 7:56:34 PM	84.37	####	########	0.021114231	1.4474904	L14 TRANSMISSION LINE LOCKOUT FROM BELLROCK SUB TO DEXTER SUB - N12 TRANSMISSION LINE TRIP AND RECLOSE FROM SOMERSET SUB TO BELLROCK SUB - FOUND FAILED 1802 115KV CIRCUIT BREAKER AT BELLROCK SUB. LOSS OF SUPPLY TO DEXTER 13KV. ONE 12KV FEEDER AT TIVERTON DID NOT TRANSFER PROPERLY. MANUALLY TRANSFERRED THE 13KV FEEDERS AT BATES ST SUB VIA SCADA TO M13 LINE. SEE ALSO IDS EVENT # 7491312 (Bates St is Southeast, Tiverton and Dexter are Coastal) PowerOn Order Id: 1418614-1
7491282	6/5/2010	2010	06	Capital	53-78F3	Transmission	Lightning	No failure or Unknown	No failure or Unknown	Thunderstorms	Rain - heavy	06/05/2010 7:25:49 AM	06/05/2010 9:38:20 AM	132.52	1271	########	0.002657311	0.35342241	E-183W line locked out from Franklin Square to Wampanoag Sub. At Phillipsdale Sub, 2242 line was dropped, but transferred to X3 line in a few seconds. 2242 feeds from Phillipsdale to Waterman Ave Sub. 78F3 breaker opened on loss of supply, but 3-4 tie breaker did not close at Waterman Ave, 78F3 feeder did not transfer to 2267 line. Manually closed breaker. Loss of supply. Relay issue. Lightning. PowerOn Order Id: 1424065-1
7435704	6/5/2009	2009	06	Capital	53-2219	Transmission	Deterioration	Crossarm	Crossarm	Calm to light wind (0-12 mph)	Rain - light / moderate	06/05/2009 2:27:10 PM	06/05/2009 3:13:45 PM	46.58	25	1175.00	5.30161E-05	0.00249176	S171N transmission line lockout from Woonsocket Sub to Hartford Ave Sub - loss of supply to Wolf Hill Sub - Lincoln Control switched to alternate line - failed crossarm structure 82 near Farnum Pike - PowerOn Order Id: 1283617-1
7359272	6/9/2008	2008	06	Coastal	56-42F1, 56-46F2	Transmission	Device Failed	Circuit breaker	Circuit breaker	Calm to light wind (0-12 mph)	Extreme hot or cold (below 10 or above 90 degrees)	06/09/2008 6:52:40 PM	06/09/2008 7:16:12 PM	23.53	5995	########	0.012612264	0.25964223	L190 and G185N lines locked out, G185S tripped and reclosed when the 9085 breaker failed at Kent County Sub. West Kingston had no source for 20 seconds, nor did Wakefield, so the PTR loop scheme at Bonnet Sub tried to transfer. The pole 481 PTR opened, but the pole 476 PTR did not close becuase the 84T3 from Davisville had no source either. Manually closed PTR pole 481 to restore service to Bonnet. Loss of supply to T2 at Old Baptist Sub - 46F4 transferred to tie breaker but 46F2 did not transfer - - PowerOn Order Id: 1105539-1
7357511	5/31/2008	2008	05	Coastal	56-85T3	Transmission	Lightning	No failure or Unknown	No failure or Unknown	Thunderstorms	Rain - heavy	05/31/2008 9:51:36 AM	###################	42.10	5	210.00	1.0519E-05	0.0004418	1870 line trip and reclose from Kenyon to Wood River Subs - lightning strike at Str 109. Wood River bus UV transferred, 1-2 tie closed but 85T4 did not close. 85T3 lost service, but loop scheme relcosers transferred all load excpet 5 customers. PTR at pole 137-50 R/W was closed manually to backfeed the remaining customers back towards the substation.
7342369	2/10/2008	2008	02	Capital	53-107W80, 53-107W81, 53-107W83, 53-107W84, 53-107W85	Transmission	Unknown	No failure or Unknown	No failure or Unknown	Wind - Strong (32-54 mph)	Fair	###################	###################	2.22	3518	7036.00	0.007401158	0.01480232	During test energizing of P11 Transmission line (previously locked out), 7118 CB did not clear fast enough at pawtucket #1 Sub and caused stuck breaker / 74 TR differential relay operation resulting in loss of 5 feeders. Cause: Str 37, phase on crossarm, replaced insulator.

R-I-1-5

Request:

On Chart 3 explain the significant increase in animal related interruptions, and confirm whether this was this one event or a widespread trend. Also, provide the detail for the substation interruptions and how many were metal clad switchgear, if any.

Response:

The number of actual outage events caused in the animal-related category in CY 2013 and CY 2014 were comparable. However, the top four animal-related outages in CY 2014 impacted nearly 11,000 customers, which is more than the total customers interrupted by all animal events in CY 2013. These four events affected circuit main line conductors. Therefore, the Company concludes that the increase in animal-related customer interruptions was caused by the events impacting more main-line conductors in CY 2014 than fused taps or transformers, which impacted fewer customers.

The table contained in Attachment DIV-R-I-1-5 contains the requested information relating to substation events that occurred during CY 2014. Failure of metal-clad switchgear equipment did not contribute to any outages. However, an animal contact at the metal-clad Merton Substation caused one event and, after a motor vehicle incident, a circuit breaker at the metal-clad Harrison Substation did not successfully clear the fault because of a failed trip coil, resulting in a high-side transformer fuse clearing the fault.

Please note that animal-related events that occur inside substations or to a sub-transmission line are classified in the substation and sub-transmission categories, not the animal-related category, which is generally used for animal contact to distribution line equipment.

Prepared by or under the supervision of: James H. Patterson

Attachment DIV-R-I-1-5
In Re: Rhode Island Division's Review of
FY 2017 Proposed Electric ISR Plan
Responses to Division's Data Requests - Set 1
Issued October 8, 2015

Event_ID	year	month	District	Classification	Feeder_s_	Cause_Group	Failed_Component	Time_Off	Time_On	Duration	CI	CMI	SAIFI	SAIDI	Event_Description
7652087	2011	09	Capital	Main line - overhead	53-1149	Animal	Insulator - disc	9/19/2011	9/19/2011	73	47	2189	0.000	0.005	1149 feeder lockout at Franklin Square Sub - Squirrel at K&M Assoc on Waldo St. - Blown glass disc insulators - only one cust left out - PowerOn Order Id: 1687654-1
7652350	2011	09	Capital	Main line - overhead	53-1149	Animal	No failure or Unknown	9/21/2011	9/21/2011	42	47	1100	0.000	0.002	FEEDER LOCKOUT 1149 CABLE FROM FRANKLIN SQ SUB. CAUSE WAS A SQUIRREL AT K&M ASSOCIATES. PowerOn Order Id: 1688490-1
7652511	2011	09	Capital	Main line - overhead	53-112W43	Animal	No failure or Unknown	9/23/2011	9/23/2011	55	957	44135	0.002	0.091	112W43 feeder lockout at Staples Sub - Swan hit lines from P.107 to P.108 W. Wrentham Rd cumberland PowerOn Order Id: 1688929-1
7599828	2011	07	Capital	Main line - overhead	53-7F4	Animal	No failure or Unknown	7/2/2011	7/2/2011	24	2639	63336	0.005	0.131	7F4 feeder lockout at Elmwood 12kV Sub. Found squirrel at pole 25 Narragansett Ave. Closed breaker to restore service. It seems that the pole top recloser at pole 24 Narragansett Ave did not operate to clear the fault. PowerOn Order ID:1582885-1
7709325	2012	10	Capital	Main line - overhead	53-7F4	Animal	Switch - Solid Blades	10/14/2012	10/14/2012	82	2669	176711	0.006	0.366	7F4 lock out at Elmwood Outdoor Sub & 7F4 pole top recloser at P24 Narragansett Ave also locked out - due to an animal on the PTR. Fault current also damaged the 7F4-2 disconnects back at the Sub. PowerOn Order Id: 1869023-1
7703948	2012	08	Coastal	Main line - overhead	56-65J12	Animal	No failure or Unknown	8/25/2012	8/25/2012	29	586	16994	0.001	0.035	65J12 feeder lockout at Clarke St Sub Jamestown - caused by squirrel contact riser p6 Southwest Ave, failed arrester. PowerOn Order Id: 1854232-1
7745015	2013	06	Coastal	Main line - overhead	56-14F3	Animal	No failure or Unknown	6/2/2013	6/2/2013	33.27	1186	39138	0.002	0.081	14F3 Circuit Breaker locked out of the Drumrock Sub - T-man patrolled feeder dead bird at pole 31 Centrerville - found no damage, closed breaker. A&B Phase targets. PowerOn Order Id: 2009503-1 & 2009504-1 & 2009505-1\r\n
7758143	2013	08	Capital	Main line - overhead	53-2211	Animal	No failure or Unknown	8/27/2013	8/27/2013	111.73	31	3472	0.000	0.007	2211 pole top recloser lockout at pole 764 R/W near Manton Sub. Animal contact. Could not get PTR to close, backfed customers from 22 feeder via Geneva Sub. PowerOn Order Id: 2037171-1
7764468	2013	10	Coastal	Main line - overhead	56-37W43	Animal	Conductors	10/15/2013	10/15/2013	74.12	405	17020	0.001	0.035	Pole top recloser trip and reclose at pole 39 Valley Rd. Found primary wire down P3 Old Beach Rd, Newport, caused by animal contact P3 Old Beach Rd. Crew Opened loadbreak P13 Greenbough Place to isolate and make repairs. PowerOn Order Id: 2049701-1
7762517	2013	09	Capital	Main line - overhead	53-112W43	Animal	No failure or Unknown	9/21/2013	9/21/2013	47.9	41	1968	0.000	0.004	Pole top recloser lockout at P2-3 Carnation St, Cumberland RI - Squirrel contact at that pole - PowerOn Order Id: 2044400-1
7739131	2013	04	Coastal	Main line - overhead	56-59F3	Animal	No failure or Unknown	4/25/2013	4/25/2013	52.23	274	14248	0.001	0.029	Pole top recloser locked out at P60 Commander Perry Hwy. Tman found birds nest P5 in the R/W off of Pond St. PowerOn Order Id: 1999089-1
7909109	2014	08	Capital	Main line - overhead	53-108W53	Animal	Tap	8/7/2014	8/8/2014	457.92	1068	69548	0.002	0.144	108W53 had locked out earlier at Riverside Sub (see other IDS event). While switching the circuit back to normal, when the tie was broken to 108W62 at pole 17 River St, B phase went dead along the entire 108W53 feeder. To restore service to the overhead
7841422	2014	04	Capital	Main line - overhead	53-28J2,	Animal	Conductors	4/13/2014	4/13/2014	185.28	2409	104525	0.005	0.216	107W81 feeder lockout @ Pawtucket #1 Sub - Animal contact @ airbreak pole 20 School St caused broken insulator and phase down. A, B and C Targets, 3 operations. 107W81 is the supply to Hyde Sub. Isolated between pole 18 Division and pole 23 School St a

Event_ID	year	month	District	Classification	Feeder_s_	Cause_Group	Failed_Component	Time_Off	Time_On	Duration	CI	CMI	SAIFI	SAIDI	Event_Description
7861201	2014	05	Coastal	Main line - overhead	56-37W43	Animal	No failure or Unknown	5/22/2014	5/22/2014	51.28	2927	77097	0.006	0.159	37W43 feeder lockout at Jepson Sub - Osprey nest P 18 Moitoza Ln, broken insulator P 18 Moitoza. Backfed most of the feeder from 37W41. Made some repairs and closed the feeder breaker to restore the remaining customers. PowerOn Order Id: 2106805-1
7992003	2014	12	Coastal	Main line - overhead	56-68F3	Animal	Lightning arrester	12/22/2014	12/22/2014	71.3	3125	221875	0.006	0.458	68F3 CIRCUIT BREAKER LOCKED OUT AT KENYON SUB DUE TO ANIMAL CONTACT AT POLE 9 R/W LOAD BREAK SWITCH CAUSING DAMAGE TO LIGHTNING ARRESTERS. ARRESTERS WERE CUT CLEAR AND 34 TIE CIRCUIT BREAKER WAS CLOSED TO RESTORE SERVICE - ISSUES WITH GETTING THE 68F3 CI
7862961	2014	05	Coastal	Main line - overhead	56-63F5	Animal	No failure or Unknown	5/29/2014	5/29/2014	93.67	2436	221596	0.005	0.458	POLE TOP RECLOSER AT POLE 50 TIOGUE AVE COVENTRY LOCKED OUT. INFORMED AFTERWARDS BY CUSTOMER GOOSE FLEW INTO LINE BETWEEN P8 AND P9 TIOGUE AVE WEST WARWICK. TARGETS A AND B PHASE. 11 OPERATIONS SINCE CARD LAST UPDATED PowerOn Order Id: 2108062-1

R-I-1-6

Request:

On Chart 3 explain the significant increase in interruptions due to deteriorated equipment. Provide the criteria in determining if an interruption is caused by deteriorated equipment, and if this criteria has changed from previous years. Has National Grid identified a trend in major pieces of equipment or specific types of equipment that tend to fail?

Response:

The driver of the increase to customers interrupted by deteriorated equipment was an increase in failures to overhead equipment and underground cable that affected the main line of the circuit, therefore interrupting all customers on the circuit, relative to the events that impacted a smaller customer population. Although the number of events in the deteriorated equipment category decreased from CY 2013 to CY 2014, the number of customers interrupted per event increased due to this one-year trend.

Please note that the deteriorated equipment category is primarily for distribution line equipment. Outages caused by deteriorated equipment at substation and on sub-transmission lines are classified in the substation and sub-transmission categories. The criteria in determining whether an interruption is caused by deteriorated equipment on the distribution line system has not changed since 2010. The criteria includes the following: interruptions caused by failures or deterioration of Anchor and Guy, Bushing, Cable, Capacitor, Circuit breaker, Conductors, Connector, Crossarm, Cutout, Elbow, Insulator, Lightning arrester, No failure or Unknown, Overhead Device Other, Pole, Recloser, Riser/Siphon, Splice, Switch, Switchgear, Tap, Termination, and Transformer and U/G Other Device.

National Grid has not performed a reliability analysis on the increase in deteriorated equipment failures on the distribution line system between CY 2013 and CY 2014. However, the Company has included projects in the FY 2017 plan, such as the underground cable replacement projects and the Inspections & Maintenance program, to address deteriorated assets on the underground and overhead main line systems.

Prepared by or under the supervision of: James H. Patterson

R-I-1-7

Request:

Chart 5 would indicate a general trend of improvement in tree related interruptions and substation interruptions. Does this lead National Grid to believe it can moderate spending in both of these areas without jeopardizing its ability to meet its reliability metrics?

Response:

Although Chart 5 indicates a general trend of improvement in tree-related and substation-related interruptions, it is important to recognize that these trends are complicated by fiscal year and calendar year breakdowns. The calendar year breakdown shown in Chart 3 also demonstrates a general downward trend, but shows that tree-related and substation-related interruptions increased from 2013 to 2014. Despite these reliability trends, the Company believes that moderating spending at this time will place its ability to meet reliability metrics at risk.

National Grid's hazard tree removal program is vital to preventing degradation in reliability. Of particular concern is that the spread of the emerald ash borer throughout New England will increase the risk of tree-related outages caused by ash tree failures unless addressed through a mitigation program. Lessons learned from Consumers Energy in Michigan has shown that costs more than double when there is a reactive instead of proactive approach to emerald ash borer. In addition, as normal and storm-related "wear and tear" on the tree population increases the number of hazard trees along the distribution system, moderation of the hazard tree funding can be expected to impact the Company's ability to meet the growing hazard tree population, therefore, increasing the impact of hazard trees on reliability.

At this time, the Company has not evaluated whether a reduction in annual pruning mileage and lengthening of the cycle would jeopardize its ability to meet reliability metrics. However, environmental and climate data supports that a four-year cycle is the appropriate cycle length for the state of Rhode Island. This four-year cycle also allows the Company to inspect circuits for hazard trees.

Finally, substation-related interruptions may also be trending downward. Notably, substation projects are driven by other factors in addition to reliability performance. For example, substation projects are also driven by asset condition issues such as clearances and safety, including fault duty rating issues and arc flash mitigation issues. Although all of these factors ultimately have some impact on reliability performance, at this time, the Company also does not believe that it should decrease the spending or programs in this area as a result of a modest downward trend in reliability indices.

Prepared by or under the supervision of: Ryan A. Moe

R-I-1-9

Request:

Explain the continuing trend in Damage and Failure expenditures even with the significant increases in Asset Condition expenditures.

Response:

Although the Company has experienced an increase in the identification of damage/failure distribution line work (excluding storm related events) by local Operations in FY 2015 and FY 2016, the proposed Asset Condition expenditures in FY 2017 for investments targeting distribution line asset condition are actually lower than they were in FY 2015 and FY 2016. In addition, the Company does not anticipate a reduction in damage/failure distribution line spend in FY 2017 as a result of the Asset Condition expenditures in recent years. Although the ongoing Inspection & Maintenance program may eventually reduce expenditures due to deteriorated or damaged equipment within the damage/failure category, the repairs have only been completed on approximately 20% of the distribution line system. Cable failure in the Company's conventional (UG) and residential (URD) underground systems also contributes to the damage/failure spend. The Company has increased expenditures to the UG and URD Cable Replacement programs in recent years to proactively address asset deterioration in these two categories. However, similar to I&M, these two programs have not matured to the point that the Company could anticipate a reduction in damage/failure spend due to a corresponding reduction in UG and URD failures. As these programs mature, the Company will evaluate the impact on the damage/failure category and reduce the expenditures, as appropriate.

The overall increase in expenditures in the Company's Asset Condition category in FY 2017 is driven by projects that address substation asset condition, particularly the conditions of the South Street substation and the Pawtucket Metal-Clad substations, as opposed to distribution line asset condition. Similar to the line expenditures, targeted investments on indoor substation and metal-clad substations have not progressed to a point where the Company could anticipate reductions in substation damage/failure spend.

Consequently, the Company expects the current damage/failure trend to continue in FY 2017 regardless of the increase in Asset Condition spend.

Prepared by or under the supervision of: James H. Patterson

R-I-1-11

Request:

Explain why National Grid is not reimbursed by RIDOT for most of the road and bridge projects. Please confirm that these funds should not be included in the reimbursement for capital in the ISR Plan.

Response:

National Grid is fully reimbursed by RIDOT for most road and bridge projects. Reimbursement is typically collected after construction and in two phases. Project documentation is first reviewed by RIDOT and, if approved, 90% of the costs are reimbursed. The final 10% of the costs is collected after RIDOT completes a final audit. As a result of the timing of the collection, the costs reimbursed for FY 2017 RIDOT projects are likely to occur beyond FY 2017. Conversely, reimbursements for RIDOT projects completed in FY 2016 and earlier may collected in FY2017. The FY 2017 ISR plan for the Customer and Public Requirements includes the net impact of the reimbursements. The annual reconciliation filing will true-up the revenue required depending on the amount of work completed and reimbursements collected in the fiscal year.

Because of the timing of construction and reimbursement, there will be years when the final RIDOT portfolio capital balance is greater than zero in a given fiscal year, and years when it is less than zero. These annual funds required for the RIDOT portfolio should be included in the reimbursement for capital in the ISR plan and reconciled at year end, consistent with the current practice.

Prepared by or under the supervision of: James H. Patterson

Raquel J. Webster
Senior Counsel

November 17, 2015

BY HAND DELIVERY AND ELECTRONIC MAIL

Luly E. Massaro, Clerk
Rhode Island Division of Public Utilities and Carriers
89 Jefferson Boulevard
Warwick, RI 02888

RE: National Grid's Proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan
Responses to Division Data Requests – Set 2

Dear Ms. Massaro:

I have enclosed five copies of National Grid's[1] responses to the Division's Second Set of Data Requests issued in the above-referenced matter.

The Company will be providing its responses to data requests R-II-1 and R-II-2 shortly.

Thank you for your attention to this transmittal. If you have any questions, please contact me at 781-907-2121.

Very truly yours,

Raquel J. Webster

Enclosures

cc: Steve Scialabba
Leo Wold, Esq.
Jim Lanni
Al Contente

[1] The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

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T: 781-907-2121 ■ raquel.webster@nationalgrid.com ■ www.nationalgrid.com

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R-II-3

Request:

The Company is requesting increased vegetation management dollars to address the ash bore infestation. Provide all statistical data which documents how many years it takes a tree to be killed once infested by the Emerald ash borer, and then the number of years from the time the tree dies to when it becomes a hazard tree which is in serious risk of falling on the power line? Provide the criteria under which the Company considers the tree to be a hazard tree.

Response:

Once infested with Emerald Ash Borer (EAB), a tree will typically die within two to three years. This time varies depending on the size of the tree. Larger trees could take as long as five years, and smaller trees could die in as little as one year.

The U.S. Department of Agriculture researchers report that wood moisture levels in EAB infested trees are much lower than non-infested trees and that under experimental stress-loading, only infested trees exhibited failure at branch unions. In addition, "[i]n a wood resistance evaluation of infested and non-infested ash stems, significantly lower resistance was observed in advanced EAB infested ash stems when drilled at the base compared to drill sites 1 m above. This was not observed at similar drill site heights in the visually non-infested ash stems." (Source: http://naldc.nal.usda.gov/catalog/56360) These tests seem to verify field reports that EAB infested trees are prone to dropping large limbs or failure at the base.

In addition to experimental data, field reports from arborists in the Midwest and within the New York National Grid forestry team indicate that that Ash tree failure will occur in large branches or in a significant section of the whole tree or tree top, making these trees extremely dangerous to work in and around. Based on this information, an Ash tree should be considered a hazard as soon as it becomes infested. Please see Attachment 1 to R-II-3 and Attachment 2 to R-II-3 and the links below for additional information.

http://www.emeraldashborer.info/faq.cfm#q5

http://www.ncforestservice.gov/forest_health/fh_eabfaq.htm

National Grid considers any tree that is dead, diseased, decaying, or dying with the ability to strike power lines to be a hazard tree.

Prepared by or under the supervision of: Ryan Moe

Biol Invasions (2013) 15:371–383
DOI 10.1007/s10530-012-0292-z

ORIGINAL PAPER

Factors affecting the survival of ash (*Fraxinus* spp.) trees infested by emerald ash borer (*Agrilus planipennis*)

Kathleen S. Knight · John P. Brown · Robert P. Long

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Abstract Emerald ash borer (*Agrilus planipennis*) (EAB), an Asian woodboring beetle accidentally introduced in North America, has killed millions of ash (*Fraxinus* spp.) trees and is spreading rapidly. This study examined the effects of tree- and site-level factors on the mortality of ash trees in stands infested by EAB in OH, USA. Our data show that ash populations in forested sites can progress from healthy to almost complete mortality of mature trees within 6 years. Although the end result of nearly complete mortality does not vary, survival analysis with 5 years of data showed that some factors affected the rate of mortality. We found more rapid mortality in stands with lower densities of ash trees. This finding supports an extension of the resource dilution hypothesis whereby concentration of EAB on few trees in low ash density areas leads to rapid decline of these trees. This contradicts an extension of the resource concentration theory that greater host density increases relative pest abundance and host mortality. Although reductions in ash density via diversification may be desirable for other silvicultural, conservation, and management objectives in preparation for EAB, our study shows that the management strategy of reducing ash density is unlikely to protect the remaining ash trees. Survival analysis also showed that mortality was more rapid for trees shaded by other trees and for trees initially exhibiting dieback. In management scenarios where hazard tree removal must be spread over several years due to budget constraints, focusing initial tree removal on stressed trees is recommended.

Keywords Host density · Pest · Insect · Forest · Resource concentration · Resource dilution

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Introduction

Introduced pests and pathogens are a threat to trees and forests worldwide. In eastern North America, introduced pests and pathogens cause significant mortality of host tree species, unleashing a cascade of effects on forest ecosystems, including shifts in species composition, changes in understory light, temperature, and moisture, increases in coarse woody debris, and effects on carbon and nitrogen cycling (Lovett et al. 2006; Gandhi and Herms 2010). The relationship between host plant density and effects of pests is key to both

understanding the ecology of plant-host interactions and making forest management recommendations.

Two general theories regarding the relationship between host plant density and specialist pests, the resource concentration hypothesis (Root 1973) and the resource dilution hypothesis (Otway et al. 2005) make opposite predictions that may give insight into the effects of invasive pests of trees. The resource concentration hypothesis states that specialist herbivore pests are more likely to find and stay on hosts and attain greater relative abundance (per host) in areas with greater host density (Root 1973). The theory was first applied to exotic pests in agricultural systems (Root 1973) and has since been applied to invasive pests in natural systems (Rand and Louda 2006). The resource concentration hypothesis has been extended to also encompass the effect of the pest on host populations, which may then affect the composition of the plant community (Carson and Root 2000, Long et al. 2003, Carson et al. 2004). Many examples of outbreaking specialist insects in areas of high host density support this hypothesis and play an important role in regulating plant community composition (Carson et al. 2004). In contrast, the resource dilution hypothesis states that greater herbivore loads occur in areas of lower host density (Otway et al. 2005), as seen in a grassland biodiversity experiment. Evidence for these hypotheses has been mixed, and the spatial scale at which the relationship is studied (Sperry et al. 2001), the identity of the host and insect species (Vehviläinen et al. 2007), as well as the biology of the insect species, especially the mechanism by which they locate hosts (Hamback and Englund 2005), may be important in the shape and direction of the relationship.

Studies of the relationship of mature tree density to pest-mediated mature tree mortality in pine species provide support for the extension of the resource concentration and resource dilution hypotheses to effects on host populations. A study of pinyon pine (*Pinus edulis*) attacked by three monophagous herbivores isolated the effect of host tree density and found support for the resource concentration hypothesis (Sholes 2008). Other evidence, also supporting the resource concentration hypothesis, comes from the mountain pine beetle on lodgepole pine (*Pinus contorta*) (Mitchell et al. 1983) and ponderosa pine (*Pinus ponderosa*) (Larsson et al. 1983; McCambridge and Stevens 1982). In these systems, tree density and vigor are closely correlated, and the latter is probably ultimately responsible for increased mortality (Larsson et al. 1983; Mitchell et al. 1983). This is supported by experimental evidence that increasing tree vigor by thinning and fertilization results in decreased susceptibility to pest attack (Waring and Pitman 1985). Southern pine beetle infestations, which exhibit a wave-like dispersal pattern, have also been shown to follow the predictions of the resource concentration hypothesis (Showalter and Turchin 1993).

The mortality of trees exposed to native or exotic pests or pathogens is related to both tree and site characteristics. At the tree level, tree size, crown class, and vigor influence the survival of trees attacked by insect pests (Campbell and Sloan 1977; Haavic and Stephen 2010; Volney 1998). Additionally, a variety of site characteristics, including host tree density (Larsson et al. 1983; McCambridge and Stevens 1982; Mitchell et al. 1983), climate, and site index (He and Alfaro 2000; Robertson et al. 2008) alter tree survival patterns in areas infested by insect pests. Understanding the relationships among tree characteristics, site attributes, and tree survival facilitates the development of management strategies to protect forest health. For example, stand thinning and fertilization have been used to decrease mortality of lodgepole pine attacked by mountain pine beetle (*Dendroctonus ponderosae*) (Waring and Pitman 1985).

The emerald ash borer (*Agrilus planipennis*) (EAB), a specialist pest insect that feeds on ash (*Fraxinus* spp.) provides an opportunity to test the factors that affect the mortality of trees exposed to pests. EAB, a buprestid beetle native to east Asia (Haack et al. 2002), was accidentally introduced near Detroit, Michigan, USA in the 1990s (Siegert et al. 2007a) and discovered in 2002. Since its introduction, it has been detected in 15 US states and two Canadian provinces (http://emeraldashborer.info), and has killed millions of ash trees in the core infestation zone of Michigan and Ohio (Cappaert et al. 2005; Herms et al. 2004; Poland and McCullough 2006). EAB has also spread westward from its native Asian range through Russia where it has killed many ash trees and is a threat to ash in Europe (Baranchikov et al. 2008). EAB larvae live beneath the bark of ash trees and consume phloem tissue, creating feeding galleries that eventually cut off the transport of carbohydrates in the phloem tissue, girdling the tree.

Ash is an important component of many North American ecosystems. There are 16 species of ash in

the USA (USDA Plants Database 2010), five of which occur in Ohio. Blue ash (*F. quadrangulata*) inhabits calcium-rich sites (Braun 1961). Black ash (*F. nigra*) and pumpkin ash (*F. profunda*) occur in swamps and wet woods, with the former more prevalent in northern areas (Gleason and Cronquist 1991) and the latter more prevalent in the south (McCormack et al. 1995; Penskar 2004). White ash (*F. americana*) occurs in moist upland hardwood forests, often in mixed stands with other tree species. Green ash (*F. pennsylvanica*) exhibits broad habitat tolerance, and occurs in swamps, riparian areas, and moist upland areas (Gleason and Cronquist 1991). In swamps and riparian areas, ash may be the dominant tree species (K.S. Knight, personal observation). As early-successional species, ash trees may occur at high densities in disturbed sites.

The objective of this study was to determine the stand-level and tree-level factors that affect the mortality of ash trees in stands infested by emerald ash borer. In particular, we tested the relationship between host density and the rate (speed) of host mortality.

Methods

Field data collection

Stands (N = 31) were located in forested areas on both public and private lands in counties infested by EAB (Fig. 1). In some large parks, multiple stands were selected. A stand is defined as a forested area with homogeneous species composition, landscape position, and hydrology. Stands were chosen to represent a range of ash densities as well as different habitats to encompass the five ash species present in Ohio. A minimum of three plots were placed in each stand, with up to three additional plots in areas where each plot contained few ash. Plot placement depended on the shape and size of the stand and the abundance of ash. In large stands with abundant ash, the plots were placed 50–100 m apart along a transect located in the forest interior. In stands where ash was not abundant, plots were positioned by pacing 50 m and placing a plot at the end of the pacing distance if at least two ash trees ≥10 cm DBH were present. If no ash were present at that point, then pacing continued to the first location where the required ash trees were present. In small stands, plots were placed to include at least two ash trees >10 cm DBH in each plot, to be away from forest edges and trails, and to be at least 20 m from other plots. These plot placement methods are not random and probably overestimate the abundance of ash in stands where ash is sparse.

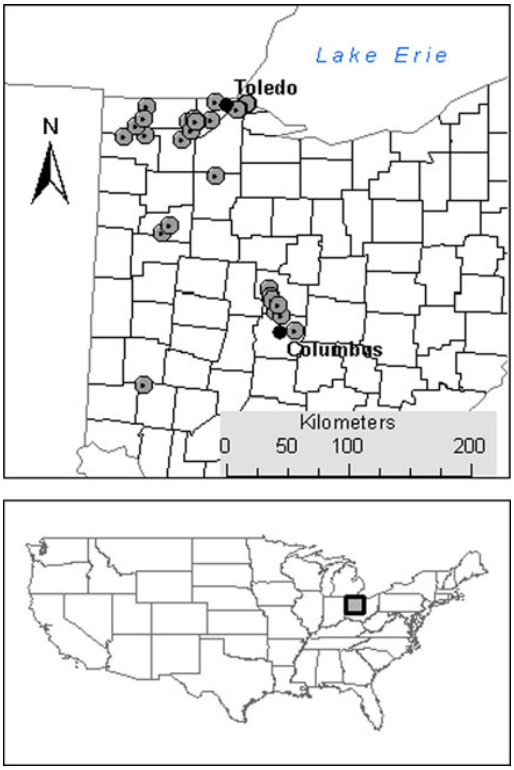

Fig. 1 Map of site locations in Ohio, USA

Data collection began in 2005 in stands in the Toledo, Ohio area, which was infested the earliest. Additional stands were added in 2006 and 2007 in other parts of Ohio, for a total of 98 plots and 1,160 ash trees ≥10 cm DBH in stands infested by EAB by 2007. Yearly data collection continued through 2009, providing 3–5 years of data for each site. Circular plots 400 m^2 were used to collect data for ash trees ≥10 cm DBH and nested 200 m^2 plots were used to collect data for ash trees 0.1 cm to 10 cm DBH. Individual ash trees were tracked through time by matching plot position and tree diameter. Trees with two trunks that divided below breast height (1.4 m), less than 5 % of the total number of stems, were counted as separate trees. In summer (June–August) each year through

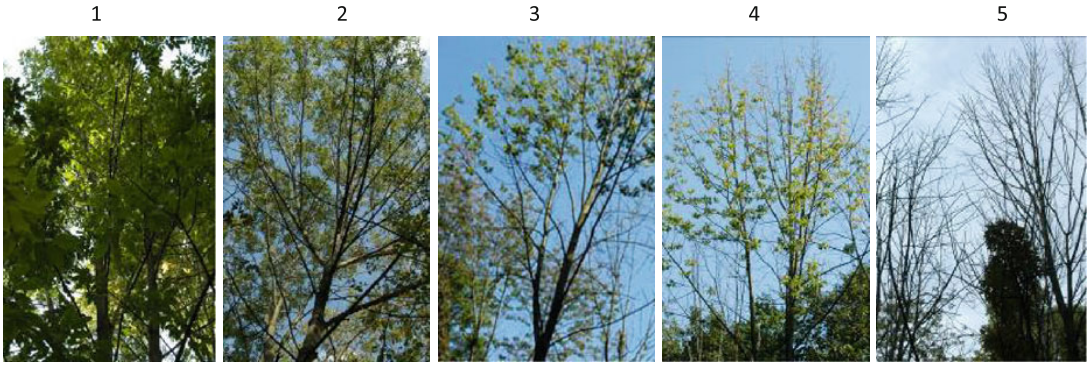

Fig. 2 Ash canopy health condition rating scale from Smith (2006)

2009, all ash trees were rated on an ash canopy health condition scale of 1–5 (Fig. 2) using protocols developed by Smith (2006) which are modifications of protocols developed for bronze birch borer (Ball and Simmons 1980). The rating scale has been correlated with EAB gallery cover and tree water stress (Flower et al. 2010), as well as with FIA canopy health rating methods (unpublished data).

The rating scale is defined as follows:

1. Ash tree with a full, healthy canopy.
2. Ash tree with a thinning canopy but no dieback.
3. Ash tree with dieback, defined as dead twigs or branches near the top of the tree, exposed to sunlight. Dead branches that are low and shaded were not rated and considered a normal part of branch senescence.
4. Ash tree with less than 50 % of a full canopy, which could occur through a combination of dieback and thinning.
5. Ash tree with a dead canopy, defined as no foliage in the canopy portion of the tree. The canopy is counted as dead even if live epicormic sprouts low on the trunk or stump sprouts are present.

In addition to the canopy health condition rating, for each ash tree the diameter at 1.4 m height was measured (DBH), the canopy class was classified as dominant, codominant, intermediate, or suppressed (Smith et al. 1996), EAB exit holes between 1.25 and 1.75 m height on the trunk were counted, and the ash species was identified. Black ash is easily identified by its corky bark (Leopold et al. 1998) and sessile leaflets (Gleason and Cronquist 1991), while blue ash is easily identified by its shaggy bark and square twigs (Braun 1961; Leopold et al. 1998). White ash, green ash, and pumpkin ash are more difficult to distinguish in natural areas, and we used seed morphology and habitat characteristics to identify these species. Beginning in 2007 and continuing through 2009, researchers searched the ground for 5 min in each plot to collect samaras. Pumpkin ash samaras are distinct due to the large calyx (>2 mm) and often large size (>5 cm) (Gleason and Cronquist 1991). Green ash samaras generally have long narrow seeds with the wing decurrent for half of the length of the seed body, and white ash samaras generally have cigar-shaped seed bodies with very little of the seed enclosed by the wing (Gleason and Cronquist 1991). Stands were classified as xeric, mesic, or hydric environments based on observations of standing water and plant species composition. Xeric sites were defined as upland sites that very rarely experience flooding or standing water, and were the only sites that included white ash. Mesic sites were sites that were sometimes flooded and sometimes dry, and generally green ash was present. Hydric sites were defined as sites that often had standing water, and were the only sites that included black ash and pumpkin ash. Some sites contained admixtures of green and white ash or green and pumpkin ash. At these mixed species sites, it was generally not possible to distinguish the two species.

Beginning in 2008, purple panel traps coated with sticky adhesive (Tanglefoot®) and baited with a Manuka oil lure (Synergy Semiochemical) (Crook et al. 2008) were used to detect EAB in a subset of the stands (N = 19). Not all stands were used due to cost

and logistical constraints. Two traps per stand were used in 2008 and two to four traps per stand were used in 2009. The traps were hung in the canopies of ash trees in May, the lures were replaced and the traps were checked in late June or early July, and traps were removed and checked at the end of August or early September. The number of EAB caught on the trap was recorded. In general, in the first year of detection only one or two EAB were caught, while later in the infestation, hundreds of EAB would be caught on the traps. The traps detected EAB in 2008 or 2009 at least a year before exit holes were observed in seven of the 19 stands. In these seven stands, exit holes were generally observed 1 year after EAB was first caught on the traps. In the other 12 stands, exit holes had already been observed by 2008.

Data analysis

EAB is difficult to detect at low densities at the beginning of an infestation because infestation generally begins in the tree canopy and few visible symptoms are present (Cappaert et al. 2005). For data analysis, initial stand infestation (T = 0) was considered to be 2 years before the first EAB exit holes appeared on any tree in the stand or 1 year before the first EAB was caught on a trap in the stand, and these two metrics were generally in agreement. This is a minimum estimate of initial infestation, and it is probable that EAB was present at very low densities before that time. The timing of the beginning of the surveys in the plots relative to initial stand infestation ranged from 2 years before to 2 years after infestation (T = −2 to T = 2). The duration of infestation observed in our study plots ranged from 1 to 6 years (T = 1 to T = 6) after initial infestation.

Survival analysis with both plot-level and tree-level predictors was used to analyze the survival rate of individual trees over time. This analysis shows what factors affect how rapidly individual trees die. Survival analysis of individual trees over time was performed in SAS® (SAS version 9.2 2008) using proc PHREG, which implements the Cox proportional hazards model (Cox 1972).

$$\lambda(t;\mathbf{z}) = \exp(\mathbf{z}\beta)\lambda_0(t)$$

where, λ-lambda-hazard function, t-time, **z**-a *1xp* vector of covariates, $\boldsymbol{\beta}$-a *px1* vector of unknown parameters, λ_0(t)-an unspecified but non-negative function.

The survival analysis only included trees ≥3 cm DBH, as EAB has been observed to attack ash saplings as small as 3 cm DBH (K.S. Knight, personal observation), and censored all trees that were dead in the first survey year, as it was not possible to know when they died, which reduced the sample size to 908 trees. An all subsets macro was written to analyze all possible models from the candidate set of predictors. The best model chosen had the lowest Aikake Information Criterion (AIC) value. The individual trees (N = 908) were repeated measures on plots (N = 98) and this dependency was accounted for with the COVSANDWICH option. This option implements a robust variance estimator without need for a specific variance structure (Allison 2010) and accounts for the repeated measures performed on trees within plots. The EXACT method was used for any ties in survival time.

Tree-level predictors used in the all subsets procedure were as follows:

CC-Crown Class (class variable: dominant, co-dominant, intermediate, suppressed)
ACE-Ash Canopy health class at first Evaluation (class variable: 1, 2, 3, 4, 5)
DBH-diameter of the tree at 1.4 m (continuous variable)
RM-Relative Median, ash canopy health class relative to the plot median class at evaluation (class variable: greater than, equal, less than)
SPP- Ash species (class variable: white ash, green ash, black ash, blue ash, pumpkin ash, white/green ash, green/pumpkin ash)

Plot-level predictors used in the all subsets procedure were as follows:

ACM-Ash Canopy health class Median, the median ash canopy health class at evaluation (class variable: 1, 2, 3, 4, 5)
Hydrology-plot hydrology (class variable: hydric, mesic, xeric)
TPHA-number of ash trees per hectare (continuous variable)
BAPHA-basal area of ash trees per hectare (continuous variable)

A validation set was created by randomly selecting 20 % of the trees, which were selected before creating the model and not used in the creation of the model. Using the best model, survival probability estimates

for these trees were estimated for the same period as was observed. Trees having survival probability estimates of <0.50 were estimated as dead, while those greater or equal to 0.50 were estimated as alive. The estimated class–alive or dead–was then compared to the observed condition for each tree and percentage of correct values was calculated for the final model.

Contrasts between the several levels of each class variable were performed using a Bonferroni correction for multiple comparisons. We performed 15 pairwise comparisons, so the Bonferroni correction yields a p value of $0.05/15 = 0.00333$. For class variables, levels within a class are examined using the hazard ratio, which is the hazard rate of the first class divided by the hazard rate of the second. For continuous variables, the hazard ratio is the ratio resulting from comparing the selected value of the variable to a one unit increase in the value of the variable. Allison (2010) suggests using the formula of 100(hazard ratio-1) to examine the hazard ratio resulting from comparing unit changes in continuous variables. This is the estimated percent change in the hazard rate.

Results

The stands experienced dramatic ash mortality over the 6 years time period after EAB infestation. Approximately one quarter of the trees were dead by year three, half of the trees were dead by year four, three quarters were dead by year five, and more than 99 % were dead by year six (data not shown). The survival analysis showed that both tree-level and plot-level factors were important in predicting the survival rate of ash trees (how rapidly the ash trees died).

Ash species and hydrology were closely correlated and models with both of these predictors would not converge, so the model was run with only one or the other. The best model and validation test results were identical with these two runs, except that one model included ash species and the other model included hydrology. Only the hydrology model is presented here.

The best model, selected from the all subsets analysis, included all significant terms CC ($p < 0.001$), hydrology ($p < 0.001$), ACE ($p < 0.001$), and TPHA ($p = 0.009$) (Table 1). This model had the lowest AIC of 3,950. This model correctly predicted 73 % of the validation data. There was a dependency introduced by the repeated sampling of trees on plots, $p < 0.0001$. This was accounted for in the proc PHREG analysis by keeping the COVSANDWICH option enabled.

Table 1 Significance tests for model main effects

Effect	df	Wald χ^2	p
Crown class	3	43.40	<0.0001
ACE	3	30.82	<0.0001
Hydrology	2	25.22	<0.0001
TPHA	1	11.07	0.0009

Dominant and codominant trees have greater survival rates (i.e., slower mortality) than intermediate and suppressed trees (Fig. 3). Multiple comparisons tests for CC indicate that the dominant and codominant classes individually differ from each of the intermediate and suppressed classes (Table 2). Each of these significant pairwise comparisons has an approximate 0.40 hazard ratio. For example, the hazard of a dominant tree dying is about 41 % of the hazard of an intermediate tree dying. The confidence intervals for CC hazard ratios varied in width from 0.23 to 0.60 for codominant versus intermediate crown class to 0.18–0.92 for dominant versus codominant crown class.

Initially healthier trees had greater survival rates (i.e., slower mortality) than initially less healthy trees (Fig. 4). Pairwise comparisons for ACE are not as readily split into groups as the CC results. Pairwise comparisons for ACE have one dissimilar class and several overlapping classes (Table 2). ACE class 1 is different from all other classes, suggesting that even trees with mild canopy thinning (ACE = 2) are predisposed to die more rapidly than trees with full, healthy canopies. The hazard ratios range from 0.69 (1 vs. 2) to 0.19 (1 vs. 4) (Table 2). The single other pairwise difference is ACE class 2 versus 4 and the hazard ratio is 0.27, which shows that trees with canopy thinning survive longer than trees with >50 % canopy dieback.

Trees at hydric and xeric sites had greater survival rates than trees at mesic sites (Fig. 5). Tests for pairings of the levels of hydrology indicate that mesic sites differ from both hydric and xeric sites (Table 2). Hydric sites have an estimated 0.50 hazard ratio versus mesic sites, and xeric sites have an estimated 0.35 hazard ratio versus mesic sites (Table 2).

Ash tree density had a positive relationship with survival rates (Fig. 6). For TPHA, a one unit increase (i.e., one tree) has a small effect so increases of 10 and 100 units were examined. Since the parameter estimates are exponentiated the hazard ratios change in

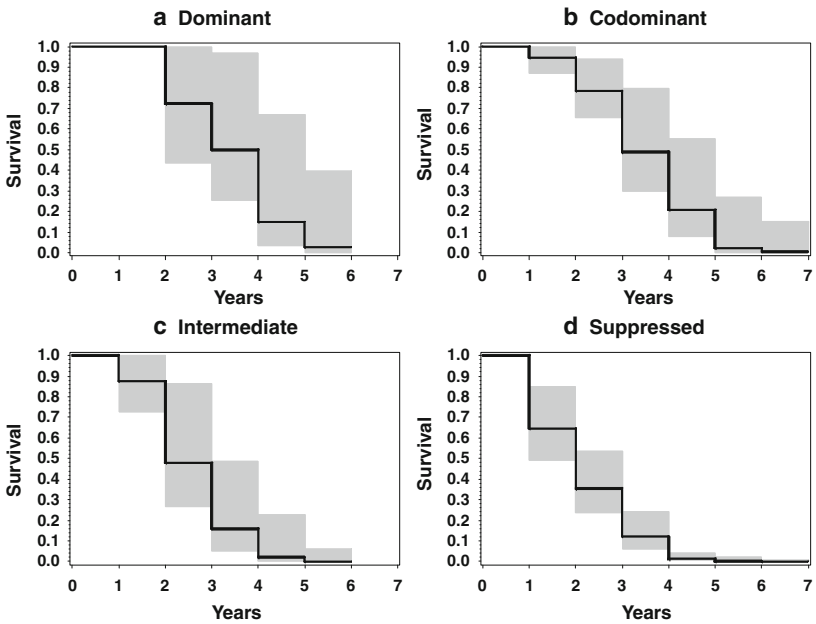

Fig. 3 Model estimates of survival rates of ash trees for the four levels of CC (crown class) over the 6 years time period following infestation by emerald ash borer. The graphs from the model estimates are useful for understanding differences among the four CC's, not for interpreting absolute levels of survival within infested stands. Dominant and co-dominant trees survived longer than intermediate or suppressed trees. Default levels for other predictors were trees with >50 % dieback (ACE = 4) in mesic stands (hydrology = mesic) (categories with the lowest survival rates) with 747 ash trees per ha (TPHA = 747, the mean TPHA for the default class levels). Confidence intervals (*grey shaded area*) are at the 95 % level

non-linear fashion. Using Allison's (2010) formula, a change of ten trees per hectare has a 0.9 % decrease in the hazard rate and an increase of one hundred trees per hectare has an 8.9 % decrease in the hazard rate.

Discussion

Overall, the results suggest a pattern of almost complete mortality of ash trees within 6 years according to our definition of initial infestation. This means that 5 years after EAB is caught on traps or 4 years after EAB exit holes appear, >99 % mortality of ash in a stand is probable. Some trees died much earlier: half of the trees were dead by year four, only 2 years after EAB exit holes were first observed at the site. Both site-level (hydrology and ash density) and tree-level (initial health and crown class) factors were important in determining how quickly the ash trees died.

We found that ash trees in low density stands died faster. This effect on the host population contradicts the resource concentration hypothesis through its logical extension to host populations (Carson et al. 2004). Although pest biomass was not measured, the slower mortality in high host density sites contradicts the resource concentration hypothesis theory that greater host density leads to greater pest biomass per host (Root 1973) which would logically lead to greater and more rapid host mortality (Carson et al. 2004), and instead suggests support for the resource dilution hypothesis that greater herbivore loads occur in areas of lower host density (Otway et al. 2005). Our analysis focuses on the speed of mortality rather than the ultimate proportion of dead trees, yet is the first time the resource dilution hypothesis has been supported for an insect pest of forest trees.

We propose that some insects may cause greater or more rapid mortality in areas of lesser host density because the insects are concentrated onto a smaller number of host plants. The negative density dependence of mortality observed in our study may be due to the particular biology of EAB and ash. EAB adults have been shown to detect olfactory cues from ash

Table 2 Multiple comparisons tests using a Bonferroni corrected alpha of 0.00333 for class variables in the best survival model for ash trees in stands infested by emerald ash borer in Ohio 2005–2009

Contrast	Hazard ratio			Wald χ^2	df	p
	Lower CL	Estimate	Upper CL			
Crown class						
Dominant versus codominant	0.59	1.09	2.00	0.16	1	0.6895
Dominant versus intermediate	0.18	0.41	0.92	10.43	1	**0.0012**
Dominant versus suppressed	0.20	0.43	0.93	10.36	1	**0.0013**
Codominant versus intermediate	0.23	0.37	0.60	37.83	1	**<0.0001**
Codominant versus suppressed	0.21	0.40	0.77	17.06	1	**<0.0001**
Intermediate versus suppressed	0.48	0.94	1.85	0.07	1	0.7908
Ash canopy health at evaluation[a]						
1 versus 2	0.48	0.69	0.99	8.97	1	**0.0027**
1 versus 3	0.20	0.41	0.83	13.81	1	**0.0002**
1 versus 4	0.07	0.19	0.53	22.48	1	**<0.0001**
2 versus 3	0.32	0.59	1.10	6.09	1	0.0136
2 versus 4	0.11	0.27	0.70	16.27	1	**0.0001**
3 versus 4	0.69	2.16	6.74	3.94	1	0.0472
Hydrology						
Hydric versus mesic	0.26	0.50	0.94	10.54	1	**0.0012**
Hydric versus xeric	0.62	1.42	3.23	1.55	1	0.2130
Xeric versus mesic	0.18	0.35	0.70	19.93	1	**<0.0001**

The hazard ratio is the hazard rate of the first class divided by the hazard rate of the second (e.g., the hazard rate of a dominant tree dying is about 41 % of the rate of an intermediate tree)

[a] Canopy health rating of 1 is healthy and 2–4 are stages of decline (Smith 2006)

Bold values indicate statistical significance at the Bonferroni corrected α-level of 0.00333

trees (Rodriguez-Saona et al. 2006). Mated female EAB also have the ability to fly long distances (Taylor et al. 2007), which may enable them to find individual ash trees even in stands where ash trees are rare and scattered. In stands with a low density of ash, the EAB female adults may be "concentrated" onto the few ash trees in the stand to lay their eggs, causing rapid decline of these trees. In contrast, in stands with a high density of ash, the EAB female adults may be "diluted" among the stressed ash trees in a stand, slowing the decline of these trees. We expect the resource dilution hypothesis would primarily apply to smaller spatial scales within the dispersal distance of the insect, and may break down at larger regional scales. Another possible explanation, similar to observations of lodgepole pine and mountain pine beetle (Waring and Pitman 1985), is that in high density ash stands, as the initially stressed trees are killed by EAB, the stand is "thinned", increasing the vigor of the remaining trees and increasing their survival. In low density ash stands, where the majority of the trees are non-ash, the mortality of one infested ash tree will not necessarily positively impact the vigor of remaining ash trees. Research that examines the relationship between EAB population dynamics and the decline and mortality of ash trees is needed to understand the possible mechanisms leading to the observed relationship.

Whatever the cause may be, our finding that mortality is more rapid in lower-density ash stands has direct implications for the management of ash forests threatened by emerald ash borer. Our results suggest that lowering the density of ash in a stand will not protect the stand from EAB; rather, the remaining ash trees will die, perhaps even at a slightly faster rate. As invasive insect pests become a more widespread problem due to accidental introductions and climate change, it is important to appreciate that the biology of both the insect and the host may determine the direction of the relationship between host density and host mortality, and that recommendations to reduce the host density may not prevent the remaining

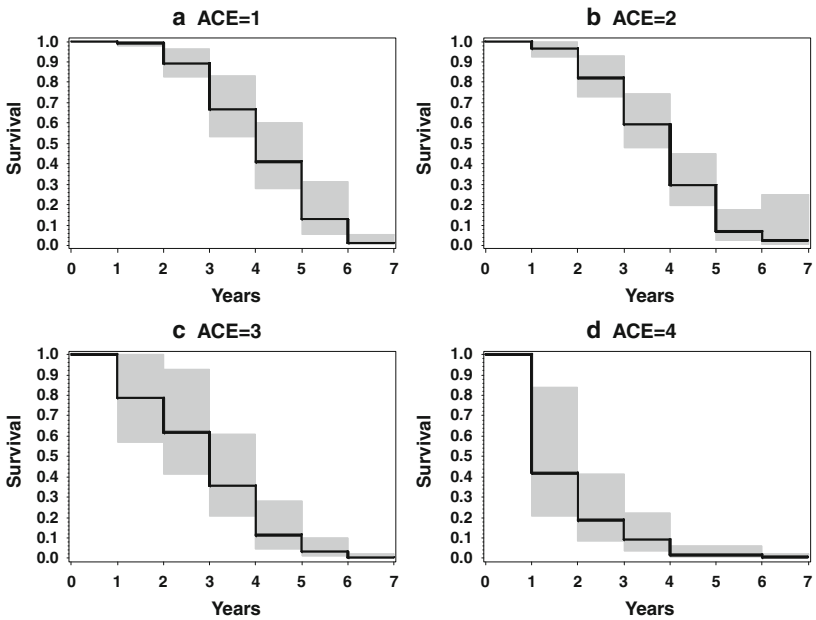

Fig. 4 Model estimates of survival rates for ash trees with four levels of ACE (ash canopy health at evaluation) over the 6 years time period following infestation by emerald ash borer. The graphs from the model estimates are useful for understanding differences among the four ACE's, not for interpreting absolute levels of survival within infested stands. Trees that were initially healthier survived longer. Default levels for other predictors were suppressed trees (CC = 4) in mesic stands (hydrology = mesic) (categories with the lowest survival rates) with 747 ash trees per ha (TPHA = 747, the mean TPHA for the default class levels). Confidence intervals (*grey shaded area*) are at the 95 % level

host trees from succumbing to the pest in all cases. Nonetheless, reductions in host density may be worthwhile as a part of a management strategy to diversify ash-dominated forest stands to mitigate EAB impacts on forest ecosystem function, ecological services, and economic or cultural values (D'Amato 2010).

Another site-level factor, hydrology, also influenced the mortality rate of ash trees. We found that trees in mesic stands exhibited more rapid mortality than those in xeric or hydric stands. It is unclear what the mechanism responsible for this finding might be. Trees that inhabit more stressful environments may allocate greater resources to defense (Herms and Mattson 1992), so it is possible that the ash trees inhabiting xeric or hydric sites may be better defended than those in mesic sites. Ash species were closely correlated with hydrology due to differing flooding tolerance of different ash species, so differences in mortality rates may be due to species differences. Other site characteristics that covary with hydrology may also be to blame, including stand density, climate, site index, landscape characteristics, and ecological region, which other studies have found to be correlated with tree mortality due to pests and pathogens (He and Alfaro 2000, Jules et al. 2002, Robertson et al. 2008).

Tree-level factors also affected the mortality of ash trees in stands infested by EAB. Dominant and co-dominant ash trees survived longer than intermediate and suppressed trees. This may be due to the dominant and co-dominant trees having greater light exposure, possibly leading to greater carbohydrate reserves. Large trees also have a larger phloem area, which may take longer for EAB larvae to girdle. This finding is in agreement with other studies that have found both the absolute and relative size of trees to affect survival rates. Small, suppressed trees were found to have greater probability of mortality in several tree species attacked by insects, including trees attacked by gypsy moth (*Lymantria dispar*) (Campbell and Sloan 1977), oaks (*Quercus* spp.) attacked by red oak borer (*Enaphalodes rufulus*) (Haavic and Stephen 2010), jack pine (*Pinus banksiana*) attacked by jack pine budworm (*Choristoneura pinus*) (Volney 1998),

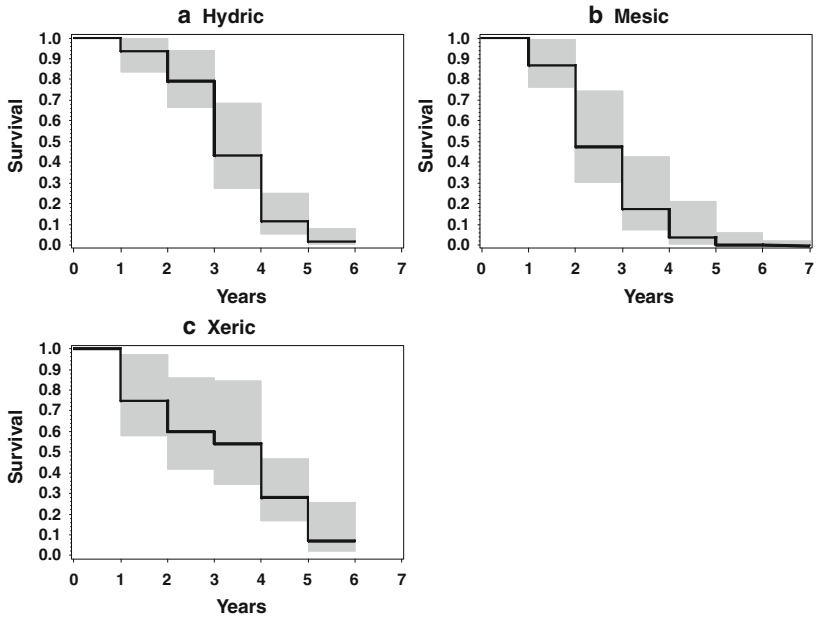

Fig. 5 Model estimates of survival rates for ash trees in forests with three hydrology types over the 6 years time period following infestation by emerald ash borer. The graphs from the model estimates are useful for understanding differences among the three hydrology types, not for interpreting absolute levels of survival within infested stands. Trees in xeric and hydric sites survived longer than trees in mesic sites. Default levels for other predictors were suppressed trees (CC = 4) with >50 % dieback (ACE = 4) (categories with the lowest survival rates) in stands with 747 ash trees per ha (TPHA = 747, the mean TPHA for the default class levels). Confidence intervals (*grey shaded area*) are at the 95 % level

and white spruce (*Picea glauca*) attacked by the white pine weevil (*Pissodes strobi*) (He and Alfaro 2000). Analysis of FIA data for insect-damaged trees in Minnesota (Woodall et al. 2005a) and for oak species in Missouri (Woodall et al. 2005b) showed that both slow-growing small trees and slow-growing large trees had increased mortality rates. These findings are helpful to managers who must prioritize the removal of ash hazard trees due to yearly budget or personnel constraints. Our results suggest that removing the intermediate and suppressed ash trees first, followed by the dominant and co-dominant trees in later years, would be a reasonable strategy. Managers of sites where concerns about hazard trees or long-term effects of high-grading are minimal may choose to harvest the largest, healthiest trees first to get the maximum value for the timber.

Trees initially rated as healthy survived longer than trees that were initially exhibiting decline. This may be due to the healthy trees having greater reserves that could allow them to survive longer during attack. Alternatively, attraction of EAB to volatiles emitted by stressed ash trees (Rodriguez-Saona et al. 2006) may result in the observed EAB preference for stressed trees (McCullough et al. 2009a, b). EAB females may select stressed trees for oviposition because EAB larvae develop slower in healthy trees (2 year development in healthy trees versus 1 year development in stressed trees), possibly due to tree defenses against larval feeding which may be greater in healthy trees (Siegert et al. 2007b; Tluczek et al. 2008).

We expect that EAB will initially infest, and then continue to re-infest, trees that are stressed until these trees die, and then move on to healthier trees. This effect of initial tree vigor on tree survival rates is in agreement with other studies. Trees initially exhibiting symptoms of stress or low vigor, including canopy decline, canopy dieback, previous defoliation, low crown ratio, and low crown density often have a greater probability of mortality once exposed to the additional stress of insect pests. Examples include trees attacked by gypsy moth (Campbell and Sloan 1977), pine trees (*Pinus* spp.) infested by pine needle gall midge

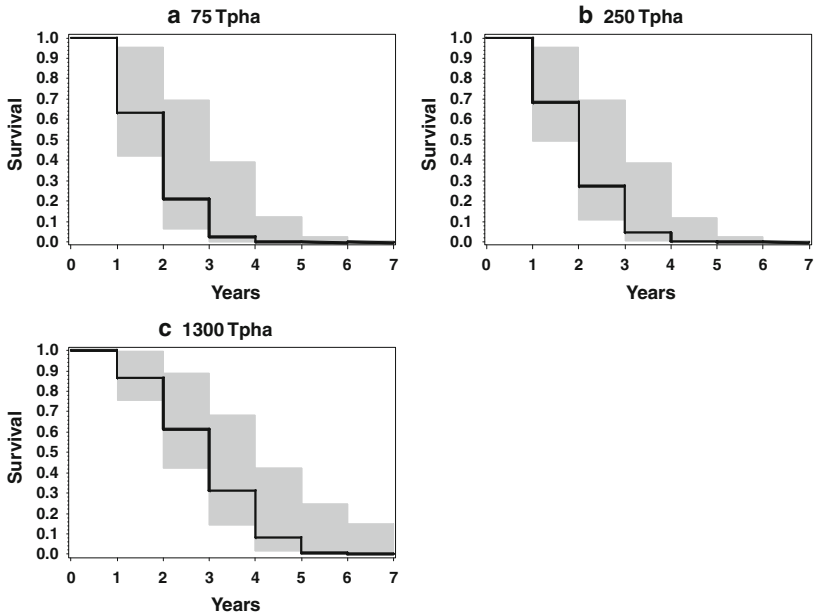

Fig. 6 TPHA (trees per ha) was modeled as a continuous variable. For illustration purposes, this figure shows model estimates of survival rates for ash trees in forests with three values of TPHA, which are roughly the fifth, fiftieth, and ninety-fifth percentiles of recorded TPHA. The graphs from the model estimates are useful for understanding differences among forests with different ash densities, not for interpreting absolute levels of survival within infested stands. Trees in sites with greater ash density survived longer than trees in low-density sites. Default levels for other predictors were suppressed trees (CC = 4) with >50 % dieback (ACE = 4) in mesic stands (hydrology = mesic) (categories with the lowest survival rates). Confidence intervals (*grey shaded area*) are at the 95 % level

(*Thecodiplosis japonensis*) (Park and Chung 2006), jack pine attacked by jack pine budworm (Volney 1998), and sugar maple (*Acer saccharum*) attacked by forest tent caterpillar (*Malacosoma distria*) (Hartmann and Messier 2008). The management implications of our study are again applicable for managers who must prioritize removal of ash hazard trees. Our results suggest that prioritizing removal of trees that are initially exhibiting dieback, and then removing the other trees in later years, is a reasonable strategy.

Conclusions

Survival analysis of yearly surveys of ash trees in EAB-infested stands showed that nearly complete stand mortality can occur within 6 years. Shaded trees and trees initially exhibiting dieback had the most rapid mortality. Trees in hydric and xeric sites survived longer than trees in mesic sites. Trees in sites with a low density of ash trees died more rapidly than trees in high-density ash sites, suggesting that rapid host mortality may result from concentration of insects onto few trees in areas with low host density.

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Chapter 1: Emerald Ash Borer Biology and Invasion History

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INTRODUCTION

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is native to eastern Asia and is primarily a pest of ash (*Fraxinus*) trees (Fig. 1). Established populations of EAB were first detected in the United States and Canada in 2002 (Haack et al., 2002), and based on a dendrochronology study by Siegert et al. (2009), the original EAB introduction likely occurred in the early to mid-1990s in Michigan. In European Russia, EAB was first found near Moscow in 2003, but not officially identified until 2005 (Izhevskii and Mozolevskaya, 2010). EAB has become a serious pest of ash in North America and European Russia, is causing widespread tree mortality, and is spreading rapidly on both continents (Cappaert et al., 2005; Poland and McCullough, 2006; Kovacs et al., 2010; Baranchikov, 2013; EAB Info, 2013; Orlova-Bienkowskaja, 2013; Straw et al., 2013; Herms and McCullough, 2014). In this chapter, we discuss the biology of EAB, its native and introduced range through 2013, and the likely pathways by which it was introduced and spread.

General Biology

The life cycle of EAB is typically completed in one year, but two years is often required, especially in vigorous hosts, in cooler climates, or when eggs are laid late in the season (Cappaert et al., 2005; Wei et al., 2007; Wang et al., 2010). In addition, Petrice and Haack (2007) reported that EAB may require two years to complete development in cut logs or firewood, especially when the wood has dried. EAB can successfully infest both healthy and stressed ash

Figure 1. Adult emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae). (Photo credit: David Cappaert, Michigan State University, Bugwood.org)

trees in North America and European Russia, where the native ash species did not coevolve with EAB (Liu et al., 2003; Wei et al., 2004; Poland and McCullough, 2006; Baranchikov et al., 2008; Rebek et al., 2008). However, within EAB's native range in China and the Russian Far East, species of Asian ash are usually resistant to the borer, except during periods of environmental stress such as prolonged drought (Yu, 1992; Zhao et al., 2005; Baranchikov et al., 2008). In addition, EAB has been reported to kill species of North American ash that were planted in China and Russia (Liu et al., 2003; Zhao et al., 2005; Baranchikov et al., 2008). EAB infests nearly all sizes of ash trees, from saplings that measure 2-3 cm in diameter to mature trees (Haack et al., 2002; Wei et al., 2007), and infests both open-grown and interior-forest trees (Poland and McCullough, 2006; McCullough et al., 2009; Wang et al., 2010) (Figs. 2-3).

In China and the Russian Far East, the principal native hosts of EAB include *Fraxinus mandshurica* Ruprecht and *Fraxinus chinensis* Roxburgh (Yu, 1992; Zhao et al., 2005; Wei et al., 2007; Baranchikov et al.,

2008; Izhevskii and Mozolevskaya, 2010), whereas in North America, EAB has been able to infest and kill all species of native *Fraxinus* so far encountered, including *F. americana* L., *F. nigra* Marshall, *F. pennsylvanica* Marshall, *F. profunda* (Bush) Bush, and *F. quadrangulata* Michx. (Anulewicz et al., 2008; EPPO, 2013). In European Russia, EAB has infested and killed primarily the introduced North American species *F. pennsylvanica* and the native European species *Fraxinus excelsior* L. (Baranchikov et al., 2008; Izhevskii and Mozolevskaya, 2010; Duan et al., 2012). It is important to note that Jendek (1994) synonymized two other Asian *Agrilus* species and one subspecies with *A. planipennis*, type China (EAB), including *Agrilus feretrius* Obenberger (type Taiwan), *Agrilus marcopoli* Obenberger (type Mongolia), and *Agrilus marcopoli* ulmi Kurosawa (type Japan) (Jendek and Grebennikov, 2011). Besides ash, which is the only larval host reported for *A. planipennis* in China (Yu, 1992; Liu et al., 2003; Zhao et al., 2005), other tree genera (*Juglans*, *Pterocarya*, and *Ulmus*) were reported as larval hosts in Korea and Japan for A. *marcopoli* and A. *marcopoli ulmi* (Ko, 1969; Akiyama and Ohmomo, 1997). However, in a recent EAB pest risk assessment prepared by the European and Mediterranean Plant Protection Organization (EPPO, 2013), it was reported that Japanese buprestid specialists now consider the non-*Fraxinus* host records for Japan to be in error.

The adult flight season of EAB usually begins in May or June in the Great Lakes region of North America and at similar latitudes in Asia, with peak flight occurring in June to July, and usually ending by September (Cappaert et al., 2005; Wei et al., 2007; Wang et al., 2010). Adults are most active on sunny days when air temperatures exceed 25° C (Wang et al., 2010), but during rainy or cool weather the adults often rest in bark crevices and on leaves (Rodriguez-Saona et al., 2007). EAB adults consume host foliage throughout their life and can live for several weeks under favorable laboratory conditions (Fig. 4; Wang et al., 2010; EPPO, 2013).

EAB adults use visual and olfactory cues to locate host trees and mates. Shades of purple and green are highly attractive to EAB adults (Francese et al., 2005, 2008, 2010; Crook et al., 2009). Moreover, EAB

Figure 2. Recently planted ash trees showing thinning crowns and epicormic shoots typical of EAB infestation. (Photo credit: Leah Bauer, USDA Forest Service, Bugwood.org)

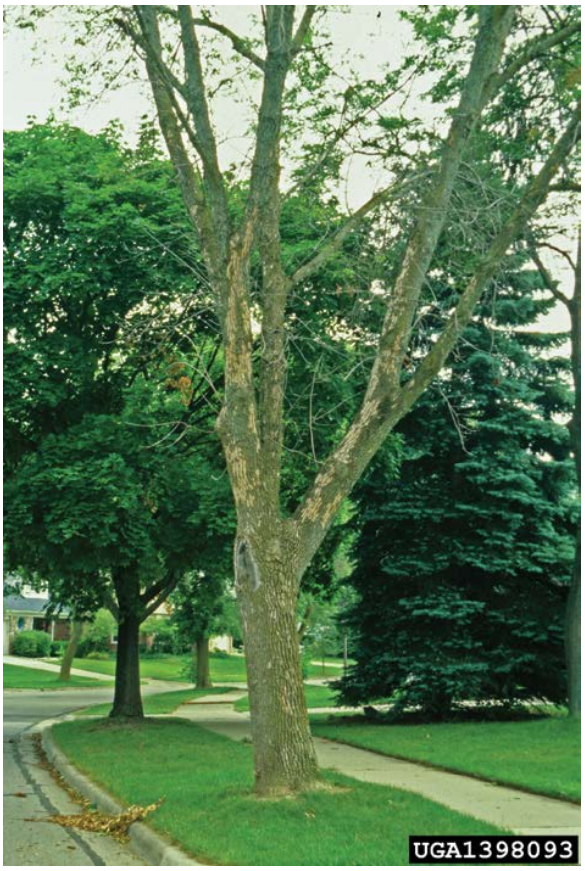

Figure 3. Mature ash tree showing dieback typical of EAB infestation and bark removal by woodpeckers as they search for EAB life stages. (Photo credit: Steven Katovich, USDA Forest Service, Bugwood.org)

adults are attracted to dead EAB adults when placed on foliage or traps as decoys (Lelito et al., 2007, 2008; Petrice et al., 2013). This is not surprising given that EAB adult males are known to hover near host trees when searching for mates, and then landing on or near prospective mates when they are located (Lelito et al., 2007; Rodriguez-Saona et al., 2007). Various volatiles from ash bark and foliage elicit positive responses in EAB adults under laboratory conditions, and some of these compounds increase EAB attraction to purple or green traps (Rodriguez-Saona et al., 2006; Crook et al., 2008; Crook and Mastro, 2010; Grant et al., 2011; Poland et al., 2011; Poland and McCullough, 2014). Also, close range sex pheromones have been identified for EAB, and field testing has found them to increase attraction of EAB to traps (Lelito et al., 2009; Silk et al., 2011; Ryall et al., 2012).

EAB adults mate on the trunk, branches, and foliage of their host plants. Oviposition usually begins about 5-10 days after adult emergence. Eggs are laid individually or in small clusters between layers of bark and in bark crevices along the trunk, major branches, and exposed roots (Wei et al., 2007; Anulewicz et al., 2008; Wang et al., 2010; Jennings et al., 2014) (Fig. 5). Under laboratory conditions, average adult female longevity is about 7-9 weeks, with total fecundity usually averaging between 40 to 74 eggs per female and with a maximum of 307 eggs (Rutledge and Keena, 2012; Jennings et al., 2014). Average EAB adult male longevity is about 43 days (EPPO, 2013).

Egg hatch usually occurs after 7-18 days, depending on local temperatures. Neonate larvae chew through the surface of the egg that is in contact with the tree, and tunnel directly through the outer bark to the cambial region where they feed on the inner bark (phloem) and outer sapwood, creating frass-filled galleries (Wei et al., 2007; Wang et al., 2010). Larval galleries tend to be more serpentine-shaped in vigorous host trees (Fig. 6), while more meandering in less vigorous hosts or when larval densities are high (Wei et al., 2007; Wang et al., 2010) (Fig. 7).

Chamorro et al. (2012) described the morphology of EAB eggs, larvae, and pupae in great detail. Briefly, EAB has four larval instars, and as is typical of larvae in the genus *Agrilus*, there are two heavily sclerotized processes, often called urogomphi, at the terminal

Figure 4. Typical leaf feeding damage by EAB adults. (Photo credit: Deborah Miller, USDA Forest Service, Bugwood.org)

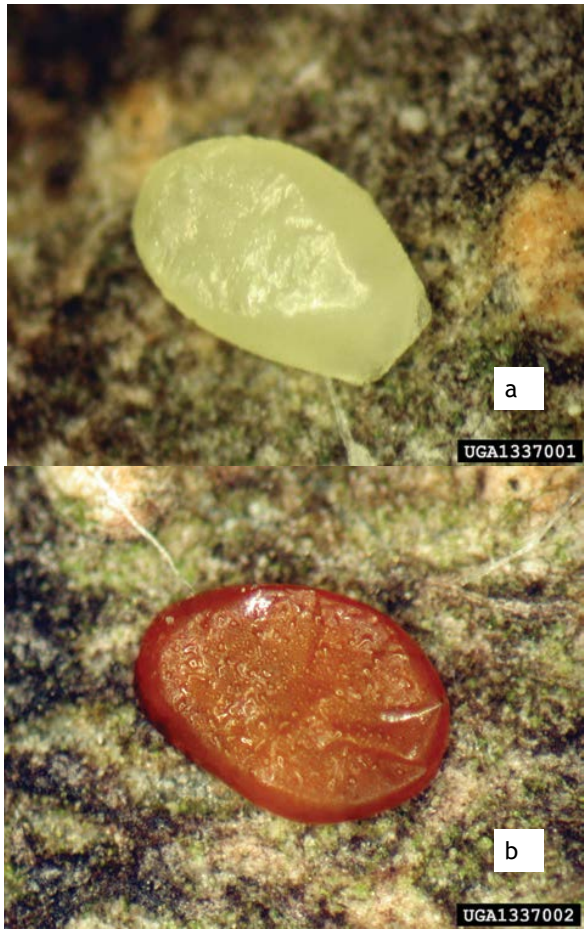

Figure 5. EAB eggs are white in color when first deposited (a) and then turn yellowish-brown within a few days (b). (Photo credit: Houping Liu, Michigan State University, Bugwood.org)

end of the abdomen (Fig. 8). Measurements of the urogomphi can be used to distinguish the larval instars (Liu et al., 2007; Petrice et al., 2009; Wang et al., 2010). For individuals that complete their life cycle in one year, larvae overwinter as mature fourth instars (Cappaert et al., 2005; Wang et al., 2005, 2010). For individuals that develop over two years, the first winter is usually spent as early instar larvae. Once a larva completes its feeding as a fourth instar (Fig. 9) it constructs a pupal cell, usually in the outer sapwood of thin-barked branches or trees or in the outer bark of thick-barked trees (Abell et al., 2012). Before creating the pupal cell, 4th-instar larvae construct a tunnel that extends nearly to the surface of the outer bark that will later be used by the new adult when it exits the tree (Wang et al., 2010). In the newly completed pupal cell, the 4th-instar larva folds itself into a J-shape or U-shape before overwintering (Fig. 10).

In spring, the larvae that overwintered in pupal cells develop into prepupae by gradually unfolding their body as they become shorter and more cylindrical. Prepupae then molt into naked or exarate pupae (Wang et al., 2010). Pupation occurs in late spring and early summer and usually lasts 3-4 weeks (Fig. 11). After eclosion, the newly formed or pharate adult will remain in its pupal cell for about one week before it chews its way out of the tree by enlarging the exit tunnel that it created earlier when it was a mature larva (Wei et al., 2007; Wang et al., 2010). The exit hole constructed by the adults is typically D-shaped, with the flat side of the "D" corresponding

Figure 6. EAB larval gallery in a vigorous host as evidenced by the tight zig-zag pattern of the gallery and the attempt by the tree to compartmentalize the gallery. (Photo credit: Edward Czerwinski, Ontario Ministry of Natural Resources, Bugwood)

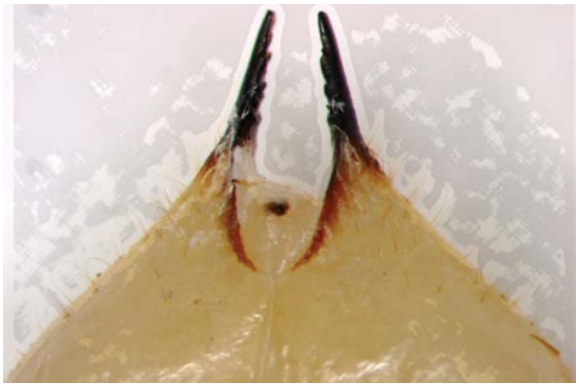

Figure 8. Close-up of the paired terminal processes found at the tip of the last abdominal segment of EAB larvae. (Photo credit: Pennsylvania Department of Conservation and Natural Resources, Bugwood.org)

Figure 7. EAB larval galleries on a less-vigorous host tree as evidenced by the meandering pattern of the galleries. (Photo credit: Edward Czerwinski, Ontario Ministry of Natural Resources, Bugwood.org)

Figure 9. Fourth instar EAB in its gallery, which is constructed in the cambial region of the tree. (Photo credit: Pennsylvania Department of Conservation and Natural Resources, Bugwood.org)

to the upper side of the adult's body (Fig. 12). Upon emergence, adults readily walk or fly to host foliage and feed (Wang et al., 2010).

As is typical for many *Agrilus* species, trees often die after 1-3 years of successive borer infestation, with death usually beginning in the crown branches and moving downward in subsequent years to the main trunk (Haack and Benjamin, 1982; Cappaert et al., 2005; Ryall et al., 2011; Foelker et al., 2013). However, in small diameter ash trees, initial EAB infestations often begin on the main trunk (Timms et al., 2006; Wei et al., 2007; Tluczek et al., 2011). In many EAB-infested ash trees, epicormic branches develop along the lower trunk before the tree dies (Cappaert et al., 2005; Wang et al., 2010) (Figs. 2, 13).

Native Range of Emerald Ash Borer

EAB is native to China, Japan, Korea, Mongolia, the Russian Far-East, and Taiwan (Yu, 1992; Jendek, 1994; Jendek and Grebennikov, 2011; Chamorro et al., 2014). The recent report of EAB from Laos (Jendek and Grebennikov, 2011) is no longer considered valid given that the specimens examined from Laos were later described as a new species: *Agrilus tomentipennis* (Jendek and Chamorro, 2012). Although EPPO (2013) raised doubts on the occurrence of EAB in Mongolia, Jendek and Grebennikov (2011) state that the type specimen for A. *marcopoli* is from Mongolia. In addition, as stated above, the occurrence of EAB in Japan and Taiwan is based on specimens that were formerly considered A. *marcopoli ulmi* and A. *feretrius*, respectively (Jendek, 1994; Jendek and Grebennikov, 2011).

INITIAL DISCOVERY AND SPREAD OF EAB IN NORTH AMERICA

EAB was first discovered in North America in 2002 (Haack et al., 2002; Cappaert et al., 2005; Poland and McCullough, 2006; Herms and McCullough, 2014). The first adults were reared from declining ash trees near Detroit, Michigan, in May 2002, and were sent to several taxonomists for identification. Later, in July 2002, they were positively identified as *A. planipennis* by Eduard Jendek in Slovakia, who is the world

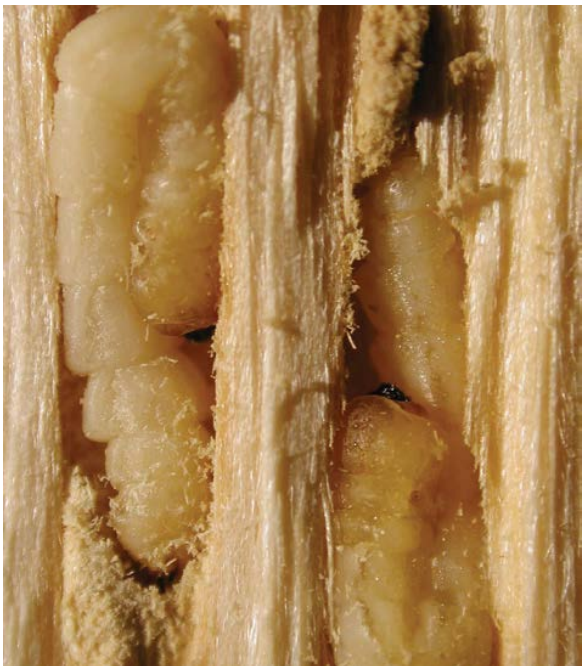

Figure 10. Fourth instar EAB larvae in their typical overwintering position (J-larvae) inside pupal cells that were constructed in the outer sapwood. (Photo credit: Houping Liu, Michigan State University, Bugwood.org)

Figure 11. EAB pupae are naked and gradually mature into adults within their individual pupal cells during spring and summer. (Photo credit: Deborah Miller, USDA Forest Service)

authority on Asian *Agrilus*. Moreover, beetles that looked similar to EAB were collected in July 2002 in Windsor, Ontario, and identified as EAB in August 2002.

Michigan and Canada enacted quarantines on all known EAB-infested counties starting in July and September 2002, respectively (Haack et al., 2002). A federal EAB quarantine was first enacted

in the United States in October 2003 (USDA APHIS, 2003). The EAB quarantine zone has expanded each year since 2002 in both the United States and Canada as a result of regional surveys in several states and provinces. When new EAB populations were discovered, quarantines were usually enacted at the county level. As a result of intense survey efforts, the steady range expansion of EAB has been well documented in North America (Fig. 14). However, it is important to realize that it usually takes several years before EAB populations are large enough to be detected during surveys. Range expansion of EAB is a result of both natural spread and artificial movement of infested ash material.

By the end of 2002, EAB had been found in six southeastern Michigan counties in the Detroit area. This number increased to 13 counties by the end of 2003, and 20 by 2004, all still within Michigan's Lower Peninsula. In 2005, EAB was found for the first time in Michigan's Upper Peninsula. EAB was first found in Ohio in 2003; Indiana in 2004; Illinois and Maryland in 2006; Pennsylvania and West Virginia in 2007; Wisconsin, Missouri and Virginia in 2008; Minnesota, New York, and Kentucky in 2009; Iowa and Tennessee in 2010; Connecticut, Kansas, and Massachusetts in 2012; and Colorado, Georgia, New Hampshire, and North Carolina in 2013 (EAB Info, 2013) (Fig. 14). In Canada, EAB has been detected in just two provinces as of 2013, first in Ontario in 2002, and then in Quebec in 2008 (Fig. 14). Overall, as of December 2013, EAB was known to occur in 22 U.S. states and two Canadian provinces.

Figure 12. EAB adults construct D-shaped exit holes as they chew through the bark and emerge from their host tree. (Photo credit: Deborah Miller, USDA Forest Service)

Figure 13. EAB infested ash tree with epicormic shoots that often develop during the latter years of infestation prior to tree death. (Photo credit: Edward Czerwinski, Ontario Ministry of Natural Resources, Bugwood.org)

INTRODUCED RANGE AND SPREAD OF EAB IN RUSSIA

There are few early records of EAB from Russia. During the 1900s, all EAB records were from southern Primorskiy Kray in the Russian Far East and consisted of small numbers of specimens collected during 1935-1999 (Alekseyev, 1979; Jendek, 1994; Volkovich, 2007; Yurchenko et al., 2007; Fig. 15). In 2004, EAB populations were also found in southern Khabarovsk Kray in the Russian Far East in the area between Khabarovsk and Dzonki, a distance of about 100 km as measured along the Amur River

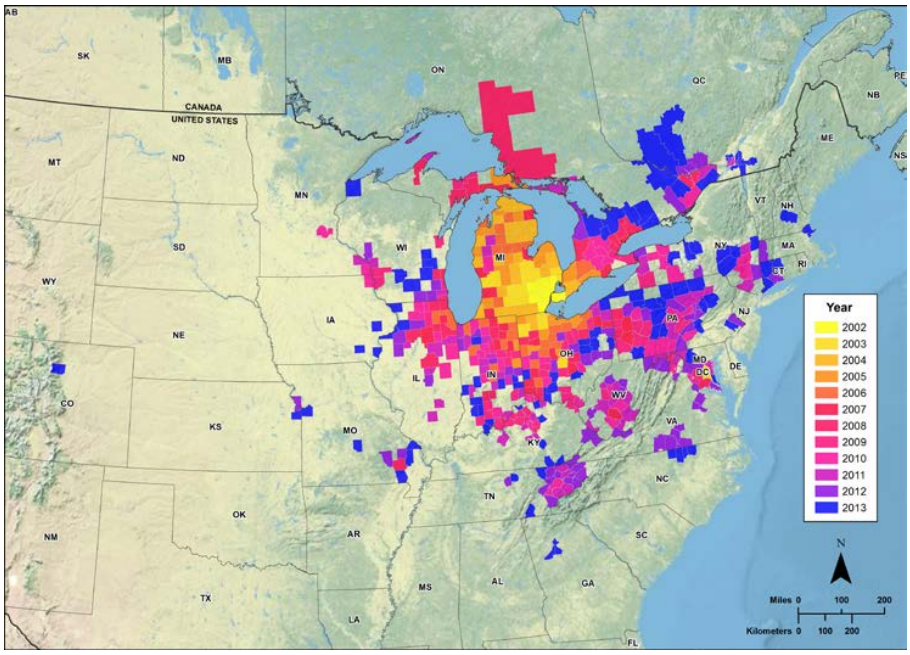

Figure 14. (top) Annual spread of EAB in North America from 2002 through 2013 as determined by year of first detection. Service layer credits: US National Park Service. Data sources: USDA Animal & Plant Health Inspection Service (APHIS), Canadian Food Inspection Agency (CFIA). Map developed by USDA Forest Service, Northeastern Area State and Private Forestry, Office of Knowledge Management (T. Luther 04/15/2014).

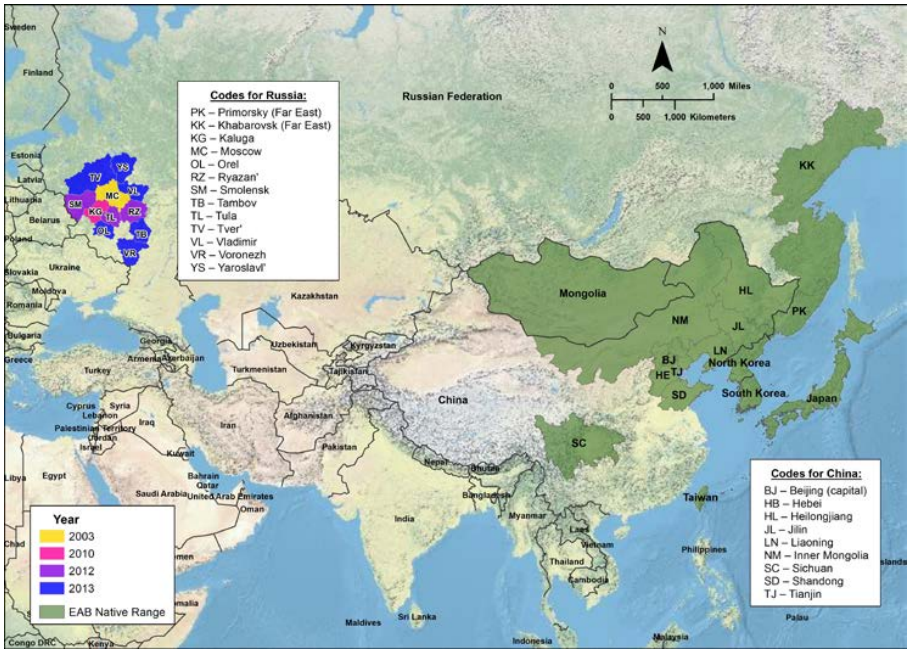

Figure 15. (bottom) Known range of EAB in Asia and introduced area of EAB in European Russia as of 2013. Service layer credits: US National Park Service. Data sources: https://sites.google.com/site/eduardjendek/world-distribution-of-agrilus-plannipennis_ and Baranchikov (2013). Map developed by USDA Forest Service, Northeastern Area State and Private Foresty, Office of Knowledge Management (T. Luther 04/15/2014).

(Yurchenko, 2010; Fig. 15).

Historically, EAB was a rare species in the Russian Far East, where it was associated exclusively with weakened and dying local native ash trees such as *F. mandshurica* and *F. chinensis*. Widespread tree mortality associated with EAB was first noticed in the Russian Far East in 2004, affecting introduced North American ash trees (*F. pennsylvanica*) that were growing along streets in Vladivostok (Yurchenko, 2010), many of which were rather mature trees with trunks measuring 20-40 cm in diameter. Subsequent detailed investigations of dead North American ash trees (*F. americana* and *F. pennsylvanica*) in parks and arboreta in Khabarovsk demonstrated that these trees had been killed by EAB during the previous 5-10 years when the trees were 28-35 years old (Yurchenko, 2010).

In European Russia, beetles that were later to be identified as EAB were first collected on the streets of Moscow in June 2003 (Fig. 15; Volkovich, 2007). These beetles were positively identified as *A. planipennis* in 2005 by A. B. Alekseyev – the leading Russian expert on Buprestidae (Izhevskii and Mozolevskaya, 2010). It was soon recognized that EAB was responsible for the widespread ash dieback in Moscow (Baranchikov et al., 2008; Mozolevskaya et al., 2008). From 2006-2013, EAB spread outward from Moscow (Fig. 15). In 2006, 10 EAB adults were collected 30 km west of the Moscow Ring Highway (Volkovich, 2007), and by 2009, EAB-killed ash trees were found in many settlements of the Moscow Oblast region, with the most westward known infestation in Mozhaisk, about 100 km from Moscow (Baranchikov et al., 2010a). EAB was found in the Kaluga Region in 2010, and in the Smolensk and Ryazan Regions in 2012 (Baranchikov and Kurteyev, 2012; Baranchikov, 2013). Similarly, in 2013, EAB was first reported in the Orel, Tambov, Tula, Tver, Vladimir, Voronezh, and Yaroslavl Regions (Baranchikov, 2013, Orlova-Bienkovskaya, 2013). The current known range of EAB in European Russia is close to the borders of Belarus and Ukraine (Fig. 15).

Special EAB surveys were conducted during 2008-2009 on *F. pennsylvanica* in several cities throughout southern Siberia (Abakan, Krasnoyarsk, Novosibirsk, Tomsk, and Ulan-Ude) and the central Urals (Yekaterinburg). However, no additional EAB populations were found during these surveys (Baranchikov et al., 2010b).

PATHWAYS OF EMERALD ASH BORER DISPERSAL

It is not known for certain how EAB reached North America or European Russia. In North America, wood packaging material such as pallets and crating from Asia is considered the most likely source (Haack et al., 2002, Cappaert et al., 2005, Haack, 2006). Recent genetic analyses by Bray et al. (2011) and Keever et al. (2013) found that North American EAB populations were most similar to Chinese populations, less so with Korean populations, and least similar to Japanese populations. As for European Russia, Izhevskii and Mozolevskaya (2010) suggested that EAB could have been introduced on ash nursery stock imported from North America or on wood packaging material from Asia. Genetic analyses may not help determine the source of the Moscow EAB population because molecular testing has shown high similarity among North American, Chinese, Far-East Russian, and Moscow EAB populations (EPPO 2013).

In North America and Europe, EAB can spread naturally through adult flight, which can expand the infested area by several kilometers each year (Taylor et al., 2010; EPPO, 2013). However, EAB dispersal over distances of 10s or 100s of kilometers most likely results from human movement of infested host material such as ash nursery stock, logs, and firewood (Cappaert et al., 2005; Haack, 2006; Poland and McCullough, 2006; Haack et al., 2010; Herms and McCullough, 2014). For example, a nursery in Michigan sold EAB-infested nursery stock to a Maryland nursery in 2003, which then sold some of the trees to individuals living in Maryland and Virginia before realizing the trees were infested (Muirhead et al., 2006). Similarly, a sawmill near Shipshewana, Indiana, which regularly purchased ash sawlogs from southern Michigan was apparently responsible for introducing EAB to the local area (Robertson and Andow, 2009). Firewood is believed to be a major pathway by which EAB

has been introduced to many residential areas, vacation properties, and campgrounds (McCullough et al., 2003; Robertson and Andow, 2009; Haack et al., 2010). In addition, EAB adults have been documented to hitchhike on or inside vehicles, as well as on passengers, which may explain their high frequency of establishment along major highways, especially at rest areas and truck stops (Buck and Marshall, 2008). The means of long-distance EAB dispersal in European Russia is not clear given that movement of ash nursery stock, firewood, and logs is rare in Russia, and therefore hitchhiking by EAB adults on vehicles is considered the most likely explanation (Straw et al., 2013).

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On the cover: Cover design by Sheryl Romero and Denise Binion, Forest Health Technology Enterprise Team. Background image: Understory green ash seedlings (*Fraxinus pennsylvanica*, Oleaceae) released after large ash trees were killed by emerald ash borer in Okemos, Michigan in 2014, photo by Leah S. Bauer; (bottom row, left to right) Fully mature *Tetrastrichus planipennisi* larvae break free of emerald ash borer larval skin and pupate in the larval gallery under the tree bark. (Photo credit: Clifford Sadof); EAB adult and typical leaf feeding damage. (Photo credit: Deborah Miller, USDA Forest Service, Bugwood.org); Emerging *Tetrastrichus plannipennisi* adults. (Photo credit Leah S. Bauer).

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R-II-4

Request:

According to the statistics provided in response to request R-I-1-12, the Company averages 108 Hazard Tree removals per circuit per year. Provide the statistics and backup data which show the number of hazard trees per year per circuit that actually contacted a line and created an outage for the same 8 year period.

Response:

National Grid does not track which outages were caused by hazard trees.

Prepared by or under the supervision of: Ryan Moe

R-II-5

Request:

Provide an electronic copy of a complete and detailed budget, by line item and year, for the South Street Station Rebuild Project along with the project timeline.

Response:

Please see Attachment 1 to R-II-5 for the budget details and reimbursement details for the South Street Station Rebuild Project for FY 2016 through FY 2020.

Prepared by or under the supervision of: Sonny Anand

The Narragansett Electric Company
d/b/a National Grid
FY 2017 Electric ISR Proposed Plan
Attachment 1 to R-II-5

All costs are capital $
Distribution Forecast

South Street Station Rebuild Project
FY 2016 - FY 2020

		FY16	FY17	FY18	FY19	FY20	Total
C051212	Substation	$5,414,090	$10,553,779	$15,989,766	$5,161,606	$2,800,000	$39,919,241
C051213	Line	$1,640,056	$4,807,795	$4,643,341	$1,141,183	$2,215,088	$14,447,463
						Total	$54,366,704

Transmission Forecast (includes reimbursement dollars)

		FY16	FY17	FY18	FY19	FY20	
C055584	Substation	$2,367,322.54	$14,596,974.23	$4,210,741.55	$1,453,548.12	$0.00	$22,628,586.44
C055585	Line	($519,182.40)	$1,467,676.94	($682,928.02)	$123,633.63	$773,475.23	$1,162,675.38
C055586	Substation	$139,507.62	($171,709.39)	$65,444.89	$60,987.06	$86,516.89	$180,747.07
						Total	$23,972,008.89

Reimbursements

		FY16	FY17	FY18	FY19	FY20	Total
C055585	Line	($1,069,000.00)	($2,863,000.00)	($1,370,000.00)	$0.00	$0.00	($5,302,000.00)
C055586	Substation	($481,000.00)	($1,287,000.00)	($587,000.00)	$0.00	$0.00	($2,355,000.00)
						Total	($7,657,000.00)

R-II-6

Request:

Provide a detailed budget for the transmission items related to the South Street Station Rebuild which are the responsibility of the developer.

Response:

Please see the Company's response to R-II-5.

Prepared by or under the supervision of: Sonny Anand

R-II-7

Request:

Please provide the interruption statistics including major event days for each year and each category contained in Chart 3 and Chart 5 (pages 6 and 8, respectively) of Section 2 of the FY 2017 Electric ISR Plan.

Response:

Please see Attachment R-II-7(a) for an update to Chart 3 that includes major event days for each calendar year from 2008 through 2014.

Please see Attachment R-II-7(b) for an update to Chart 5 that includes major event days for each fiscal year from 2008 through 2015.

Prepared by or under the supervision of: Jim Patterson

CHART 3 UPDATED
RHODE ISLAND INTERRUPTION BY CAUSE
MAJOR EVENT DAYS INCLUDED
BY CALENDAR YEAR (2008 - 2014)

Calendar Year with Major Event Days	CI						
Cause	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Tree	314,416	107,610	74,116	132,780	217,931	122,661	70,277
Deteriorated Eqmt	97,210	88,643	85,047	71,485	48,891	46,390	79,260
Intentional	51,741	54,349	58,356	51,720	49,950	66,252	43,132
Human Element/Other	50,780	36,999	54,275	27,616	47,404	58,321	29,908
Sub-Transmission	63,381	46,082	28,046	51,279	74,296	74,786	33,556
Substation	64,889	86,482	10,713	65,718	74,256	18,882	30,888
Lightning	15,111	36,859	27,874	34,386	21,002	23,310	5,745
Unknown	93,160	28,101	13,545	41,843	45,626	52,953	19,657
Human Element/Company	20,423	26,067	8,450	28,298	7,335	15,549	13,259
Animal	15,952	18,031	11,769	16,977	9,912	10,326	21,247
Transmission	52,795	18,438	25	8,721	19,112	119,638	18,284
Adverse Environment	5,569	5,303	3,926	5,926	5,416	4,486	3,220
Grand Total	845,427	552,964	376,142	536,749	621,131	613,554	368,433

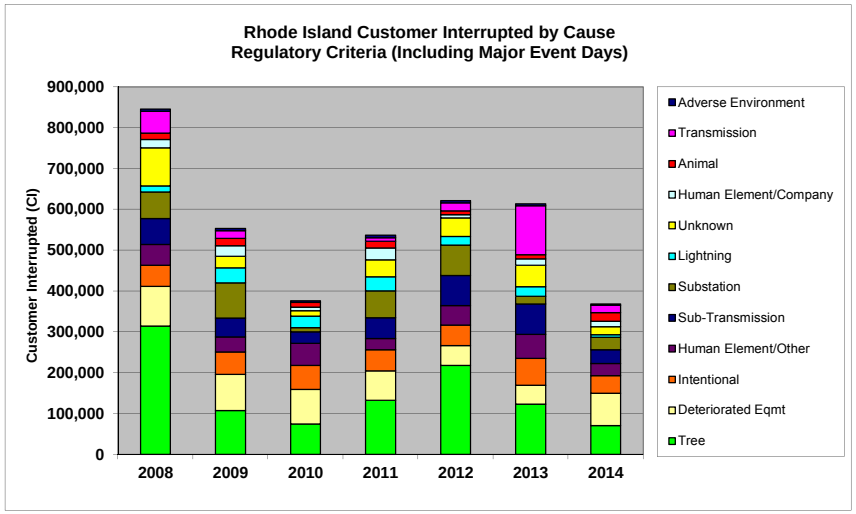
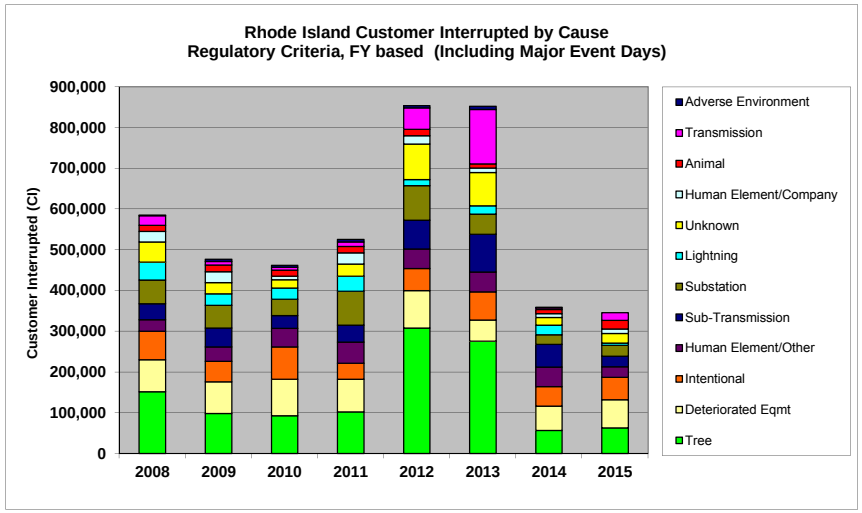


CHART 5 UPDATED
RHODE ISLAND INTERRUPTION BY CAUSE
MAJOR EVENT DAY INCLUDED
BY FISCAL YEAR (2008 - 2015)

Fiscal Year with Major Events Days	CI							
Cause	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Tree	152,101	98,498	93,107	102,553	308,183	275,792	56,964	63,009
Deteriorated Eqmt	78,512	77,776	89,517	79,854	91,605	52,045	59,239	68,992
Intentional	69,276	49,731	78,878	38,999	53,916	69,063	48,219	55,268
Human Element/Other	28,737	35,540	45,842	51,837	48,301	48,754	48,008	25,659
Sub-Transmission	38,740	46,619	31,528	41,963	70,662	92,292	55,492	26,191
Substation	58,404	55,863	39,553	82,926	84,611	49,351	23,243	26,527
Lightning	44,182	28,002	27,874	36,883	15,087	21,002	23,882	5,234
Unknown	49,341	27,276	19,946	30,267	86,950	81,538	18,501	23,529
Human Element/Company	25,703	27,056	8,866	27,305	21,087	10,860	9,652	11,507
Animal	15,103	16,385	14,761	15,335	15,413	9,866	10,098	21,232
Transmission	23,694	8,721	7,093	11,370	52,795	134,182	4,568	18,284
Adverse Environment	1,724	5,655	5,249	6,046	4,891	7,390	811	6,786
Grand Total	585,517	477,122	462,214	525,338	853,501	852,135	358,677	352,218



R-II-8

Request:

For vegetation management under Core Activities, please provide a list of all customer requests and safe calls made in FY 2015 and YTD FY 2016. Include an explanation for the customer request or call, the associated cost to complete the request or call, and note any reimbursement provided by the customer. Provide a copy of the Company's policy for customer requests and safe calls related to vegetation management, and in particular, customer obligations for cost reimbursement.

Response:

Please see Attachment 1 to R-II-8 for a summary of customer requests from FY 2015 and FY 2016. Because of the way that these calls are tracked, it would not be feasible to assign a cost to each individual call.

For each customer call, National Grid will respond as soon as possible, with higher priority given to emergency calls. Each call will then be evaluated on a case by case basis and our arborists or contractors will discuss with the customer what can be done to resolve the problem. There has been no reimbursement provided by customers to date, nor is there any policy covering reimbursement.

Prepared by or under the supervision of: Ryan Moe

Trouble Jobs	**Phone/Cable**	**Trim**	**Capital**	**No Action**	TOTAL
	FY15	FY15	FY15	FY15	FY15
Barrington	13	25	3	20	61
Bristol	8	29	4	15	56
Burrilliville	8	16	4	6	34
Central Falls	0	4	5	2	11
Charlestown	3	30	27	20	80
Coventry	13	48	35	19	115
Cranston	15	57	25	30	127
Cumberland	11	37	41	28	117
East Greenwich	5	17	4	12	38
East Providence	14	45	12	14	85
Exeter	2	11	4	3	20
Foster	0	23	6	6	35
Glocester	1	33	9	10	53
Hopkinton	2	23	21	8	54
Jamestown	4	20	6	4	34
Johnston	14	53	15	19	101
Lincoln	10	22	6	9	47
Little Compton	4	11	8	4	27
Middletown	7	25	12	12	56
Narragansett	11	30	15	10	66
Newport	7	51	28	20	106
North Kingstown	6	65	15	21	107
North Providence	7	21	1	14	43
North Smithfield	4	20	6	11	41
Pawtucket	9	18	21	15	63
Providence	11	64	17	30	122
Prudence Island					
Portsmouth	6	21	0	12	39
Richmond	3	9	8	3	23
Scituate	5	28	17	9	59
Smithfield	6	37	7	10	60
South Kingstown	8	59	72	35	174
Tiverton	2	17	7	17	43
Warren	1	9	2	13	25
Warwick	21	74	27	51	173
West Greenwich	2	17	2	2	23
Westerly	14	65	41	19	139
West Warwick	4	28	9	14	55
Woonsocket	7	20	3	3	33
Total	268	1,182	545	550	2,545

Phone/Cable No work is performed. National Grid does not trim phone or cable lines.

Trim Trees are trimmed away from power lines, giving adequate clearance.
These costs are included in the vegetation opex component of the ISR

Capital These are for capital work, such as removing a tree or trimming so a new piece of of equipment or wire can be installed. These costs are included in the capital component of the ISR.

No Action No action I s taken because the trees do not pose a threat to power lines.

Trouble Jobs	Phone/Cable	Trim/worked	CAP	No Action	TOTAL
	FY16	FY16	FY16	FY16	FY16
Barrington	4	35	0	19	58
Bristol	5	22	3	13	43
Burrilliville	0	14	1	2	17
Central Falls	0	4	2	0	6
Charlestown	9	70	11	17	107
Coventry	10	43	10	40	103
Cranston	20	96	3	71	190
Cumberland	9	31	4	30	74
East Greenwich	3	22	3	12	40
East Providence	8	29	2	28	67
Exeter	0	20	5	3	28
Foster	1	12	2	4	19
Glocester	3	26	3	17	49
Hopkinton	2	8	10	6	26
Jamestown	4	19	3	3	29
Johnston	7	29	9	23	68
Lincoln	4	22	2	10	38
Little Compton	0	8	1	4	13
Middletown	2	25	0	11	38
Narragansett	4	24	7	10	45
Newport	2	39	13	18	72
North Kingstown	5	31	7	20	63
North Providence	8	21	4	23	56
North Smithfield	0	5	3	9	17
Pawtucket	5	22	9	27	63
Providence	16	50	16	38	120
Prudence Island	0	1	0	1	2
Portsmouth	3	26	3	10	42
Richmond	1	17	6	10	34
Scituate	1	23	5	18	47
Smithfield	1	23	7	10	41
South Kingstown	14	68	8	22	112
Tiverton	7	21	4	11	43
Warren	2	6	0	8	16
Warwick	22	82	11	52	167
West Greenwich	0	6	1	8	15
Westerly	13	55	10	24	102
West Warwick	0	22	8	17	47
Woonsocket	3	17	2	10	32
Total	198	1,094	198	659	2,149

Raquel J. Webster
Senior Counsel

November 18, 2015

BY HAND DELIVERY AND ELECTRONIC MAIL

Luly E. Massaro, Clerk
Rhode Island Division of Public Utilities and Carriers
89 Jefferson Boulevard
Warwick, RI 02888

RE: National Grid's Proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan
Responses to Division Data Requests – Set 2

Dear Ms. Massaro:

I have enclosed five copies of National Grid's[1] response to data request R-II-2, which is part of the Division's second set of data requests in the above-referenced matter.

The Company will be providing its response to data request R-II-1 on Thursday, November 19.

Thank you for your attention to this transmittal. If you have any questions, please contact me at 781-907-2121.

Very truly yours,

Raquel J. Webster

Enclosures

cc: Steve Scialabba
Leo Wold, Esq.
Jim Lanni
Al Contente

[1] The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

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T: 781-907-2121 ■ raquel.webster@nationalgrid.com ■ www.nationalgrid.com

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R-II-2

Request:

The Attachment DIV R-I-1-3 provides additional detail for each transmission outage event. Many of the event descriptions point to failures of structures or equipment which the Division believes should have been identified in an inspection program. How does the Company assure the transmission inspection and maintenance program is adequately addressing pole deterioration before failure, switch failure before the switch is needed for operation, breaker transfer failures, broken bracket, insulator failure, tie breaker failure, breaker failures, tie switch failures to close, and many of the other failures which are described that are directly inspection and maintenance deficiency issues? Although these are not distribution failures they impact the reliability to the distribution customers.

Response:

National Grid has robust policies and procedures in place to inspect and maintain the transmission system. The Company does not believe that a deficiency in the substation and transmission line inspections and maintenance process was the cause of the interruptions in 2014. A detailed description of the 2014 outages is included in the table below.

Both distribution and transmission substations are inspected according to National Grid's Substation Maintenance Procedures. These procedures ensure that a visual and infrared inspection is performed regularly, and all operable equipment is maintained according to applicable prescribed standards.

National Grid's inspection and maintenance program for the New England overhead electric transmission line system is comprised of four distinct sub-programs. An Aerial Visual Inspection is performed twice a year in a helicopter to identify any significant or obvious issues such as broken cross-arms, damaged insulators, and bird nesting. The second sub-program is an Electrical Connector Inspection performed once a year in a helicopter using an infrared camera to identify connectors operating at an elevated temperature. A Ground Level Visual Inspection is performed every five years by foot on every component of the transmission line to identify any damage. The fourth inspection is the Wood Pole Inspection and Treatment inspection, which is performed every ten years by foot. The Company executes a contract with an external vendor that specializes in inspection and remedial treatments to perform a visual inspection and, as needed, ground-line excavation and inspection, sounding and boring, internal treatment, and surface treatment. The Company collects and reviews this data from all sub-programs, and initiates any additional work for maintenance activities, as needed.

R-II-2, page 2

Table 1: Calendar Year 2014 Transmission Interruptions Narrative

Outage	Description
7894586	The Tiverton Substation did not transfer to the alternate transmission line when the primary transmission line locked out during a lightning storm. A blown secondary potential transformer fuse was found and an associated relay utilized in the transfer scheme was replaced. The damage was possibly caused by the storm lighting strikes that occurred in the area. The scheme was tested and returned to service.
7889290	An oil transmission cable faulted due to third-party damage on South Main Street, Providence. A 4kV circuit breaker incorrectly operated at the Rochambeau Substation due to a stuck breaker contact that failed to identify that its associated breaker was open, which caused an outage.
7891483	A transmission structure was identified near failure. During the switching to electrically isolate the structure for repairs, the bearings on a motor operated disconnect switch at the Tower Hill substation seized. This caused the drive shaft to bend when the disconnects attempted to open, which resulted in an incorrect "open" indication to Dispatch even though the switch was not fully open. When another switch was opened a flash occurred and the transmission line locked out. An inspection of the switch revealed a design flaw with how the switch bearings were protected from the weather. They were replaced with a new designed bearing and the switch was returned to service.

Prepared by or under the supervision of: Jim Patterson

nationalgrid

Raquel J. Webster
Senior Counsel

November 23, 2015

BY HAND DELIVERY AND ELECTRONIC MAIL

Luly E. Massaro, Clerk
Rhode Island Division of Public Utilities and Carriers
89 Jefferson Boulevard
Warwick, RI 02888

RE: National Grid's Proposed FY 2017 Electric Infrastructure, Safety, and Reliability Plan
Responses to Division Data Requests – Set 2

Dear Ms. Massaro:

I have enclosed five copies of National Grid's[1] response to data request R-II-1, which is part of the Division's second set of data requests in the above-referenced matter.

This transmittal completes the Company's responses to the Division's second set of data requests in this matter.

Thank you for your attention to this transmittal. If you have any questions, please contact me at 781-907-2121.

Very truly yours,

Raquel J. Webster

Enclosures

cc: Steve Scialabba
Leo Wold, Esq.
Jim Lanni
Al Contente

[1] The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

40 Sylvan Road, Waltham, MA 02451
T: 781-907-2121 ■ raquel.webster@nationalgrid.com ■ www.nationalgrid.com

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R-II-1

Request:

As a follow-up to the response provided by the Company to Request R-I-1-1, please list all other contributors other than the CYME model that are the basis for East Bay construction and upgrade projects. Include a detailed description of each factor or contributor to the decision for each proposed project. Also, for each contributor or factor state the factual basis or if the factor is simply based in part or whole on assumptions and experience with no factual data.

Response:

Attachment 1 to R-II-1 includes a table that summarizes the issues analyzed in the East Bay study, the analysis basis (contributor) for each issue, a detailed description of each analysis factor or contributor, and statements regarding the factual, assumptive, or experience based inputs into the analysis. Most important to understanding the content of the table is to understand National Grid's Distribution Planning Guidelines (DPG) included as Attachment 2 to R-II-1, which provides the overarching guidance for all analysis methods.

Prepared by or under the supervision of: Ryan Constable

Attachment 1 to R-II-1

East Bay Study – Analysis Summary

Report Section	Category	Issue Identified	Analysis Basis (Contributor)	Analysis Description	Factual Basis
4.1.1	Normal Configuration - Thermal Loading	The distribution system in the East Bay area is heavily loaded with limited capacity to supply new load. Excluding out of phase feeders and a small pocket of 4.16kV load, by 2020 approximately 50% of the feeders are projected to be loaded above 90% of Summer Normal (SN) rating. By 2026, 70% of the feeders are projected to be loaded above 90% of SN rating.	2014 Annual Plan Spreadsheet and CYME Models	The Annual Plan Spreadsheets are screening tools used by planners to quickly review system issues. As the name implies, this screening tool is updated annually with the latest loads and growth rates. Because it includes past actual load levels and future forecasts, it provides simple and quick insight into station equipment that often limits distribution feeders but is not included in CYME models. CYME models are also used for further details. These models provide a visual representation of loading on all distribution line components.	The factual basis of this analysis is the use of actual load levels updated annually compared against factual equipment limits and application of the DPG. The forecast information, by its nature, is an assumption based on factual weather data and assumed economic data. The above data and assumptions are included in the Annual Plan Spreadsheets and the CYME models.
4.1.2	Contingency Configuration - Thermal Loading	A contingency analysis was performed for all feeders in the study area. This analysis calculated a MWh 'exposure' or risk assuming a worst case component failure. Because the feeders are heavily loaded, nearly all exceed the MWh exposure recommended in the Distribution Planning Guide (DPG). The DPG recommends mitigating any exposure in excess of 16MWh.	Manual calculation	The analysis basis, with assumptions, is described within the study document (see section 4.1.2). Note that CYME contingency analysis module does not include an ability to calculate a MWHr load-at-risk. Therefore, using the CYME contingency analysis module also requires a manual effort.	The factual basis of this analysis is its consistency with Distribution Planning Guidelines. Contingency analysis, by its nature, is an analysis based on assumptions and experience.

Prepared by or under the supervision of: Ryan Constable

Report Section	Category	Issue Identified	Analysis Basis (Contributor)	Analysis Description	Factual Basis
4.2	Voltage Performance	No subtransmission and minor distribution line voltage issues were identified.	PSS/e load flow program - 23kV sub-transmission system. CYME - radial distribution system.	The PSS/e load flow program was utilized to model the electrical system to the 23kV sub-transmission level and check voltage performance against the DPG. Similarly, CYME was used to check voltage performance on the radial distribution system against the DPG. More details are provided in Section 4.2 and Appendix 9.3 and 9.4 of the report.	The factual basis of this analysis is the use of actual load levels within each model, the modeling of the voltage control equipment, and the application of the DPG.
4.3	Asset Condition - Stations	A number of substations in the study area have asset condition, safety, and reliability concerns. Details are provided in Section 4.3 of the study report.	The asset condition, safety, and reliability concerns at each station were identified using 1) Cascade review; 2) field visits; 3) consultation with various company departments. ; and 4) review of substation equipment inspection reports by Substation O&M Services.	Asset condition reviews are typically conducted using inspection and maintenance records, ad-hoc inspections, and consultation with Subject Matter Experts. Cascade is the Company's substation asset management software.	The factual basis of this analysis is in the inspection and maintenance reports. Where applicable, inspection and maintenance data for like equipment may be gathered to demonstrate a performance or failure trend in a family of devices. Personnel and equipment experience is gathered during this analysis

Report Section	Category	Issue Identified	Analysis Basis (Contributor)	Analysis Description	Factual Basis
4.3	Asset Condition - Subtransmission	Most of the 23kV sub-transmission system in the East Bay area consists of aged pole plant and small wire installed on congested public roadways. Only a small portion of this system has been rebuilt in the last 20-years. The remainder of the system consists of a mixture of 795 Al, 336.4Al, 2/0Cu, and 1/0Cu wire with 12.47kV under-build. A major investment to replace both the pole plant and wire size would be required to increase the capacity of this system.	The source of this data was the Geographic Information System (GIS) and consultation with Operations.	Asset condition reviews are typically conducted using inspection and maintenance records, ad-hoc inspections, and consultation with Subject Matter Experts. Smallworld GIS is the Company's distribution line asset database. Overhead assets are inspected on a planned interval within the Company's newly initiated Inspection & Maintenance (I&M) Program. The I&M program has not been deployed in the study area as of yet.	The factual basis of this analysis is in the equipment records. In this particular case, formal inspection and maintenance reports did not exist. Operations experience was mainly relied on for this analysis.
4.4.1	Reliability Performance	No issues	Interruption Disturbance System (IDS)	IDS is the Company's historical interruption database. The planner performs a high level review using 3 year average feeder level reliability indices, Circuit Average Interruption Frequency Index (CKAIFI) and Circuit Average Interruption Duration Index (CKAIDI). These feeder level values are compared against system targets. If a circuit appears to be trending away from system reliability targets further analysis and consultation will be done..	The factual basis of this analysis is historical actual interruption events.

Report Section	Category	Issue Identified	Analysis Basis (Contributor)	Analysis Description	Factual Basis
4.4.2	Arc Flash	No Issues	CYME, ASPEN (Advanced System for Power Engineering) Oneliner, ArcPro	ASPEN Oneliner is the Company's main protection and fault analysis software for the transmission, subtransmission, and substation systems. CYME is the Company's main protection and fault analysis software for the distribution system. ArcPro is analysis software to specifically calculate arc flash energy. The planner uses the ASPEN Oneliner to determine source impedance which is entered into CYME. CYME is then used to determine fault current levels and clearing times. These parameters are then entered into ArcPro to arrive at the arc flash energy.	The factual basis is the equipment parameters entered into the various models and the proven protection curves. As done for any fault analysis, assumptions are made for bolted versus high impedance faults, location of faults, worker clearances, etc. These assumptions are based on experience, current work methods, and consultation with subject matter experts.
4.4.3	Fault Duty / Short Circuit Availability	No Issues	CYME and ASPEN (Advanced System for Power Engineering) Oneliner	ASPEN Oneliner is the Company's main protection and fault analysis software for the transmission, subtransmission, and substation systems. CYME is the Company's main protection and fault analysis software for the distribution system. The planner uses the ASPEN Oneliner to analyze substation fault current levels and CYME to analyze distribution line fault current levels.	The factual basis is the equipment parameters entered into the various models to determine impedance characteristics. As done for any fault analysis, assumptions are made for bolted versus high impedance faults, location of faults, etc. These assumptions are based on experience, current work methods, and consultation with subject matter experts.

Prepared by or under the supervision of: Ryan Constable

Report Section	Category	Issue Identified	Analysis Basis (Contributor)	Analysis Description	Factual Basis
4.4.4	Reactive Compensation	No Issues	ISO-NE Power Factor Survey, PSSE loadflow, CYME	The ISO-NE Power Factor Survey is report issued yearly on the reactive compensation performance of all the member utilities. The report checks performance during peak and light load conditions. The PSS/e load flow program was utilized to model the electrical system to the 23kV sub-transmission level and check reactive compensation against the DPG. Similarly, CYME was used to check reactive compensation on the radial distribution system against the DPG.	The factual basis of this analysis is the use of actual load levels within each model, the modeling of the capacitor control equipment, and the application of the DPG. Where EMS data is unavailable an assumed power factor is applied within to residential and commercial/industrial load.

Prepared by or under the supervision of: Ryan Constable

nationalgrid

Distribution Planning Guide

Rev. 1

Approved by: _____ **Date:** 2/15/11

Patrick Hogan, Sr. VP
Distribution Asset Management
National Grid USA Service Company

Amendments Record

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
0	10/14/2009	Initial draft	Curt J. Dahl Manager, T&D Planning LI John F. Duffy, Jr. Distribution Planning	Patrick Hogan Sr. Vice President Distribution Asset Management
1	2/15/2011	Final approved document	Max F. Huyck Network Asset Planning Jeffery H. Smith Distribution Asset Strategy	

Distribution Planning Criteria Strategy
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Strategy Statement

This document describes the National Grid Electric Distribution Planning Criteria that will be applied by the Distribution Planning Department in future distribution studies. These criteria are applicable to the New England (NE) and upstate New York (UPNY) areas of National Grid.

The electric distribution system on Long Island, NY shall continue to follow the LIPA Transmission and Distribution Planning Criteria.

For normal loading conditions, all types of facilities are to remain within their normal ratings at all times. For N-1 contingency situations it is expected that load shall be returned to service within 24 hours via system reconfiguration through switching, the installation of temporary equipment such as mobile transformers or generators, or by the repair of a failed device. Where practical, switching flexibility should be integrated into the system design to minimize the duration of customer outages following an N-1 contingency to meet reliability objectives. The following shall guide contingency planning on the distribution system:

1.) For the loss of a power transformer or substation bus fault that disrupts distribution load, the following planning criterion applies:

- The initial load increase at the remaining transformers within the area must not exceed either the summer or winter STE rating or 200% of nameplate.
- Load will need to be transferred or shed in a reasonable number of steps to reduce loading to the summer or winter LTE level within 15 minutes.
- Load on remaining transformers will be reduced to the summer or winter normal limit within 24 hours.
- The quantity of load at risk of being out of service following post contingency switching should be limited to 10MW.
- Repairs or the installation of mobile equipment are expected to require 24 hour implementation.
- Contingency risk shall be quantified via a MWHr metric calculated by determining the duration load is expected to be out of service at peak loading conditions considering a switch before fix restoration process.
- If more than 240MWHrs of load is at risk at peak load periods for a transformer or substation bus fault, alternatives to eliminate or significantly reduce this risk shall be evaluated and prioritized considering the load at risk, reliability impacts, and the cost to mitigate.

2.) For the loss of a sub-transmission supply line, the following planning criteria apply:

- The initial load increase at the remaining sub-transmission supply lines within the area must not exceed the summer or winter LTE rating.
- Every effort must be made to return the failed sub-transmission line to service within 12 hours.
- The quantity of load at risk of being out of service following post contingency switching should be limited to 20MW combined, considering all substations served via the supply line.
- Contingency risk shall be quantified via a MWHr metric calculated by determining the duration load is expected to be out of service at peak loading conditions considering a switch before fix restoration process.
- If more than 240MWHrs of load is at risk at peak load periods for a single line fault, alternatives to eliminate or significantly reduce this risk shall be evaluated and prioritized considering the load at risk, reliability impacts, and the cost to mitigate.

3.) For the loss of a distribution feeder, the following planning criteria apply:

- Feeders shall tie to neighboring feeders as much as practical as the flexibility to reconfigure feeders has a positive reliability impact for a wide range of possible contingencies.
- Following a contingency, all adjoining tie feeders can be loaded to their maximum thermal emergency or LTE rating.
- Feeder ties and cascading of load within the area can be utilized to the emergency limits of feeders to offload adjoining feeders.
- Contingency risk shall be quantified via a MWHr metric calculated by determining the duration load is expected to be out of service at peak loading conditions considering a switch before fix restoration process.
- If more than 16MWHrs of load is at risk at peak load periods for a single feeder fault, alternatives to eliminate or significantly reduce this risk shall be evaluated and prioritized considering the load at risk, reliability impacts, and the cost to mitigate.

Application of these criteria will result in somewhat less load at risk than previous criteria in either New York or New England which generally limited load at risk to between 20 and 28 MW pending the installation of a mobile device. Therefore it is expected that the Load Relief budgets will increase from historic levels for a given load growth rate. The capital cost associated with meeting the existing and proposed criteria for both normal and N-1 contingency conditions in New England and upstate New York are shown in Table 1:

Table 1 - Comparison of Capital Costs between Existing and New Criteria

Criteria	Present Value ($ Millions)	15 Year Annualized ($ Millions)
Existing NE/NY Criteria	$800	$80
New Criteria	$1,250	$130

The new criteria may result in an increase in capital requirements up to $50M/year over the existing criteria for the 15-year period studied.

Based on the results of the sample areas (expanded to the overall system) the following approximate quantities of additional facilities may be required over the next 15years.

Transformers (at existing or new substations)	180
Sub-Transmission Lines	46
Distribution Feeders	319

The new criteria will be applied to new installations and/or significant rebuilds initially. This is a long-term strategy and it is expected to take the full 15 year horizon to achieve compliance with existing facilities system-wide.

Performance targets for the adoption of the new planning criteria are:

- Quantification of equipment (sub-transmission lines, transformers, feeders) with load at risk forecast above the guidelines above.
- Identifying high load at risk areas and as part of annual summer preparedness and communicate monitoring plans for the Regional Control Centers.

- Developing project recommendations to eliminate or significantly reduce load at risk areas based on MWHr metrics, reliability performance and mitigation costs.

This policy shall be reviewed and revised as often as needed to reflect any major standards or criteria changes. It is recommended that a 2-3 year review cycle be performed.

Amendments Record

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
0	10/14/2009	Initial draft	Curt J. Dahl Manager, T&D Planning LI John F. Duffy, Jr. Distribution Planning	Patrick Hogan Sr. Vice President Distribution Asset Management
1	2/15/2011	Final approved document	Max F. Huyck Network Asset Planning Jeffery H. Smith Distribution Asset Strategy	

Strategy Justification

1.0 Purpose and Scope

This document describes the National Grid Electric Distribution Planning Criteria that will be applied by the Distribution Planning Department in future distribution studies. These criteria are applicable to the New England (NE) and upstate New York (UPNY) areas of National Grid.

A map showing National Grid electric service territory within New England and upstate New York is attached in Appendix A.

The electric distribution system on Long Island, NY shall continue to follow the LIPA Transmission and Distribution Planning Criteria.

This policy shall be reviewed and revised as often as needed to reflect any major standards or criteria changes. It is recommended that a 2-3 year review cycle be performed.

2.0 Strategy Description

2.1 Description of Distribution System

The distribution system of National Grid is comprised of all lines and equipment operated at a voltage below 69kV in New England and below 115kV in New York. The components of the distribution system are distribution substations, sub-transmission lines, and distribution circuits or feeders.

2.1.1 Distribution substations

The distribution substations within National Grid are a mixture of stations with one, two, and three or more transformers. The distribution substations step down voltage to a distribution or sub-transmission level. In Upstate New York approximately 70% of the substations have either a single source or a single transformer. In New England 40% of the substations have a single source and/or transformer.

A typical substation involves a 115/13 kV, 25-40 MVA rated transformer with either a load tap changer built into the transformer or individual voltage regulators applied to the feeders. In many locations, two or three transformers are within one substation and will interconnect via bus tie breakers. Many of the distribution substations supplied by the 115kV circuits also include one or more capacitor banks for reactive support.

National Grid maintains approximately 680 distribution substations containing approximately 1,530 power transformers. The total number of distribution substations, transformers, circuit miles of overhead and underground within NE and UPNY is listed in Distribution Line Overarching Strategy paper dated July 2008.

2.1.2 Sub-Transmission systems

The sub-transmission system within National Grid is designed to provide adequate capacity between transmission sources and load centers at reasonable cost and with minimal impact on the environment. The National Grid sub-transmission system provides supply to distribution substations as well as large three phase customers. It consists of those parts of the system that are neither bulk transmission nor

distribution. The typical voltages for the sub-transmission system include 46, 34, and 23 kilovolts. In New York, the sub-transmission also includes the 69 kV.

Sub-transmission systems may be designed in a closed or open loop system originating from transmission substations, and generally providing a redundant supply for distribution substations. In other cases, a single radial sub-transmission supply line may serve load. The substations served from a sub-transmission line will serve approximately 10-40 MW of load depending on the voltage.

Generally, the sub-transmission system is presently designed with conductors ranging from 336.4 ACSR (UPNY) to 795 kcmil AAC (NE) overhead conductor and from 500 to 2000 kcmil copper underground conductor. However, most of the sub-transmission lines are older designs and built with smaller wire such as 2/0 AWG copper installed along right-of-ways or on public streets.

There are approximately 930 sub-transmission lines in New England and upstate New York within National Grid.

2.1.3 Distribution Feeders

Distribution feeders originate at circuit breakers connected within the distribution substations. Feeders are generally comprised of 477 or 336 kcmil aluminum mainline overhead conductors and 1/0 AWG aluminum branch line conductors. Some feeders have underground getaway cables exiting from the substation with 500 to 1000 kcmil aluminum or copper conductor. Feeders are designed in a radial configuration. The feeder mainline will typically have several normal open tie points to one or more adjacent feeders for backup. Protection for faults on the feeders consists of relays at the circuit breaker, automatic circuit reclosers at points on the mainline, and fuses on the branch circuits.

The National Grid Primary distribution system in New England and upstate New York is comprised of approximately 3,770 feeders.

2.1.4 Secondary Networks

Low voltage secondary networks have historically been employed in several urban areas to maximize the reliability for the customers in these areas. They typically have a 120/208V class secondary system that is connected as a grid with many downtown customers connected. Most of the secondary networks have from 4-10 supply feeders. The low voltage secondary network supply feeders will typically have 10-30 network transformers connecting into the secondary grid.

Spot secondary networks are used in areas to serve specific large loads in urban areas. Some of these are served at 120/208V, while others are served at 277/480V. Typically, 2-3 supply feeders are used to serve the spot networks.

2.2 Distribution Planning Criteria

2.2.1 General Items impacting the Distribution Planning Criteria

2.2.1.1 Load Forecasting

The load forecast used by Distribution Planning for New England and New York will be based on a regional econometric regression model that considers historic loading, weather conditions, various

economic indicators. The forecast is adjusted for known spot load additions and DSM forecasts. Presently, distribution planning is based on a forecast that considers loading during extreme weather conditions such that those weather conditions are expected to occur once in 20 years. Separate models are used for NE and UPNY.

2.2.1.2 Equipment Ratings

Distribution Planning maintains equipment ratings for New England and New York. The summer and winter normal and summer and winter long time emergency (LTE) ratings will be used. The major equipment ratings to be used by Distribution Planning relate to transformers, overhead lines, and underground cables. The normal and LTE rating limits for these items may be applied for the time associated with each rating. Generally, the durations for emergency loading are as listed below in Table 2. System operators must be aware of the limiting factor involved in any contingency:

Table 2 - Equipment Rating Durations

Equipment		Normal	LTE	STE
Transformer		Continuous	24 hour	15 Min
Overhead Line		Continuous	24 hour	N/A
Underground Cable		Continuous	24 hour	N/A

There is also a short time emergency rating which may be determined for substation transformers, in no instance should this rating exceed 200% of nameplate rating. In addition to the items in the above table, ratings are reviewed for switches, circuit breakers, voltage regulators, and instrument transformers.

2.2.1.3 Planning Study Areas

A planning study area within National Grid is a grouping of distribution substations, feeders, transformers, and sub-transmission lines within a specific geographic area that are interconnected and can be studied as a group. Some areas are totally independent, while others will have points of interconnection with other study areas. A listing of the planning study areas that exist in NE and UPNY to be used by Distribution Planning are presented in Appendix B.

2.2.1.4 Load Flows

Distribution planning studies will utilize the PSS/e load flow program for the study of the sub-transmission lines and networks. The distribution feeder load flow analyses will be done using the Cymedist feeder analysis software program.

2.2.1.5 Distribution Analysis Alternatives

When performing distribution system analyses, Distribution Planning shall consider both traditional capacity enhancements as well as alternatives for "Non-Wires" customer load management alternatives where appropriate. The factors below could impact capacity planning analysis

a. Distributed Generation
b. Controllable Load Curtailment
c. Energy Storage devices
d. Demand Side Management

e. Distribution Automation
f. Smart Grid solutions

2.2.2 Distribution Substation Transformer Planning Criteria

2.2.2.1 Normal transformer load planning criteria

A substation transformer will not be loaded above its Normal rating during non-contingency operating periods.

2.2.2.2 Contingency N-1 substation transformer planning criteria

For an N-1 contingency condition that would involve the loss of a power transformer or substation bus, the following planning criteria apply:

- The initial load increase at the remaining transformers within the area must not exceed either the summer or winter STE rating or 200% of nameplate.
- Load will need to be transferred or shed in a reasonable number of steps to reduce loading to the summer or winter LTE level within 15 minutes.
- Substations will be designed to allow the installation of a mobile transformer within a maximum of 24 hours for a failed transformer.
- Load on remaining transformers will be reduced to the summer or winter normal limit within 24 hours.
- Feeder ties within the area can be utilized to their emergency limits. Cascading of load between feeders and substations may be needed to reduce loading to normal limits within the time frames required.
- The quantity of load at risk of being out of service following post contingency switching should be limited to 10MW.
- Contingency risk shall be quantified via a MWHr metric calculated by determining the duration load is expected to be out of service at peak loading conditions considering a switch before fix restoration process.
- If more than 240MWHrs of load is at risk at peak load periods for a transformer or substation bus fault, alternatives to eliminate or significantly reduce this risk shall be evaluated and prioritized considering the load at risk, reliability impacts, and the cost to mitigate.

2.2.2.3 Automatic transfer of load

Many locations with two or more transformers at a substation utilize automatic bus transfers. In some stations, one bus tie breaker is used, while in other substations a breaker and half design is utilized and there may be several feeder bus tie breakers. Based on the loading limitations in Section 2.2.2.2, it may be necessary to block the automatic transfer on either the main bus tie or one of the feeder bus tie breakers to avoid exceeding the STE limit during an N-1 contingency. Cases where automatic restoration are disabled will be documented and communicated with Regional Control Centers as part of an annual summer preparedness review. Recommendations to add capacity to the area will be evaluated and prioritized based load at risk, reliability and cost with other Load Relief alternatives.

When available, the use of the Energy Management System (EMS) control shall be implemented as needed to block automatic transfer. During an N-1 contingency, the System Operator will be required to maintain the loading on transformers as specified in Section 2.2.2.2.

2.2.2.4 Substation reactive support criteria

Reactive compensation shall be required for substations in the form of station capacitor banks or static VAR compensators. These should be sized to offset the reactive losses of the transformers at full load. Two or three stage capacitor banks may be needed for larger transformers to manage power factor and to limit voltage fluctuations.

2.2.2.5 Impact of planned maintenance

Capacity in all areas should allow the off loading of any distribution substation transformer for planned maintenance during the off peak months without exceeding the normal ratings of the other area equipment. However, in areas of the system with limited feeder ties, it may be more economical to allow the installation of a mobile transformer for maintenance.

2.2.3 Distribution Sub-transmission Planning Criteria

2.2.3.1 Normal sub-transmission load planning criteria

A sub-transmission supply line will not be loaded above its normal rating during non-contingency operating periods.

2.2.3.2 Contingency N-1 sub-transmission planning criteria

For an N-1 contingency condition that would involve the loss of a sub-transmission supply line, the following planning criteria apply:

- The initial load increase at the remaining sub-transmission supply lines within the area must not exceed the summer or winter LTE rating.
- Load on the remaining sub-transmission line will need to be reduced to normal levels within 24 hours.
- Feeder ties and cascading of load within the area can be utilized to the emergency limits of feeders to offload a sub-transmission line.
- Every effort must be made to return the failed sub-transmission line to service within 12 hours.
- The limit of load at risk for the loss of any sub-transmission line will be 20MW.
- The quantity of load at risk of being out of service following post contingency switching should be limited to 20MW combined, considering all substations served via the supply line.
- Contingency risk shall be quantified via a MWHr metric calculated by determining the duration load is expected to be out of service at peak loading conditions considering a switch before fix restoration process.
- If more than 240MWHrs of load is at risk at peak load periods for a single line fault, alternatives to eliminate or significantly reduce this risk shall be evaluated and prioritized considering the load at risk, reliability impacts, and the cost to mitigate.

2.2.3.3 Automatic line transfer systems

Auto transfer of load on the sub-transmission may be employed, but may not exceed the emergency (LTE) ratings of the remaining supply lines. When available, EMS control of sub-transmission lines will be utilized to block auto transfers and avoid overloading of lines as needed.

2.2.3.4 Sub-transmission reactive support criteria

Reactive compensation for sub-transmission lines shall be required in the form of station and distribution capacitor banks.

2.2.4 Distribution Feeder Planning Criteria

2.2.4.1 Normal feeder load planning criteria

A distribution feeder circuit will not be loaded above its normal rating during non-contingency operating periods.

2.2.4.2 Contingency N-1 feeder planning criteria

For an N-1 contingency condition that would involve the loss of a distribution feeder, the following planning criteria apply:

- Feeders shall tie to neighboring feeders as much as practical as the flexibility to reconfigure feeders has a positive reliability impact for a wide range of possible contingencies.
- Following a contingency, all adjoining tie feeders can be loaded to their maximum thermal emergency or LTE rating.
- Feeder ties and cascading of load within the area can be utilized to the emergency limits of feeders to offload adjoining feeders.
- Contingency risk shall be quantified via a MWHr metric calculated by determining the duration load is expected to be out of service at peak loading conditions considering a switch before fix restoration process.
- If more than 16MWHrs of load is at risk at peak load periods for a single feeder fault, alternatives to eliminate or significantly reduce this risk shall be evaluated and prioritized considering the load at risk, reliability impacts, and the cost to mitigate.

2.2.4.3 Automatic transfers on feeders

In some cases, it will be necessary to adjust a feeder rating to below normal summer or winter thermal rating due to automatic backup or Second Feeder Service commitments to certain customers.

2.2.4.4 Feeder reactive support criteria

Reactive compensation for feeders should be installed to provide additional capacity, improve voltage regulation and meet external power factor standards where applicable. A mixture of fixed and switched capacitor banks may be used as needed. All feeders in a planning area shall have proper reactive compensation prior to any requests for other load relief infrastructure improvements.

2.2.4.5 Feeder load balance criteria

Distribution Planning studies are based on three phase average loading. Load balance between the three phases on any feeder is assumed to be within a reasonable level.

Distribution feeder load balance shall require correction of the load imbalance for either of the following cases:

- Any feeder with the calculated neutral current exceeding 30% of the feeder ground relay pickup setting.

- Any feeder exceeding 100A between the high and low phase amps.

2.2.5 Network criteria

Secondary network criteria and loading limitations are defined in the National Grid distribution standards. The criteria are different for NE and UPNY based on the history of how various networks evolved.

2.2.6 Voltage criteria

2.2.6.1 Allowable Voltage Range at Service Point for Distribution Customers

The normal and emergency voltage to all customers shall be in line with limits specified by state regulators and within the limits of ANSI C84.1

These upper and lower voltage limits for each state in the service territory are listed in Table 3 below:

Table 3 - Voltage Requirements by State

State	Upper	Nominal	Lower
Massachusetts	126	120	114
New Hampshire	126	120	114
New York	123	120	114
Rhode Island	123	120	113

The values in Table 3 are in line with the National Grid Overhead Construction Standards.

Voltage on the sub-transmission and primary feeders is determined by many factors including:

- Primary mainline conductor sizes
- Distance of lines
- Reactive compensation

Voltage on the feeders is controlled by the station load tap changer or station regulators on feeders, the application of distribution capacitor banks, and the application of pole or padmounted line regulators. Voltage regulation of the feeders and supply lines must be adequate to ensure the voltage requirements in Table 3 above are maintained.

2.3 Residual risk and project prioritization

2.3.1 Residual risk after compliance with new criteria

The goal of the new planning criteria is to maintain the performance of the electric distribution system. Generally, after compliance with the new criteria, the residual risk for the worst case will be 10 MW of load out for 24 hours for a substation transformer failure or 20 MW out for 12 hours for an overhead supply line failure.

2.3.2 Methodology to prioritize capital projects

Prioritization of capital projects utilizes scoring system that considers the consequence of not completing the project and the probability that the consequences will be realized. A risk score between 1 and 49 is developed utilizing a 7x7 scoring matrix.

3.0 Risks/Benefits

The principal impacts of the planning criteria are reliability performance, customer service and efficiency. Due to the extended time frame for strategy compliance, the impact of the strategy will not be initially visible at the system level. These benefits will be most apparent in those areas where it has been implemented.

3.1 Safety & Environmental

Safety and environmental factors are not principal drivers of the planning strategy. However, the planning criteria will ensure equipment loading is maintained within accepted ratings reducing the risk of premature equipment failure that could result in environmental and public safety concerns.

3.2 Reliability

The planning criteria will provide operating flexibility to facilitate the restoration of customer outages following an N-1 contingency event. With an expected long implementation schedule, the impact will not be initially visible at the system level but will be significant in the areas where the criteria have been implemented. A long range reliability improvement of 11.4 minutes in SAIDI and 0.073 in SAIFI on a system basis is forecasted if the strategy is implemented over a 15 year planning horizon. Additionally, lower feeder loading will support future distribution automation to further improve reliability.

3.3 Customer/Regulatory/Reputation

The customer benefit associated with planning criteria is significant. Improved system reliability and lower equipment loading provide greater flexibility in serving both existing and new customers.

3.4 Efficiency

The planning strategy provides a consistent approach for feeder/substation and study area loading analysis across NE and UPNY. All studies being conducted under one criterion will create a consistent reference for ranking projects as part of the business planning process.

4.0 Estimated Costs

The estimated costs to adopt the new planning criteria are summarized as follows:

The capital cost associated with meeting the existing and proposed criteria for both normal and N-1 contingency conditions in New England and upstate New York are shown in Table 4:

Table 4 - Comparison of Capital Costs between Existing and New Criteria

Criteria	Present Value ($ Millions)	15 Year Annualized ($ Millions)
Existing NE/NY Criteria	$800	$80
New Criteria	$1,250	$130

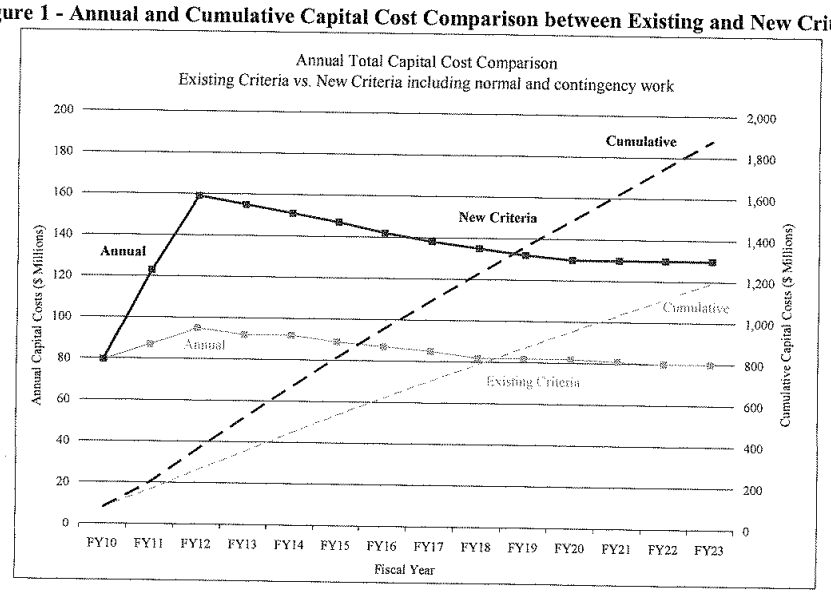
The new criteria may result in increased in capital costs of $50M/year in the Load Relief budget category compared to previous criteria for the 15-year period studied.

Based on an analysis of normal loading issues, it is projected that capital work associated with normal loading will remain at present levels or slightly higher for several years and then ramp down as contingency projects

will tend to drive the load relief spending.

These combined normal and contingency capital costs are shown in Figure 1 below:

Figure 1 - Annual and Cumulative Capital Cost Comparison between Existing and New Criteria



5.0 Implementation

Based on the results of the sample areas (expanded to the overall system) the following approximate quantities of additional facilities are forecasted to be required over the next 15 years in NE and UPNY.

Transformers (at existing or new substations)	180
Sub-Transmission Lines	46
Distribution Feeders	319

The new criteria will be applied to new installations and/or significant rebuilds initially. This is a long term strategy and it is expected to take many years to implement system-wide.

6.0 Data Requirements

The data sources required for the proper execution of the planning strategy include:

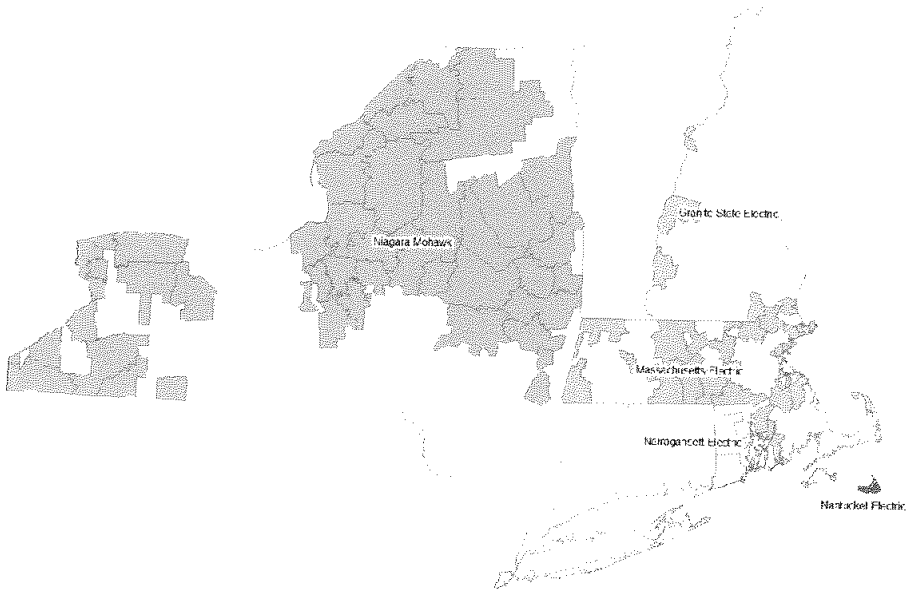
6.1 Planning Tools:

Cymedist (Cyme) – for radial feeder load flow and voltage analysis
Smallworld GIS – to support Cyme analysis
PSS/e – for network load flow analysis
FeedPro - for equipment loading and ratings
EMS and PI or ERS access in NE and UPNY

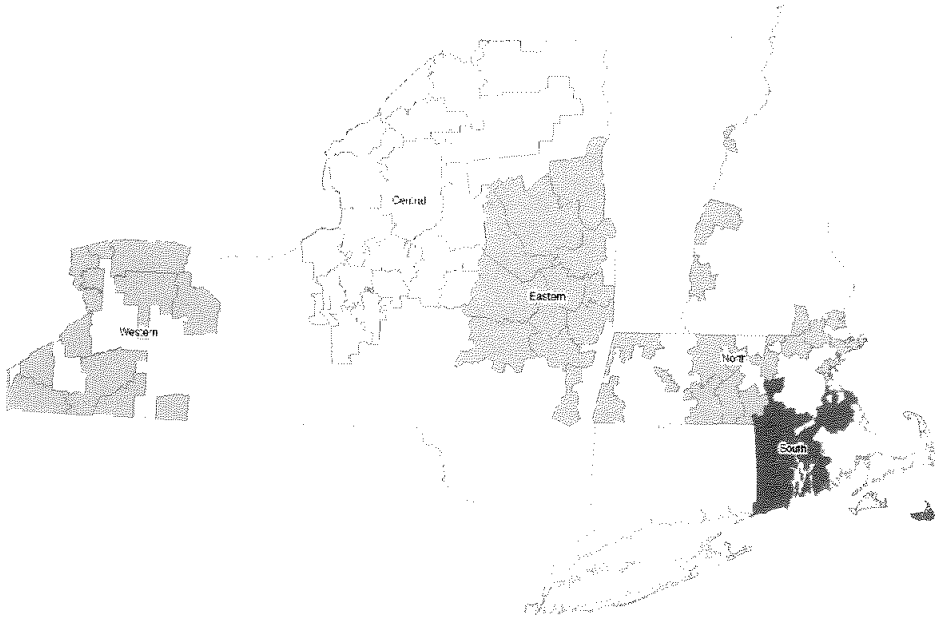
Appendix A – Service Territory Maps

Maps of Electric Distribution Service Territories for five companies and five divisions:

Companies

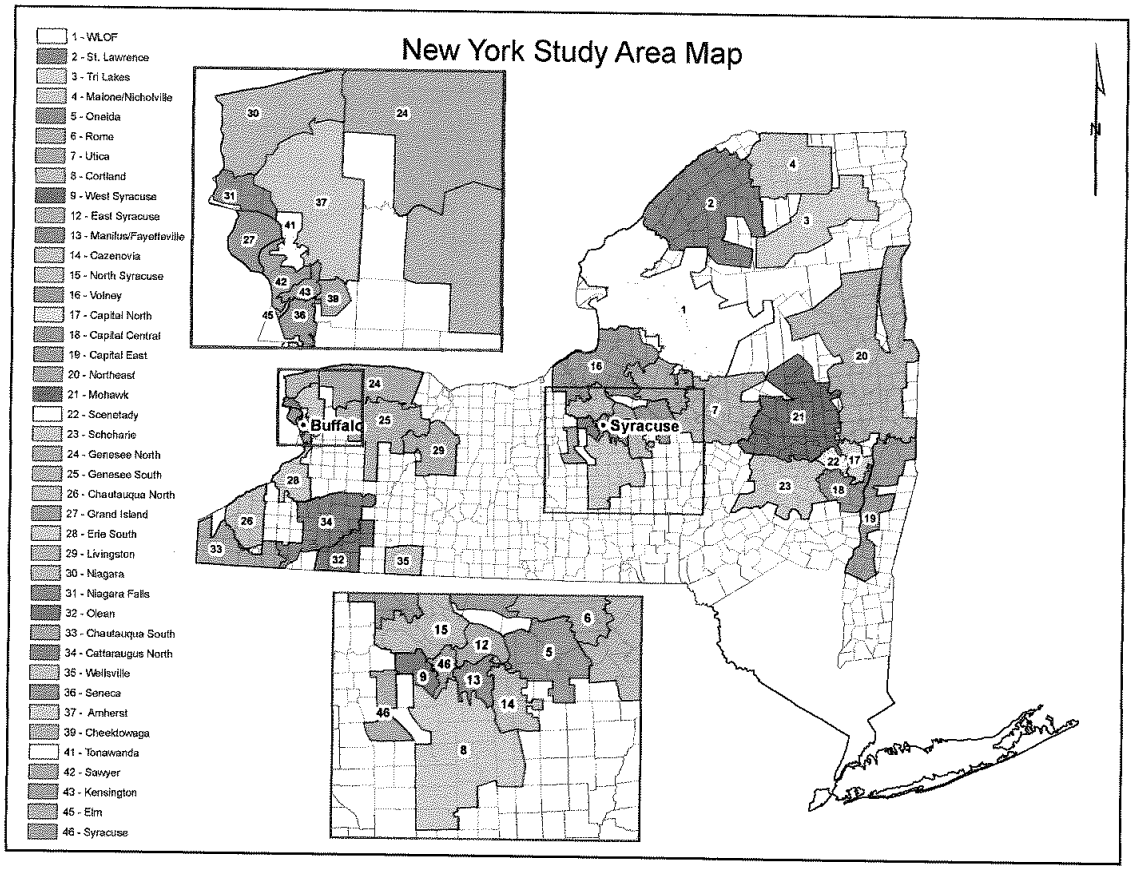


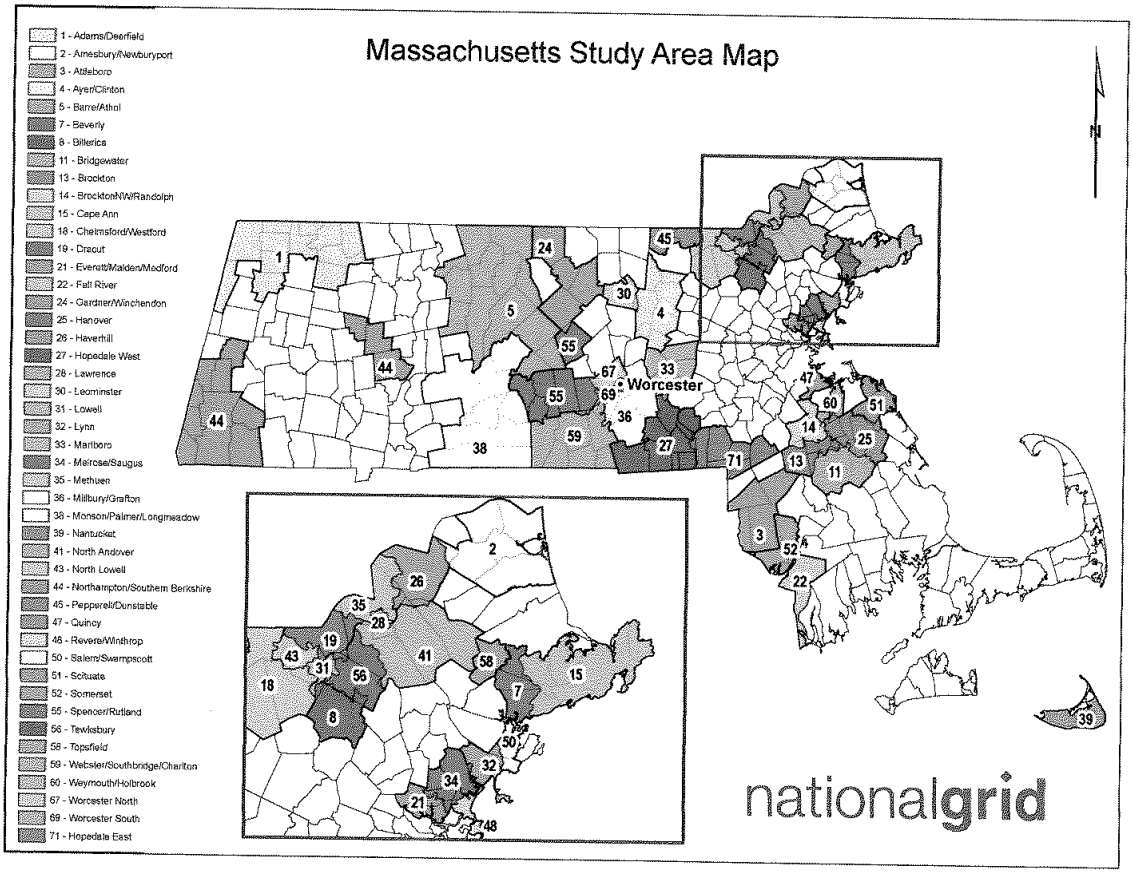
Divisions

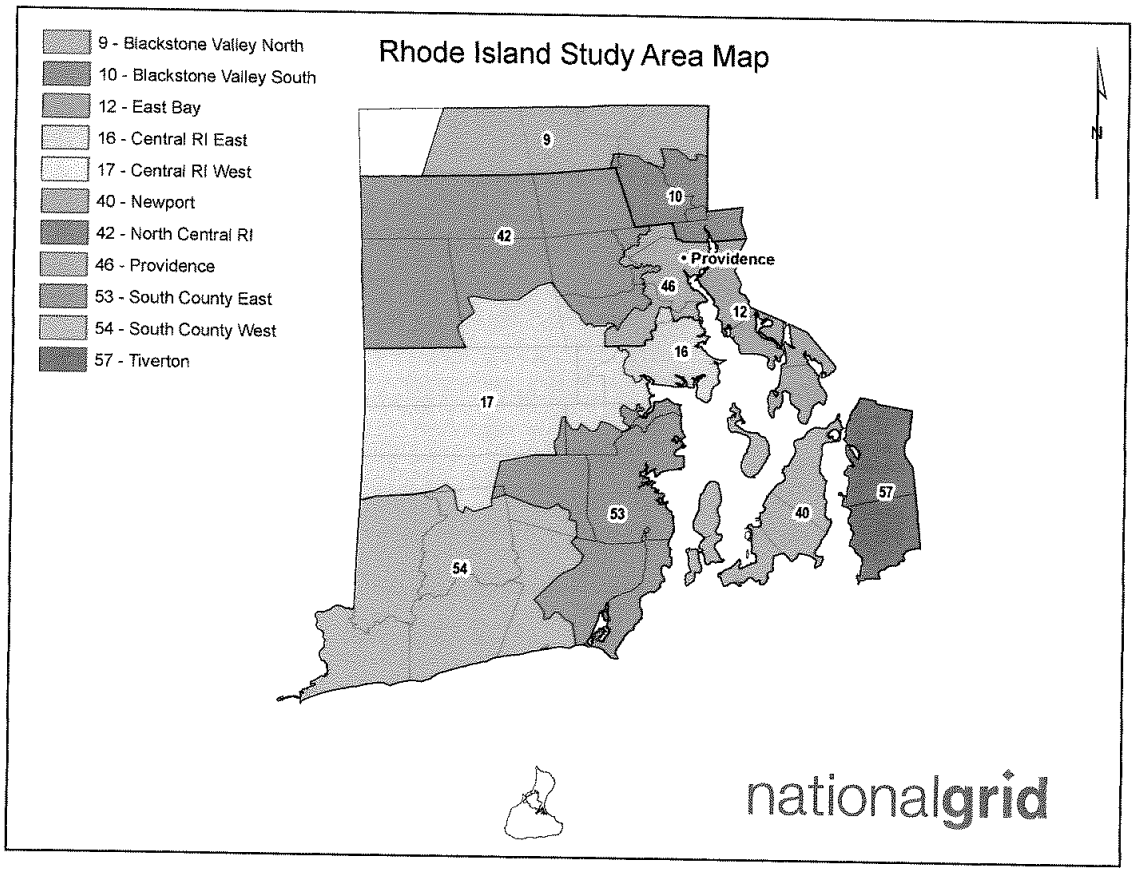


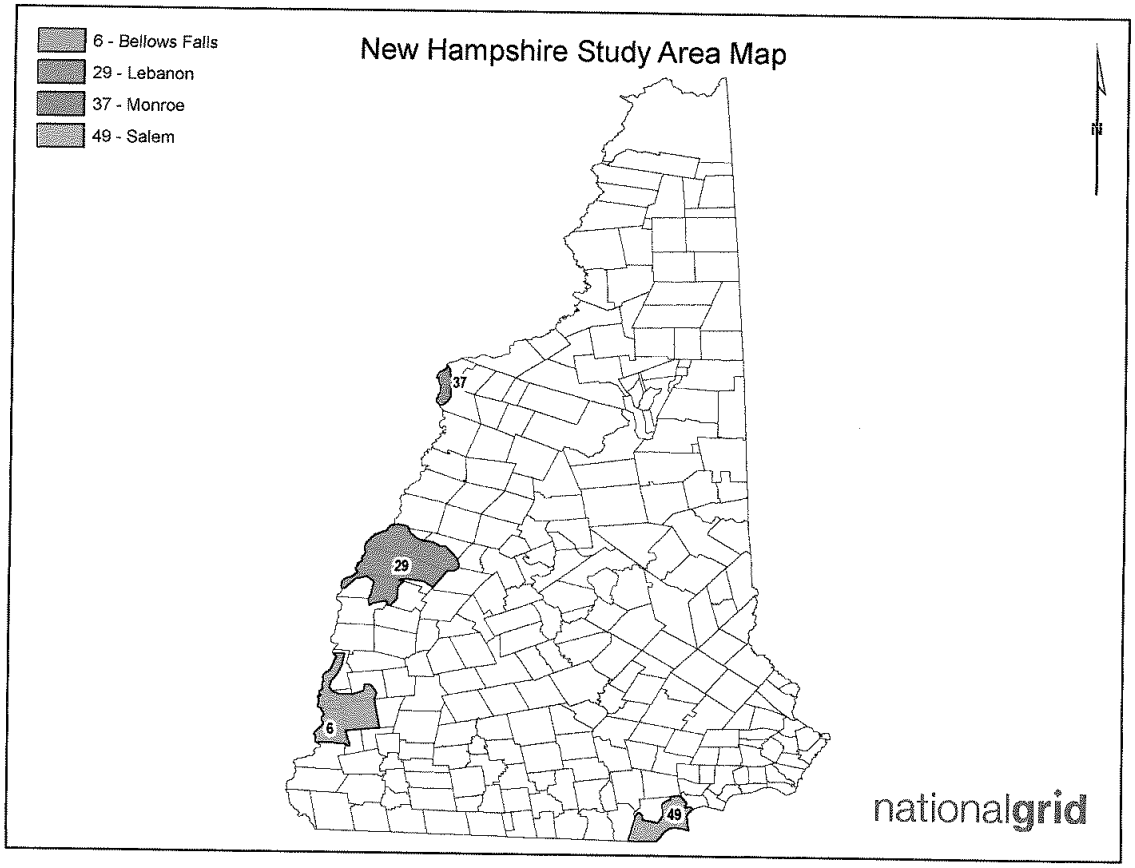
Appendix B - Distribution Planning Study Areas

To foster the annual capacity planning assessment, the distribution system across UNY and NE has been segmented into Planning Study Areas as shown in the following figures.




Massachusetts Study Area Map
1 - Adams/Deerfield
2 - Amesbury/Newburyport
3 - Attleboro
4 - Ayer/Clinton
5 - Barre/Athol
7 - Beverly
8 - Billerica
11 - Bridgewater
13 - Brockton
14 - Brockton/W/Randolph
15 - Cape Ann
18 - Chelmsford/Westford
19 - Dracut
21 - Everett/Malden/Medford
22 - Fall River
24 - Gardner/Winchendon
25 - Hanover
26 - Haverhill
27 - Hopedale West
28 - Lawrence
30 - Leominster
31 - Lowell
32 - Lynn
33 - Marlboro
34 - Melrose/Saugus
35 - Methuen
36 - Millbury/Grafton
38 - Monson/Palmer/Longmeadow
39 - Nantucket
41 - North Andover
43 - North Lowell
44 - Northampton/Southern Berkshire
45 - Pepperell/Dunstable
47 - Quincy
48 - Revere/Winthrop
50 - Salem/Swampscott
51 - Scituate
52 - Somerset
55 - Spencer/Rutland
56 - Tewksbury
58 - Topsfield
59 - Webster/Southbridge/Charlton
60 - Weymouth/Holbrook
67 - Worcester North
69 - Worcester South
71 - Hopedale East
Worcester
nationalgrid


Rhode Island Study Area Map
9 - Blackstone Valley North
10 - Blackstone Valley South
12 - East Bay
16 - Central RI East
17 - Central RI West
40 - Newport
42 - North Central RI
46 - Providence
53 - South County East
54 - South County West
57 - Tiverton
Providence
9
10
42
46
12
16
17
53
54
40
57
N
nationalgrid


6 - Bellows Falls
29 - Lebanon
37 - Monroe
49 - Salem
New Hampshire Study Area Map
N
37
29
6
49
nationalgrid